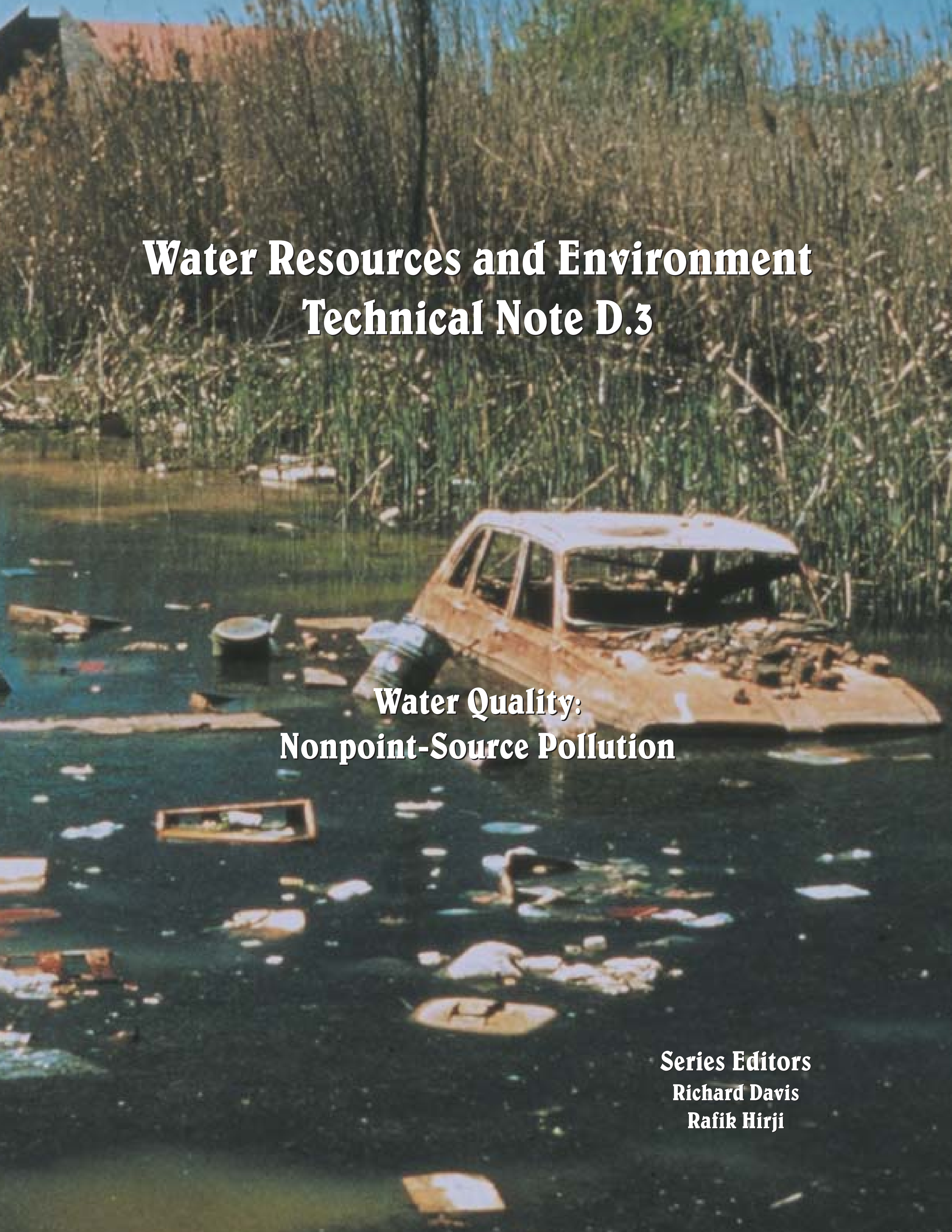

Water Resources and Environment
Technical Note D.3

Water Quality:
Nonpoint-Source Pollution

Series Editors
Richard Davis
Rafik Hirji

Water Resources and Environment

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The World Bank
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Water Resources and Environment Technical Notes

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Unless otherwise stated,
all dollars = U.S. dollars.
All tons are metric tons.

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Urban river pollution

This series also is available on the World Bank website (www.worldbank.org).

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FOREWORD

The environmentally sustainable development and management of water resources is a critical and complex issue for both rich and poor countries. It is technically challenging and often entails difficult trade-offs among social, economic, and political considerations. Typically, the environment is treated as a marginal issue when it is actually key to sustainable water management.

According to the World Bank's recently approved Water Resources Sector Strategy, "the environment is a special 'water-using sector' in that most environmental concerns are a central part of overall water resources management, and not just a part of a distinct water-using sector" (World Bank 2003: 28). Being integral to overall water resources management, the environment is "voiceless" when other water using sectors have distinct voices. As a consequence, representatives of these other water using sectors need to be fully aware of the importance of environmental aspects of water resources management for the development of their sectoral interests.

For us in the World Bank, water resources management–including the development of surface and groundwater resources for urban, rural, agriculture, energy, mining, and industrial uses, as well as the protection of surface and groundwater sources, pollution control, watershed management, control of water weeds, and restoration of degraded ecosystems such as lakes and wetlands–is an important element of our lending, supporting one of the essential building blocks for sustaining livelihoods and for social and economic development in general. Prior to 1993, environmental considerations of such investments were addressed reactively and primarily through the Bank's safeguard policies. The 1993 Water Resources Management Policy Paper broadened the development focus to include the protection and management of water resources in an environmentally sustainable, socially acceptable, and economically efficient manner as an emerging priority in Bank lending. Many lessons have been learned, and these have contributed to changing attitudes and practices in World Bank operations.

Water resources management is also a critical development issue because of its many links to poverty reduction, including health, agricultural productivity, industrial and energy development, and sustainable growth in downstream communities. But strategies to reduce poverty should not lead to further degradation of water resources or ecological services. Finding a balance between these objectives is an important aspect of the Bank's interest in sustainable development. The 2001 Environment Strategy underscores the linkages among water resources management, environmental sustainability, and poverty, and shows how the 2003 Water Resources Sector Strategy's call for using water as a vehicle for increasing growth and reducing poverty can be carried out in a socially and environmentally responsible manner.

Over the past few decades, many nations have been subjected to the ravages of either droughts or floods. Unsustainable land and water use practices have contributed to the degradation of the water resources base and are undermining the primary investments in water supply, energy and irrigation infrastructure, often also contributing to loss of biodiversity. In response, new policy and institutional reforms are being developed to ensure responsible and sustainable practices are put in place, and new predictive and forecasting techniques are being developed that can help to reduce the impacts and manage the consequences of such events. The Environment and Water Resources Sector Strategies make it clear that water must be treated as a resource that spans multiple uses in a river basin, particularly to maintain sufficient flows of sufficient quality at the appropriate times to offset upstream abstraction and pollution and sustain the downstream social, ecological, and hydrological functions of watersheds and wetlands.

With the support of the Government of the Netherlands, the Environment Department has prepared an initial series of Water Resources and Environment Technical Notes to improve the knowledge base about applying environmental management principles to water resources management. The Technical Note series supports the implementation of the World Bank 1993 Water Resources Management Policy, 2001 Environment Strategy, and 2003 Water Resources Sector Strategy, as well as the implementation of the Bank's safeguard policies. The Notes are also consistent with the Millennium Development Goal objectives related to environmental sustainability of water resources.

The Notes are intended for use by those without specific training in water resources management such as technical specialists, policymakers and managers working on water sector related investments within the Bank; practitioners from bilateral, multilateral, and nongovernmental organizations; and public and private sector specialists interested in environmentally sustainable water resources management. These people may have been trained as environmental, municipal, water resources, irrigation, power, or mining engineers; or as economists, lawyers, sociologists, natural resources specialists, urban planners, environmental planners, or ecologists.

The Notes are in eight categories: environmental issues and lessons; institutional and regulatory issues; environmental flow assessment; water quality management; irrigation and drainage; water conservation (demand management); waterbody management; and selected topics. The series may be expanded in the future to include other relevant categories or topics. Not all topics will be of interest to all specialists. Some will find the review of past environmental practices in the water sector useful for learning and improving their performance; others may find their suggestions for further, more detailed information to be valuable; while still others will find them useful as a reference on emerging topics such as environmental flow assessment, environmental regulations for private water utilities, inter-basin water transfers and climate variability and climate change. The latter topics are likely to be of increasing importance as the World Bank implements its environment and water resources sector strategies and supports the next generation of water resources and environmental policy and institutional reforms.

Kristalina Georgieva
Director
Environment Department

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This Note was drafted by Gary Wolff of the Pacific Institute for Studies in Development, Environment, and Security, building on an earlier draft by Random Dubois of the United Nations Food and Agriculture Organization.

Within the Bank, David Hanrahan and Manuel Marino reviewed the draft and provided helpful comments.

INTRODUCTION

Water quality problems can arise from the discharge of pollutants from both point sources–specific points of discharge of high-pollutant concentration such as sewers–and nonpoint, diffuse sources–low-concentration sources covering a large area. Point-source discharges from sewers, wastewater treatment plants, and factories are visible and can be chemically characterized relatively easily. Historically, they have been the focus of efforts to control surface water pollution in both developed and developing countries. However, substantial loads of pollutants can also enter water bodies from diffuse, or nonpoint sources (NPS). Runoff from agricultural activities is a typical NPS pollution source, since it can occur throughout the agricultural portions of a watershed rather than from a small number of well-defined points. This form of pollution is much less visible and much more difficult to characterize, and has not been subjected to the same level of management as point-source pollution.

The Bank has recognized the importance of minimizing pollution from diffuse sources for many years. The Bank's *Environmental Assessment Sourcebook* identifies erosion, overuse of biocides, and soil salinization as contributing to downstream water quality problems. Numerous Bank-funded projects, such as the Baltic Sea Joint Comprehensive Environmental Action Programme, have assisted countries in reducing NPS pollution. More recently, the Bank's Environment Strategy describes the impacts of NPS pollutants–such as sediments, nutrient losses, and agrochemicals–on water users, especially the poor.

Photo by Curt Carnemark, World Bank

Highland catchment, Pakistan

Three of the Notes deal with water quality. Technical Note D.1 discusses general concepts on water quality and integrated water resources management, the objectives of water quality assessment, and the iterative steps in water quality assessment and protection. Technical Note D.2 focuses on point sources of pollution, particularly discharges from wastewater treatment plant. This Note, D.3, looks at diffuse sources of water pollution, including the causes and effects of nonpoint source pollution; successful approaches to managing NPS; physio-chemical and biological techniques for monitoring NPS; and the integration of policy-level and local-level actions needed to tackle NPS. Of these, community involvement is critical because of the difficulty of identifying and impossibility of monitoring the myriad sources that, by definition, constitute NPS.

CAUSES AND EFFECTS OF NONPOINT SOURCE POLLUTION

NPS pollution is more difficult to control than point sources for two reasons. First, the sources, by definition, occur over large areas at low concentrations, and so are very difficult to identify and quantify. Secondly, they often involve large numbers of property owners who can be difficult to reach efficiently. Even when there is only one or a small number of property owners involved–for example, when sediments are originating from a newly logged forest–it can be difficult to manage the problem because of its surface extent.

There are a number of NPS pollutants. Sediments can originate from any activity that disturbs the soil surface, such as construction, agricultural activities such as tilling, or forestry operations. Nutrients, salts, and pathogens from farms, and heavy metals and acid drainage from mining projects, are other contaminants coming from diffuse sources in rural areas. Other sources of NPS pollution have occurred only since the industrial revolution. These include pesticides and other agrochemicals in runoff from farms; oil, grease, metals, and chemicals from urban areas; and deposition of airborne pollutants released from cars, factories, and other atmospheric sources. In areas with many on-site sanitation facilities (such as septic tanks or pit latrines), nonpoint pollution may result from leaching or overflow, especially during rainstorms.

Although NPS pollutant concentrations tend to be much lower than those from point sources (for example, sewers or other "end-of-pipe" discharges), the environmental impacts of NPS pollution can be as large or larger than those from point sources. This is because the source areas are often so extensive that large quantities (loads) of pollutants reach water bodies, despite the low source concentrations (Box 1). When point-source discharges are relatively well-controlled, NPS becomes the major contributor to water pollution. The U.S. Environmental Protection Agency, for example, reports that more than half the remaining water quality problems in the United States are from NPS pollution now that effluent discharges have been controlled.

NPS pollution can still be a major contributor to water pollution even when point sources are not well-controlled. For example, eutrophication due to

BOX 1.
NPS POLLUTION IN LAKE VICTORIA

Lake Victoria is bordered by Kenya, Uganda, and Tanzania. It is an important source of food and water, as well as transport and irrigation, for the estimated 25 million people living around its shores. The lake provides one of the major export commodities, the Nile perch fishery, for the riparian countries. Eutrophication has been worsening since the 1960s, to the point where about 25 percent of the lake's volume is now unavailable to most fish species, including the Nile perch, because of low oxygen levels.

The extent of eutrophication is controlled by the amount of phosphorus entering the lake. The phosphorus comes primarily from NPSs, particularly atmospheric deposition (estimated 25,000 tons per year) and rivers (about 5,700 tons per year). The riverine input is particularly significant in enclosed areas such as Winam Gulf. Point sources, such as sewage treatment plants, contribute relatively minor amounts in comparison, even though these plants are poorly maintained and, in some cases, do not operate at all. The large atmospheric input of phosphorus is unusual and is a consequence of the large surface area of the lake and the prevalence of dust and smoke from poor agricultural practices in the region.

Although the origins of the atmospheric phosphorus are uncertain, it is likely that agricultural practices that maintain ground cover (to prevent dust storms) and avoid burning crop stubble and grasslands will reduce this source of nutrient input. Riverine NPS nutrient inputs are primarily the result of erosion of agricultural lands, many of which have been converted from forests and are highly susceptible to soil loss.

excess nutrient loads carried by the Danube River is widely recognized as the most serious problem facing the Danube River and the Black Sea. The northwestern shelf of the Black Sea is severely degraded by eutrophication. A study by the Black Sea Environmental Program (BSEP) found that more than half of the nutrient load into the Danube River come from agricultural diffuse sources, while about 25 percent is from households and 12 percent from industrial sources. These numbers are typical of many eastern European countries.

Although this Note is applicable to any of these sources, it will focus particularly on NPS pollution from agriculture because of the importance of this source in many regions of the world.

CONSEQUENCES OF NONPOINT SOURCE POLLUTION

NPS pollution from a wide range of land use operations can impose significant costs on users of rivers, lakes, estuaries and near-shore areas, and groundwater.

Wetlands and productive nearshore areas can become blanketed in silt from erosion of agricultural lands, forestry operations, and new urban developments, thereby reducing the services–such as food and fiber–they provide to dependent communities. These costs are often borne disproportionately by the poor. The lifespan of reservoirs and the output from hydropower plants can be severely reduced because of siltation, and pumping equipment can be damaged from abrasion. For example, the high suspended sediment load in Kenya's Athi River, largely due to upstream land clearance, caused serious problems to the water supply intake for Mombasa, resulting in the eventual abandonment of the Mombasa Water Supply intake. The Sabaki River Waterworks, constructed in the late 1970s to supply Mombasa, required the inclusion of extensive primary settling basins before the conventional sedimentation clarifiers, which cost over $1 million.

Nutrients, washed off cropland, forestland, and poorly drained urban areas not only represent a loss for landowners, but can cause eutrophication and excessive plant growth–algal blooms or nuisance exotic plants such as *Salvinia*–when physical conditions are suitable in downstream water bodies (see Note G.4). Phosphorus is often the nutrient that controls the extent of freshwater algal blooms; it is usually attached to sediment particles originating from diffuse sources. Sediment-bound phosphorus is released more slowly into the water than is phosphorus from point sources such as sewage treatment plants, which typically contain a higher proportion of organic phosphorus and dissolved orthophosphorus. Consequently, diffuse-source phosphorus can support algal blooms for extended periods.

There are a number of studies that estimate the costs of erosion and soil loss. An example from Zimbabwe illustrates the cost of just the nutrient loss component of soil erosion to landowners (Box 2). Nutrient loss also imposes significant costs on downstream communities. An Australian study has estimated the cost of downstream eutrophication from nutrients, mostly originating from NPS pollution, at between $90 million and $120 million per year.

Surface flows and groundwater inflows can carry salts into streams when groundwater tables rise after land is cleared for agriculture. This occurs in regions where there are naturally high salt concentrations because of old marine deposits or depositions from prevailing oceanic winds. These increases in riverine salinity impose significant costs on downstream irrigation and urban water users, as well as affecting the ecology of the rivers and lakes. For example, increasing dryland and riverine salinity is now accepted as the greatest environmental problem facing Australia; some 2.6 million hectares are currently affected by dryland salinity at a cost of more than $250 million a year to agriculture–without including the costs imposed on downstream and environmental water users.

Groundwater is more often contaminated from NPS pollution than from point sources. For example,

BOX 2.
THE COST OF SOIL EROSION IN ZIMBABWE

In the mid-1980s, a study assessed the cost of soil erosion to the Zimbabwean economy. The study concentrated on the issue of nutrient depletion, and monetized it by estimating the replacement costs of the lost nutrients. Data were compiled from experimental plots to determine the quantitative relationships between soil losses and losses of nitrogen, phosphorus, and organic carbon. These relationships were extrapolated to the dominant farming systems in the country, allowing the losses to be estimated at the national level. Finally, the cost of nutrient losses was computed by calculating the equivalent cost of fertilizers and soil amendments needed to replace the nutrients.

The highest erosion rates were found in arable and communal grazing lands. On average, 1.6 million tons of nitrogen, 0.24 million tons of phosphorus, and 15.6 million tons of organic matter were estimated to be lost annually. The financial cost based on mineral fertilizer replacement was $1.5 billion per year, which was more than 16 percent of Zimbabwe's agricultural production and equivalent to 3 percent of national GDP.

A more complete measure of economic cost would account for physical damage to farms from the erosion, as well as downstream and off-site damages. These include loss in irrigation or flood control capacity due to sediment; expenses to remove sediment from river beds, lakes, and reservoirs by dredging; and damage to fisheries, tourism, recreation, and habitat downstream.

Source: Norse, D., and R. Saigal. 1993."National economic cost of soil erosion in Zimbabwe," in *Environmental Economics and Natural Resources Management in Developing Countries*. Washington, D.C.: CIDIE/ World Bank.

nearly half of China's groundwater has been impaired by NPS pollutants from agricultural sources. Another recent study found that 16 percent of on-farm wells in Poland had levels of nitrate in excess of recommended drinking water levels. Nitrates in groundwater can cause severe health problems in infants– the so-called "blue-baby" syndrome.

While the above examples illustrate the costs of specific forms of pollution, there is relatively little research on the total economic costs of environmental degradation caused by NPS pollution. One attempt to account for all aspects of the cost of soil erosion estimated that the worldwide off-farm costs of soil erosion are about $150 billion annually.

THE ESSENTIALS OF NPS MANAGEMENT

The most successful interventions to control NPS pollution have been preventive, although polluted runoff can sometimes be treated in, for example, natural and constructed wetlands (see Note G.3). The most cost-effective interventions are usually those that invest in widespread changes in behavior and the decentralized investments to support those changes, rather than centralized infrastructure.

Three lessons have emerged from Bank experience with NPS pollution. Successful initiatives require:

- A partnership approach
- Long-term commitments
- An integrated approach

PARTNERSHIP APPROACH

The traditional "command and control" approach is increasingly being replaced with one that requires a greater level of industry involvement for the regulation of point-source pollution (see Note D.2). However, command and control has never been effective for NPS pollution. NPS pollution is much more difficult to attribute to an individual source (for example, one farmer), making both monitoring and enforcement of discharge standards nearly impossible. Even when NPS pollution clearly originates from a single landowner, such as a large forestry enterprise, it can still be difficult to control because of its areal extent. Consequently, the most successful and cost-effective programs encourage landusers to take responsibility for the NPS pollution they generate and to adopt improved management techniques. This requires the traditional regulation-monitoring-enforcement model to be replaced with an approach that treats all users of land as stakeholders in a partnership engaged in sustainable land use.

Under this approach, farmers and other landusers receive education, technical support, and financial assistance in their efforts to conserve soils, protect water resources, and maintain habitats. Environmental investments become part of a strategy that promotes equitable development and creation of nonfarm employment opportunities.

Local implementation is critical in this approach. Those who are most closely associated with land and water resources are best positioned to guide interventions knowledgeably, and to assure long-term results through their commitment. Even more importantly, effective implementation requires ownership of programs by those directly involved in agriculture or other land uses. This ownership can only be achieved through local landusers' meaningful participation in identification, design, and implementation of environmental management plans. Government agencies and development organizations need to adopt participatory approaches, requiring in many cases significant changes in current planning systems, methods of project review and approval, and training programs. Box 3 presents two success stories.

LONG-TERM COMMITMENT

Behavioral change is usually slow. The motivation for people to change develops gradually through many information channels. Even when the types of changes are understood, the particular changes

BOX 3.
INTEGRATED PEST MANAGEMENT TO REDUCE PESTICIDE USE IN RICE PRODUCTION

Integrated pest management (IPM) is a collection of techniques to control agricultural pests, including the use of pesticides when appropriate. IPM replaces some pesticide use by bio-control agents and physical interventions, and so reduces the NPS pollution of waterbodies by pesticides. IPM is knowledge-intensive, and requires extensive collaboration among farmers within a region, as well as among farmers, research institutions, and governmental entities.

An Indonesian national IPM policy was announced in 1986 because extensive areas of rice production were infested with the brown planthopper (*Nilaparvata lugens*), which could not be controlled by conventional means. The IPM program included bans on some insecticides, reduction of subsidies for pesticides, and strengthening of research and extension institutions. By mid-1992, about 1,000 pest observers, 3,000 extension staff, and at least 150,000 farmers had been trained to observe and understand the local ecology of the planthopper and its natural enemies and to follow simple threshold rules for action. During 1987-90, the volume of pesticides used on rice fell by more than 50 percent, while yields increased about 15 percent. Farmers' net profits were estimated at $18 per-IPM-trained farmer per year, achieved with an average investment per farmer of about $4. The federal government benefited from a $120 million-per-year reduction in pesticide subsidies, and downstream water users benefited from reduced pesticide loading in streams and rivers.

In Bangladesh in 1992, the NOPEST project tested eight IPM management techniques in two rice growing districts. Farmers participating in NOPEST cut pesticide use by 75 percent, while increasing yields by about 10 percent, even though all the IPM strategies were not effective. A subsequent program named INTERFISH was designed to reach 22,500 farming households. Participatory learning was emphasized in both NOPEST and INTERFISH. In 1994, INTERFISH boosted yields by an average of 7 percent, while reducing the cost of pesticides.

Sources: Schillhorn van Veen, Tjaart W., Douglas A. Forno, Steen Joffe, Dina L. Umali-Deninger, and Sanjiva Cooke. 1997. *Integrated pest management*. Environmentally sustainable development studies and monographs series no. 13. Washington: the World Bank.

Srivastava, Jitendra P., Nigel J.H. Smith, Douglas A. Forno. 1999. *Integrating biodiversity in agricultural intensification*. Washington: the World Bank.

required may take time to develop. For example, an understanding that excess nutrients from agriculture are destroying the fisheries of the Black Sea has not been sufficient to give farmers either the motivation or the information needed to change farming practices. They need to feel responsible for the effects of the nutrient-enriched runoff, and may also need technical assistance through pilot and demonstration projects for new technologies or practices. Projects to reduce NPS pollution need to explicitly acknowledge that change will take time, perhaps a decade or more, and be budgeted and managed accordingly.

The most effective strategies for controlling NPS pollution embed NPS issues in the development and land-use regulatory process. For example, all farmers can be required to implement best management practices (BMPs) for nutrient management. Although a requirement of this type is perceived as a financial burden initially, it becomes a part of standard practice over time, and often more than pays for itself by reduced off-farm damages. An example of such a long-term approach is the U.S. EPA strategy for controlling NPS pollution from animal feeding operations (Box 4). This strategy will probably take 20 years to fully implement.

INTEGRATED STRATEGY

Also central to long-term success is the use of an integrated strategy that places the management of environmental issues in agriculture and rural settlements within the greater context of urban and rural production activities as well as environmental management efforts in riverine, estuarine, and coastal areas. For example, the Baltic Sea Joint Comprehensive Environmental Action Programme (JCP) integrates policies and interventions in a way that allows individual interventions to contribute to the cumulative success of the program. Coordinated pursuit of both preventive measures for NPS pollution and curative measures for point-source pollution enhances the effectiveness of both categories of pollution control.

Land-use practices are the source of most waterborne NPS pollutants. Furthermore, maintenance of coastal lagoons and wetlands–and the fisheries and tourism that depend on them–is often linked to control of NPS pollution. Institutional strengthening, regulations, and incentive mechanisms, and identification and transfer of lessons learned, would help exploit these linkages and maximize the net benefits of interventions and policies.

BOX 4.
THE U.S. NATIONAL STRATEGY FOR POLLUTION MANAGEMENT FROM ANIMAL FEEDING OPERATIONS

There are approximately 450,000 animal feeding operations (AFOs) in the United States. Calculations based on the 1992 National Water Quality Inventory suggest that at least 7 percent of U.S. waterbodies are impaired by pollution from a specific type of feedlot–known as concentrated animal feeding operations, or CAFOs. The U.S. EPA and U.S. Department of Agriculture (USDA) national strategy calls for mandatory nutrient management plans for CAFOs (and voluntary plans for all other AFOs) to be prepared and implemented by the year 2008. The year 2008 is "a national expectation" for voluntary plans, not a requirement. Current estimates are that 15,000 to 20,000 mandatory plans will be required, which implies that around 95 percent of plans will be voluntary. Since there are no penalties for failure to prepare a voluntary plan, the NPS problem associated with AFOs will require a regulatory and social commitment of at least a decade, and probably considerably more.

The strategy provides financial incentives for voluntary compliance. These include $174 million under the Environmental Quality Incentive Program in 1999, up to $40 million per year from Clean Water Act grant programs, and up to $600 million per year in low-interest loans from the Clean Water State Revolving Loan Fund. Although these total over $800 million per year, the annual cost of implementing best management practices at all AFOs is estimated to be around $4.5 billion. Again, a long-term regulatory and social commitment will be required to bridge this funding gap.

Agricultural policies have often overlooked these links. For example, subsidies for irrigation water, fertilizers, pesticides, land-clearing for cattle, and other activities have been direct contributors to NPS pollution from agriculture. Attempts to change farmer behavior without changing the distorted economic context within which they make decisions is difficult and often ineffective. These subsidies can often be shown to be economically inefficient if the wider environmental context (including downstream users dependent on good quality water) is included in the decisions.

MONITORING AND ASSESSING NPS POLLUTION

AMBIENT AND RUNOFF WATER QUALITY OBJECTIVES

Because NPS pollutants originate across large areas, monitoring or assessing their impacts can be prohibitively expensive. In some instances, such as regional studies that establish a baseline, this expense is justified. Periodic, comprehensive water quality assessments are essential for long-term planning and understanding of how water quality is changing as human uses of land and water resources change. Nonetheless, there are many instances in which considerably less expensive efforts are appropriate.

Beneficial uses of a waterbody range from withdrawals for drinking and other domestic purposes, use for fishing and other food collection, to transportation purposes, to *in-situ* uses such as wildlife habitat or protection of biodiversity. NPS pollution can impair any of these beneficial uses. Actual or potential downstream beneficial uses strongly influence the selection of ambient water quality objectives, as well as water quality objectives for runoff. The process of establishing ambient water quality objectives for different uses is discussed in Note D.1.

MODELING NPS POLLUTANT TRANSPORT

Pollutant transport modeling is a useful tool for linking ambient water quality objectives with the choice of technical interventions and policies for controlling runoff. Nonpoint-source pollutants move in very complicated ways from their sources through both surface and sub-surface pathways into receiving waters. The pollutants can undergo chemical changes en route and, without modeling, it is very difficult to assess the benefits of various interventions.

For example, a BMP might involve modifying the seasonal timing of manure application to fields in order to reduce nutrient leaching during heavy rains. A model that simulates leaching, using actual rainfall, soil type, and topography can show the soil types for which this BMP works well. Such a model is designed for field-scale application. A watershed-scale model can be used to find out whether the BMP will have watershed-scale benefits sufficient to justify education, training, and demonstration projects that are targeted at less than half the farm area in the basin.

PHYSICAL AND CHEMICAL MONITORING

Monitoring before and after policies are adopted or interventions occur is obviously necessary to determine whether policies or actions are successful. Note D.1 describes the establishment of a monitoring program and the standards for the most common pollutants–here we discuss just the issues relevant to NPS pollutants.

In some cases, physical or chemical testing of runoff or ambient water quality is sufficient to identify a problem and to monitor progress toward solving it. For example, runoff may mostly exit a large farm in a few drainage ditches. If so, it is possible to directly evaluate different tillage practices for their impact on soil erosion, or different fertilizer application rates on nitrogen and phosphorus loads in runoff. Some of the water quality parameters that can be readily measured with physical or chemical monitoring are described below.

Nutrients. Nitrogen and phosphorus are sometimes referred to as macro-nutrients, since plants such as water weeds and nuisance algae use them in relatively large quantities. Nitrogen can take many different chemical forms in water, so there are a variety of measurements and reporting formats for nitrogen. They are described in Box 5.

Phosphorus occurs in natural water almost solely as phosphates (PO_4 ions). Orthophosphates are applied to agricultural land or urban landscapes as fertilizers; phosphates are present in laundering and cleaning detergents; and organically bound phosphates are released by biological processes such as degradation of organic materials or conversion of orthophosphates by living creatures. Improperly managed manure is a significant source of organic phosphorus in some rural areas with high livestock densities. Total phosphorus (TP) is a measure of the weight of phosphorus present in all forms of phosphorus in a water sample and is commonly monitored because of the relative simplicity of the laboratory procedures. However, like nitrogen, the most appropriate form of phosphorus to monitor depends on the beneficial use of the waterbody. If algal blooms are a concern, then bio-available phosphorus (filterable reactive phosphorus, or FRP) is a more relevant measure than TP, since a considerable portion of the phosphorus may not be readily available to algal growth.

Other nutrients are also essential for plant growth, but usually in much smaller quantities than nitrogen or phosphorus. They are usually not monitored because of the costs involved, unless there is good reason to believe they may be controlling plant growth.

Silt and sediment. Sediment loads in water can be determined through two tests. A settleable solids test measures the solids that will naturally be deposited when water velocity is low. Settleable solids are important because they are the fraction of total sediments that reduce the available space in a reservoir, flood control channels, or drainage ditches. They can also destroy the habitat of bottom-dwelling (benthic) organisms. However, the finest fraction of the sediment load will not settle even when surface waters become still. These fine sediments are measured as total suspended solids (TSS). TSS and, depending on turbulence, sometimes settleable solids, are important to quantify because they determine the loss of water clar-

Box 5.
Monitoring nitrogen

Nitrogen takes numerous forms in water. Ammonia, organic nitrogen, nitrites, and nitrates are the most common forms. High ammonia (NH_3) concentrations can be toxic to aquatic species, but dissolved ammonia will eventually volatilize or oxidize if the waterbody is well mixed. Organic nitrogen includes the many nitrogen compounds present in human and animal wastes. Total Kjeldahl nitrogen (TKN) is the sum of ammonia nitrogen and organic nitrogen.

Nitrite (NO_2) and nitrate (NO_3) nitrogen are the two oxidized forms of nitrogen. Nitrites oxidize to nitrates relatively quickly in most waters. Ammonia and organic nitrogen are also oxidized to nitrates when bacteria are present that can metabolize these substances. Total nitrogen (TN) is the sum of TKN, nitrite nitrogen, and nitrate nitrogen. Because of the simplicity of its measurement, TN is often used as a summary measure for monitoring purposes.

The choice of which form of nitrogen to monitor depends on the beneficial use and characteristics of the waterbody. For example, monitoring groundwater for nitrates in order to avoid nitrate poisoning (methemoglobenemia, or "blue-baby syndrome") may be misleading if dissolved oxygen is very low in the groundwater. Monitoring TN may be a more appropriate procedure, since this shows the potential for NO_2 to form.

ity (turbidity) and hence the ability of light to penetrate into the water column and support plant growth. Benthic algae and many submerged aquatic plants cannot establish in turbid waters (see Note G.4).

Photo by R. Hirji, World Bank

Siltation of gauging station, Pangani River, Tanzania

Salts. Naturally occurring freshwaters contain dissolved salts. Improper irrigation practices can lead to salt buildup in soils, which may be removed by subsequent drainage projects (see Notes E.1 and E.2). Salts may also be leached by rainfall from soils after the vegetative cover is removed–as a result of clearcutting of forests or excavation–and water tables rise.

Salinity is one of the simplest pollutants to measure. Total salt concentration can be measured by simple electrical conductivity (EC) tests in the field, or by total dissolved solids (TDS) analysis in the laboratory.

Bioaccumulative substances (persistent organic pollutants). Organochlorine-based pesticides like DDT and DDE and other bio-accumulative substances like PCBs are of particular concern because they accumulate in the fatty tissues of living organisms, and become more concentrated in those tissues as they go up the food chain. For example, autopsies of dead Beluga whales that washed up on the shore of the St. Lawrence River in Canada revealed high concentrations of the pesticide Mirex. Careful research showed that Mirex was not used in the feeding area of the whales, but had accumulated 600 miles away in the tissues of migrating eels that were eaten by the whales.

Sometimes these compounds are referred to as persistent organic pollutants (POPs). The twelve that are most troublesome (the "dirty dozen") are, with some repetition:

- Pesticides: aldrin, dieldrin, chlordane, toxaphene, DDT, endrin, mirex, heptachlor
- Industrial chemicals: polychlorinated biphenols (PCBs), hexachlorobenzene
- Byproducts of incineration: dioxins, furans, PCBs, hexachlorobenzene, toxaphene.

All can enter waterbodies as NPSs, since incineration byproducts are often deposited on land or absorbed by water droplets in the air. When a land-based source exists, such as pesticides from a farm, these substances can sometimes be detected in runoff waters relatively near that source. As they move downstream in a watershed they often fall below the analytical detection limits in water, even though these detection limits are very low (typically, parts per trillion).

For some compounds, however, even concentrations near or below the detection limits are believed to be harmful. For example, the worm fumigant, ethylene dibromide (EDB), once widely used in agriculture, is banned in the United States. The State of California Department of Health Services has issued an "action level" for it in water sources of 50 nanograms per liter (50 parts per trillion), which is below the detection limit in some instances. Consequently, failure to find these substances in runoff does not indicate that it is not present or not harmful. In these cases, chemical monitoring cannot assess whether a potential problem exists and biological monitoring should be used, as discussed below.

There are other reasons for using biological monitoring. There are over 10,000 organochlorine compounds in commercial use today, and it is not feasible to analyze water samples for all of them. In addition, impacts on living organisms from these compounds are very complex, particularly when there are multiple compounds present. Even if chemical analysis identifies which compounds are present, their impact is often impossible to assess from chemical characterization alone. In these cases, biological monitoring provides a more useful approach.

Other organic compounds. Other classes of organic compounds that can enter waterbodies from NPSs include chlorinated phenoxy acid herbicides (e.g., 2,4-D and silvex), polyaromatic hydrocarbons (PAHs), petroleum hydrocarbons, phenols, and oil and grease. Ambient water quality objectives exist for some of these classes of compounds (for example, total phenols) or individual compounds, and some laboratory tests for these parameters are inexpensive (for example, total phenols or oil and grease). As with organochlorines, however, water quality objectives do not exist for most synthetic organic compounds because their impacts on living things are not well understood. Unless a particular synthetic compound is (or has been) used extensively in an area, chemical monitoring of synthetic organics may be unnecessary, especially since a long-term commitment is required to solve most NPS pollution problems. Again, biological monitoring may be appropriate.

Heavy metals. Ambient water quality objectives have been established for heavy metals for a number of beneficial uses in developed countries. Water quality objectives may exist to protect against acute and chronic toxicity, or just acute toxicity. Acute toxicity causes death of the affected organisms in a short period of time. Chronic toxicity, however, may reduce reproductive success or individual rates of growth, or cause mutations or cancers that reduce normal lifespan. Biological monitoring for acute toxicity is much simpler and less expensive than monitoring for chronic toxicity.

BIOLOGICAL MONITORING

Monitoring the effects of pollutants on aquatic organisms has both advantages and disadvantages over chemical monitoring. Biological monitoring complements rather than replaces chemical monitoring, as discussed in Note D.1.

Biological monitoring can be undertaken in three ways. First, water can be tested for the presence of pathogens by measuring biological organisms that are indicative of pollution sources that may contain pathogens. Second, selected living organisms can be tested for acute toxicity under laboratory conditions. Third, selected living organisms can be tested for chronic toxicity under laboratory conditions.

Monitoring for pathogens with indicator organisms. There is no single procedure that can be used to identify all waterborne pathogens. Because most pathogens are enteric (i.e. they live in the intestinal tracts of warm-blooded creatures), measurement of *escheveria coli* (e-coli) as an indicator of fecal contamination has become the most widely used test in this category. Some enteric pathogens, however, may be present even when e-coli concentrations are low. Protozoa such as *Giardia lamblia*, *Entamoeba hystolica*, and *Cryptosporum*, for example, reproduce through cysts that can survive in conditions where e-coli cannot. There are also bacterial pathogens that are not enteric, such as those in the Legionellacea family, that are widespread in the aquatic environment and cause pneumonia-like outbreaks. Pathogen monitoring must be based on the predominant types of waterborne pathogen-related illnesses in each region.

Monitoring for acute toxicity. Acute toxicity is evident in indicator organisms in relatively short time periods, usually less than 4 days. Acute toxicity tests are usually reported as the lethal concentration (LC) required to kill 50 percent of the exposed organisms in a specified time of observation (e.g., 96-hour LC_{50}). A wide variety of organisms may be tested, but the most commonly used organisms in acute toxicity testing are fish. A wide variety of freshwater and marine or estuarine fish have been used, depending on the particular receiving water of concern. The test species should represent an important economic resource in the receiving water, or an important ecological link in the healthy functioning of the aquatic ecosystem to be protected.

Monitoring for chronic toxicity. Chronic toxicity is not as apparent as acute toxicity. Nonetheless, chronic toxicity may cause changes in appetite, growth, metabolism of food, or reproductive behavior in fairly short periods of time for microscopic organisms. As with acute toxicity tests, test organisms should be selected because of their economic importance (for example, clams) or their ecological significance in the aquatic ecosystem to be protected. For example, growth rates and population densities of the ciliated protozoa *Tetrahymena pyriformis* can reveal chronic toxic effects within a 96-hour period. Ciliated protozoa occur in freshwater, salt marshes, and estuaries worldwide, and are important regenerators of nitrogen and phosphorus deposited in sediments. Consequently, a reduction in their growth rate from NPS toxicity can have important implications for eutrophication and the general health of a marsh.

AN INTEGRATED APPROACH TO NPS POLLUTION CONTROL

An integrated approach to NPS pollution control includes specific interventions and programmatic activities. Source-control interventions prevent or reduce the production of NPS pollution; on-site treatment reduces off-site NPS pollution; and community-scale action controls NPS pollution before it becomes great enough to cause significant economic or environmental problems. For example, soil erosion can be reduced by plowing around the contours of the land rather than down- and up-slope; by filter strips between the plowed area and drainage channels on each farm; or by wetlands that trap soil particles in runoff from a group of farms.

Programmatic activities are categorized in this section based on the scheme developed by the Baltic Sea Joint Comprehensive Environmental Action Programme. There are two major groups of activities and 14 subgroups that provide structure for an overall program, but are not all required for all projects. Source control, on-site treatment, and off-site treatment interventions are discussed within the subgroups for which they are most relevant.

POLICY AND FINANCIAL MEASURES

Increase regional capacity and establish regional objectives. Where a particular watershed crosses jurisdictional boundaries, it is important to develop a regional approach to managing NPS pollution from the watershed. In the Baltic Sea example, an important step was preparation of an Annex on Agriculture to the Helsinki Convention. The Annex is a mechanism by which regional objectives for NPS management can be defined; general guidance at the national level can be provided; local implementation can be mandated; and specific policy linkages can be specified between agriculture and the management of coastal lagoons and wetlands. Another example of regional objective-setting and improvements to regional institutional capacity is the creation of the Chesapeake Bay Foundation (a nongovernmental organization) in the United States as a coordinator and leader of NPS pollution control efforts for the Chesapeake Bay, which receives runoff from a number of states.

Establish environmental indicators and monitoring practices. As described in the last section, there are many potential NPS pollutants, many possible monitoring locations, and many chemical or biological approaches to monitoring pollution. Development of an effective and efficient monitoring program is a significant technical and policy task (see Note D.1). Effective monitoring, however, is not limited to technical measurements; it includes measures of progress in establishing a regional framework for addressing NPS problems, and measures of community involvement and satisfaction with policies that were mandated or recommended as best management practices. The monitoring programs for recent NPS pollution control projects in Poland and Georgia are described in Box 6.

Mandate community participation. Many governmental organizations responsible for implementation of regional objectives are more comfortable with and have traditionally used technocratic, top-down

Road construction, Yemen

approaches. However, one of the lessons from Bank experience has been that NPS projects, especially those in rural communities, require community participation to be successful. To give these communities some standing in discussions about NPS management, it is important to provide a governmental mandate, such as an official policy requiring their involvement.

Develop community-based approaches. Mandated community participation is a policy that provides an opportunity for the views of citizens to be taken into account. While providing a basis for involvement, it does not provide the support for community organization and participation. Communities, particularly if they have a history of powerlessness, need active encouragement to organize into user associations or other locally governed entities that take ownership of the NPS problem. The borrowing country may need to provide expert assistance to communities, training in the use of data and other information, and financial support to representatives who need to spend time attending meetings. However, the benefits of free, active involvement can be considerable.

Develop codes of good practice (best management practices). Development of codes of good practice or best management practices are prescriptions for desirable management activities that are known, from either previous experience or scientific investigation, to reduce the loss of pollutants from NPSs to waterways. They allow landusers to participate in control of NPS pollution without extensive water quality sampling or monitoring. For example, rice-wheat farmers on the Indo-Gangetic Plain of India have reduced fertilizer use by basing application rates on soil samples analyzed for soil nutri-

Box 6.
Monitoring programs in Poland and Georgia

The Bank-sponsored Rural Environmental Protection project in Poland aims to significantly increase environmentally responsible agricultural practices in that country. Poland accounts for nearly half the catchment of the Baltic Sea; hence, nitrogen releases from agriculture are of local, national, and regional significance. At the local level, 16 percent of samples taken from farm wells contained nitrate concentrations in excess of recommended levels. Improper storage of animal wastes appears to be the main reason for nitrogen releases from Polish agriculture. Improved storage facilities will be monitored for possible leakage via groundwater wells adjacent to the storage facilities. Other monitoring tools include a social assessment survey of beneficiaries and other stakeholders, and a financial and economic study to assess the fiscal impacts on farmers from adopting environmentally responsible practices.

The Bank-sponsored Agricultural Research Extension and Training project in Georgia builds on the Polish experience. Primary components of the project are adaptive research and technology dissemination; financial support for agricultural practices that reduce NPS pollution; reform of the agricultural research system; and a pilot environmental pollution control program. Indicators to be monitored include a network of ambient water quality measurement sites; the number of farmers and farmed areas that adopt improved techniques; changes in awareness of environmental issues among farmers; the satisfaction rate of farmers; the number of specialists trained in design and maintenance of biogas units; and the number and type of educational materials disseminated on environmentally sustainable practices.

Source: Project Appraisal Document, Rural Environmental Protection project (P06802), Poland November, 1999; Project Appraisal Document, Agricultural Research, Training and Extension project, (P08204) Georgia. January, 2000.

ent deficiencies. Customized fertilizer blends are formulated to boost the limiting nutrient(s) in each area, increasing the effectiveness of fertilization while reducing the quantity required. This saves the farmer money, reduces stress on the aquatic environment, and has supported the development of local, privately owned soil laboratories. In Kenya, flowers growers have responded to the EU policy of zero pesticide residues in exported cut flowers by adopting significant changes in the way pesticides are handled, stored, and applied to maintain their market share of the flower industry. Table 1 lists some BMPs for environmentally sound agriculture, including those that assist in protection of terrestrial biodiversity as well as water quality.

BMPs provide a uniform approach to pollution control. They are inefficient where there is considerable local variation in the factors that determine the pollution.

Disseminate lessons learned. Lessons learned in one agricultural or cultural setting are rarely transferable to other settings without some modification. Nonetheless, thoughtful transfer of information and experience is enormously important both for development of codes of good practice and for a general understanding of how and why control of NPS pollution in agricultural areas is not possible without development of sustainable agricultural practices.

On former grasslands in southern Uruguay, for example, continuous cultivation of wheat, maize, and sugarbeets caused such severe soil erosion that fields were often abandoned. A technique originally

Table 1.
Source control best management practices for agricultural NPS pollution

Practice	Relevant Nonpoint Source Pollutants (NPS)				
	Soil/Silt	Nutrients	Salts	Pesticides	Metals
Public education	X	X	X	X	X
Improved containment and spill prevention	X	X	X	X	X
Conservation tillage	X	X			
Delayed seedbed preparation	X				
Contour farming	X	X			
Stripcropping	X	X	X	X	
Mixed cropping	X	X		X	
Fallow management	X	X	X	X	
Precision Irrigation	X	X	X		
Subsurface drainage			X*		X*
Precision fertilization		X	X		
Manure digestion prior to application			X		X
Precision pesticide & herbicide application					X
Grazing restrictions	X	X	X		
Rotation grazing	X	X	X		
Runoff and groundwater monitoring	X	X	X	X	X
Selective timber harvest (rather than clearcutting)	X	X			

*With proper irrigation, reduces leaching. With excess irrigation, leached substances may be transported farther or faster.

developed in New Zealand–sowing with several species of legumes and adding phosphate fertilizer–restored the land. Farmers mixed an inoculum of nitrogen-fixing Rhizobium bacteria with the legume seeds. Subsequently, dung-eating beetles, earthworms, and other creatures that recycle nutrients effectively were added to restored pastures. Soil-related NPS problems also were reduced by implementing grazing and cereal crop rotation practices.

Adopt the use of targeted incentives. The traditional regulatory approach requires a person or business to behave in a way that a government agency thinks is best for society. An incentive approach uses financial rewards to complement, not replace, the compliance approach. In the United States, for example, an experimental program in the state of Illinois exempts farmers from property tax on land within 100 feet of creeks that are left in a natural condition. These lands serve as buffer zones between intensive agriculture and aquatic and riparian habitat, trapping pollutants and filtering runoff water before it enters the creek. Farmers with large confined animal facilities, however, are still required to prepare nutrient management plans (see Box 4) under U.S. EPA regulations. Thus, the property tax incentive for buffer zones is only one component of a more comprehensive approach that includes a regulatory component.

These incentives need to be "targeted" for two reasons. First, poorly targeted incentives may be ineffective, or even perverse. The U.S. tax credit for installation of wind generators in the 1970s is an often-cited example. Because the credit was for installation, not operation, many wind generators were installed but failed to operate for more than a few years. The desired outcome–production of electricity from the wind–was not targeted specifically enough, diminishing the effectiveness of the incentive. Second, government cannot afford to pay for all environmental investments. Incentive policies should be chosen deliberately to create goodwill and motivate people and businesses to participate in creating sustainable land-use practices. The target of the incentive is not just a pollutant or a behavior, but people who will appreciate being rewarded for their efforts.

Environmental fees, charges, or taxes are also incentive policies. The U.S. state of Iowa, for example, imposes a charge on all pesticides purchased in Iowa, and uses revenue to support farmer education and training, agricultural research, demonstration projects, and other activities related to low pesticide use. Farmers have a financial incentive to both use less pesticides and take advantage of the knowledge and information services provided by the state. Some other incentive policies that have been used to control NPS pollution are listed in Table 2.

FIELD-LEVEL ACTIVITIES

Public awareness and environmental education. Public awareness activities increase understanding of the relationship between day-to-day actions and NPS pollution. Two examples from the Clean Water Program (an urban NPS pollution control program) in Alameda County, California are presented in Box 7.

Environmental education centers located adjacent to wetlands, rivers, and other natural features enhance public awareness of the feature. Even when a staffed or enclosed center is not affordable, relatively simple and inexpensive educational signage can be important. Both economic theory and practical experience demonstrate that people value natural features more when they find them interesting, or when they understand the long-term benefits arising from the features.

For example, the Bank-sponsored project in Poland (Box 6) provides environmental education for selected farmers about the downstream impacts of farm practices, but equally importantly includes education on specific environmentally sound farm practices. Effective environmental education–for example, through field activities–increases the capacity of participants to make wise choices that balance economic, environmental, and other considerations. The Bank-sponsored project in Georgia (Box 6) also includes public awareness and environmental education activities.

Table 2.
Incentive policies that have been used to control NPS pollution

Incentive Type	Recipient or Payer	Example Locations
Property tax exemptions for filter strips and buffer zones	Landowner	Illinois
Accelerated depreciation	Investor	Sixteen of the OECD Countries*
Low-interest loans	Farmer	United States
Grants	Farmers, local government	United States
Manure charges	Farmer	The Netherlands
Impervious surface charges	Landowner	Arcata, California; Olympia, Washington
Pesticide charges	Farmer	Iowa, Denmark, Finland, Norway, and Sweden
Fertilizer charges	Farmer	Norway, Sweden

*Accelerated depreciation allowed for specified types of environmental investments; investments in nonpoint source control may not qualify in some, or many, countries.

Establish networks of demonstration sites. There is no substitute for seeing best management practices being carried out by a peer. Demonstration sites clarify details that can't be explained in writing and show skeptics how systems actually work in practice.

Demonstrations can take place at different geographic scales. They can be small-scale and widely distributed so that many people have access to them. This scale of demonstration is useful after interventions have been proven to work under local physical and cultural conditions. Demonstration sites can also be full-scale working facilities (or villages) that have adopted or experimented with innovative techniques earlier than most others, such as a farm operated with best management practices. It is de-

Box 7.
Public awareness campaigns

The Clean Water Program in Alameda County, California, is a consortium of 14 cities, 2 flood control districts, and the county government. The program's purpose is to reduce urban NPS pollution entering the San Francisco Bay and tributary creeks within the county. The public awareness component of the program has found that the most effective techniques create an unforgettable link in people's minds between a polluting action and something they value.

For example, surveys indicated that many people did not know that untreated stormwater runoff in their neighborhoods enters the bay. In response to this finding, a message was spray-painted on the curb adjacent to every storm drain inlet in the county over several years (as part of routine maintenance). The message read: "Do not dump. Drains to Bay." Simultaneously, advertisements were placed on public transit showing fish and other creatures being force-fed motor oil through a funnel, or with plastic litter stuck in their mouths, with simple messages reminding people that storm drains are directly connected to creeks and the bay. The combination of visual "shocks" and unavoidable and simple information near the point of pollution has significantly increased public awareness.

sirable to demonstrate that the cumulative effects of plot and farm/village-scale BMPs can lead to improvements in water quality at watershed scale. However, this is usually difficult to achieve because of the long time lags inherent in water quality improvements at a large scale, and also because of the influence of confounding effects–not least from climate variability–on the interpretation of water quality monitoring at watershed scale.

The Bank-sponsored Agricultural Pollution Control Project is a pilot project along the Lower Danube River in the southern part of Romania (Box 8). Long-term planning calls for successful techniques from the project to be disseminated nationwide, and for the project area to be a demonstration watershed for the nation. Pilot projects in rural communities are also valuable ways to determine which innovative techniques for provision of domestic wastewater treatment can be sustained in those settings, accounting for local capacity to operate, maintain, and eventually pay for the services. Constructed natural systems for wastewater treatment and other innovative techniques for management of human wastes are discussed in Note D.2.

Rehabilitate previously drained wetlands. Wetlands and other natural habits can filter suspended solids and reduce the loads of nutrients, pesticides, and biological contaminants in runoff and tributary streams before they enter rivers, bays, or oceans (see Note G.3). In many regions wetlands have been drained for agricultural use. Because not all NPS pollutants can be eliminated or controlled at the source, restoration of natural features such as wetlands and riparian corridors are part of a cost-effective set of interventions to reduce NPS pollutant loads. Typically, wetlands can remove 50-90 percent of suspended solids, 50-80 percent of phosphorus, 30-60 percent of nitrogen, and 20-60 percent of pesticides during low and moderate flows. However, they are much less effective in high flows and can even act as sources of contaminants if scouring occurs.

Portions of the very extensive agricultural lands of the eastern and southern Baltic Sea region, which were historically coastal and interior wetlands, have been abandoned because tillage or grazing is not feasible under the new social conditions in former Soviet Bloc countries. As part of regional efforts to enhance water quality in the Baltic Sea, pilot reha-

Box 8.
Ecological restoration as an outcome of NPS pollution control

The Trans-Boundary Diagnostic Analysis carried out as part of the Baltic Sea Environmental Program found that about 27 percent of nutrients entering the Black Sea originate in Romania. The other five Danube river basin countries account for 43 percent of nutrient loading, while 11 noncoastal countries account for the remaining 30 percent. Calarasi County, an area of 74,200 hectares with 64,000 hectares of arable land, has been identified for a pilot project in Romania.

The Romanian Agricultural Pollution Control Project extends the approach used in the Polish and Georgian projects described in Box 6. The project will promote environmentally friendly agricultural practices; monitor water and soil quality; train local staff in sampling, analytical techniques, and data interpretation; strengthen policy and regulatory capacity; and increase public awareness. In addition, the 23,000-hectare Boianu-Sticleanu polder (a polder is a tract of lowland reclaimed from a body of water) will be ecologically rehabilitated in order to establish biological filtration mechanisms that are expected to significantly reduce nutrient loads to downstream waters.

The polder includes large areas of cultivated lands, small areas of floodplain forests, degraded lands, and Iezer Calrasi, a 3,200-hectare area proposed for designation as a nature reserve. Iezer Calrasi is an important part of a corridor for bird migration, including many species listed under the Bonn and Bern Conventions. In addition, it was identified–by World Wildlife Fund studies under the Danube Pollution Reduction Program and in the National Environmental Action Plan–as a high-priority wetland to be rehabilitated in the Lower Danube River Basin.

Source: Srivastava, Jitendra. 2001. Project Information Document, Romanian Agriculture Pollution Control Project. Washington: The World Bank.

bilitation projects are being discussed for some of these areas for flood control and water quality management, nature conservation, and recreational purposes. Similarly, the Romanian Agricultural Pollution Control Project described in Box 8 includes rehabilitation of the Boianu-Sticleanu polder, a reclaimed floodplain near the Black Sea that is part of the target area for improved on-farm management techniques.

Install physical facilities. Implementation of BMPs may require installation of physical facilities. Recent publications that present design criteria and other technical data for a wide range of NPS interventions in urban and rural areas are noted in the Further Information section.

Infrastructure is sometimes needed to support source control BMPs, such as those listed in Table 1. Although this infrastructure can be described in principle, it needs to be designed for local conditions and determined in the field to be both cost-effective and environmentally effective. For example, the construction of on-farm holding pits for manure in Poland required high-quality, concrete lined pits at a cost of approximately $7,000 each. This quality of construction is necessary to protect groundwater because Polish soils tend to be sandy. In heavy clay soils, however, less expensive holding pits are adequate; for example, a much less expensive (about $1,000) holding pit design has been proposed for use in Georgia.

Common on-site treatment facilities for NPS pollution are small detention or infiltration basins; filtration in sand beds, grass swales, vegetative strips; and buffer strips between source areas and receiving waters. Off-site treatment of NPS pollutants can use any of the techniques that are used on-site as well as restored or constructed natural systems (Box 9). Both on and off-site treatment systems often mimic natural processes. The primary exception is detention basins (usually for silt removal) integrated with flood control channels.

Energy and materials recovery from wastes. One means of preventing NPS pollution in rural areas is to apply sewage sludge to fields based on an understanding of their composition and impacts. Although there have been concerns about heavy metals and other industrial pollutants in sewage sludge, most sewage sludges can be made suitable

Box 9.
A constructed wetland that cleanses urban runoff

Another component of the Clean Water Program in Alameda County, California (see Box 7) is a 55-acre freshwater marsh that was designed to remove pollution from urban runoff before it reaches San Francisco Bay. Water from a 4.6 square-mile area drains into the marsh. A Gross Pollutant Trap (GPT) collects large pieces of trash behind a series of weirs before they can reach the main body of the marsh.

Water then flows into one of two ponds. The first is a five-acre, six-foot-deep lagoon with a central island. Incoming water mixes with marsh water containing bacteria and other microorganisms that remove pollutants. The large surface area of this system provides wind exposure, which contributes to increased mixing and more effective chemical and biological processes. The second pond is a four-acre section of shallow water averaging three feet in depth and covered in aquatic plants. The plants take up nutrients through their roots. Bacteria in the pond sediments break down biological matter and mediate the removal of nitrogen to the atmosphere. Sediments are trapped in the plant roots along with attached nutrients and other pollutants such as agrochemicals. Water from both ponds then flows through a channel before being released to a natural marsh that borders the Bay. The large surface area of this channel allows sun, soil, bacteria, and plants to provide a final removal of pollutants before discharge.

Fish and plant tissue, sediments in the marsh, and water exiting the marsh have been tested for a wide range of chemical constituents. These tests showed that suspended solids and nutrients were removed by the marsh, and that urban toxicants had been removed. The marsh itself remains a healthy and viable ecosystem, despite the fact that urban runoff has been flowing through the system since the early 1980s.

Source: Countywide Clean Water Program, 1998 http://www.cleanwaterprogram.com/indexFlash.htm.

for application to agricultural or grazing land by controlling the ingress of industrial pollutants into urban wastewater (see Note D.2). Sludges that satisfy the U.S. standards are suitable for land application in temperate climates.

Digestion of manure prior to land application biologically stabilizes the manure, reducing the potential for nutrient losses to waterways. The energy produced during the microbial decomposition can also be tapped for local use. Although this form of energy production cannot compete against current market prices for energy in developed countries, it can still be viable in developing countries where centralized power sources are not available. In fact, inclusion of off-farm environmental benefits often shows that digestion has greater economic benefits than costs. Financial incentives that reflect these off-farm benefits may be warranted when nutrient pollution is severe. The Georgian project presented in Box 6 includes on-farm demonstration of the use of manure digestion to provide biogas for cooking and other domestic purposes.

CONCLUSION

Nonpoint-source (diffuse) pollution differs in many respects from point-source pollution. The latter is usually the result of industrial processes or domestic activities that take place in relatively small, indoor-source areas. Conventional, centralized treatment of the wastewater discharge stream from such sources is a reasonable approach to environmental protection, although pollution prevention should also be practiced. In contrast, preventing pollution from reaching waterways through both source reduction and interception is the most reasonable approach for most nonpoint-source pollution. Decentralized treatment may be justified on occasion.

Bank experience indicates that success in managing NPS pollution involves partnerships, long-term commitments, and integration and linkages with sectors and activities other than just those that produce NPS pollution. Reducing and controlling nonpoint source pollution from farming, for example, may require that conventional farming practices be replaced with new practices such as buffer strips along streams or that a levy is introduced to discourage pesticide use. Dramatic changes in farming practices, however, are not possible without changes in other sectors of society–for example, food and water policies and practices. Such widespread social change is possible, but achieving it will require partnerships and long-term commitments among the many stakeholders in a country or region.

FURTHER INFORMATION

The following references provides information on costing water quality management:

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The following references provide information on practices that reduce NPS pollution:

Food and Agriculture Organization of the United Nations (FAO). 1993. *Prevention of water pollution by agriculture and related activities.* Water report No. 1. Rome: FAO.

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Stukenberg, J. R., S. Carr, L. W. Jacobs, and S. Bohm. 1993. *Document long-term experience of biosolids land application programs.* Alexandria, Virginia: Water Environment Research Foundation.

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Schillhorn van Veen, T. W., D. A. Forno, S. Joffe, D. L. Umali-Deninger, and S. Cooke. 1997. *Integrated pest management.* Environmentally sustainable development studies and monographs series no. 13. Washington: World Bank.

NPS pollution can be treated via wetlands and engineering solutions as described in:

Water Environment Federation (WEF). 1998. *Urban runoff quality management.* Manual of practice 23. Arlington, Virginia: WEF.

Water Environment Federation (WEF). 1999. *Evaluating the use of constructed wetlands in urban areas.* Arlington, Virginia: WEF.