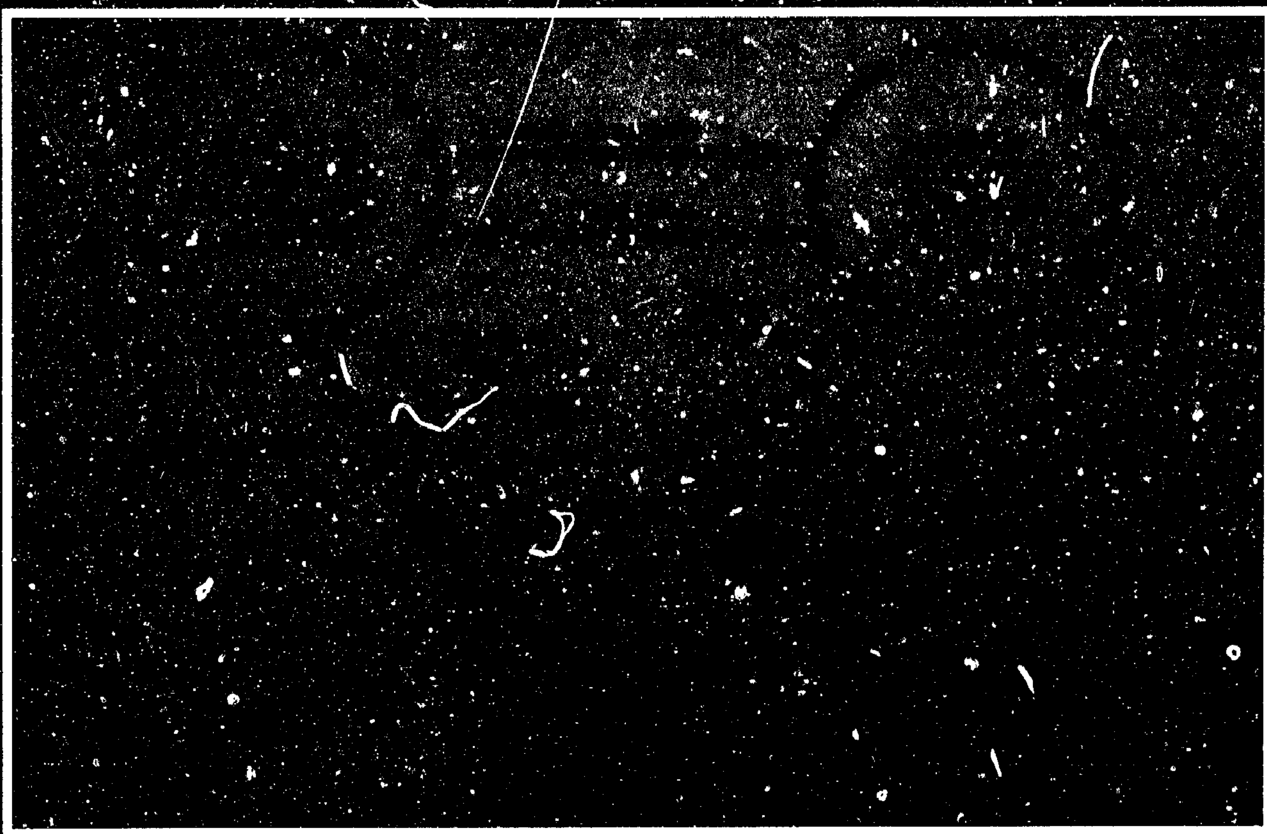
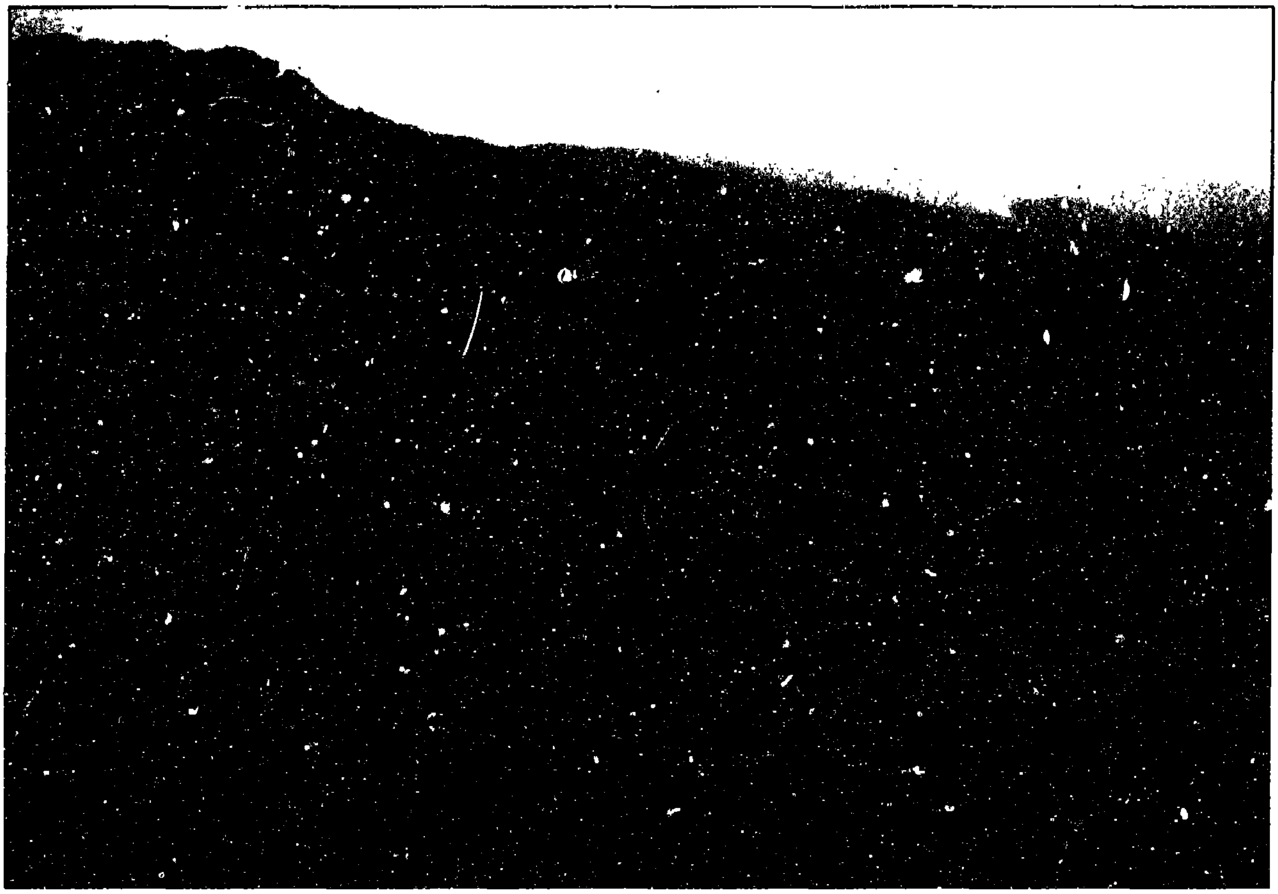
INTEGRATED WATER RESOURCE MANAGEMENT



MEETING THE SUSTAINABILITY CHALLENGE

". . . by the Year 2025, about 44 percent of the world's people will be living in the humid tropics."



M. M. Hufschmidt
Visiting Senior Fellow, Program on Environment, East-West Center
Honolulu, Hawaii, U.S.A.
K. G. Tejwani
Director, Land Use Consultants (Int.)
New Delhi, India

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I. THE CHALLENGE

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In 1990, the countries located in the humid tropics (generally thought of as that area lying between 23.5 degrees north and south latitudes where rainfall in excess of 100 mm occurs four and a half months per year) contained over two billion people, about 38 percent of the total world population of 5.3 billion. By the year 2025, these countries are expected to have 3.8 billion people, or about 44 percent of the world population of 8.5 billion. See Figure 1.

Although in 1990, about two-thirds of the population of the humid tropics lived in rural areas, more and more people are moving to urban areas so that by the year 2025, about 56 percent of the people will be living in cities and their suburbs. See Figure 2.

It is clear that this rapid increase in population will by itself place greater demands on the essentially fixed (although highly variable) supply of fresh water. Thus, in certain humid tropic countries with high population growth rates, the fresh water available per person will show sharp declines by the year 2025. For example, in India the yearly renewable water resources per person (including inflows from upstream countries) will fall from 2.44 thousand cubic meters in 1990 to 1.45 thousand cubic meters in 2025.

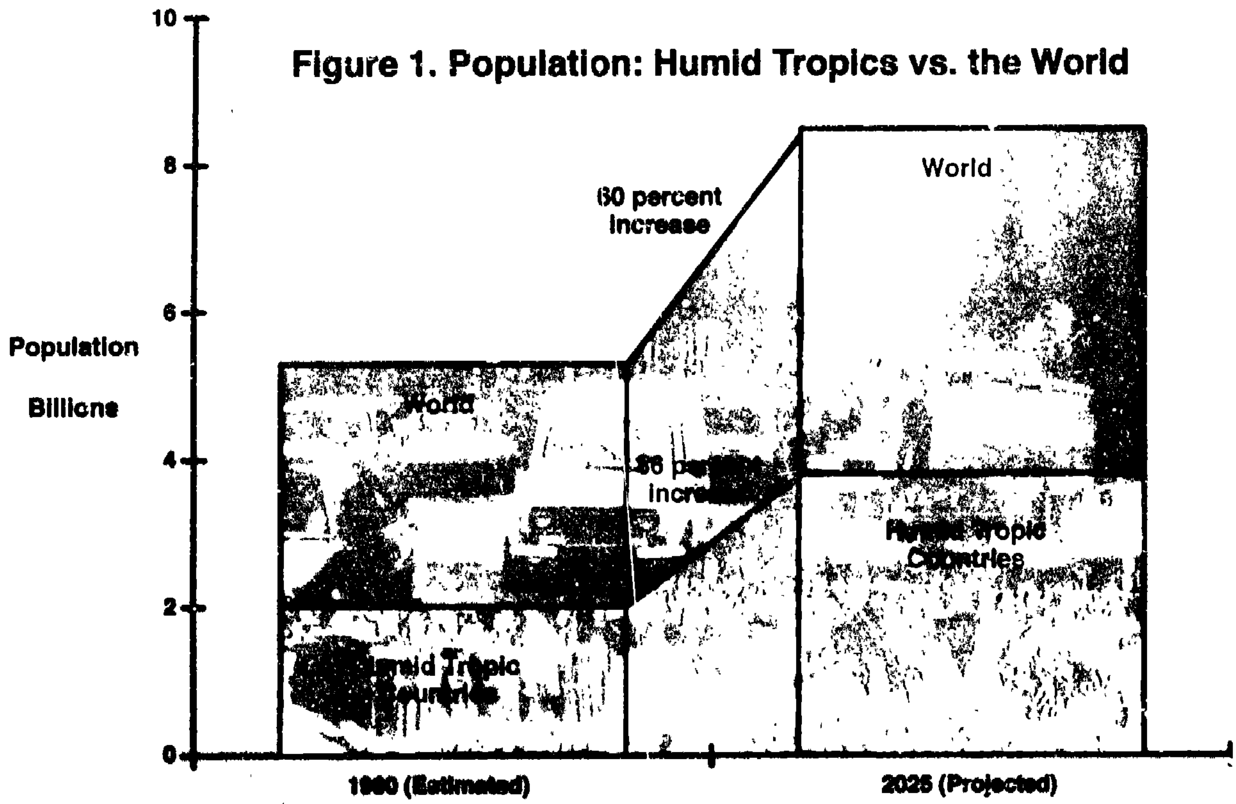


Figure 1. Population: Humid Tropics vs. the World

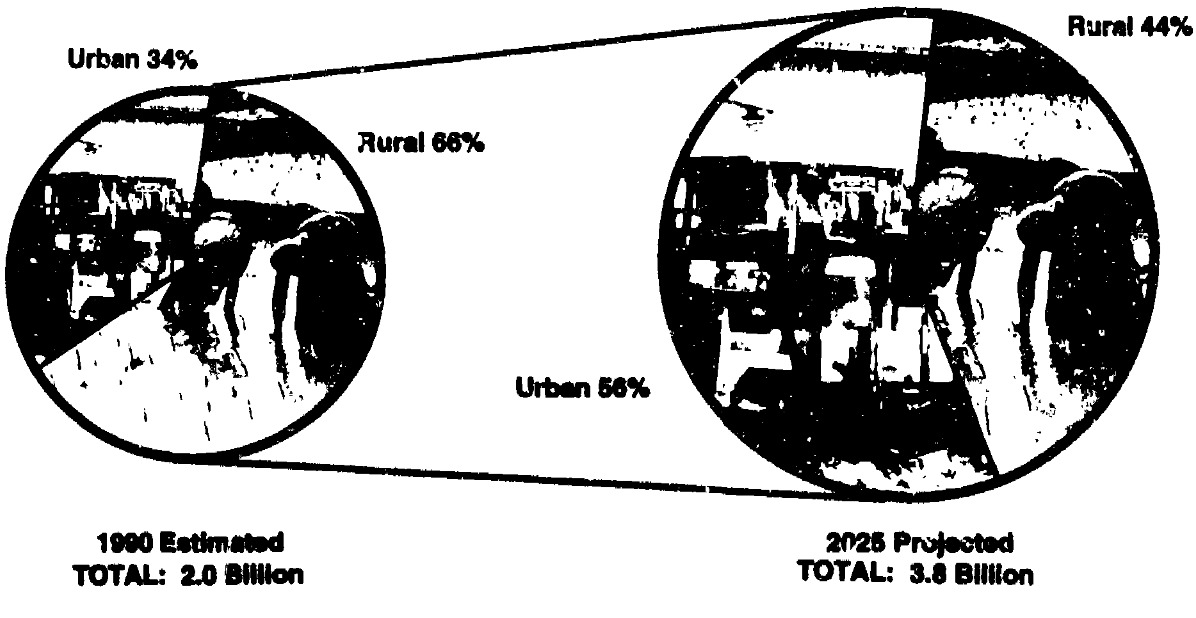
Source: U.N. Department of Economic and Social Affairs, 1991

In addition, the economies of many humid tropic countries, especially those located in Asia and South America, are growing rapidly. With the consequent increases in standards of living, there will be greater and greater demands on the water resources, both for productive purposes—agriculture and industry—and for such human uses as potable water, sanitation, and recreation. At the same time, both surface water and groundwater are becoming increasingly polluted from such uses. With these demands for water growing, and supplies of acceptable quality diminishing, meeting these demands will become more and more challenging. Thus, even in nominally water-rich countries of the humid tropics, sophisticated levels of water management will be increasingly needed.

II. SUSTAINABLE WATER RESOURCE DEVELOPMENT

The general concept of sustainable resource development was highlighted in the Brundtland Commission report entitled, Our Common Future (World Commission on Environment and Development, 1987). In calling for sustainable development of the world's resources, the Brundtland Commission defined this condition as the ability to meet the needs of the here and now

Figure 2. Urban and Rural Population: Humid Tropics



Source: U.N. Department of Economic and Social Affairs, 1991.

". . . it is the value to society of the services to be provided by the water resources that are to be maintained or increased if possible."

without compromising the ability of future generations to meet their own needs. To apply this general concept and definition to water resources it is useful to consider three distinct versions of sustainability: (1) as a purely physical concept for a single resource (*e.g.*, water); (2) as a physical concept for a group of resources or an ecosystem (*e.g.*, a watershed or river basin); and (3) as a social-physical-economic-ecological concept (Dixon and Fallon, 1989).

Narrow concepts limiting

Clearly, the first definition of sustainability as a purely physical concept is too narrow, if only because a significant portion of freshwater resources in some areas occurs as a geological stock of—for practical purposes—nonrenewable groundwater which, once depleted, will be replenished only over centuries. Also, it is not merely the quantity of freshwater that is relevant, but also its quality and its distribution in time and space in relation to other elements of the ecosystem as defined, for example, by a watershed or coastal zone.

However, even the second definition of sustainability—as a physical concept for an ecosystem—is too narrow, as we are not so much concerned with sustaining the particular quality or space and time pattern of the water-land-biotic system as embodied in a watershed as we are with the services to be provided by the ecosystem, including productivity and biological diversity. This leads us to consider the third definition of sustainability—as a social-physical-economic-ecological concept—as the starting point for our application of the term to water resources and their management.

Present and future objectives must be satisfied

Taking off from this third concept, we can define sustainable water resource management as a set of activities that ensures that the value of the services provided by a given water resource system will satisfy present objectives of society without compromising the ability of the system to satisfy the objectives of future generations. Services comprise the broad array of water uses—ranging from domestic, agricultural, industrial to recreational and maintenance of ecosystems. This does not mean that any particular space or time pattern or quantity or quality of water resources need be maintained intact, nor that the current mix and levels of water services—for economic development in general, including agricultural production, energy generation, municipal and industrial supplies—need be maintained. Rather, it is the value to society of the services to be provided by the water resources that are to be maintained or increased if possible. Such values may include economic productivity, human health, environmental quality, and social fairness.

The state of the physical resources—the water, land, and biota—is of key importance in maintaining or increasing the social value of the services provided by the resources. Accordingly, in carrying out the tasks of water resource management, we must focus on the state or condition of the surface and underground water, the soil, and the biota in the land and water ecosystems.

For example, in managing forests, agroforested areas, and agricultural lands, we must be concerned with the rates of soil loss, erosion, and sedimentation levels as these affect the condition of these resources in terms of on- and off-site productivity and potential water services. Also, upstream land uses, ranging from forestry, grazing, cropping, and mining to urban and industrial activities, may degrade the downstream land, surface water, and groundwater resources via runoff of sediments, pesticides, fertilizers, organic and toxic wastes, and salinity.

Varied and extensive degradation can result

These effects are often manifested by: (1) the loss of useful reservoir and stream channel capacities caused by sedimenta-

BOX A: **Sustainability: A Practical Approach**

Freshwater is largely a renewable resource. Accordingly, we should be able, in most situations, to manage water resource systems on a sustainable basis while achieving other objectives of society. Sometimes we may need to sacrifice some economic productivity for this generation in order to achieve sustainability for the next generation. A practical approach toward sustainability is to maintain and, if possible, increase the social value of water and water-related services over time, where the social value includes economic, environmental and equity values. This approach accommodates—indeed requires—changes in the quantity, quality, and the spatial and temporal characteristics of the water resource as well as changes in the specific mix of water and water-related services. In this sense, we define and apply sustainability to water resource management as a concept that combines social, economic, and ecological as well as physical elements.

Meeting the sustainability challenge for water resource development in the humid tropics will require an increasingly sophisticated level of management called Integrated Water Resource Management (IWRM). The core concepts of IWRM as applied to developing countries have been recently presented by several authors, notably Koudstaal *et al* (1992) and Rogers (1993). Commonly held principles include management for multiple-purposes such as irrigation, domestic water supply, and enhancement of fishery and wildlife resources; for multiple-objectives including economic productivity, human health, environmental quality, and social equity; and through use of multiple means such as physical structures, regulations, and economic incentives.

"... sustainability in a physical sense cannot be maintained indefinitely for all segments of a water resource system."

Sediment from eroding soil that has been overgrazed degrades the downstream land and water resources.

tion from upstream; (2) the biological degradation of lakes and reservoirs from fertilizers and other organic nutrients from the upstream watershed; (3) the salinization of downstream land caused by inadequate drainage of irrigation systems; and (4) the pollution of groundwater aquifers by seepage or injection of organic and inorganic substances to the aquifer from urban and industrial sources.

Only so much water is available

Sustainability of water services can also be viewed physically by considering that in any river basin only a set amount of water is available for urban and industrial water uses, irrigation, hydroelectric energy generation, and instream and in-lake purposes such as fisheries and recreation. Although the water services from these set and variable supplies can be extended by reservoir storage, more efficient use, recycling and wastewater treatment and reuse, and importation from other river basins, there are usually economic limits to such extensions. Accordingly, even with no environmental deterioration, there is a physical limit to the water economically available to provide sustainable services.

Some natural deterioration inevitable

Although it is important to limit the rates of environmental deterioration in water resource systems, it is generally not possible to reduce these rates to zero. Erosion is a natural phenomenon that is often controllable only at high cost. In some cases, productivity declines from soil loss can be offset by application of other inputs, such as fertilizers. Also, even at moderate rates of sedimentation, reservoirs lose much of their storage value over time. Downstream sections of many irrigation projects become salinized over time. Accordingly, sustainability in a physical sense cannot be maintained indefinitely for all segments of a water resource system.

The important point is to avoid situations of irreversibility of the system as a whole in which the social value of water or water-related services is lost completely. Examples of this situation are: (1) when a groundwater aquifer becomes so polluted with toxic chemicals as to be unusable because cleanup costs are prohibitive; (2) when the productive soil mantle has been lost through erosion, rendering the land essentially unproductive without massive resource inputs; and (3) groundwater mining, when pumping of a groundwater aquifer proceeds at a rate far exceeding the natural recharge rate of the aquifer. In this latter situation, the groundwater level keeps dropping until the aquifer is physically depleted or, more commonly, pumping costs rise until they are prohibitively high.

III. INTEGRATED WATER RESOURCE MANAGEMENT: A SYSTEMS VIEW

"Integration" is one of those terms whose meaning is gener-

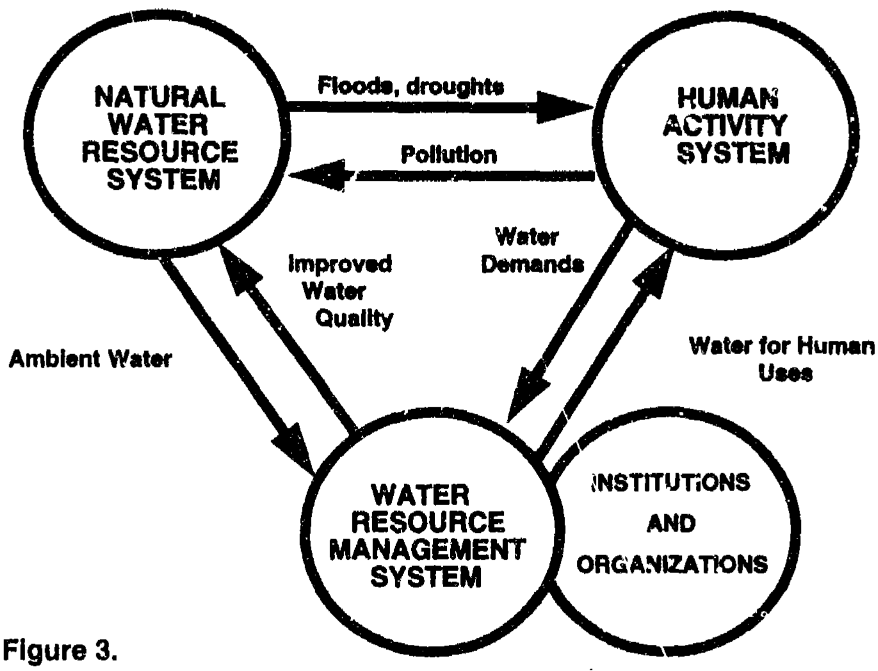


Figure 3.
Integrated Water Resource Management: Proposed Framework
Adapted from Figure 1 in Hufschmidt, 1993.

ally assumed rather than being rigorously defined. For our purposes, the need for integration in water resource management arises when there are one or more systems, defined as "a regularly interacting or interdependent group of items forming a unified whole" (Websters New Collegiate Dictionary, 1974). Integration, then, is the act of forming or blending these items into a whole, or incorporating two or more subsystems into a larger overall system. This definition can be illustrated for integrated water resource management by referring to three interrelated systems shown in Figure 3.

Natural availability for human uses

The first of these is the natural water resource system, which consists of the hydrologic cycle with its components of precipitation, evaporation, surface runoff, and groundwater flows, as well as the broader "hydrologic whole or continuum". The latter was defined by Leopold (1990) as including the soil, biota, and atmosphere as well as water. In the aggregate, this system is the water and water-related natural resource endowment (or "supply") available for human uses (including enjoyment of the resource in its natural state).

The second is the human activity system composed of the many activities of people that affect or are affected by the natural water resource system. At one extreme, as in the Nile Valley, humans have modified the natural system extensively by storage reservoirs, diversion works, and canals to meet their irrigation needs. At the other extreme, as in Bangladesh,

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"Maintaining the integrity of the hydrologic whole or continuum, as proposed by Leopold (1990), is essential to the sustainable use of the natural water resource system."

humans living in the floodplains of major streams, such as the Ganges and Brahmaputra Rivers, are at the mercy of natural forces. Between these extremes are many river systems that are only partially controlled by developments. In the aggregate, these human activities comprise the "demand" side for water uses such as irrigation, domestic water supply, waste disposal, navigation, hydroelectric power, fisheries and recreation, and for reduction of damages from flooding, water pollution, and drought.

Harmonization of supply and demand the goal

Finally, the water resource management system consists of the activities and relationships in the public and private sectors concerned with harmonizing the supply and demand sides so as to achieve the objectives of society. In this context, demand includes both uses for water such as irrigation and in homes, and avoidance of adverse impacts such as pollution arising from natural processes or human activities, while supply also includes adverse impacts such as natural floods, low flows, and pollution, imposed by nature or human activities. As shown in Figure 3, an essential support to the water resource management system is the institutional framework for management, consisting of the organizations and the rules and codes governing the use and control of water resources.

IV. THE NATURAL WATER RESOURCE SYSTEM: PRESERVING ITS INTEGRITY

Maintaining the integrity of the hydrologic whole or continuum, as proposed by Leopold (1990), is essential to the sustainable use of the natural water resource system. Leopold defines this as the maintenance of balance in the hydrologic processes of precipitation, evapo-transpiration, runoff, groundwater flows, and storage. A key first step is achieving a scientific understanding of the natural water resource system by expanding and deepening the physical information base. In most cases, the complete river basin should be used as the basic unit for data collection and interpretation, with appropriate subdivisions based on geology, climate, soil type, land and water use, and land cover. In some cases, other natural water resource regions, such as groundwater aquifers and estuaries, will be appropriate. All components of the hydrologic cycle, including precipitation, evapo-transpiration, streamflow, soil moisture, and groundwater flows and stocks, should be measured and analyzed. Quantitative assessments should use a complete water-budget approach, which accounts for all water stocks, flows, and withdrawals, with emphasis on interactions between surface water and groundwater, and water quantity and quality.

Achieving an adequate scientific understanding of water resources in the humid tropics is a challenging task. It requires coordination of meteorological and hydrologic data collection and interpretation activities, which are often scattered throughout many government agencies. Successful assessments and analyses require: (a) common standards for water resource assessment; and (b) unified data collection and measurement systems to record hydrologic, meteorological, and water use measurements, and other water-related data.

"A complicating factor . . . is that political and administrative boundaries rarely coincide with those of a river basin."

Sectoral projects must consider the hydrologic continuum

The hydrologic region—river basin, groundwater aquifer, or other entity—should form the basic spatial unit for preparing and implementing water resource plans. Effective management of water resources must address the physical realities of the hydrologic cycle, including the biophysical linkages between the forests, land, streams, and lakes of the river basin.

Managing water resources on a river basin basis has many theoretical advantages (Easter *et al.*, 1986). In undertaking water resource development on a sectoral basis—for irrigation, hydroelectric power, domestic and industrial water supply, or other purposes—the relationship of the individual project to the entire hydrologic continuum must be investigated. To do this effectively requires detailed basin-wide management plans. Preparing such detailed plans may be difficult for such huge river basins as the Mekong in Southeast Asia, the Ganges in South Asia, and the Amazon in South America. These large river systems have many tributary watersheds, each of which constitutes a sizeable planning unit. Furthermore, some of them are international in scope.

Large river basins may defy detailed planning

Detailed integrated planning for such large river basins is probably administratively infeasible. The leading example of detailed river basin management, the Tennessee Valley Authority (TVA) in the United States, has purview over a relatively small subtributary area of the Mississippi River basin, with a drainage area of only three percent of the 3.22 million square kilometers of that basin. In Southeast Asia, the Lower Mekong Commission represents a special case of management of an international river basin, but up to now its activities have been largely limited to collecting and analyzing basic data and to framework planning (Committee for Coordination of Investigations of the Lower Mekong Basin, 1988).

At the other extreme are many small watersheds composed of tributaries and subtributaries of larger river basins. Detailed planning for such watersheds is administratively feasible, although in most cases such planning has been limited to basic data collection and broad-brush planning, with detailed planning and implementation continuing to be done by public or private agencies on a project or sectoral basis.

Of course, there are many examples of river basins and

Box B: **Elements of an Integrated Water Resource Plan**

No.	***Element***
1.	Flood control
2.	Irrigation
3.	Hydroelectric power
4.	Navigation
5.	Domestic and industrial water supply
6.	Watershed management, soil conservation, and erosion control
7.	Recreation use of water
8.	Aquatic ecosystem maintenance
9.	Pollution abatement
10.	Insect control
11.	Drainage
12.	Sediment control
13.	Salinity control

watersheds between these extremes, including the relatively small but populous river basins in the Philippines, the island of Java in Indonesia, and islands in the Caribbean. In many of these cases, detailed water resource planning on the river basin basis would be both desirable and feasible.

A complicating factor limiting the use of the river basin or watershed for implementation of plans is that political and administrative boundaries rarely coincide with those of a river basin. Implementation is usually carried out either by provincial or district (city or village) governments or by regional offices of national sectoral agencies (agriculture, irrigation, energy) usually organized on a provincial basis. Thus, when water resource management plans are prepared using river basin or watershed boundaries, their implementation is not likely to proceed on this basis. Also, urban water resource plans, involving water supply, groundwater management, pollution control, flood control, and storm drainage, typically do not conform with river basin boundaries.

Multiple Purposes

Maintaining sustainable hydrologic systems is complicated by the conflicts and complementary effects among the various water uses. An integrated plan requires the balanced consideration of a wide range of water uses and management purposes, including withdrawal uses and water problems such as flooding and pollution. See Box B. Using this approach to planning allows beneficial complementary effects to be cap-

Purpose

Flood damage prevention or reduction, protection of economic development, conservation storage, river regulation, recharging groundwater, water supply, development of power, and protection of life.

Agriculture production.

Provision of power for economic development and improved living standards.

Transportation of goods and passengers.

Provision of water for domestic, industrial, commercial, municipal, and other uses.

Conservation and improvement of the soil, sediment abatement, runoff retardation, forests and grassland improvement, and protection of water supply.

Increased well-being and health of the people.

Improvement of habitat for fish and wildlife, reduction or prevention of fish or wildlife losses associated with development, enhancement of sports opportunities, and provision for expansion of commercial fishing.

Protection or improvement of water supplies for municipal, domestic, industrial, and agricultural use, and for aquatic life and recreation.

Public health, protection of recreational values, and protection of forests and crops.

Agricultural production, urban development, and protection of public health.

Reduction of silt load in streams and protection of reservoirs.

Abatement or prevention of salt water contamination of agricultural, industrial, and municipal water supplies.

tured and tradeoffs among the conflicting uses to be critically examined. As Rogers (1993) points out, the "opportunity cost" of water, measured by its value in competing uses, is fundamental to such tradeoff analysis.

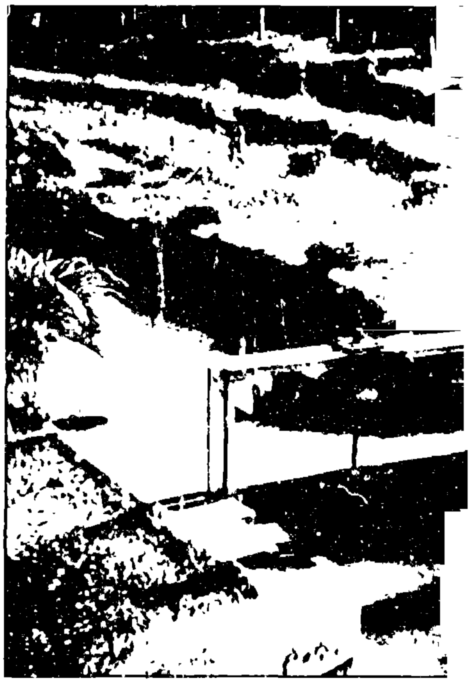
Environmental purposes, such as the maintenance and enhancement of fish and wildlife habitat and biologically diverse ecosystems, are important although often neglected. In urban areas of the humid tropics, control of point and non-point source water pollution is becoming increasingly important, as in Bangkok, Jakarta, Sao Paulo and Lagos.

Environmental consequences of water developments, in the form of their impacts on the hydrologic whole or continuum, must be carefully examined at the assessment and planning stages. Ideally, environmental values should be combined with economic criteria and technical standards in water planning. Three types of undesirable environmental consequences of water development are particularly important:

•*Creation of favorable habitats for parasitic and water-borne diseases by construction of poorly conceived reservoirs and irrigation systems.*

•*Adverse impacts on ecological systems, caused by erosion, pollution, and changes in streamflow regimes.*

•*Stream and reservoir sedimentation, soil salinization, and waterlogging.*



The amount of water being diverted to irrigate crops can be reduced through both technical and institutional means.

Ideally, environmental consequences can be assessed in a multiple-objective planning approach which represents a true synthesis of environmental, social fairness, and economic values. A practical alternative is the environmental impact assessment approach in which major impacts on the hydrologic continuum of a specific project are measured and evaluated. Such an assessment should begin at the earliest stages of project planning and continue to the final selection of a project. Means for avoiding or reducing adverse environmental effects should be included.

V. THE HUMAN ACTIVITY SYSTEM: INFLUENCING THE DEMAND SIDE FOR WATER

A key task of integrated water resource management is to influence human activities so as to reduce adverse impacts on the natural water resource system and to minimize economic and social losses from natural hazards. This task involves three kinds of actions:

•*Actions affecting the demand for water services.*
•*Actions affecting pollution from human activities.*
•*Actions affecting human adjustments to floods and droughts.*

Managing the Demand for Water Services

One of the most serious problems facing water managers is the effective allocation of an essentially fixed supply of water resources among rapidly growing and competing demands. In many cases, even in humid areas, developing more supplies to meet the projected rising "demands" is no longer appropriate. Demand management strategies that involve policies and activities to reduce per person or unit-of-activity use rates are being increasingly advocated, especially for urban areas and irrigation projects. Adopting demand management as an integral part of water management would involve the following:

•Formulating and evaluating demand reduction approaches and strategies as complements to or substitutes for supply augmentation projects.

•Using prices as a tool for demand management, including volumetric pricing of supply or wastewater on the basis of marginal supply or disposal costs, along with increasing block rates. (Marginal cost is the cost of adding the next unit of supply or disposal capacity, in contrast to average unit cost of the entire supply or disposal capacity.) Where appropriate, seasonal pricing and temporary drought surcharges would be imposed.

•Using efficient technical means to reduce urban water use and transmission losses in the supply system. This includes changes in plumbing codes to require water-saving plumbing fixtures, programs of leak detection and control, and sustained maintenance.

•Recycling and other technical means to reduce withdrawal rates for water for industry, especially for cooling purposes.

•Using technical means for reducing irrigation water use, including drip and sprinkler irrigation, land levelling, and canal lining, along with institutional means such as modifying water rights systems to encourage efficient use.

•Use of lower-grade water for certain domestic, commercial, industrial, and agricultural purposes. Such a use of brackish water and treated wastewater for non-potable purposes often involves the installation of dual water supply systems.

"Demand management strategies that involve policies and activities to reduce per person or unit-of-activity use rates are being increasingly advocated . . ."

Reducing Pollution from Human Activities

Reducing the demand for water services will also have beneficial effects in reducing water pollution. Additional measures required to minimize adverse impacts of water pollution are:

•Reducing the generation of pollutants at the source by changes in industrial production processes, by-product recovery, and wastewater enforcement, pricing policies, and tax incentives.

•Adopting a "polluter-pays" policy, including the levy of effluent charges adequate to achieve the desired reduction. These charges must be earmarked for financing the cleanup costs of any residual pollution.

•Installing basic sanitation facilities in rural and low-income urban areas. The community must be involved in planning,

installing, and maintaining these facilities—which should be low in cost but meet minimum standards.

•Reducing water pollution from agricultural, grazing, and forestry activities by lowering soil erosion and consequent sedimentation, cutting discharges of pesticides and fertilizers, and reducing the saline content of irrigation return flows. Tools which may be used are subsidies, removal of subsidies which worsen conditions, changes in property rights, tighter regulation of forestry activities, and enforceable stipulations on the types and methods of applying agricultural chemicals.

"The adverse effects of natural disasters such as floods and droughts can be significantly reduced by making human adjustments . . ."

Human Adjustments to Floods and Droughts

The adverse effects of natural disasters such as floods and droughts can be significantly reduced by making human adjustments, such as:

•Controlling human occupancy of flood-prone lands. Effective enforcement of regulations encouraging compatible land uses, such as recreational, agricultural, and some commercial uses, while restricting non-compatible uses, can achieve this goal.

•Where human occupancy of floodplains is high, as in Bangladesh, adopting a loss-minimization strategy, including floodproofing structures and adopting flood insurance, warning systems, and evacuation and restoration plans.

• Following flood disasters, base redevelopment programs on risk-minimization land use controls and management strategies. Public investments, subsidies, and controls on private investment for redevelopment would be in accordance with these necessary human adjustments.

•Planning for human adjustments to drought which are based on specific rules for reducing water withdrawals to achieve efficient and equitable sharing of limited water resources through pooling of available supplies, allocation to the uses of greatest social value, with appropriate compensation to "losers."

VI. MAKING MANAGEMENT WORK

As shown in Figure 3, a management system is needed to preserve the integrity of the natural water resource system and to influence water-related human activities. Certain actions are needed to guide the planning and implementation of public and private programs and strategies to make management work effectively in an integrated way. The following are important examples:

•Establish unified national objectives and priorities for water resource management, including setting guidelines for resolving the inevitable conflicts among different water uses and between the objectives of national economic growth and self-

Participation of women in the planning for water resource improvements would recognize their key roles as providers, users, and guardians of water.

sufficiency, regional development, equitable income distribution and social impacts, environmental quality, and sustainability of the resource base.

•Develop constructive international agreements on water management, involving the fair sharing of benefits and costs of development/management of international river basins, and clear definition of rights and responsibilities of affected nations.

•Guide national investments in water resource development by means of capital investment budgets and programs, national/local cost-sharing, international or bilateral grants and/or loans, cost-sharing by provincial, local, and private agencies, and private investment. This involves linking the water resource sector to the national economy, as proposed by Rogers (1993).

•Adopt project formulation and evaluation criteria involving analyses for benefits-costs, risk-assessment, and multiple objectives (including environmental impacts) to be used for project and program feasibility studies and monitoring and evaluation of performance.

•Establish an appropriate balance between development—the creation of new projects, such as dams and irrigation systems—and management focussing on more efficient use of existing facilities.

•In cases where involuntary resettlement from development projects, such as storage reservoirs, cannot be avoided, plan for such resettlement so as to minimize economic and social dislocations, promote development opportunities for the displaced, and compensate for adverse effects fairly.

•Emphasize negotiation and mediation rather than confrontation.

•Adopt approaches for allocation of water and waste assimilation capacity that take account of the interdependency of water uses and the role of pricing policy. Alternative approaches are allocation via water markets with clear property rights versus allocation via administrative mandate; or by some combination of these two.

•Adopt a practical approach toward centralization versus decentralization of water planning and implementation, depending on the specific circumstances. In many cases, some combination of a centralized national irrigation or power agency and regional or local irrigation agencies is preferred.

•Promote public involvement/local participation in project planning and implementation, especially for irrigation, upstream watershed management, and rural and urban water supply and sanitation projects. The pivotal role of women as providers, users, and guardians of water should be recognized by arranging for their participation in these plans and decisions.

•Provide for adequate and reliable funding of project operation and maintenance, e.g., from user charges, especially for projects to be turned over to local water users for operation and maintenance.

•Plan for effective monitoring of projects and their evaluation for several years of operation.
•Provide practical training in the theory and practice of water resource planning and implementation, with special emphasis on how to achieve integration throughout the entire management process.

Organizing for Effective Implementation

Effective implementation of water-resource programs requires a set of national institutions and organizations incorporated in national legislation and the organizational structure of government. Two important actions are:
•Establishing a national water code to clarify the general principles of property rights. These may involve private ownership of surface water and groundwater rights (riparian or prior appropriation), full government ownership, with rights to use (including limitations) granted by government, or mixed public-private rights to water use which recognize water as a collective good. The code should include a water rights system which recognizes the hydrologic realities of surface water, groundwater, and return flow linkages, and the stochastic (probabilistic) nature of precipitation and streamflows.
•Effective organization for water resource management. This includes integration of activities of different agencies at the planning and implementation stages, spatial integration by river basin, water resources demand region, or political jurisdiction, and division of responsibilities for water resource management among national, provincial, local public, and private sectors. The activities involve water allocation, regulation of use and abuse, development, preservation, and operation of water supply and treatment facilities.

VII. THE URBAN CONTEXT

Integrated water resource management is becoming especially important in the urban settings of the humid tropics. Although historically the population of the humid tropics has been predominantly rural, this is no longer the case. For example, in 1990, about one-third of the two billion people living in the humid tropics were in urban areas (Figure 2) as defined by the U.N. Department of Economic and Social Affairs (1991). The humid tropic countries in Asia were the least urbanized—26 percent, while humid tropic countries in South America were 73 percent urbanized. Mega-cities, with 1990 populations in excess of 10 million, include Calcutta and Bombay in India and São Paulo and Rio de Janeiro in Brazil.

According to projections of the United Nations, the popula-

". . . the problems of urban water supply, sanitation, water and land pollution, flooding and storm drainage, and groundwater deterioration are all interrelated."

The forecasted population growth in the humid tropics of Asia will result in seven cities of more than ten million people by the year 2000.

tion of the humid tropical countries in the year 2025 is expected to be almost 3.8 billion, of which about 2.1 billion or 56 percent would be urban. By the year 2000, there will be about 10 mega-cities in the humid tropics. Of these, seven will be in Asia (U.N. Department of Economic and Social Affairs, 1991).

The major water-related problems of these large and rapidly growing cities in the humid tropics are fourfold:

•*The need for dependable supplies of potable water;*

•*Severe and growing sanitation problems, including pollution of streams, lakes, estuaries, and groundwater from domestic and industrial sewage and solid wastes;*

•*Large and increasing flood damages from occupancy of flood-plains and high peak flows arising from urbanization of the watershed;*

•*Depletion of groundwater aquifers, with associated land subsidence, caused by reduction of infiltration and overpumping of the aquifers.*

These typical urban water problems are accentuated by the extremely rapid growth of many urban areas in developing countries and by the intense rainfall and consequent high water levels often experienced in these areas in the humid tropics. Solution of these problems calls for an integrated approach to water resource management that is specifically adapted to urban settings in the humid tropics.

Specific examples of many of these water resource problems and related management issues discussed here are given by Gladwell, Lee, Lindh, Niemczynowicz, and Low in Bonell, Hufschmidt, and Gladwell (1993). They point out that the problems of urban water supply, sanitation, water and land pollution, flooding and storm drainage, and groundwater deterioration are all interrelated.

Water and land decisions made separately

Nothing less than a fully integrated approach to water and land management at the urban scale will suffice to deal adequately with them. The reality is that in most cities in the humid tropics land use and water management decisions are made without regard for the other. Even within the water resource sector, urban water supply, sanitation, water pollution control, flood control, and urban storm drainage are typically handled by different agencies, with little or no coordination among them. Also, all of these activities typically are undertaken with grossly inadequate basic data and scientific analyses of the urban hydrology.

Some of the detailed elements of an integrated approach to water management are presented in the following sections.

Urban water supply. A major constraint to providing potable water to rapidly growing urban areas is a shortage of investment funds. Historically, provision of infrastructure such as water supply, sanitation, transport, utilities, and basic housing has

BOX C: **Urban Water Supply**

Problems	Implications for Integrated Management
+ Many urban zones are not served, especially in poor sections. Major causes are bias toward high-cost technology, shortage of investment funds, unequal distribution of infrastructure.	+ • Increased cost recovery from water users. • Adopt low-cost appropriate technology. • Promote community involvement in water supply.
+ Unreliable performance of water system, including a high rate of "unaccounted for" water. Major causes are poor operation and maintenance, faulty metering and billing.	+ • Increased cost recovery to finance adequate operation and maintenance. • Improved organization and staff training for operation and maintenance. • Community involvement in managing local water supply.
+ Conflict with other water users (*e.g.*, irrigation) for diminishing available water supplies.	+ • Reduce water withdrawal by demand management, recycling and wastewater reuse. • Integrated system management of surface water and groundwater to make best use of available water for various competing purposes.

Adapted from H[illegible]chmidt in Bonell *et al.*, 1993.

lagged behind population growth and economic activity in these cities. The recent rapid increases in population have accentuated the problem. The capital investment needs for infrastructure, including water supplies, are enormous in relation to the needs. It may take decades to attain satisfactory levels.

A special problem is the provision of minimal levels of water service for squatter settlements around such major cities as Calcutta, Dhaka, Manila, Lagos, and Sao Paulo. At least in the short term, these settlements will have to make do with low-cost facilities such as standpipes, or even with high-cost mobile vendors. The upgrading of facilities to higher standards will have to be a long-term objective.

Over-exploitation increases cost, pollution

As urbanization proceeds, the readily available surface water and groundwater supplies are over-exploited; the groundwater aquifers show rapid declines as in Bangkok and Jakarta; and the surface and groundwater supplies become increasingly polluted. New and more remote sources of supply thus are sought, increasing the cost of supplying water to cities and bringing the urban water user increasingly into conflict with other water applications, principally irrigation. Examples of this situation exist in Bangkok, Jakarta, Surabaya, and Madras. Serious problems of water allocation among these competing uses are the result.

The urban water supply problem is further aggravated by the deterioration of existing systems arising from inadequate op-

" . . . the capital investments required for urban sanitation, including solid waste collection and sewage collection and treatment are so extensive as to be beyond the immediate financial capacity of most cities . . ."

"New and more remote sources of supply thus are sought, increasing the cost of supplying water to cities and bringing the urban water user increasingly into conflict with other water applications . . ."

eration and maintenance. In some cases, over 50 percent of the available supply is lost through leakage of water mains or is otherwise unaccounted for.

Urban sanitation and water pollution. Most of the streams and estuaries in or adjacent to cities in the humid tropics are grossly polluted as centralized collection and disposal of urban-generated sewage is inadequate, continuing to lag seriously behind urban growth. Further, much centrally collected sewage continues to be discharged into streams and estuaries without treatment. Even in the few instances—as in Singapore where point-source pollution is adequately collected and treated—non-point sources of pollution including litter, solid wastes, and sediment from the land and streets contribute to gross water pollution, especially during periods of high rainfall and associated runoff. In some cases, groundwater is also at risk of pollution.

As with urban water supply, the capital investments required for urban sanitation, including solid waste collection and sewage collection and treatment are so extensive as to be beyond

BOX D: Urban Water Pollution

Problems and Causes	Implications for Integrated Management
Gross pollution of urban streams, lakes, estuaries, and groundwater is increasing, because:	
+ Much domestic sewage is uncollected and flows directly into water bodies.	+ • Low-cost appropriate sanitation technologies. • Community involvement in building and operating sanitation systems.
+ Most domestic sewage that is collected is discharged into water bodies without any treatment.	+ • Appropriate low-cost treatment technologies *e.g.*, detention basins. • Wastewater reuse. • Cost-sharing.
+ Much industrial waste is discharged untreated on land and into water bodies.	+ • Appropriate incentives (subsidies for pollution control activities; effluent charges). • Recycling.
+ Much pollution of surface water bodies originates from "non-point" sources—urban land runoff—litter, solid wastes, sediment.	+ • Community involvement in sanitation & cleanup. • Watershed management program.
+ Centralized sewage collection and treatment systems are costly and beyond immediate capacity of urban governments to finance.	+ • Appropriate low-cost technology for wastewater collection and treatment. • Community involvement. • Cost sharing via sewer charges.
+ Existing sewage collection and treatment systems are poorly maintained and operated, leading to sewage spills and failure of treatment systems, especially during heavy rainfall periods.	+ • Community involvement in operation and maintenance of systems. • Adequate financing of operation and maintenance via sewer charges and property taxes.

Adapted from Hufschmidt in Bonell et al., 1993.

BOX E: Urban Flooding and Storm Drainage

Problems	Implications for Integrated Management
+ Rapid urbanization, including human occupancy of floodplains, has magnified flood risks and consequent damages.	+ Effective land use planning, including floodplain zoning, flood proofing, evacuation programs, and redevelopment of flood-prone areas.
+ Costly structural flood control measures are beyond financial capacity of cities.	+ Emphasize non-structural measures and low-cost physical measures, e.g., using streets for temporary flood storage.
+ Planning effective urban storm drainage systems requires rainfall and runoff data with very fine time and space resolutions; these are generally not available for humid tropics cities.	+ Establishing and maintaining hydrologic data systems suited to urban areas in humid tropics.
+ Effective flood control programs, combining structural and non-structural measures requires a high level of management not available in most cities.	+ Building management capacity and appropriate institutions for integrated flood management.

Adapted from Hufschmidt in Bonell *et al.*, 1993.

the immediate financial capacity of many cities, especially the fast-growing ones. With few exceptions, such as at Singapore, wastewater treatment to the secondary level is not a realistic option, at least for the next decade or two.

In some cities, such as Jakarta and Surabaya in the humid tropics, water pollution is alleviated during the rainy season by using large volumes of water for flushing the streams and estuaries. However, during the dry periods, water otherwise used for purposes such as irrigation or expensive reservoir storage would be required for this purpose. In any event, such flushing is not a long-range solution to the problem.

Waste control considered unimportant

Again, as with urban water supply, operation and maintenance of sewage collection and treatment systems and solid waste and litter control programs are often weak and ineffective. These low status activities are seriously underfunded and their effective management is often given low priority by urban managers and policy-makers.

In coastal cities and in cities such as Bogota, located near large rivers, wastewater can often be disposed of satisfactorily, even with little or no treatment, via long outfalls. However, in most inland cities, such as Bandung, this option is not available and some degree of treatment is required if gross pollution downstream is to be avoided.

Flooding and storm drainage. Human occupancy of urban floodplains in the humid tropics has greatly magnified the risk of flood damage, not only of the occupied regions, but as well of

BOX F: **Groundwater Depletion and Land Subsidence**

Problems	Implications for Integrated Management
+ Excessive pumping of groundwater causes land subsidence in urban areas with consequent flood losses and damage to structures.	+ Aquifer-wide regulation of pumping rates, involving permits, metering, and monitoring.
+ Unsustainable groundwater pumping rates cause aquifer depletion, with increasing pumping costs, and saline water intrusion to coastal aquifers.	+ Conjunctive groundwater-surface water management, involving appropriate timing of groundwater pumping, and artificial recharge of aquifers.

Adapted from Hufschmidt in Bonell *et al.*, 1993.

downstream areas because of sharp increases of storm runoff from roads, streets, housing, parking lots, and other impervious areas.

Structural flood control works—reservoirs, levees, storm drains, and channelization—are extremely costly, and usually beyond the financial capacity of cities. Thus some cities, such as Bangkok and Jakarta, have accommodated to flooding, as the flooding is gradual rather than torrential. In other cases, such as at Dhaka in 1987 and 1988, sudden flooding caused severe damages.

Cost-effective flood management for most cities in the humid tropics will involve a mixed strategy of inexpensive structural means such as drainage channels plus flood warning, flood- plain zoning, flood proofing, and evacuation measures. However, installing and operating an effective program of this type requires a high level of management, usually not available to these cities.

Urban storm drainage for flood control is closely related to non-point source water pollution as much of this diffuse pollution from the urban landscape reaches the streams and estuaries via these drainage works.

Groundwater depletion and land subsidence. In some cities, such as Bangkok and Jakarta, over-pumping of groundwater, along with high concentrations of buildings, roads and streets, has led to serious subsidence of land with consequent flooding and damage to buildings. Centralized control of groundwater pumping is required to reduce or eliminate such subsidence. This involves an advanced management program, with pumping permits, metering, monitoring, and regulation of pumping rates.

"... operation and maintenance of sewage collection and treatment systems and solid waste and litter control programs are often weak and ineffective."

In some cases, such as in Bangkok, conjunctive surface water-groundwater management is a preferred strategy. This could include artificial groundwater recharge via water-spreading fields and injection wells to raise groundwater levels. A possible problem is pollution of groundwater arising from these recharge activities.

Integrated water management for urban areas. Such management is especially complex in the humid tropics, involving:

•Meshing quite different water uses and purposes—e.g., water supply, water pollution control, storm drainage and flood damage alleviation, and water-based recreation—which are usually managed by different agencies.

•Planning and scheduling the construction of water-related infrastructure—e.g., water mains, sewers and sewage treatment plants, urban storm drains—must be meshed with urban land use plans, programs, and schedules for related infrastructure, e.g., highways, streets, electricity, gas, communications facilities, housing, parks, and recreational areas.

Integrated management to preserve the integrity of the water resource system is especially challenging in the urban context. It requires:

•That the boundaries for water planning extend beyond the immediate service area of the urban complex to include the upstream watersheds from which the urban area draws its water, and the downstream sections of streams, including coastal estuaries, which receive the effluent and flood waters from the urban area. In addition, planning boundaries need to incorporate the affected groundwater aquifers. The planning unit must be large enough to capture all of these important physical linkages (Rogers, 1993).

•Conjunctive use of surface water and groundwater.

•Careful analysis of the impacts on the natural environment of water supply storage dams and reservoirs, sewage collection, treatment and disposal, urban storm drainage and flood control works, plus urbanization itself, which increases flood peaks and non-point source pollutants. Special attention is required for areas downstream from urban areas.

Integrated management to influence human activities takes on a special character in large urban areas because of high population densities and the large social, economic, and environmental costs of mistakes. Needed actions are:

•Using demand management, including pricing policy, recycling and wastewater reuse to limit the growth in demand for potable water supplies.

•Mobilizing the local communities, including the women, especially in poor urban areas, to take major responsibilities for providing and maintaining a basic water supply and sanitation services and facilities.

Disposal of trash and garbage is only one of the activities which must be integrated into water resource management.

" . . . there is a general awareness at various levels within the concerned countries that some action needs to be taken to restore the adverse cycle of degradation . . ."

•Reducing damages from urban flooding by controlling human occupancy of flood-prone lands, and adopting a cost-effective flood management strategy.

•Reducing generation of solid wastes and water pollutants at the source by using technical means, including recycling and effluent charges.

•Closer meshing of urban solid waste collection and disposal, street cleaning, storm drainage, and disposal and treatment of sewage. In crowded urban areas, land and water pollutants are inseparable.

Integrated urban water management requires a special form of organization that transcends the professional specialities of water supply, wastewater collection and treatment, urban drainage, and flood management. Planning for water resources must be closely linked with urban land use, transportation, and other public facility planning.

VIII. THE UPLAND WATERSHED CONTEXT

The major natural resource management problem of the upland watersheds in the humid tropics relates to land use. Under increasing population pressure, large sections of the uplands are being deforested and converted to agricultural uses, including grazing. The severe impact of upland forest use or conversion on soil erosion rates, sedimentation in streams and reservoirs, water quantity in streams, peak stream discharges and nutrient input in streams has been extensively discussed in the literature (Bonell and Balek, Fleming, Lal, Rose, Roche, and Tejwani in Bonell, Hufschmidt, and Gladwell, 1993). The causes and consequences of watershed degradation are well known and there is a general awareness at various levels within the concerned countries that some action needs to be taken to restore the adverse cycle of degradation of the production base and the devastation of natural resources.

Degradation both human and nature-caused

When humans first cleared the land of forest or grass cover, the process of degradation of the natural resources started. Recently, however, because of very high pressures of human and/or livestock populations in developing countries, the process of watershed degradation has accelerated. The causes are both natural- and human-based. Natural causes include the region's geology, geomorphology, and rainfall erosivity—all phenomena over which humans have no control. Among the human-based factors, the large populations result in intense pressure on the natural resources of land (which is limited and non-renewable), freshwater and forest and other natural vegetation (which are renewable but limited).

The pressure of human population ever in search of arable land is exerted both on good arable land and on non-arable land in fragile upland ecosystems. In fact, many hilly and mountainous lands are quite densely populated. For example, the population density is 1,432 persons per square kilometer in the Indian Himalaya as compared to 483 per square kilometer for the whole of India (Tejwani, 1984a, b). The livestock population of upland watersheds is also generally very high. All of these land uses—forestry, agriculture, pasture—are therefore subject to overuse and mismanagement not only by the people but also by governmental activities such as improper road construction, mining, and forest extraction. All of these contribute to erosion and environmental degradation which is already high due to the young and fragile geological structures (Tejwani, 1991).

Damage both up- and down-stream

As a consequence, the production base is weakened and/or destroyed and the upland water resources are diminished. Downstream, the adverse impacts include higher rates of sedimentation of reservoirs, loss of irrigation and hydropower generation potential, increases in operating and maintenance costs of irrigation and hydropower generation, the rising and the

Bench terraces and agroforestry demonstrate an ages-old commitment in Bali to soil and water conservation.

BOX G: Integrated Watershed Management Defined

Watershed management is the rational utilization of land and water resources for optimal production with minimum hazard to the natural resources. It is essentially related to soil and water conservation, protecting land against all forms of deterioration, building and maintaining soil fertility, conserving water for farm use, proper management of local water for drainage, flood control, sediment reduction, and increased production from all land uses (Tejwani 1993).

Integrated watershed management is the process of formulating and implementing a course of action involving natural and human resources in a watershed, taking into account the social, political, economic, and institutional factors operating within the watershed and the surrounding river basin and other relevant regions to achieve specific social objectives. Typically this process would include (1) establishing watershed management objectives, (2) formulating and evaluating alternative resource management actions involving various implementation tools and institutional arrangements, (3) choosing and implementing a preferred course of action, and (4) through monitoring of activities and outcomes, evaluating performance in terms of degrees of achievement of the specified objectives (Easter, Hufschmidt, and McCauley, 1985).

widening of stream beds causing local floods, loss of fish breeding grounds, declines in fish production, and loss of inland water transport (Hamilton, 1983; Tejwani, 1993).

To counteract these adverse impacts of faulty land use in the uplands, watershed management approaches have been adopted by many countries and promoted by the United Nations' Food and Agricultural Organization (FAO) and other international donor agencies. Integrated watershed management is defined, for our purposes, in Box G.

Integrated watershed management gives promise of including often-ignored land and water interactions in planning and implementing development projects. These interactions are of the utmost importance in many river basins in the humid tropics where high levels of soil erosion in the upper watersheds not only reduce forest and agricultural productivity, but also cause sedimentation and water pollution problems downstream (Magrath and Arens, 1989).

Humanity's water resource record not all bad

However, although humans have been destroying forests and wetlands, there is a continuous record of human efforts to develop water resources for irrigation, to protect the irrigation systems, and to conserve soil and water resources. There has been a continuous thread of worship of the land, water, plants, animals, and nature. The problem of sedimentation of tanks and ponds received attention and the maintenance, repair, and desilting of tanks and ponds was made a socio-religious responsibility in India and Sri Lanka. This responsibility was cooperative in nature. The centuries-old bench terraces in the Indian Himalaya and in the mountainous regions of Java and Bali and the water conveyance and application practices in these areas are a unique testimony to the traditional skills and commitment to develop and conserve the natural resources of land and water (Tejwani, 1993).

In more modern times, the British, Dutch, and French colonials took active steps to develop irrigation systems and to control soil erosion and sedimentation. The program components comprised erosion control on agricultural as well as non-agricultural lands.

Western watershed management

Botero (1986) points out two western historic roots of watershed management: (1) the movement to restore the European Alps, which began in the last quarter of the nineteenth century; and (2) the conservation movement in the United States, which led to the establishment of the U.S.A. Soil Erosion Service (later the U.S.A. Soil Conservation Service) in the early 1930s. Soon after its establishment in 1946, FAO began adapting land restoration, torrent control techniques, vegetation manipulation, and soil and water conservation methods developed in Europe and the United States, respectively. The goal was to put together an integrated watershed management

"All of these land uses—forestry, agriculture, pasture—are therefore subject to overuse and mismanagement not only by the people but also by governmental activities . . . "

approach suitable for situtions encountered in the developing countries (Botero, 1986).

In Asia and the Pacific region, China, India, Indonesia, Pakistan, and the Philippines have had projects and extensive programs for development and conservation of land and water resources. The programs cover all land uses, a wide variety of practices of conservation, and in some cases provide for small-scale water resource development and increased production. Most governments of the developing countries have varying degrees of concern about the sustainability and conservation of their land-water-vegetation systems. Some governments, subject to the availability of funds, are willing to invest in and undertake programs related to soil conservation, afforestation, and flood control. In addition, some funds are made available as aid and "soft loans" by multilateral aid agencies, bilateral aid agencies, international banking institutions, and non-governmental aid agencies.

The rationale for an integrated watershed approach to rural development, whether directed toward agriculture, forestry, rangelands, or water resources, is that the approach has a strong biophysical and economic logic— summarized in Box H.

BOX H: Rationale for the Watershed Approach

The rationale for the watershed approach to water and related land resource management can be summarized as follows:

- **The watershed is a functional region that includes the key interrelationships and interdependencies of concern for water and land management.**
- **The watershed approach is suitable for evaluating the biophysical linkages of upstream and downstream activities.**
- **The watershed approach is holistic, enabling planners and managers to consider all relevant facets of resource development, including on-site and off-site changes and impacts.**
- **There is strong economic logic in the watershed approach since it internalizes many of the externalities involved in both land and water management practices.**
- **The watershed approach allows for ready assessment of environmental impacts, including the effects of water and land use activities on ecosystems, both upstream and downstream.**
- **The watershed approach to water resource management can be integrated with other programs, including forestry, soil conservation, rural and community development, or farming systems.**

Source: Easter, Hufschmidt and McCauley ,1985

"... an integrated watershed approach to rural development, whether directed toward agriculture, forestry, rangelands, or water resources, ... has a strong biophysical and economic logic ..."

Uplands and lowlands within the watershed are linked through the hydrologic cycle. Many of the impacts of land use activities on ecosystems are related to changes in hydrologic processes caused by land use activities. Many of the impacts, which would have been external to traditional development project planning, are accounted for when the integrated watershed approach is used. Thus, by focussing on the watershed, one can generally improve program planning and implementation of development efforts. This is particularly true when actions motivated by individual interests conflict with the biophysical imperatives for sustainable use of the watershed (Dixon and Easter in Easter, *et al.,* 1986).

Problems and Management Issues

In spite of the demonstrated benefits of integrated watershed management and the availability of technological packages, an evaluation of many watershed management projects reveals that often the projects did not yield the results which were expected from them. In fact, sometimes they have caused biophysical damage, resulting in a loss of credibility of the program. Experience has shown that if a country wishes to embark on an effective integrated watershed management program, it must look at the whole gamut of policy, organizational, institutional, and strategy issues involved in such a program. This critical examination of the whole process may help to avoid pitfalls or mistakes experienced by others.

It is difficult to prescribe specific organizational/institutional solutions, strategies, and policies which would be universally applicable to the diverse economic, social, and cultural situations in different countries. However, one can raise the most important and basic issues to provide guidance to planners and decision-makers as they seek to resolve the many challenging problems associated with watershed management. Even when management issues are identified, effective solutions may be hard to find and even when they are found, they may still be difficult to apply because of various social, economic, and cultural constraints, including the following:

Awareness. Most developing countries know the importance of water resource and related development in meeting the needs of food for the people, forests for fuelwood, and hydropower for industrial growth. However, they appear to be largely unaware of the relationship of the upstream watershed conditions to the production base downstream.

"... if a country wishes to embark on an effective integrated watershed management program, it must look at the whole gamut of policy, organizational, institutional, and strategy issues ..."

It is true that people in densely populated countries or densely populated localized areas in sparsely populated countries are a major cause of watershed degradation. However, in certain situations, the government itself or the agents of government are responsible for the degradation. For example, a recent analysis in Indonesia of the degree of soil erosion associated with various land uses and the responsible agents has revealed that the government or its agents are often more responsible for watershed degradation than the people (Tejwani, 1992). Some evidence in India and Thailand tends to support this conclusion (Narayana and Rambabu, 1983; Henderson and Rouysungnern, 1984; Gadgil, 1989). Until this situation is recognized and corrected, existing practices and programs of watershed management will continue to be largely ineffective.

Institutional Arrangements. Appropriate institutional arrangements are especially important to the success of watershed management programs (Gibbs, 1986). Perhaps the most important institutional factors affecting the watershed are ownership, rights, and tenure. At one extreme, the lands are entirely in the hands of the government, and the right to use the land or its renewable resources such as trees and forage are subject to governmental regulation. At the other extreme, the land is in private hands, with these owners having great leeway in its use, subject only to general restrictions on some types of use that could create adverse off-site effects. In some cases, private ownership—typically of agricultural and grazing lands—is concentrated among a relatively few owners, who, in turn, lease the right to use the land to tenants.

Customary use rights are significant

Between these extremes are the "common property" rights to land where rural groups have acquired by custom the right to use certain renewable resources such as forage, shrubs, fallen wood, fruits, and nuts and even certain types of trees. The underlying ownership may be in national, provincial, or local governmental hands, but the customary use rights are handled by the local community. In most upper watersheds, the institutional arrangements for land use are a mix of these various types.

From the standpoint of effective watershed management, the major issue is the extent to which the specific institutional arrangements are well adapted to this purpose. As Gibbs (1986) points out, perhaps the most important attribute is security of tenure. In terms of this criterion, outright ownership and long-term leasing by operating farmers are superior institutional arrangements.

Effective management of "common property" lands also requires certainty in the application of rules in order to avoid the "free-rider" problem. In this situation, some persons reap the benefits of the land resource, such as fuelwood and forage, without making any contribution to its management. In many cases, community-based control of such common property resources offers a better opportunity to overcome this obstacle than sole reliance on the regulatory powers of national or provincial governments.

Problems of Plan Implementation. In most cases, agencies charged with watershed management responsibilities have en-

"Perhaps the most important institutional factor affecting the watershed are ownership, rights, and tenure."

Farmers that own their land or have long-term leases are the most apt to participate in watershed improvement programs.

BOX I: Important Reasons for Failure of Implementation of Watershed Management Plans

- Little or no local participation.
- Inadequate extension and technical assistance programs.
- Inadequate testing and development of management practices.
- Delays in delivery of key inputs, including financial resources.
- Fragmented governmental management structure.
- Exclusion of downstream interests.
- Inappropriate institutional arrangements.
- Political boundaries unrelated to watershed boundaries.

Adapted from Hufschmidt in Bonell *et al.*, 1993.

countered problems in implementing soil conservation and watershed management programs in the rural upland areas. These implementation problems arise from a number of reasons, as shown in Box I.

Watershed residents must be motivated

Many of these reasons are closely related to the reality that actual land use decisions are in the hands of watershed residents—typically, many small farmers living in small rural communities. Implementation of watershed management programs must largely be done by them or through their collaboration. It follows that undertaking watershed management practices must be shown to be in their interest, and appropriate incentives must be provided to them. Crucial to this approach is a thorough understanding of the behavioral and social dimensions of rural watershed management. This involves: (a) collection of baseline data on existing social and behavioral conditions and human-environmental relations; (b) identification of different social and ethnic groups in the watershed; (c) recognition of the cultural basis of different land use patterns; (d) giving special attention to ethnic minorities and the rural poor; and (e) learning from other areas (Lovelace and Rambo, 1986).

"...implementation tools can be grouped into legal arrangements; monetary incentives or disincentives; technical assistance, education and research; and direct public installation or investment."

Implementation Tools. Closely related to institutional arrangements are the implementation tools (*i.e.*, ways of installing and operating watershed management measures). According to Easter *et al.*(1986), implementation tools can be grouped into legal arrangements; monetary incentives or disincentives; technical assistance, education and research; and direct public installation or investment. An integrated watershed management plan and program will generally include a combination of these implementation tools.

A wide range of potential legal arrangements or regulations can be used to implement an integrated watershed management plan. Regulation of activities on rural lands, especially those in private ownership, is often fraught with difficulties, particularly in developing countries where enforcement capabilities are weak. Economic incentives would appear to be an appropriate tool to achieve environmental objectives of watershed management. Governmental cash subsidies have been used as incentives for farmers to install various watershed management practices, but their effectiveness has been limited. As pointed out in Easter *et al.* (1986), many governments may find it hard to implement cost-sharing or low interest rate loan incentives because of budgetary constraints and the difficulties of distributing such incentives to the appropriate population.

". . . many governments may find it hard to implement cost-sharing or low interest rate loan incentives because of budgetary constraints . . ."

Watershed costs should follow watershed benefits

Because integrated watershed management provides both on-site and off-site benefits, it is only fair that people living in the watersheds not be made to pay for all of the works (Tejwani, 1987). Equitable fiscal management systems, therefore are needed to determine who actually pays (the farmer, the community, the government) and for what and how much. In Colombia, for example, two percent of hydropower revenues is set aside for upstream watershed rehabilitation.

If the government or its agents are responsible for degradation, it is obvious that they must pay fully for rehabilitation measures.

Technical assistance to farmers through extension services and demonstration projects is often a successful means of promoting watershed management on rural lands. Direct installation and maintenance of watershed management measures by government is appropriate for publicly-owned land such as upland forest and for off-site management measures such as check dams on small streams. Direct installation of on-site measures on private lands is more problematical. Such investments over extensive areas can be costly and will be limited by budgetary considerations. However, they often are desirable in the case of small farmers in developing countries. In such cases, farmers should be involved in installing the structures in order that they will have a stake in maintaining them (Easter *et al.*, 1986).

Organizational Aspects

Generally, watershed management activities are entrusted to forestry departments, and soil and water conservation on agricultural lands to agricultural departments. In the Himalayan region several different organizational approaches are being attempted:

•If more than 50 percent of the land in a watershed is used for agriculture, responsibility for watershed management is assigned to the agriculture department; conversely, if more than 50 percent is forest land, responsibility is given to the forestry department. This model has been adopted in India. It may be

hard to implement effectively as it calls for each department to have professionals in all relevant disciplines (agriculture and forestry) if the project is to succeed.

•Creation of a separate soil conservation or watershed management department. This model has been adopted by Nepal within the Ministry of Forests. Pakistan has also attempted implementation of watershed management projects through its forestry department as well as its soil conservation department. Centralization of authority and responsibility is seen as a major advantage of this model.

•Creation of an independent authority or a society for specific watersheds. India has attempted to implement the Dhauladhar project by a society, led by foresters. Pakistan has implemented Tarbela and Mangla Reservoir Watershed projects through its "Water and Power Development Authority" led by engineers. Similarly, in the Philippines, management of the upper Agno River Basin was assigned to the National Power Corporation, and management of the watershed land above the Magat and Pantabagan Reservoirs was assigned to the National Irrigation Administration. Here, too, centralization of authority and responsibility is seen as an advantage.

In each of these cases, the projects are managed and funded by the governments. Responsibility is not passed on to the people. People are involved only as laborers or as petty contractors by way of subsidies and/or incentives on private lands. The success of these approaches is variable and depends upon the quality of leadership and effectiveness of the attempts made to integrate all of the activities and to involve the people.

In addition to the forestry and agriculture departments with primary responsibility for watershed management, other government departments—for example, animal husbandry, horticulture, roads, irrigation, hydropower, and mining—deal directly or indirectly with watershed conditions. These departments generally work in isolation and have little or no concern for the interdependencies involved.

Because integrated watershed management for sustainable use of natural resources is a relatively recent development, it is understandable that some of these departments are oblivious to the need for co-ordination. However, with the increased pressure on natural resources, there is an urgent need to coordinate these diverse governmental activities.

"...farmers should be involved in installing the structures, in order that they will have a stake in maintaining them..."

Operational Issues

Conservation vs. Production. Watershed management programs are invariably promoted with the focus on conservation, forest plantation and protection, downstream benefits, and environmental stability. All of these program components have long-term and social benefits. However, farmers living in the watershed will not change their land use patterns or practices on which they are now subsisting unless they understand the proposed change will benefit them directly and immediately. Accordingly, in highly-populated subsistence-farming communities, it is essential to combine increased production—for example, water resource/irrigation/horticulture development—with watershed conservation measures. Also, mechanisms are needed to share the benefits of government-owned forest plantations, often established and protected with the help of the people.

Program Components. There is a critical need to examine the relative proportion of biological measures and structural measures for erosion control in watershed management programs. In general, because of high maintenance costs, structural measures should be kept at a practical minimum, usually 20 percent or less of the total cost of management measures.

Research and Demonstration. With the exception of China, India, Indonesia, Pakistan, Malaysia, and Philippines in Asia; Kenya, Nigeria and Zimbabwe in Africa; and Venezuela in South America; research is either non-existent or grossly inadequate in the humid tropics. In the short run, the organization of research can follow any of the three following courses of action (Tejwani, 1986):

- *Adapt findings of research conducted elsewhere outside the country. Sufficient research information on watershed management practices is believed to be available to enable a country to adapt a management package for its immediate needs, and then modify it. Further, in almost all countries, the subsistence farming societies have developed traditional methods of natural resource management on a sustained basis which can be a rich source for building up a package of practices to be further refined. Nepal has successfully adopted this course.*
- *Develop a package of practices based on previously conducted research within a country.*
- *For the long run, initiate new research in response to the needs of development programs.*

Training of water management professionals should be carried out primarily in and by the humid tropics countries.

The results of research must be expressed in practical ways through demonstrations, operational research projects, and "lab-to-land" programs. India, Indonesia, Philippines, Thailand, Ethiopia, and Costa Rica have had good experience with such demonstration activities. A good linkage is needed between research and development agencies but is often lacking.

Since research is expensive and fragile, it needs to be nurtured closely on a long-term basis, and the relevance of research to practical application needs to be critically looked at.

Some foreign-aided projects provide funds for research but often the funds are not used effectively since there is no existing

infrastructure for research nor can the funds be used to develop one.

Training. Trained people are needed in large numbers for planning, implementing, and evaluating watershed management programs. The term "training" is used here in its widest sense to include university education, vocational training, in-service, and farmer training. Social, cultural, and ecological aspects must be included. With few exceptions, training in watershed management is non-existent or grossly inadequate in the developing countries of the humid tropics. The major training issues are:

•Updating of the curricula of university courses in agriculture, engineering, and forestry to include natural resource and watershed management and conservation.

•Planning for training the needed people if watershed management programs are to be initiated. This would require in-service training since currently graduates in agriculture, engineering and forestry are not oriented to integrated land use activities. It is important to project the need for trained people for 10 years.

•In-service training must include all categories of personnel—field technicians, junior-level managers, middle level supervisors/technologists, and project managers/supervisors.

•The type of training needed, e.g., short-term, long-term, regular, or irregular will vary with the type and level of personnel and the purpose of training—professional, orientation and refresher.

•Establishing training facilities. International agencies have correctly emphasized technical cooperation and assistance in developing countries, which among other things places great emphasis on the training of technical personnel. However, this invariably means training abroad for degree and non-degree courses. For non-degree training, special courses are prepared by the donor countries.

While the vital need for training received in developed countries will continue for a long time to come, such training cannot be the primary medium for mounting sustained watershed management and soil and water conservation programs in the developing countries. Evaluation of many projects in Asian and African countries has revealed that even after a project has run for a decade and millions of dollars have been spent, the countries did not have the facilities to mount their own training programs. There are some exceptions to this generalization such as the U.S.A. aid to India and Nepal.

". . . mechanisms are needed to share the benefits of government-owned forest plantations, often established and protected with the help of the people."

Mutual responsibilities for training programs

Each nation must bear a large proportion of responsibility for training as international training is costly and cannot train large numbers. However, it can provide some trainers, researchers, leaders, and managers. The remainder of these trained professionals and most of the technicians must be trained within the country. This calls for estimating the needs for trained people, planning of training programs, and establishing training facilities by the countries themselves.

Sustainable Management Strategies

Densely Populated Areas. Faced with the explosive situation of large populations, there are three land use options suitable for sustainable management:

•*Open up new land for cultivation through deforestation. This is a restricted option as there is little or no additional land to bring under cultivation in many developing countries, including the hills and mountains of Nepal, India, and Indonesia (Java and Bali).*

•*Increase the productivity of the land presently under cultivation. A wide gap exists between the yields currently obtained and those achievable in the mountainous and hilly watersheds. The input components are high-yielding seed varieties, correct water management, adequate supplies of nutrients, and pest and pathogen control. However, if the initial soil fertility and physical soil conditions are good, the inputs required are much less than those needed for the same level of yields from degraded, eroded, and less fertile soils. Therefore, it is necessary to pay attention to soil conservation and water-resource development.*

There is evidence from India and Nepal that if water resources are developed for irrigated agriculture, the farmers voluntarily prepare much better terraces for agricultural crops and tend to conserve the soil and preserve the terraces. Application of water not only gives higher yields but encourages the farmers to use high-yielding varieties of seed and fertilizer inputs.

•*Develop horticulture and high-value plant production---for example, flowers, vegetable and flower seeds, medicinal plants. All of these activities require a good infrastructure of roads, markets, and storage facilities. It will also be necessary to ensure food supplies for the people living in the mountains.*

It also should be noted that in spite of the promise held out by the second and third options above, it is clear that the land-water-plant systems in fragile upland areas cannot support an ever-increasing population. Therefore, population control is a major issue in any further development of densely populated watersheds. Although this issue is often avoided due to various social, political, and religious factors, it remains the single most important factor determining the success of any development activity in densely populated watersheds.

Sparsely populated areas. The relative impact of high density and low density human and livestock populations on soil erosion and watershed functioning is an important factor. The relative difference in the approach to soil and water conservation can be brought out by comparing Kerala State in India, Sierra Leone in West Africa, and Indonesian island groups, all of which are in the humid tropics (Tejwani, 1991; 1992). Sierra

In some areas, forests are available for clearing and conversion to cultivated land. In other regions, the forest must be conserved.

"*. . . it is clear that the land-water-plant systems in fragile upland systems cannot support an ever-increasing population.*"

Leone and Kerala State are almost similar in broad terms with respect to their tropical climates, rainfall, soils, vegetation and yet are quite different with respect to population density, agriculture, forestry, irrigation, and their general development.

Sierra Leone is twice the area of Kerala State, but it supports only 48 persons per sq. km. as compared to 655 persons per sq. km. in Kerala. Kerala, due to very high population pressures, cultivates 56.1 percent of its land as compared to only 7.5 percent in Sierra Leone; Kerala irrigates 62.4 percent of its cropped land while Sierra Leone does not irrigate any land; Kerala uses 45.2 kilograms of fertilizer per hectare, whereas in Sierra Leone there is little intensive agriculture.

Settled agriculture advisable for Sierra Leone

In Sierra Leone, the policy must be to guide its people away from shifting cultivation in uplands, encourage settled agriculture and agroforestry in uplands, utilize the vast unexploited potential of its lowlands by expanding the area under cultivation, and practicing conservation and good management. Sierra Leone must also develop its hydropower and irrigation potential.

In the case of Kerala, there are still opportunities to extend the area under irrigation, to practice intensive cropping, and to develop industry. Soil and water conservation practices are important in both Kerala and Sierra Leone. However, in the case of Sierra Leone, the forests can be managed to make available new agricultural land, while in Kerala the remaining forest would need to be zealously protected and afforestation practiced to meet the needs of its very large population.

Indonesia is faced with both high and low density population situations. On the one hand, Java and Bali are very densely populated with advanced and intensive agriculture, irrigation, and home gardens (like Kerala). On the other hand, in the less densely populated islands such as Sumatra, Kalimantan, and Celebes, it is important to guide the people away from shifting cultivation. People in Indonesia are much more familiar than those in Sierra Leone with home gardens and plantations of rubber, oil palm, tea, cacao, coconut, and cloves. Hence, the transition to sustainable management could be relatively easy. In the case of densely populated areas like India, Nepal, Java, and Bali, the emphasis should be on rehabilitation and sustained production; in the case of low population pressure areas such as Sierra Leone, priority should be given to increasing production with conservation.

IX. SUMMARY

With a fixed supply of water and rapidly increasing demands for water and its services in the humid tropics, sustainability is becoming a more and more difficult goal to achieve. Integrated water resource management, which means making better use of the resources to meet current and future demands, is increasingly seen as the answer to this challenge. As shown in Figure

SUMMARY - continued

3, integrated management involves understanding of three interrelated systems. Both a thorough understanding of the natural water resource system and detailed knowledge of how human activities affect and are affected by the natural system are needed to make the management system work.

Although water management problems and issues differ with different contexts, for example, urban or upstream watersheds, the underlying challenges to integrated water management remain the same—how to achieve sustainability in providing needed water services to the expanding populations and economies of the humid tropics.

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Cooperative efforts by each person can lead to the reaching of their individual goals. A similiar level of local, regional, and international cooperation will be needed to achieve sustainability of the humid tropics' water resources.

"... the underlying challenges to integrated water management remain the same--- how to achieve sustainability..."

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The International Hydrological Programme (IHP)

The developing nations of the humid tropics of the world will represent about one-third of the Earth's population by the end of the present decade. In the Twenty-First Century, these nations will pass the developed countries in numbers of people. Such a population shift will alter existing international economic and geopolitical relationships.

With this major change looming on the horizon, coupled with the need to treat the tropical resources wisely, the United Nations Educational, Scientific and Cultural Organization (UNESCO) and the United Nations Environment Programme (UNEP) joined with 22 other organizations in July 1989 to hold the International Colloquium on the Development of Hydrologic and Water Management Strategies in the Humid Tropics. The International Hydrological Programme of UNESCO was the lead organization.

The Colloquium developed strong evidence that the present situation, including the question of tropical forest depletion, was not only in need of serious consideration, but that the potential for vastly increased negative human impacts will be quite significant if they are not adequately considered now. It was noted that although the general characteristic of the humid regions is an overall abundance of water, this very abundance and the variability of its distribution are the leading contributors to the difficulties.

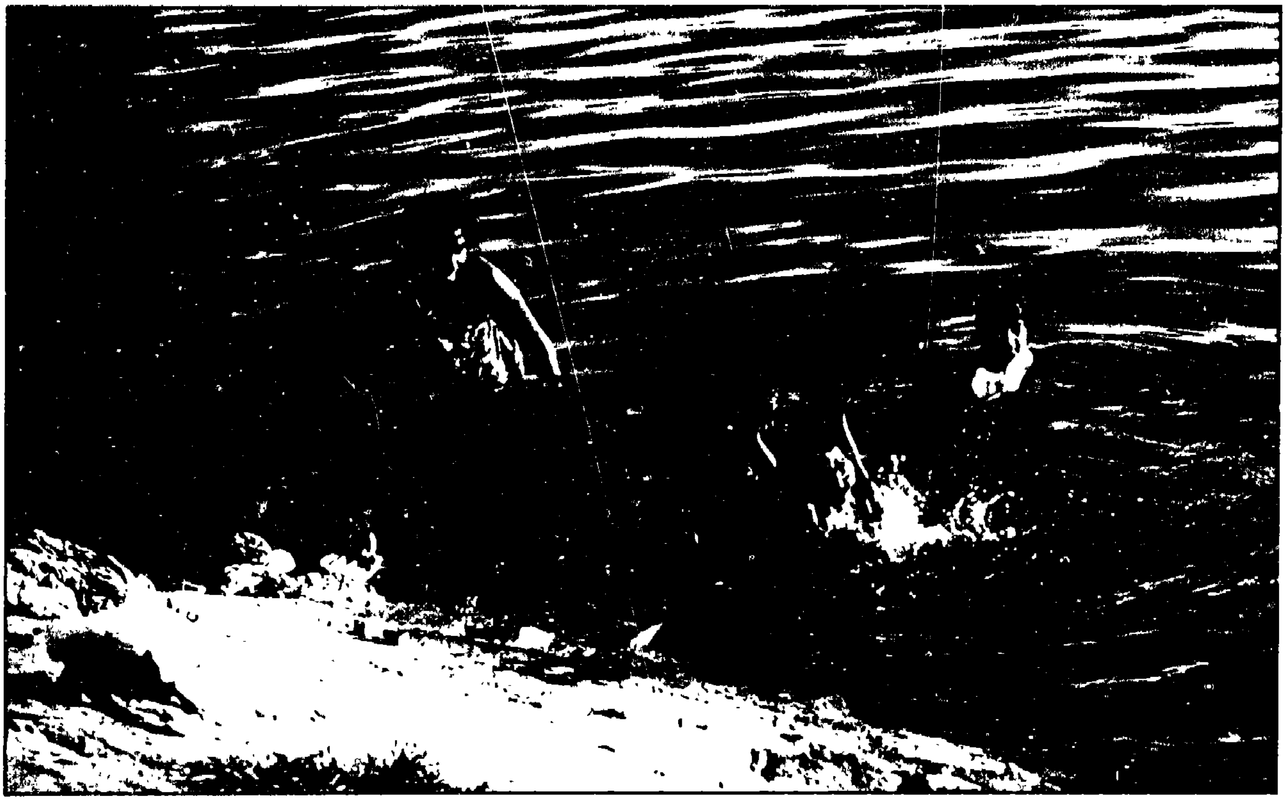
This volume on managing tropical water resources is one of several publications having their origin in the Colloquium. An executive summary of the Colloquium, **Water-Related Issues and Problems of the Humid Tropics and Other Warm Humid Regions,** was released shortly after the Colloquium was held at Australia's James Cook University. **The Disappearing Tropical Forests** was made available for distribution in May 1991. Similar volumes on tropical islands and water and health were issued in l992. A major scientific text embodying many of the topics raised at the Colloquium has been prepared.

Further information on these publications can be obtained from the International Hydrological Programme, Water Sciences Division, UNESCO, 7, place de Fontenoy, 75700 Paris, France.

Man and the Biosphere (MAB) programme activities in the humid tropics

Some of the generic characteristics of the MAB Programme, one of the sister environmental programmes of IHP within UNESCO, are improving the scientific understanding of natural and social processes relating to man's interactions with his environment; providing information useful to decision-making on resource use: promoting the conservation of genetic diversity as an integral part of land management; enlisting and co-ordinating the efforts of scientists, policy-makers, and local people in problem-solving ventures; and mobilizing resources for field activities and strengthening of regional cooperative frameworks.

MAB, launched in the early 1970s, is a nationally-based, international programme of research, training, demonstration and information diffusion. The overall aim is to contribute to providing the scientific basis and trained personnel needed to deal with problems of rational utilization and conservation of resources and resource systems, along with the problems of human settlements.



Although some initially may object to contact with water, they soon realize its universal value and seek to manage its availability.

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