Chapter 7:

# Community-based Water Quality Monitoring: From Data Collection to Sustainable Management of Water Resources[1]

**William G. Deutsch**
**Allison L. Busby**
**Jim L. Orprecio**
**Janeth P. Bago-Labis**
**Estela Y. Cequiña**

## Introduction

The following is an account of how a rural community in the Philippines worked side by side with researchers, nongovernmental and governmental workers over a five-year period to develop science-based indicators of water quality that proved relevant for developing environmental policy. The case primarily focused on the early stages of implementing a municipal-level, natural resource management plan in Lantapan. The setting and background of the project are briefly described, followed by the nature of specific indicators and how they were chosen and refined. Next, the process by which these indicators

[1] The water quality project described in this chapter was implemented through the International Center for Aquaculture and Aquatic Environments, Auburn University. Work plan collaborators included Heifer Project International/Philippines (co-principal investigator of the project), Central Mindanao University, the San Herminigildo Agro-Industrial School, Inc., the National Power Corporation and the Provincial Planning and Development Office of Bukidnon, and the University of the Philippines Los Baños. Most of the field work was conducted by the Tigbantay Wahig, Inc. people's organization of Lantapan, Bukidnon, Philippines. Honorable Mayors Teddy Pajaro and Narciso Rubio and the Municipal Council of Lantapan are acknowledged for their partnership in this work and for beginning to apply the pertinent findings of the project.

influenced policy are documented, concluding with lessons learned throughout the process.

Materials for this chapter are based on a paper presented at a SANREM Annual Meeting and Conference, held in Malaybalay, Bukidnon, Philippines in May 1997. This paper was later modified for inclusion as a chapter in a book entitled *Environmental Indicators and Public Policy* (Mary Durfee, ed.), which is currently under review for publication by the University of Akron Press. The scientific information presented here has been considerably expanded from these previous works, however, with the addition of nearly two years of community-based research data. This chapter emphasized the methods, results and applications of the biophysical data collected by the citizen monitors. The process of how the community members became involved in water quality monitoring, and their current and future work as a nongovernmental organization, is presented in Chapter 9.

## The Community-based, Water Quality Monitoring Project

Several interdisciplinary research projects on soil, water and biodiversity were designed within the larger SANREM/Philippines program, based on information gained during several weeks of reconnaissance and the interests of collaborative research teams. Among them was a project on local water quality assessment and management. The overall goal of the project was to foster the development of community-based water monitoring groups, and to collect credible water quality and quantity data that lead to environmental and policy improvements. This was primarily accomplished by conducting a series of workshops and field exercises to train interested community groups in the evaluation of water quality using portable test kits and other, basic analytical tools.

Many of the methods used were modeled after those developed in Alabama Water Watch, a citizen volunteer, water quality monitoring program that is now underway in the U.S. (Deutsch *et al.* 1998). Filipino partners on the SANREM work plan who were educators and community developers helped customize the workshops and sampling techniques to the local situation. Community participants primarily included farmers, teachers, members of certain women's organizations and some members of the local government unit. The project researchers and volunteer, water monitors selected 16 sampling sites in four main tributaries of the Manupali River (Fig. 7. 1). Sites chosen were those generally accessible and representative of the diverse portions of the overall landscape, including subwatersheds of varying degrees of forest cover, agricultural land and population. A "menu" of possible water quality indicators was

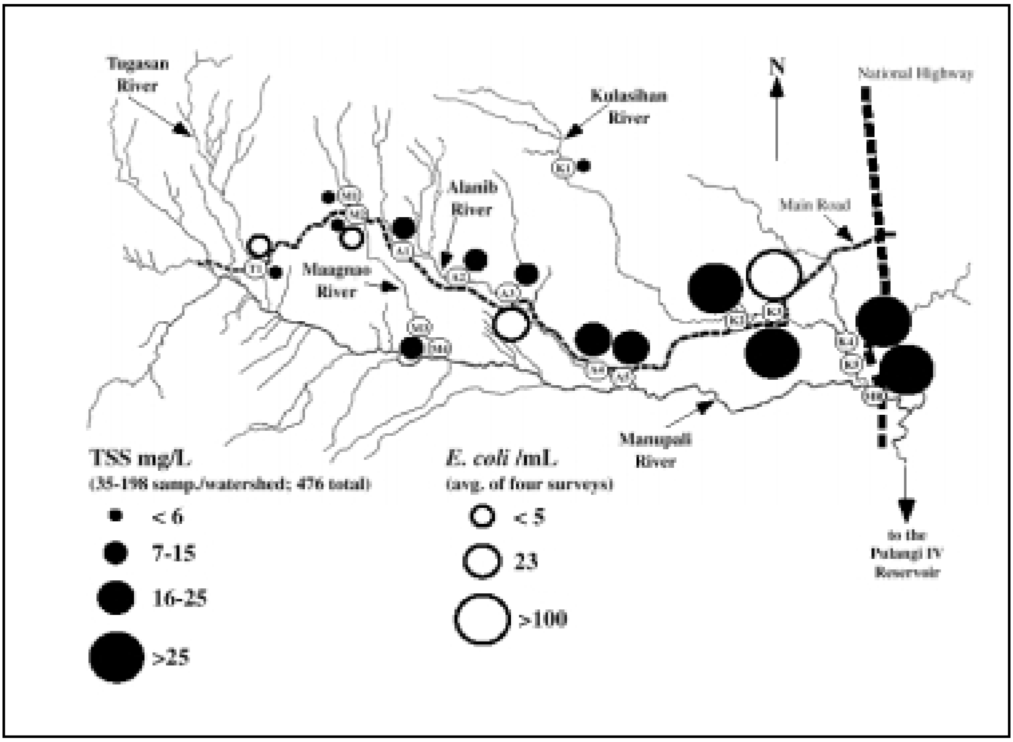


**Fig. 7.1. The Manupali River watershed, with total suspended solids (TSS) and *E. coli* bacteria concentrations in four subwatersheds, August 1995 - July 1996.**

made available to the monitors in the workshops. These included the physicochemical parameters of temperature, pH, alkalinity, hardness, nitrates, phosphates, dissolved oxygen, turbidity and total suspended solids. Biological parameters included biotic indices of stream macroinvertebrates and measurements of *E. coli* and other coliform bacteria concentrations.

## Community-based Water Quality Indicators

Many international development agencies are actively pursuing research on environmental indicators to better manage and evaluate their programs and improve efficiency and extension. They are basically trying to determine which of the thousands of biophysical and social indicators are best for determining environmental trends, reducing unsustainable practices and implementing restoration activities. Attempts to understand and define these environmental and agricultural indicators have led researchers to develop elaborate typologies that include dimensions of time, space, form and worldview (Madden 1995).

The approach of this project was to develop and test specific water quality indicators that were appropriate for natural resource management by community volunteers and the local government unit. In that regard, the following criteria were established for each indicator:

1. scientifically valid methods, for credible qualitative and quantitative information;
2. relevant to the community, for their endorsement and participation in data collection; and
3. practical and relatively inexpensive, for sustainable use and applications using locally available materials.

After several months of testing water for the 8-10 parameters presented in the training workshops, the data began to suggest that the relatively few parameters related to soil erosion, disrupted stream flows and bacterial contamination were the most productive to pursue as indicators. Both the citizen monitors and researchers concurred and there followed more in-depth study and application of these indicators. The following is a summary of the rationale and methodology behind each of the key indicators, starting with the qualitative indicator of community perception, memory and experience before the science-based project began.

### Indicator #1: Community Perceptions, Memories and Experience

For the SANREM/Philippines program, several sectors of the local community were involved with researchers and community organizers in an initial, watershed-scale evaluation of the site, called a Participatory Landscape/Lifescape Appraisal or PLLA (Bellows *et al.* 1995). During this time, scientists, development workers and some local residents worked as a team to interview people of the Lantapan community and become aware of perceptions and environmental concerns. This appraisal was vital to the development of the framework plan, which led to the water indicators research.

The first dialogues between community members and researchers regarding potential environmental indicators revealed that residents were commonly concerned with water contaminants, such as pesticides and pathogens, in addition to soil erosion and sedimentation of streams and irrigation canals. Some farmers did not water their livestock in streams during rainfall events, citing loss or illness of animals from pesticide runoff. Public health records, although scanty, indicated a higher than average infant mortality and morbidity rate in the community, and many common ailments were caused by waterborne pathogens.

Besides water quality concerns, some residents questioned or lamented the fact that some streams were no longer maintaining regular flows, but were cycling through seasonal flood and drought. Memories of stable stream flow and clean water were within the last few decades. Flash floods were increasingly common in the eastern part of the Manupali watershed, resulting in severe soil erosion, crop loss and occasional loss of livestock or human life. Overall, the pattern of watershed degradation experienced by the community was typical of that in upland landscapes of the Philippines and in many other parts of the world.

### Indicator #2: Eroded Soils in Streams

Because the community of Lantapan is primarily agrarian, measurements of soil loss and sedimentation were particularly relevant to volunteer monitors. Farmers generally understood that soil loss usually meant a reduction in the fertility of their fields, with accompanying reduction of crop production. Farmers of lowland rice clearly realized the negative impacts of upland soil erosion because the irrigation canals had become heavily silted and, as a system of water conveyance, were only about 25% efficient.

Further downstream, the Manupali River flows into the Pulangi River, which is impounded to create a series of hydroelectric generating stations. Interviews and information gathering activities of the PLLA revealed that the Pulangi IV reservoir was silting in at an alarming rate of nearly one meter per year at the dam, and that the reservoir capacity had been drastically reduced from sedimentation. This also contributed to premature wear of hydropower turbines and frequent power outages or "brown outs."

One indicator of soil erosion and sedimentation was the measurement of total suspended solids, or TSS. A relatively simple and inexpensive technique was adapted in which a known volume (usually one liter) of stream water was filtered for calculation of mg/L suspended solids. The plastic filtering system apparatus was lightweight and easily portable, with a hand pump, in a small back pack. The glass fiber filters (6 micron pore size) were prepared and weighed before and after sampling according to standard methods at a nearby university. Labeled, preweighed filters were brought to the watershed in batches for monitors to sample TSS, and sampled filters were returned to the university for processing and data recording.

After the community collected several hundred TSS samples throughout the subwatersheds of the Manupali River valley, this indicator of soil erosion began to reveal patterns of degradation that went far beyond the simple observations of “clear” and “muddy” water in various streams. Even within the first two years of monitoring (1995-96), data strongly suggested differences in erosion rates at the subwatershed level, with sharp increases in TSS concentrations from the western to eastern subwatersheds (Figs. 7.1 and 7.2). When correlated with rainfall data collected from local weather stations (three stations in the Manupali watershed), it became clear that seasonal difference in TSS occurred in each subwatershed (Fig. 7.2). These differences were probably caused by natural factors, such as changing rainfall frequency and intensity in rainy and dry seasons, as well as cropping patterns. Sometimes, a combination of these natural and human induced changes greatly increased TSS in streams, such as when farmers plowed and exposed large areas of bare soil for planting just prior to heavy spring (May-June) rains.

Most of the TSS monitoring by the community was done once or twice monthly at four main sites (bridge crossings of the four major tributaries of the Manupali River) in daytime, base flow conditions. By using the TSS indicator in this way, monitors seemed to determine important trends and patterns occurring in the river valley. Nevertheless, their overall measurements were an underestimate of the greatly increased erosion rates during strong storms. Recognizing this fact, the monitors offered to measure TSS more frequently, just before and during selected rainfall events in each subwatershed. Results were sometimes dramatic, and in one case, TSS increased by 1,000-fold within a two-hour period of a heavy rain, to reach about 18 kg of soil in each cubic meter of water. To better communicate this to farmers and other community members, such a rate of erosion was likened to the weight of a sack of seed corn in each unit volume of water that approximated the size of a small desk. The TSS indicator became an increasingly important way for the Lantapan residents to quantify environmental change and lay the foundation for local action and policy changes.

### Indicator #3: Altered Stream Flows and Soil Export

TSS is only a relative indicator of erosion and watershed degradation (a concentration value) which does not provide important estimates of soil loss in water past a given point. Because the streams of the four subwaterheds in Lantapan were similar in size, TSS trends were generally comparable, however, stream discharge measurements were required to use TSS to its full potential and calculate soil export. Moreover, the patterns of stream discharge provide important clues to watershed stability and the effects of land use change.

Typically, stream discharge measurements are made by researchers using expensive and fixed structures and instruments, such as concrete and metal wires, flumes and elaborate gauging stations. Such methods are usually impractical for rural communities using their own resources, so low-tech methods were developed and adapted for use by the volunteer water monitors in Lantapan.

Stream velocity and discharge measurements were made with locally available materials, including rope, measuring sticks and a float. A cross-

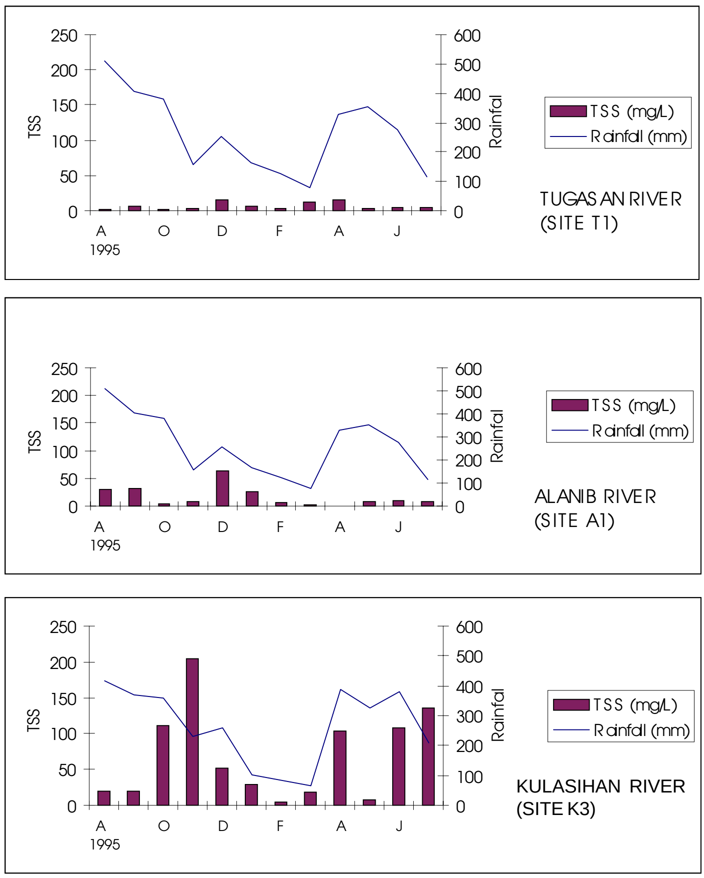


**Fig. 7.2. Total monthly rainfall and average monthly total suspended solids (TSS) in three subwatersheds of the Manupali River, August 1995 - July 1996.**

sectional map of each of the four streams was made at the main bridges, using the regular, concrete sides of the revetment wall under the bridge as boundaries when possible. A rope was stretched perpendicularly across the stream between two fixed points and stream depth was determined at one-meter intervals along the rope. Measurements of stream width and depth were used to draft cross-sectional maps and calculate area.

Another rope of known length was stretched parallel with the stream bank to mark the distance that a floating orange (or other tropical fruit) would travel while being timed. Multiple measurements of the time required to float a known distance in different parts of the stream were used to determine average current velocity. Together, the cross-sectional area of the stream (square meters) and its current velocity (meters per second) were used to estimate stream discharge (cubic meters per second).

The measurements of stream discharge provided an excellent indicator of the hydrologic cycle. Monthly discharge measurements taken in each of the four streams on the same day from 1997-99 were used to produce graphs of seasonal stream flow (hydrographs) that indicated distinct subwatershed differences. For example, the easternmost Kulasihan River had a much greater range of flow during an annual cycle than that of the Tugasan and Maagnao Rivers in the western part of the watershed, in spite of similar average discharges and rainfall patterns (Table 7.1, Fig. 7.3). The coefficient of variation in monthly flows ranged from 32% (Maagnao River) to 140% (Kulasihan River) among the subwatersheds, and seemed to provide a simple yet valuable indicator of watershed stability that followed the same pattern as the soil erosion indicator of TSS.

Hydrographs of the Maagnao and Kulasihan Rivers were compared with total monthly rainfall data that was collected at a weather station between the two subwatersheds (Fig. 7.3). This revealed that the Kulasihan River is much more dependent upon seasonal rainfall patterns for surface flow than the Maagnao River. Such instability or "flashiness" of the Kulasihan River, indicated by its abrupt flooding and drought cycle, is intensifying and becoming a serious problem for the local municipality A new culvert needed to be constructed in the Kulasihan subwatershed following the July 1997 flood (Fig. 7.3) in which three additional concrete tubes were installed to convey floodwaters and prevent washout and blockage of the main access road. Such an expense for local government, along with the property damage and loss of crops and soil from flooding that preceded the construction project, underscore the importance of the stream discharge indicator as an early alert to watershed disruptions.

**Table 7.1. Average discharge, range and coefficient of variation (CV as %) of four tributaries of the Manupali River (measured monthly on the same day), February 1997-October 1999.**

| Stream | Average Discharge and Range (cu. m/s) | CV |
|---|---|---|
| Tugasan | 1.78 (0.26- 3.84) | 51 |
| Maagnao | 1.92 (0.77- 3.40) | 32 |
| Alanib | 1.29 (0.13- 2.93) | 60 |
| Kulasihan | 1.84 (0.00-10.26) | 140 |

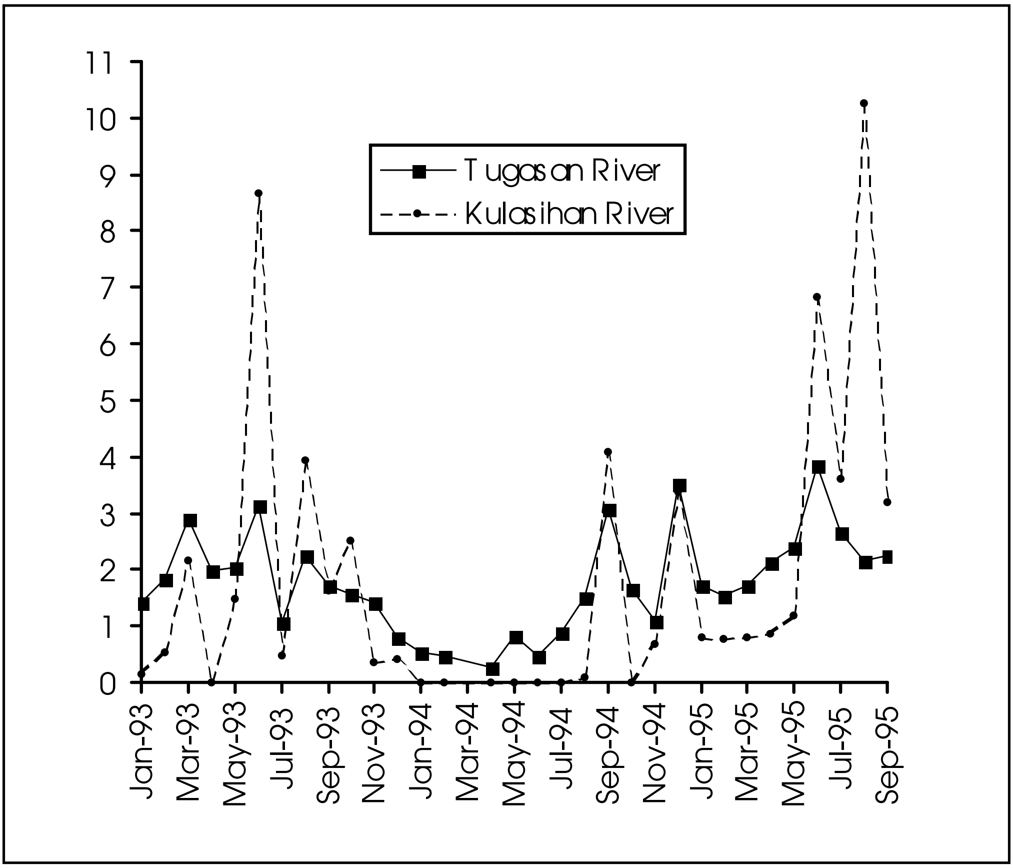


**Fig. 7.3. Stream discharge of the Tugasan and Kulasihan Rivers (measured monthly on the same day), February 1997 – October 1999.**

The database of stream discharge and soil export data documented some of the effects of the El Niño event in Lantapan. A severe drought occurred in Lantapan as a result of the El Niño, beginning in November 1997. For the subsequent nine months, the Kulasihan River had greatly reduced flows, and was completely dry for most of February-September 1998. In addition to disruptions of the natural environment, this caused hardships on local people who depended upon the river for bathing, washing clothes, watering livestock and other activities. During this same period, the flow of the Maagnao River was only slightly less than its typical amount (Fig. 7.3). Whereas the flow of the Maagnao River remained relatively stable through 1999, the Kulasihan again began to periodically flood, and its discharge of September 1999 exceeded that of the July 1997 flood.

Concurrent TSS and stream discharge measurements resulted in practical and valuable estimates of soil export. As might be expected from TSS and discharge data, soil export data varied significantly among watersheds and revealed the severe soil loss problems within the Kulasihan subwatershed. From February 1997 through September 1999, soil export estimates in the Maagnao River subwatershed ranged from less than 10 kg/h to about 125 kg/h and was generally correlated with total monthly rainfall values (Fig. 7.4). During this same period, soil export in the Kulasihan River was much more variable. For several months of the El Niño drought, soil export in the Kulasihan River was zero because of no surface flow. However, during the rainy periods of September 1997 and July 1999, soil export in the Kulasihan was measured as 1,300 and 3,400 kg/h, respectively, and exceeded the maximum measured in the Maagnao River by 10-25 times. Clearly, this indicator is a relatively simple and inexpensive, yet important, tool for local watershed management.

### Indicator #4: Bacterial Contamination of Water

Levels of potentially harmful bacteria in streams, wells and piped drinking water were of primary concern to many citizens of Lantapan because of obvious public health risks and personal experiences of illness. As with related memories of community members regarding stream degradation from pesticides and silt, older adults recounted how they freely drank from streams in the past at places where they knew they would become ill.

Evaluation of water for bacteria in the community had been infrequent, and the tests that were occasionally done by the Department of Health or the *Barangay* Health Workers only detected the presence or absence of fecal coliforms without determining a concentration value. As with all

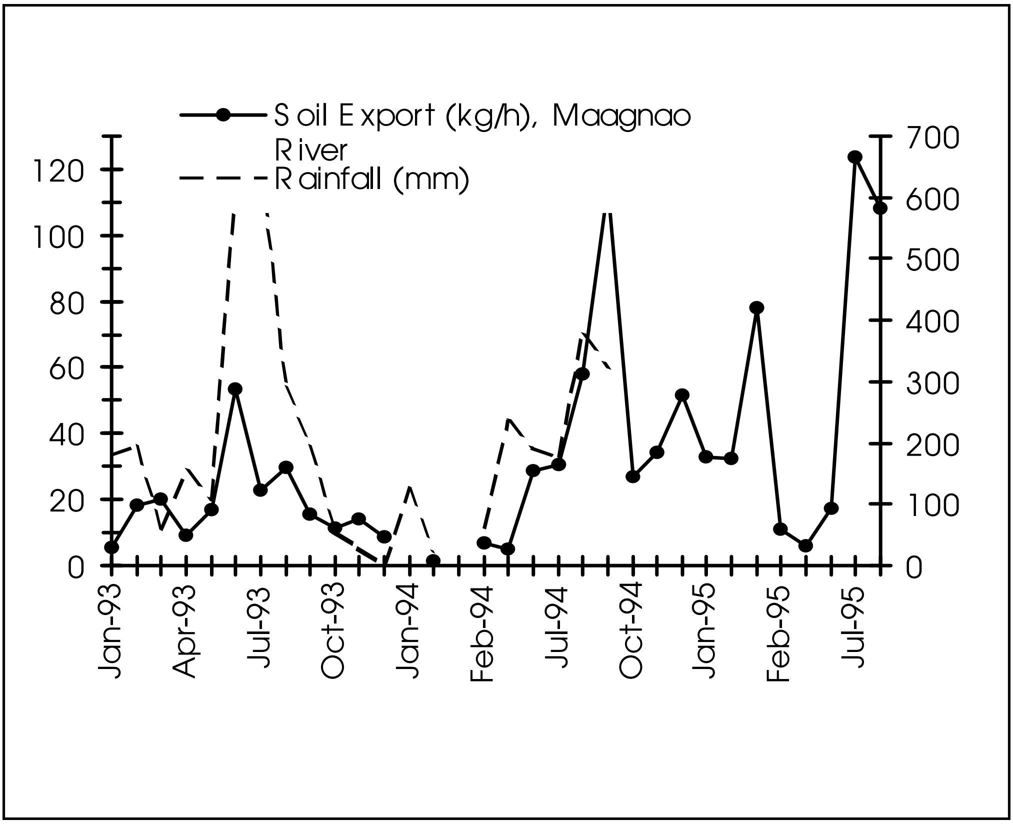


**Fig. 7.4. Soil export (kg/h) in the Maagnao River, February 1997-September 1999, with total monthly rainfall, February 1997-September 1998.**

other techniques and indicators to be developed for practical use, bacteriological monitoring methods were chosen and adapted based on simplicity, accuracy and low expense.

A relatively new technique of measuring concentration of *E. coli* and other coliform bacteria was used for the monitoring. With this method, a one milliliter sample of water is collected using a sterile, plastic pipette and squirted into a 10 mL bottle of sterile, liquid medium. The medium (with color indicators for coliforms) containing the water sample is poured onto a sterile, plastic dish which is designed to induce the liquid to solidify. Incubation of sample plates at ambient tropical temperature was sufficient to grow the bacterial colonies for enumeration in about 30-36 hours. No incubators, sterilizers or glassware were needed for this technique and necessary supplies (which cost about $1 US per sample) could be easily transported to remote areas for sampling scores of sites per day. Following the incubation period, bacterial colonies of *E. coli* and other coliforms were enumerated and reported for feedback to the community. The procedures used to monitor coliform bacteria in Lantapan were approved by the U.S. Environmental Protection Agency for the Alabama Water Watch Program in January 2000 (Deutsch and Busby 1999).

Four bacteriological surveys of the four major tributaries of the Manupali River were conducted in different seasons throughout 1995-96. Bacteriological results were surprisingly similar to the pattern observed for TSS at these same locations, and reinforced the erosion and stream discharge indicators that degradation was occurring in a west-to-east gradient across the landscape (Fig. 7.5). According to World Health Organization and U.S. Environmental Protection Agency standards, bacterial concentrations in the Tugasan and Maagnao Rivers are generally safe for human "whole body contact," whereas those in the Alanib and Kulasihan Rivers typically exceed the safety standard by 10- to 50-fold.

Bacteriological surveys were also made of the community drinking water faucets which were distributed throughout each of the 16 *barangays* of the municipality. Virtually all drinking water is gravity fed through a plastic piping system from one of several mountain springs, and is untreated with filters or chemical sterilizers. Surveys revealed several faucets which had become contaminated with *E. coli* because of breaks in the pipes and seepage into them from contaminated soils and water.

Whereas the initial participants in water quality training workshops and monitoring were predominantly young men, bacteriological monitoring generated much interest among women and girls. It is believed that this parameter was of particular interest to women because of its direct tie to family health, especially that of infants and children. It also may have been more relevant than other parameters because the measurement was made from community faucets and public springs that had a close connection to household affairs and daily chores. Strong involvement from the Federation of Lantapan Women's' Organization and other women of the community added a new dimension to community-based water quality indicators and their applications. Overall, the concentration of coliform bacteria has become an important indicator of water quality, used by diverse sectors of the community.

### Indicator #5: Demographics and Land Use

The community-based indicators of TSS, stream discharge, soil export, and *E. coli* bacteria concentrations within the four subwatersheds were compared with both demographic and land cover patterns determined from government census and remote sensing data to better understand

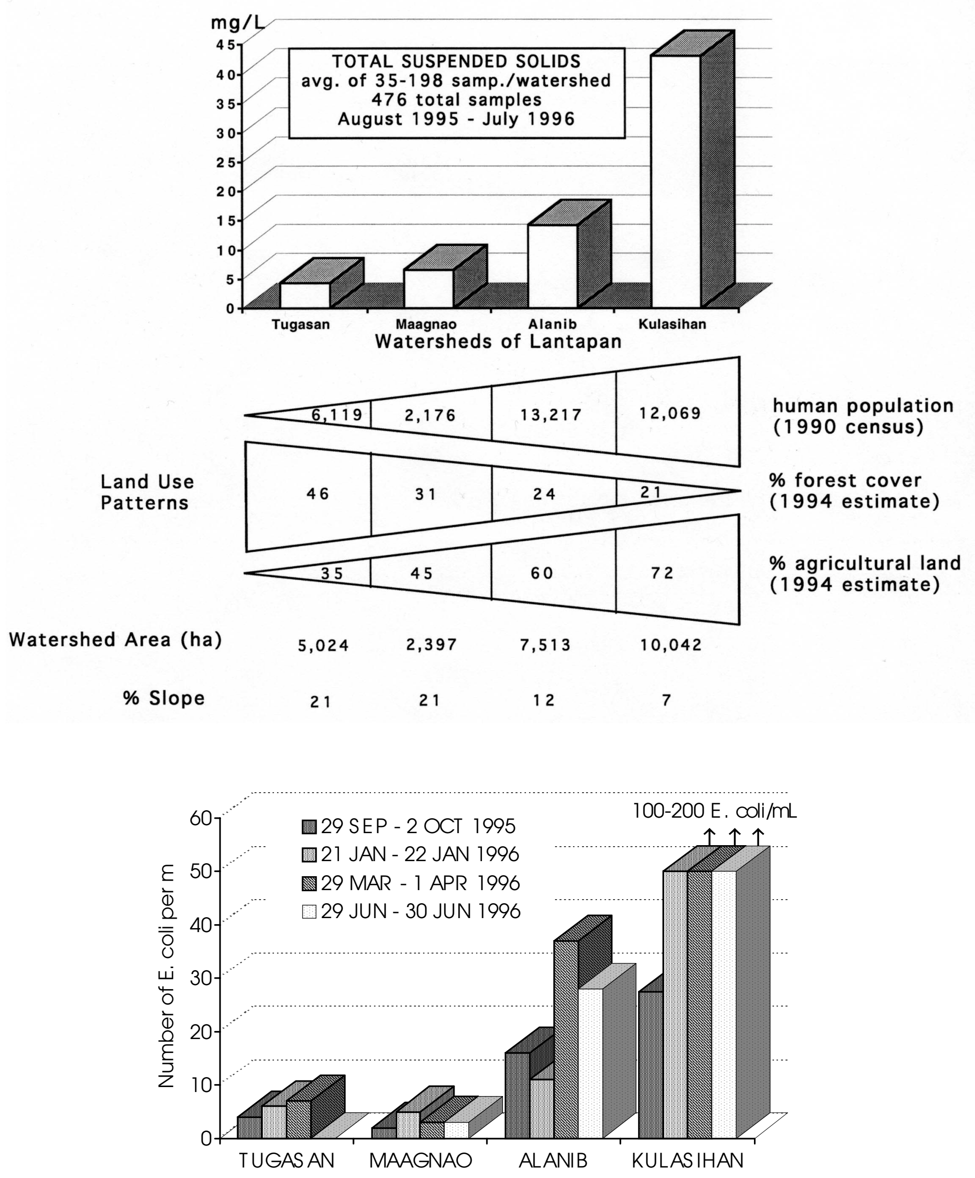


**Fig. 7.5. Total suspended solids, land use patterns and concentrations of *E.coli* bacteria in four subwatersheds of the Manupali River, August 1995 - July 1996.**

the linkages between land use and environmental quality. This comparison revealed a clear yet disturbing pattern. The progressive decrease in forest cover and increase in cleared land from west to east across the Manupali River valley were closely correlated with the patterns of water quality degradation that the community monitors had detected (Fig. 7.5).

The results of study indicate that the community-based indicators might be very important for describing landscape-scale trends. For example, abrupt increases in TSS occurred when subwatershed forest cover dropped below 30% and agricultural land made up more than 50%. Knowing such threshold levels of unsustainable soil erosion by using an indicator like TSS could be of immense value to natural resource managers and policy makers. In the case of Lantapan, the western two subwatersheds may be even more vulnerable to severe erosion with deforestation than the eastern two subwatersheds because their average slope of about 20% is much greater (Fig. 7.5). It is also noteworthy that about 75% of the population of Lantapan live in the two eastern subwatersheds (although human density in all subwatersheds is similar, ranging from 0.9-1.2 person per hectare). Much larger populations in the Alanib and Kulasihan subwatersheds, including many more houses and roads, certainly contributed to the sharply elevated levels of soil erosion, *E. coli* concentrations and other measures of water-related problems.

## From Indicators to Policy

As the water quality information increased through greater community involvement and monitoring activity, the environmental indicators helped to explain and communicate the changes in land and water that were occurring. It seemed clear that the "price of development" in Lantapan under current technologies and land use strategies included streams that were silt laden, contaminated with bacteria and unstable in their seasonal flow.

What made the emerging scenarios of development and degradation more stark was that this rather extreme environmental gradient occurred in one, medium-sized river valley, and the changes were well within human memory. Community members did not have to envision a hypothetical, pristine or highly degraded watershed or a centuries-long process. They had seen for themselves by monitoring the dynamic ecosystems of the Manupali River valley in which they lived, and many were beginning to understand the consequences of land use decisions on a landscape scale.

To increase public understanding and action, the watershed information was popularized as a "Walk Through Time," *i.e.* subwatersheds of the west, including the Tugasan and Maagnao Rivers, represented relatively natural conditions of the past whereas the Alanib and Kulasihan watersheds of the east illustrated the environmental costs of using traditional technologies to clear land for agriculture, homes and roads over the last few decades (Fig. 7.4). Put simply, a person in the middle of the watershed could "look west" to see where their environment had come from, and "look east" to see where it was going. This basic way to use indicators to describe environmental change and suggest human causes and responses contributed to policy debates and decisions.

## A Municipal Natural Resource Management Plan

The environmental information collected in the water monitoring project was provided to representatives of the local government unit in a variety of forms. At the invitation of the Mayor of Lantapan, a summary of the research findings was orally presented with visual aids to the municipal council. This prompted the local government to incorporate community-based water testing and some of the research findings and recommendations into their Natural Resource Management Plan (NRMDP, 1998). The plan is well underway, and begins with the following statement:

> *The Natural Resource Management and Development Plan (NRMDP) of Lantapan is a practical, not wishful action plan that presents practical intervention to the critical conditions of the natural resources. This has led to the identification of "hot spots" or fragile areas that need immediate attention before it will be totally degraded over the next few years. The NRMDP evolved from a strong, participatory planning and collaboration of various sector groups in the community and the local legislators that composed the Municipal Natural Resource Management Council (MNRC), together with different stakeholders from concerned government agencies at the provincial level...The plan will likely become a development model or template for natural resource management and environmental planning to other municipalities in the province of Bukidnon.*

Among the many "implementable actions" of the plan is a strategy to improve water quality, quantity and distribution. Key activities within this strategy involve continuous water quality monitoring and the expansion of membership of the Tigbantay Wahig group through the organization of community chapters (see Part II, Chapter 9). Such a strategy represents a major step toward the practical application of community-based water quality indicators by a local government unit of the Philippines.

Of extra significance was the recent mayoral appointment of the president of the Tigbantay Wahig to the newly formed Natural Resource Management Council of the municipality. This created a direct link between the water monitors and government policy makers, and was in accord with the trend toward greater citizen participation in governance, provided for in the new Local Government Code.

## Other Effects on Policy

In addition to the actions taken by the municipal government, the water quality project has affected decisions and policies of certain *barangays* and the local school system. In one recent case, a *barangay* leader in Lantapan was interested in tapping some mountain springs to convey drinking water to several household of the *barangay*. She requested the services of the water monitors to determine the bacterial level of the water prior to making the final decision of installing the pipes. The tests revealed that some of the springs had unsafe levels of coliform bacteria, and this type of information was obviously useful in choosing alternative water sources, saving government funds and minimizing the risk of waterborne disease.

Through presentations to schools and involvement of teachers and their students in the water monitoring activities, young people are becoming more aware of environmental indicators and their meaning. Some of the elementary students of Lantapan are now being taught which of the rivers of their municipality are clean and which are polluted (Mrs. Natividad Durias, Head Teacher, Alanib Elementary School, personal communication, July 1997). Beyond awareness of the environmental problems, some of the school students and their teachers have begun restoration activities including tree plantings on riverbanks to prevent soil erosion and sedimentation.

The initially informal way of extending the information of water quality indicators to schools has become more systematized through discussions with representatives of the school district and the Philippine Department of Education, Culture and Sports (DECS). The Secretary of DECS has endorsed the overall SANREM program and has requested that additional steps be taken to enhance outreach and environmental education in schools. Additionally, the water research findings are being used in various courses of the local university, through a faculty partner in the project.

## Conclusion

Largely through the practical development and application of water quality indicators, the local government and community have increasingly acknowledged the advantages of having an ongoing, citizen water quality monitoring program. Regular dissemination of the water information in a variety of forms and to different audiences has done much to convince policy makers and the public of the value of water assessment using simple indicators.

The NRMDP of Lantapan is still in a formative stage, and much remains to be done to have clear policy that results in specific conservation measures. National elections of May 1998 resulted in changes of leadership from president to mayor that might have profound effects on the way NRM planning is conducted. In the meantime, citizen participation in monitoring and restoration activities is increasing and will, hopefully, ensure that elected officials continue to implement their much-needed plan.

### Factors for Successful Use of Indicators in Policy

An evaluation of the project suggests that two key factors combined to create a strong potential for water quality indicators to have lasting policy impacts.

1. *Perceived Need and Receptivity of the Community and Local Government Unit*

The landscape of Lantapan shows obvious signs of degradation that have resulted in a general concern among local residents. As in most rural settings, daily life and well-being depends upon reliable sources of clean water and productive soil without the luxury of expensive inputs and treatments. Lawrence *et al*. (1996) found that farmers of the upland Philippines were "more articulate" about environmental problems than those in the lowlands, and that this pattern also occurred in Bangladesh and India. They attributed this to the fact that farmers are most aware of issues that affect them directly, and that soil erosion and increasingly unreliable or scarce water supplies (often attributed to deforestation) are upland farmers' principal agricultural problems over recent decades. As a result, there is a strong consensus among academics, development workers and farmers on the problems. The Lantapan project supports this observation, and found that many in the community have an interest in environmental integrity that carries a sense of urgency and goes far beyond academic interests.

As authority in natural resource management is decentralized and "people power" flourishes in the Philippines, municipal and provincial planning and policy is increasingly focused on a long-term, sustainable course. The status of NGOs is probably higher in the Philippines than in most Asian countries, and they often interact well with government (Lawrence *et al.* 1996). The ability of Lantapan citizens to enter the political process as accepted stakeholders will be vital, and the formation of the Tigbantay group, with the mentoring and backstopping by an established, Filipino NGO partner in the project will sustain the development and practical application of environmental indicators in the Manupali watershed.

### *2. Participatory Research with Focus on Indicators and Policy*

The SANREM program in general and the water quality project in particular provided financial resources and expertise that synergized with the community interests and political climate of the Philippines. A natural resource research program that stressed intersectoral collaboration, community participation and a landscape scale approach fit well with the predisposition of the local residents and the new Local Government Code.

An added emphasis on environmental indicators (Bellows *et al.* 1995), and on-site coordination of the program and water project enhanced this synergy.

Development of a "menu" of practical, low-tech water indicators (Table 7.2) gave the community options for exploring their local environment and identifying areas needing conservation and restoration. This process was facilitated in Lantapan by adapting techniques that were previously developed in other contexts of citizen monitoring (Deutsch *et al.* 1998). The Philippine experience, in turn, led to further refinement of methods and indicators for applications in other places, including improvements to U.S. programs. The physical features of water make it conducive to measuring a variety of important parameters using simple tests with color-changing chemical indicators (colorimetric methods) and inexpensive equipment. Additionally, the hands-on activities of environmental monitoring are a tremendous motivation for community participation, awareness and action.

**Table 7.2. Summary of community-based, water quality indicators.**

| Issue/Problem | Indicator | Unit of Measure |
|---|---|---|
| General Environmental Degradation | Community Perceptions, Memories, Experiences | Anecdotal, or Questionnaires/Surveys |
| Soil Erosion | Suspended Soils in Water | mg/L TSS |
| | Soil Loss in Water | kg/h soil export |
| Disrupted Stream Flow | Stream Discharge | cu. meters/second flow (monthly measurement) |
| | Flow Variability | coefficient of variation (comparisons: time, space) |
| Bacterial Contamination | Coliform Concentration | no. colonies/mL of water (*E. coli* and other coliforms) |

## Future Needs and Applications of Indicators

As the process of affecting public policy using community-based water quality indicators has progressed over the last few years, three major needs for further research and applications of findings have emerged.

1. *Test and Compare Community-based Indicators with those of Researchers*

Much more needs to be learned about the value of community-based water indicators, and their application to scientific knowledge and natural resource management. It is conceded that these indicators lack the precision of more sophisticated tests that are commonly used by researchers. Moreover, the typical sampling times, locations and frequencies of citizen monitors often miss rare but significant events affecting water quality, such as strong storms or pollution spills. In the case of the Lantapan project, TSS values collected near the stream surface may be lower than those near the stream substrate, and stream discharge and *E.coli* concentration measurements probably did not capture the extremes of an annual cycle (as would be detected by continuous monitoring equipment).

The lack of precision, and possible bias that may stem from community-based monitoring techniques must be weighed against the advantages of simplicity, mobility, cost-effectiveness and local relevance. An underlying question is how useful such measurements and derived indicators are *for environmental managers and policy makers* (such as the local government unit of Lantapan). What are the limits and constraints of the community-based approach, and does it capture enough information to be consistently valuable for environmental assessment and policy recommendations? Specific answers to these questions are important to pursue and would require side-by-side studies using different levels of analyses.

Some of the community-based indicators were similar to indicators developed by research organizations, and raise intriguing questions of comparability. For example, the Lantapan water monitoring study found that abrupt increases in TSS occurred when forest cover dropped below 30% (Fig. 7.5). A threshold of 30% minimum cover before severe environmental degradation was also recently determined for upland tropical forests by the International Centre for Research in Agroforestry (Dr. Dennis Garrity, ICRAF Forest Research and Development Center, personal communication, January 1997).

*2. Apply Indicators to Restoration Activities*

After five years of research in Lantapan, the community and local government unit is ready to incorporate environmental indicators into specific action plans to restore degraded areas or "hot spots" within the landscape. The water quality indicators have the potential to not only identify these areas more quickly, but to be a useful tool for evaluating the effectiveness of restoration activities.

Intended applications include the use of the TSS indicator to identify specific streamside areas that have disproportionate amounts of soil erosion and stream sedimentation. Concentrations of *E. coli* in piped water may be used to identify specific areas of the public drinking water system needing repair, and to make a stronger case in municipal grant proposals for federal aid to do extensive pipe replacements. This indicator of water safety may also be used to quickly evaluate the existing mountain spring sources of public water, as was already begun by one barangay leader of Lantapan. Such strategies are in accordance with national policies which "are likely to underemphasize new water supply projects and focus instead on changes leading to more efficient utilization and management of water resources" (Rola 1997).

Environmental protection policies in Lantapan will probably also include recommendations on soil, water and biodiversity conservation measures such as the establishment of streamside (riparian) zones, selected reforestation, ravine restoration and contour farming. A variety of simple indicators could help guide this process.

*3. Extend Development and Use of Indicators Beyond Lantapan*

Several initiatives are in progress to extend the methodology and significant findings of the research program, including environmental indicators, beyond Lantapan. The Provincial Planning and Development Office (PPDO) of Bukidnon has facilitated a forum in which the water project and key indicators have been presented to policy makers and planners in the 15 other municipalities of the province. The PPDO also maintains records of how municipalities use the internal revenue allotment from the federal government, and they plan to work with and encourage them to apply portions of the allotment to natural resource management (Mr. Antonio Sumbalan, PPDO of Bukidnon, personal communication, January 1997).

Additional outreach activities have included presentations regarding community-based water monitoring and indicators to scores of college and university faculty at a national seminar and workshop on environmental education and management at Central Mindanao University. The level of response and enthusiasm toward the water quality indicators suggested that significant impacts on water management could be promoted throughout the country via university researchers.

Because of strong program partnerships within the Philippine national government, the approach of local environmental management that has begun in Lantapan can be formally extended throughout the country. Already, the establishment of indicators of sustainability from research in Lantapan has contributed to the implementation of the Philippine Agenda 21 (Dr. William Dar, Executive Director, Philippine Council for Agriculture, Forestry and Natural Resources Research and Development, personal communication, July 1997). The strategy of the SANREM program in coming years is to continue this process of extension throughout southeast Asia and in other regions of the world.

## Lessons Learned

A major strength of collaboration in participatory, environmental indicator research is that development and extension of information and community action are occurring simultaneously. Instead of a traditional model of conducting the research in isolation from the local community, then trying to extend the significant findings to them through such things as technology transfer and the media, the citizens, community organizers and scientists have learned together. The startup of this collaborative, indicators research project was relatively slow and expensive, but initial results indicate that the potential for lasting benefits and project sustainability are much higher than if attempted by a community, NGO, university or government agency in isolation.

Most scientists are aware that excellent and important research findings often go underutilized because they do not enter the political process. Instead, the data remain in professional journals and away from meaningful action. The type of information needed by policy makers for natural resource management planning should be science-based, but need not necessarily meet all the requirements of the scientific community with regard to precision and rigor. This is especially true in watersheds that are degrading rapidly, with irreversible consequences. In these situations, application of partly understood conservation practices, with full community involvement, may be far better than waiting for a "complete" scientific understanding.

Glover (1995) noted that rigorous research requires a clear definition of a problem and the variables to be measured, but the objectives of government policies and programs tend to be loosely defined and sometimes contradictory. He added that, "In the research domain, there is no single recipe for policy impact. Luck and persistence, along with good science, are vital ingredients." The case study of Lantapan suggests that when science and persistence directed toward natural resource management comes from within the community, there is a much greater probability of policy impact.

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