

Agriculture and Rural Development Report 1

Reclaiming Drainage

Toward an Integrated Approach

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Cover art

The discharge of irrigation drainage water through a natural depression in North Cameroon, has created a breeding site for schistosomiasis snails. In close consultation with local groups, the depression was reconstructed. The villagers welcome the possibility of growing dry-season horticulture, and the production of fish provides a cheap additional source of protein. Snail populations have dramatically decreased by water level fluctuations, showing that an integrated approach to drainage problems can result in increased production while reducing health risks.

In: R. Slootweg & R. Keyzer (1983): Reducing schistosomiasis infection risks through improved drainage. Irrigation & Drainage Systems. Irrigation and Drainage Systems 7: 99-112.

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Preface

This report is the concluding document of a study called *Agricultural Drainage: Toward an Interdisciplinary and Integrated Approach*. The study is an initiative of the Agricultural and Rural Department (ARD) of the World Bank within the framework of the Bank–Netherlands Partnership Program—Environment/Water Resources Management Window. The study was undertaken to improve the way agricultural drainage is looked at and acted upon in line with new World Bank Water, Agricultural and Rural Development, and Environment strategies. It is a step toward implementing many of the principles advocated in those strategies, when future lending for drainage is sought, balancing productivity and sustainable development.

The study was an intensive, exciting, and highly enjoyable effort in three steps:

- The production of six country case studies by teams of international and national consultants, who thoroughly examined and analyzed each country's experience in drainage under its own specific conditions
- A workshop attended by national and international experts and decisionmakers, as well as Bank staff, to review and discuss the findings of the case studies
- The writing of the final report of the study by a six-member team that provides the contours of an approach to integration for analyzing and planning future drainage interventions.

The case studies (listed in the References section of this report) will be published on the World Bank website (www.worldbank.org/irrigation-drainage).

Acknowledgments

Many people contributed to this study in its different phases. For their inputs during the writing phase of the final report, on behalf of the authors, I would like to thank Shawki Barghouti, Evan Christen, Kevin Cleaver, Salah Darghouth, Richard Davis, Geert Diemer, Ariel Dinar, Eric Fernandes, Sushma Ganguly, Rafik Hirji, Arend Kolhoff, Nwanze Okidgbe, Lambert K. Smedema, Ashok Subramaniam, the organizers, facilitators, and participants of the Ninth International Drainage Workshop for hosting a special session to present the findings of this study (Utrecht, the Netherlands, September 2003), and the participants of the International Commission on Irrigation and Drainage 54th International Executive Council Meeting and 24th European Regional Conference, Montpellier, France, for their interest expressed during two presentations. The responsibility for the

content remains that of the authors. For editorial, technical financial-administrative and other practical assistance we would like to thank, respectively, Kathleen A. Lynch, Cora Solomon, K.S. Vijayasekhar, and Melissa Williams.

We would also like to acknowledge the funding provided by the Bank–Netherlands Partnership Program-Environment/Water resources Management Window and to thank all who facilitated such funding.

We sincerely hope that the integrated approach to drainage outlined in this report will find widespread application.

Safwat Abdel-Dayem, Washington D.C.,
United States

February, 2004

Acronyms and Abbreviations

ADA	Association of Drainage Authorities
ADB	Asian Development Bank
BCM	Billion cubic meters
BNPPEW	Bank–Netherlands Partnership Program—Environment/Water Resources Management Window
BR	Bureau of Reclamation
CGIAR	Consultative Group on International Agricultural Research
CWP	Collaborative Work Program
DfID	Department for International Development, United Kingdom
DRAINFRAME	Drainage Integrated Analytical Framework
DRI	Drainage Research Institute
EPADP	Egyptian Public Authority for Drainage Projects
EU	European Union
FAO	Food and Agriculture Organization
FCCC	Framework Convention on Climate Change
FCD	Flood control and drainage
GWP	Global Water Partnership
GWSA	Water and soil association, Germany
HIA	Health Impact Assessment
ICID	International Commission on Irrigation and Drainage
ILRI	International Institute for Land Reclamation and Improvement
IPTRID	International Programme for Technology and Research in Irrigation and Drainage
IUCN	World Conservation Union
IWASRI	International Waterlogging and Salinity Institute
IWMI	International Water Management Institute
IWRM	Integrated water resources management
NDP	National Drainage Program
NGO	Nongovernmental organization
NWMP	National Water Management Plan, Bangladesh
O&M	Operation and maintenance
PRA	Participatory Rural Appraisal
PRODERITH	Program for Integrated Rural Development in the Tropical Wetlands
RAPID	Research and Policy in Development Program
RRA	Rapid Rural Appraisal
SCARP	Salinity Control and Reclamation projects
UNESCO– WWAP	United Nations Educational, Scientific and Cultural Organization—World Water Assessment Program
US\$	U.S. dollar
WAPDA	Water and Power Development Authority
WGA	Western Governors' Association
WHO	World Health Organization
WM	Water management
WWAR	World Water Action Report
WWDR	World Water Development Report
WWV	World Water Vision

Executive Summary

This report is the concluding document of the study, *Agricultural Drainage: Toward an Interdisciplinary and Integrated Approach*, under the Bank–Netherlands Partnership Program—Environment/Water Resources Management Window. The study spanned more than two years of literature reviews, field investigations, and analysis. Work included case studies in six countries representing a cross-section of drainage situations in different climatic zones. The last phase focused on formulating the approach presented in this document.

Drainage as a human intervention in the hydrological cycle affects many different functions of natural resources systems and thereby has multiple impacts on society. Global experience provides an overview of some of these effects, positive and negative. The impact of drainage on agricultural production and productivity can be substantial, and drainage investments may have a short payback period. Drainage has a favorable impact on public health and enhances sanitation in rural areas. Improved drainage increases the value of land and buildings and protects roads and other rural infrastructure. On the negative side, drainage has often done much less well in safeguarding vital ecosystems, key environmental processes, and other resources such as fisheries.

Drainage situations exhibit substantial diversity in terms of the multiple crops and soils served, the many resources system functions affected, the scale of the systems, the development environment, the social and economic circumstances, and the ecological factors involved. The wide diversity encountered in drainage situations across the world and the variety of factors causing it show that “drainage” is a container concept. Talking about drainage in general is therefore almost meaningless—at both the analytical and intervention levels. A context-specific approach is required for both analysis and intervention.

Despite the great diversity in drainage situations and its many impacts, drainage used to be considered from a narrow sector angle, focusing solely on agricultural productivity. The sector approach isolates drainage

from the big picture of integrated management of land and water. The increasing complexity of water control systems, the conflicts of interest in many water management systems, the way the different impacts are weighted, and the need to rethink the role and perspective of drainage in the international water debate all are drivers to place drainage at the center of integrated management of natural resources. *Integration* in the context of this report means developing alliances with compatible interests in water resources management and creating negotiating space for conflicting areas.

The drainage paradox is this. Improvement of drainage, on the face of it, could be an important instrument for achieving sustainable human development, while in reality it has almost disappeared from international water discourse as a theme and a concern. Also, investment in drainage by governments and in the lending portfolios of financial institutions is decreasing. To resolve this paradox, drainage has to reclaim its rightful position as an indispensable component of the management of land and water, not from an agricultural sector perspective, but from an *integrated* perspective.

The policy statements of the World Bank in its new strategies on water resources management, rural development, and the environment strongly support the idea of an “integrated drainage” perspective. An integrated approach to drainage is a way to put the principles promoted by these strategies into action: through integrated water resources management (IWRM) and sustainable development. The art will be to translate general strategic principles into practical “how-to” approaches to drainage.

Drainage, as defined in this study, is land and water management through the processes of removing excess surface water and managing shallow water tables—by retaining and removing water—to achieve an optimal mix of economic and social benefits while safeguarding key ecological functions. Drainage is an inherent part of the hydrological cycle, a natural process that human beings adapt for their own

purposes by redirecting water in space and time and manipulating water levels.

This report presents a tool for analysis and planning—DRAINFRAME, the Drainage Integrated Analytical Framework. DRAINFRAME is a procedure for analyzing and assessing the functions and values embedded in a participatory planning process. The analytical component of the tool consists of systematic mapping of the functions (in nine iterative steps) of (the goods and services provided by) natural resources systems and the values attributed to these functions by people, and the exploration of the implications (effects and impacts) of particular drainage interventions. DRAINFRAME also provides a framework for discussing and negotiating tradeoffs related to the different functions and values directly related to and influenced by drainage. This is the communication, planning, and decisionmaking support component of the tool.

The report distinguishes four different levels at which the multifunctionality of resources systems can be explored: the large basin, the hydroecological region, the landscape, and the drainage system. The meso level of the landscape is the most appropriate level for integrated planning of drainage interventions. A *landscape* is a unit of land with homogeneous natural resources (soil, water, climate, vegetation) that performs a homogeneous set of functions. Groups in society value these functions (goods and services) and become stakeholders. Drainage interventions attempt to enhance certain functions for the benefit of these stakeholders. Institutional arrangements are created to manage these interventions.

The idea that different stakeholders are involved implies that interaction, communication, and negotiation are required when interventions are proposed to deal with a drainage problem or opportunity. This is a case of “participatory planning” that allows stakeholder involvement in decisionmaking for natural resources development and management. Central to this approach from an institutional or planning perspective is the *negotiation* of options and strategies preferred by the concerned stakeholders. The basic conditions under which comanagement can work, and by implication participatory planning, include, full access to information on relevant issues and topics, freedom and capacity to organize, freedom to express needs and concerns, a nondiscriminatory social environment, the will of partners to negotiate, and confidence that agreements will be respected.

Country- and site-specific polycentric and multistakeholder governance and management structures for drainage offer the promise of combining the potential of the public sector, local and user groups, and the private sector. The challenges are manifold. Organizational structures and procedures are needed in which drainage is not separated from other forms of land and water management and where related objectives are coordinated—irrigation, flood control, public health, and the conservation of natural areas and water bodies (wetlands). This also applies to residential and agricultural land use and to infrastructure planning. River basin organizations may provide a forum for coordination and planning, but other organizational forms may better fit national political and administrative systems.

In such a structure, there is no single, ultimate center of authority, and therefore functions and responsibilities have to be clearly assigned, circumscribed by rules for establishing cooperation and coordination procedures and for structuring decisionmaking. This integration has a financial dimension in that the introduction of the benefit-pay (-say) principle would bring all stakeholders into the fold.

Drainage is best looked at not merely as a service that needs to be reproduced but as a central component of a resources management system that requires inputs and produces goods and services with certain values. Part of this increased value may be captured to pay for investment, operation, or maintenance costs. Better use of the drainage infrastructure may also create economic value, which can be used to pay for essential maintenance services.

A shift toward an integrated approach to drainage provides a major technical and professional challenge. The physical design and operation of many drainage systems has a long-standing bias toward agricultural productivity. The challenge is to include topics like controlled drainage, flood management, management of effluent quality, drainage water reuse, vector control, and compartmentalization in the design and operation of multipurpose drainage. This has implications for new investments and rehabilitation of existing systems. To address the challenges of moving toward integration, innovative research and pilot projects should be mainstreamed in operation. The knowledge system must be reformed, and long-term investment must be made in capacity building.

This report sends five messages to the broad audience of professionals in the drainage and water management sector, planners, decisionmakers, governments, and the international community. The first message is an invitation to dare to look at all the costs and benefits of drainage. The second message calls for attention to the potential for poverty reduction offered by the integrated approach. The

third message mirrors the World Bank's water sector strategy when it calls for moving toward an integrated approach with pragmatism and vision. The fourth message emphasizes the value of learning by doing. The fifth and last message is sent to governments and the donor community to exercise their leadership to promote an integrated approach to drainage.

1. Introduction

Drainage is an inherent part of the hydrological cycle—a necessary function of a river basin or other hydrological units. Drainage is a natural process that human beings adapt for their own purposes by redirecting water in space and time and manipulating water levels. In this process, they make use of the natural properties of topography, soil, and hydrogeology and of technologies and other physical and management interventions.

The Drainage Paradox

Improved drainage can contribute to large increases in crop production in different parts of the world. Investment would be cost-effective and have the additional benefit of avoiding exploitation of new land and water resources. An estimated 50 percent of the world's irrigated land suffers from drainage problems. Twenty-five million hectares of prime agricultural land have become unproductive due to irrigation-induced waterlogging and salinity (Smedema 2000). Two hundred fifty million ha of rainfed cropland need improved drainage (Smedema et al. 2000). Improved drainage can also produce substantial benefits in the sphere of health, reduction of damage to roads and buildings, and flood control. Improvement of drainage could be an important instrument in achieving sustainable human development.

Paradoxically, drainage has almost disappeared from international water discourse as a theme and a concern. It does not appear in the glossaries of prominent water documents such as the World Water Vision (Cosgrove and Rijsberman 2000), the Framework for Action (GWP 2000), the World Water Action Report (Guerguin et al. 2003), or the U.N. World Water Development Report (UNESCO–

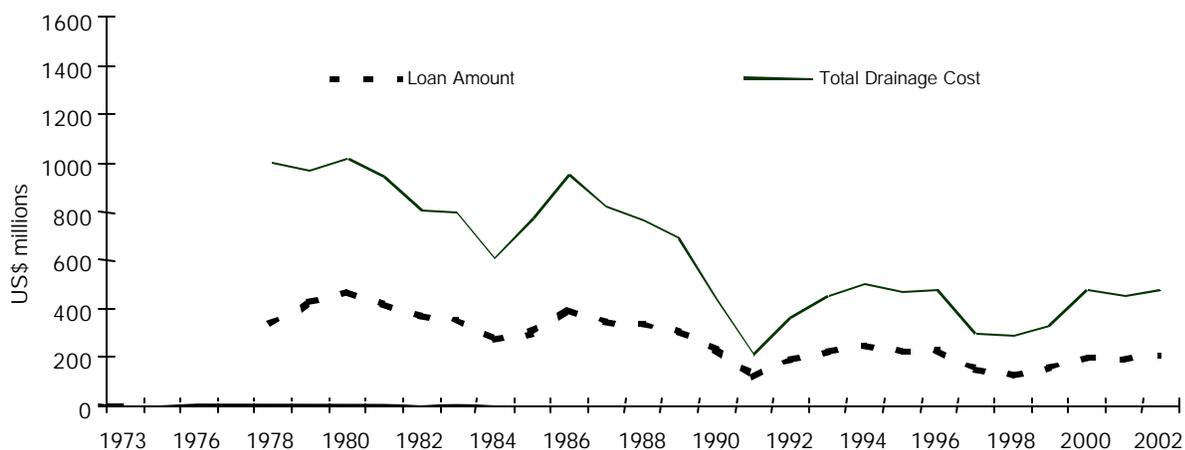
WWAP 2003). So far, drainage has not been addressed in the global Dialogue on Water, Food and Environment. It receives scant mention in the largest water-related research program in the offing, the Challenge Program of Water and Food under the Consultative Group on International Agricultural Research (CGIAR).

This neglect reflects what is happening on the investment front. Only a few countries such as Egypt and Pakistan have formal programs for land drainage. The World Bank drainage portfolio began to run low at the beginning of the 1990s (figure 1.1). The cost of World Bank–supported drainage projects dropped from US\$1,485.3 million in 1985 to only US\$88 million in 2001.¹

Some central themes in the current water debate eclipse drainage as an inherent element of the hydrological cycle. One such theme is water scarcity. Water scarcity is the most dramatic manifestation of the water crisis—large rivers no longer reaching the sea, wells gone dry, and a world map marked by a growing number of water-stressed countries. With this in mind, the idea comes almost naturally that the need to manage water arises only when it is scarce— involving reallocation from low- to high-value uses and improvement in water productivity. This inference misses the point that water management is equally important in water-rich environments—and that drainage may play a key role in the timely removal and retention of water and in making it available for reuse.²

¹ Real cost of drainage components in year 2002 dollar value, including downstream flood control measures.

² This report is not the appropriate place to discuss the concept of scarcity. In a physical sense, it relates to both quantity and quality of water, but in addition to physical scarcity there is economic, managerial, institutional and political scarcity (Molle and Mollinga 2003).

Figure 1.1 Cost of World Bank–supported drainage projects (5-year moving average)

Source: World Bank 2000.

Second, the water resources reallocation discussion (and with it mechanisms such as water pricing, demand management, and water markets) equally risks narrowing water management down to a zero-sum game—with water being used either here or there. Instead, it is often far more useful to look at water management as a chain of uses and consider the overall social, economic, and environmental productivity of the entire water control system, of which drainage is an inherent part.

A third theme at odds with the concept of drainage is the notion of water productivity, succinctly summarized in the phrase “more crop per drop.” Water productivity is an inspiring concept, but it begs the question “which drop?” A better water control system—with effective drainage management—will create the drops that can give much more crop than a system where waterlogging, acidification, salinization, or overdrainage are the order of the day. “Water productivity” moreover should not be narrowed down to crop yields but encompass the other functions of water resources, too.

A fourth example is the debate on participatory irrigation management and irrigation reform more broadly. The emphasis is often on revamping the governance, management, and financing of water supply. Drainage is conspicuous by its absence.³

³ For discussion of some exceptions to this blanket statement, see the country case studies and chapter 4 in this report. The

Drainage has become a “forgotten factor” (Scheumann and Freisem 2001). It is somewhat isolated from mainstream water management and is preoccupied almost exclusively with agricultural production. The thrust of drainage programs has been tilted toward improving farm productivity or opening up land for agriculture—be they the flood control-cum-drainage projects in Bangladesh, the national drainage programs in Egypt and Pakistan, polder management in the Netherlands, or swamp development in Indonesia.

For both conceptual and practical reasons, drainage has to be seen differently—by drainage professionals and by others involved in the policy, planning, and practice of natural resources management for sustainable human development—of which drainage is an inherent and necessary element. The target audience of this report is drainage professionals, researchers, and other specialists involved in natural resources planning and management. The intensity of problematic issues related to drainage that societies need to address is only increasing, and with it the potential for livelihood enhancement, poverty reduction, and sustainable resources management.

Broadview Water District in the U.S. state of California provides an example in which the anticipation of environmental restrictions on drainage water quality and quantity was an important factor for introducing institutional innovations in irrigation management—a tiered volumetric water pricing system in this case (Wichelns 1991, Wichelns and Dennis 2003; see also chapter 4).

The low profile of drainage is unwarranted. Drainage must reclaim its rightful position as an indispensable component of land and water management, not from a sectoral perspective but from an integrated perspective. Herein lies the resolution of the paradox.

Main Message

The main message of this report is that drainage must be viewed and handled from an integrated perspective. This has four implications:

- Acknowledging the diversity of drainage situations and the need for regionally and locally specific planning and intervention methods for drainage institutions and technology
- Mapping the multifunctionality of landscapes influenced by drainage and the plurality of values that stakeholders attribute to these functions
- Evolving institutions for governance, management, and financing of agricultural drainage as well as (re)designing physical interventions and technical infrastructure from the perspective of multifunctionality and plurality of values
- Drafting policies that create environments conducive to change and which empower actors to make the necessary changes.

An integrated approach to drainage can be developed by means of systematic mapping of the functions of natural resources systems and the values attributed to these functions by people. “Functions” is a concept summarizing the goods and services that natural resources systems provide and perform. These functions include production functions, processing and regulation functions, carrying functions, and significance functions. “Values” is the concept through which societal preferences, perceptions, and interests with regard to functions of resources are summarized. These values include social, economic, and (temporal and spatial) environmental values.

This mapping allows the exploration of the implications of particular drainage interventions. It provides an analytical tool for understanding a drainage situation. It also provides a framework for discussing and negotiating tradeoffs related to the different functions and values associated with drainage. In that sense, it is a communication, planning, and decisionmaking tool. We have called the tool DRAINFRAME, which stands for the Drainage

Integrated Analytical Framework. DRAINFRAME is a procedure for analyzing and assessing the functions and values embedded in a participatory planning process.

Schematic presentations of tools for decisionmaking and planning processes carry the danger of suggesting that reality can be easily engineered.⁴ The travails of water sector reform of the last decades testify to the contrary. The strategic approach advocated in this document is much more modest than any strong form of social engineering. It suggests a “pragmatic but principled” approach that starts from good understanding of present situations and identifies opportunities for “context-specific, prioritized, sequenced, realistic and patient” movement in the “integrated” direction. These formulations are taken from the World Bank’s Water Resources Sector Strategy paper (World Bank 2003: v–vii), and the present document on drainage can be regarded as an operationalization of this strategy paper and the World Bank’s rural development and environment strategies (World Bank 2003b, 2001a).⁵

The drainage sector can perhaps turn its predominantly technical and agricultural orientation and its lack of status in water sector policy and practice to advantage by leapfrogging toward an integrated perspective. It may not be hindered to the same extent as perhaps the irrigation sector is by the existence of powerful sector hydrocracies oriented mainly toward their own organizational survival and by more than two decades of debate and pilot projects regarding farmer participation and management turnover. The authors of this report hope to show the direction of that leap forward.

Structure of the Report

The objectives of the study, *Agricultural Drainage: Toward an Interdisciplinary and Integrated Approach*, were to

- Improve understanding of drainage systems as sociotechnical and environmental systems by

⁴ On the limitations of sociolegal engineering in the context of irrigation and drainage development in Luwu, Indonesia, see Roth (2003).

⁵ For discussion, see chapter 6. The World Bank’s Social Development Strategy Paper has not yet been published. Our discussion of participatory planning in chapter 3 provides the link to that thematic area.

developing, at the macro level, a typology of drainage situations including both technical-physical and social-managerial criteria, and, at the micro level, a strategy to understand and deal with local diversity in the nature, function, and organization of drainage.

- Document and evaluate different institutional models used in the drainage sector at both user and agency levels, including an evaluation of the appropriateness of user organization approaches developed in the irrigation sector, by studying cases of the application of “irrigation models” in drainage projects.
- By generating this knowledge, contribute to improved design and implementation of interventions in the drainage sector, to meet users’, “managers’, and funding agencies’ objectives to produce integrated and sustainable drainage development.

After this introductory chapter, chapter 2 provides a detailed problem analysis of the sector and the current approach to drainage. For readers less familiar with drainage, it gives an introduction to the diverse functions of drainage. Chapter 3 describes the DRAINFRAME tool for functions and values assessment and evaluation embedded in a participatory planning approach. The issue of appropriate scale level for integrated drainage planning is also discussed. Chapters 4, 5, and 6 discuss drainage institutions, drainage technology, and the policy framework to see how an integrated approach to drainage might be initiated from these different angles. Chapter 4 looks at the governance, management, and financing of drainage. Chapter 5 discusses how drainage technology can be reoriented toward design for multifunctionality. Chapter 6 summarizes the policy recommendations for practical steps toward an integrated approach to drainage.

Process and Method

The origins of this study lie in an inventory of drainage institutions in developed and developing countries undertaken as part of the Collaborative Work Program between the World Bank’s Agriculture and Rural Development Department and the Irrigation and Water Engineering group at Wageningen University, the Netherlands (Pant 2000; Knegt 2000). The inventory provided the base for the design of the study as described above.

The first phase of the study was a set of six country case studies covering different drainage situations. The country studies are based on a review of the literature and a field research component. The cases were Bangladesh, Egypt, Indonesia, Mexico, the Netherlands, and Pakistan. Teams of international and national consultants conducted the country case studies. The process included a planning meeting in February 2002, a meeting of international experts to discuss the literature review and field study plan in May 2002, and a workshop in which draft country case studies were discussed in October 2002, all held in Wageningen, the Netherlands. Also invited to the workshop were representatives of the governments of the countries studied and of the World Bank, the Food and Agriculture Organization, the International Programme for Technology and Research in Irrigation and Drainage, Wageningen University, and the International Institute for Land Reclamation and Improvement.

After the workshop on the country case studies, a writing team was composed to produce the final report of the study, this report. The final report is based on the country case studies but is not a summary of them. It sets the next step in the process: what are the contours of an integrated approach to drainage? The writing team had an intermediate meeting in April 2003 in Wageningen, the Netherlands, to review the early drafts of chapters and consolidate the central concepts and approach of the report. The last phase of the writing involved streamlining the different chapters, work done mostly at the World Bank headquarters in Washington, D.C., in July 2003. After internal and external reviewers’ comments and a presentation at the *Ninth International Drainage Workshop*, in Utrecht, the Netherlands, in September 2003, the report was finalized in October 2003.

The teams in all the phases of the study consisted of people with different and combined backgrounds and disciplines: academics, consultants and policy actors; engineers, ecologists, and social scientists. The study was a truly interdisciplinary effort—in which there was considerable learning for the individuals involved and for the teams through the intense interaction that was part of the study design. The learning process is ongoing. Much additional learning will occur when the approach proposed in this document is put into practice.

The Country Case Studies

Throughout this report, the source of examples and other material on Bangladesh, Egypt, Indonesia, Mexico, the Netherlands, and Pakistan are the country case studies unless a different reference is given. This

avoids excessive referencing to the country case studies. The case studies (listed in the References section of this report) will be published on the World Bank website (www.worldbank.org/irrigation-drainage).

2. Agricultural Drainage: Toward an Integrated Perspective

This chapter contains the problem analysis of the report. Its main thrust is an argument for an integrated approach to drainage. That argument proceeds in four steps:

- *Impacts and multifunctionality.* The many impacts of drainage (agricultural, public health, protection of buildings, environmental) establish the importance of the notion of the multifunctionality of natural resources systems.
- *Diversity and specificity.* The great diversity of drainage situations implies that understanding drainage requires contextualization, and intervention demands locally and regionally specific approaches.
- *Drivers of change.* The drivers of change toward an integrated approach to drainage are: the increasing complexity and interdependence of water control systems; the intensifying clash of interests of different stakeholders in such systems; changing value systems in societies; and the self-interest of the professional drainage community in rethinking its own position and approach.
- *A new definition of drainage.* A definition of drainage that transcends the current narrow focus on removal of excess water for optimal crop growth is presented as the starting point for an integrated approach to drainage.

The Many Impacts Of Drainage

Integrated water resources management (IWRM) has been defined as “a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems” (GWP 2000: 22). Drainage has often done well on the economic and social front. It has had considerable positive effects on farm productivity,

vector control, and flood mitigation. But it has often done much less well in safeguarding vital ecosystems, key environmental processes, and other resources such as fisheries. Drainage has many impacts: on agriculture, on public health, on the protection of buildings and other rural infrastructure, and on environmental services (box 2.1). Some of these effects are intended, but others often appear to have happened by accident. Appendix A provides an overview of some of these positive and negative effects, based on field observations drawn from the country case studies that inform this report.

The following main conclusions can be drawn from a review of the multiple impacts of drainage.

- Drainage can have a substantial impact on *agricultural production and productivity*. Agricultural drainage investments may have short payback periods, but drainage planning needs a relatively long planning horizon and flexibility because drainage needs may change over time (box 2.2).
- Drainage can make substantial contributions to *public health, drinking water supply, and sanitation*. This potential is not generally acknowledged and depends on the quality of operation and maintenance of the drainage system.
- *Damage to buildings and other rural infrastructure* will be less when shallow water tables are under control. Improved drainage can lead to substantial property-value increases, which are usually not taxed.
- *Environmental functions* have often been negatively affected by agricultural drainage, and drainage has also acted as a conduit for the spread of wastewater and other pollutants. There are some examples of drainage-enhancing environmental functions, but much more emphasis should be put on mitigating the negative effects of drainage and balancing its impact on production functions against its impact on environmental functions.

Box 2.1 Examples of drainage impacts

Agricultural production. In Egypt, the annual net farm income of the traditional farm increased by US\$375/ha to US\$200/ha, depending on the initial level of salinity before providing subsurface drainage. With total construction costs of US\$750/ha and maintenance costs of US\$10/ha/year, the payback period is only three to four years. In Pakistan, crop yields increased between 27 percent and 150 percent in the Mardan project area. In Mexico, economic rates of return of the subprojects in the Program for Integrated Rural Development in the Tropical Wetlands (PRODERITH), based only on the changes in agricultural yields, varied between 14.7 percent and 21.5 percent.

Public health, drinking water supply, and sanitation. Improved drainage conditions in the Netherlands helped control endemic rheumatism in rural areas. Drainage in rural areas in Egypt and Pakistan brought down the incidence of killer diseases such as malaria and schistosomiasis (bilharzias). A low water table is necessary for low-cost latrines in rural settlements. Lowering water tables in the Drainage IV project area near Faisalabad, Pakistan, allowed a thin lens of fresh water to develop for domestic water supply on top of the saline groundwater.

Buildings and rural infrastructure. A high water table is responsible for short service life and damage to buildings, particularly low-income housing in large parts of rural Pakistan, India, Egypt, and Mexico. Conversely, improved drainage increases the value of land, as in the humid part of Mexico under the PRODERITH program from US\$7,000 to US\$200,000/ha.

Floods and flood control. A sufficiently lowered water table before the rainy season reduces runoff and moderates the peak flood wave. However, uncontrolled deep drainage canals may quickly transport flooding to areas downstream. Construction of embankments along main rivers in Bangladesh has had mixed impacts on soil productivity, living conditions, fish production, sediment deposition, soil fertility, water storage, and navigation.

Environmental functions. On the negative side, drainage mobilizes salts and agricultural chemicals and spreads pollution caused by untreated domestic and industrial wastewater dumped into open drains in many countries. In the humid tropic lowlands of Indonesia, drainage of acid sulphate soils has caused serious damage to the valuable coastal aquatic life. In other cases, drainage has created wildlife refuge areas of great biodiversity value such as around Lake Sarykamysh near the Aral Sea.

Source: Case studies. For details, see appendix B.

Detailed discussion and examples are provided in appendix B. The overall implication is that drainage, as a human intervention in the hydrological cycle, affects many different functions of natural resources systems, and thereby has multiple impacts on society. Exclusive focus on the impact of drainage on agricultural productivity is unwarranted.⁶

Diversity in Drainage Situations

To what kind of situations does the term “drainage” refer? Study of drainage practices around the world reveals an overwhelming diversity in drainage situations, reaching far beyond the conventional image of drainage as an add-on to irrigation in semi-arid regions. Six main diversifying factors are described in

some detail in appendix C, which also contains a summary table of diversity in the six country case studies. They are:

- Drainage for agriculture has to serve many different users.
- Drainage systems affect many functions of resources systems and multiple sectors in society.
- The scale of drainage systems varies widely.
- Historical development leads to diverse drainage solutions.
- The main environmental factors that lead to diversity are climate and seasonality, slope and altitude, soil characteristics, groundwater characteristics, biological diversity, and ecological processes.
- Diversity in social and economic circumstances (prosperity and values, distribution of power and cultural background, sociopolitical structure) leads to diversity in drainage systems.

⁶ The concepts of effects and impacts, functions and values, and resources systems and society, are central to the framework developed in chapter 3 and are discussed there in detail.

Box 2.2 The long-term perspective of drainage planning

Assessing drainage benefits often requires a long-term perspective. The government lowland development program in Indonesia is an example. In the first stage of this program, swampland was opened, particularly in Sumatra and Kalimantan, as part of the transmigration program. This program settled poor farmers from densely populated Java in the outer islands. Minimal drainage was provided, and the emphasis was on land clearing and land settlement. After soils had ripened and a considerable change in land levels had occurred, permanent structures for controlled drainage could be installed. In the second stage of swamp development, crop yields at least doubled, and anecdotal evidence suggests further increases over time. The usual five-year planning scale associated with projects does not work in this case.

The control of waterlogging in fresh groundwater areas in Pakistan is another example of the need for long planning horizons. High water tables were combated with investment in vertical drainage wells under a series of Salinity Control and Reclamation projects (SCARPs). When the worst was over and water tables had dropped, a new equilibrium set in, with farmers in the formerly waterlogged areas pumping fresh groundwater to supplement canal water supplies. This kept the water table in check and allowed closure of public vertical wells (which operated at a very high cost to the exchequer) in most of the fresh groundwater zones.

Source: Indonesia and Pakistan case studies.

The overall conclusion that can be drawn from the review is that drainage situations exhibit very substantial diversity in terms of the elements listed above. The wide diversity in drainage situations encountered across the world and the variety of factors causing it, show that “drainage” is a container concept. Talking about drainage in general is therefore pointless—both at an analytical level and at an intervention level. A context-specific approach is required for both analysis and intervention.

Drivers of Change

What are the likely factors that will help drainage move toward an integrated approach? A number of drivers are pushing drainage to the center of integrated land and water resources management. The first driver is the *increasing complexity* of water control systems. The interlinkage and interdependence between different water uses increases rapidly when water use intensifies. The policy and practice of reuse in Egypt is an example. With an extensive drainage network in place, drains are increasingly used to convey municipal and industrial effluents. The same water is pumped back into irrigation canals, where it is used for irrigation. In some places, the same canal is also a source of drinking water. Another example of growing complexity is Java, Indonesia. As land use condenses and uplands continue to suffer from degradation, increased surface runoff, land subsidence, and conversion of flood plains into

residential areas put ever-larger demands on an underfunded drainage system.

A second force pulling drainage into an integrated water management perspective is the *conflict of interests* in many water management systems where drainage plays a central role. As water resources systems become integrated and competition for resources increases, these clashes intensify. The flood control and drainage systems in Bangladesh are an example. What one group considers inadequate drainage, another group considers water storage. An irrigation reservoir for farmers is another group’s fishing ground. The development of flood control-cum-drainage infrastructure affected these relations in a complex manner.

A third driver has triggered a different, nonsectoral perspective on drainage: the change in the *weighting of different drainage impacts*. As economies develop, values are assigned different priorities. Food self-sufficiency and agricultural development become less important. With urbanization, different demands are put on the water control systems. In West European countries, flood protection, recreation, and ecology have gained the upper hand.

A last (but not least) driver toward integrated resources management derives from drainage’s loss of luster in recent years (chapter 1). As a result, *the professional drainage community has to rethink its position and perspective* and stage a rescue operation. In spite of increases in agricultural productivity and circumstantial improvements in public health,

drainage has been associated mostly with environmental fallout. Its bad reputation was further tarnished by several ill-conceived mega-interventions such as the problematic Left Bank Outfall Drain in Sindh, Pakistan, the megalomaniacal One Million-Hectare project in Kalimantan, Indonesia, and the drying of the coastal marshlands in Iraq for counterinsurgency. Unlike some other water sectors, drainage has no sympathetic lobby to argue for balanced drainage development and no nongovernmental organization or civil society organization positively engaged in drainage. Drainage professionals out-competed irrigation professionals in a narrow view of their *métier*, and there has been no path-breaking research. Agricultural drainage as it was practiced reached the end of the tether, and funding for drainage projects has nearly dried up. There is an urgent professional and political need for drainage to reconstruct itself by moving away from exclusive association with a single sector into a central position in the context of integrated land and water resources management.

In short, the drivers of change toward an integrated approach to drainage are: the increasing complexity of water control systems; the conflicts of interest in many water management systems; new priorities in land and water management shaped by changing societal values; and the need for the professional drainage community to rethink its position and perspective.

Redefining Drainage: Toward an Integrated Perspective

We have seen that a broader, integrated perspective on agricultural drainage is a necessity because drainage is relevant for many functions of land and water resources systems. Due to the great diversity of drainage situations—in space, time, and otherwise—a context-specific approach is needed in both analysis and interventions.

Drainage in rural areas, however, has long focused on a single sector—agriculture—and drainage programs have been undertaken with a single objective—to improve agricultural productivity. Debate on opening up drainage within the professional drainage community has been lively, but many long-standing liaisons are still manifest. They show up in investment priorities (agricultural areas), in institutional settings (usually linked with irrigation or agricultural

departments), in education curriculums (typically part of agricultural engineering faculties), and research orientation (emphasis on perfecting agricultural drainage technology).

Current definitions of drainage also proclaim this single objective. The closest thing to an official definition is in the Constitution of the International Commission on Irrigation and Drainage (ICID). It reads:

Land drainage is the removal of excess surface and subsurface water from the land including the removal of soluble salts, to enhance crop growth.

This definition, in different wordings, is often repeated (e.g., Pearce and Denecke 2001). It may suit the description of “agricultural” drainage, but it does injustice to the other objectives and effects of drainage in rural areas as described above.⁷ Many of these objectives and effects are not marginal, and their impact may sometimes be similar in magnitude to the improvement of agricultural productivity. Moreover, by its nature, the “agricultural” definition is limited to the evacuation of excess water. But drainage also serves to maintain water tables and store and retain soil water. We propose the following alternative definition of drainage in rural areas:

Drainage is land and water management through the processes of removing excess surface water and managing shallow water tables—by retaining and removing water—to achieve an optimal mix of economic and social benefits while safeguarding key ecological functions.

This broad definition allows an integrated perspective on drainage to be developed. Integration, as understood in this report, is not the development of a fully articulated model of “ideal water resources management” without any loose ends. Instead, integration is meant as a move toward developing alliances with compatible interests in water resources management and creating bargaining space for conflicting interests. Drainage has to break out of its

⁷ In urban drainage, the prevailing narrow focus on managing flooding and pollution is also being questioned. Urban drainage also serves several other objectives—enhancing the urban environment, aquaculture, safeguarding the natural environment, recreation, malaria control, water supply for multiple uses, groundwater management, and defense (Reed, Parkinson, and Nalubega 2001).

isolation caused by narrow agricultural perspectives and make itself instrumental in meeting many different objectives and interests.

Integration will mean different things in different contexts, but in every context drainage would benefit from being looked at from an integrated perspective. Integrated management of drainage would mean:

- Acknowledging the multiple objectives served by the management of shallow water tables and the disposal of excess surface water, and the need to maintain the resources system over time (resources sustainability)
- Adapting drainage interventions to the natural resources system, taking into account the diversity of drainage situations and trying to optimize the goods and services produced by the natural resources system (planning and managing diversity and multifunctionality)
- Instituting inclusive forms of (drainage) governance and decisionmaking with representation of the different stakeholders (democratization)

- Improving the scientific knowledge base through a major shift in the focus of the scientific community toward the fields of sustainability, multifunctionality, and stakeholder representation in governance and decisionmaking.

A basic implication of such an integrated rather than a sector perspective is that drainage is also seen as part of the entire natural resources management system. Drainage should no longer be assessed only as a single-purpose instrument with positive and negative impacts on other functions, as was common in agricultural drainage. It should be assessed in terms of optimization of the multiple functions and values produced by the natural resources system. With this change in perspective, the unit of analysis needs to be enlarged, too, to the “agricultural production system,” beyond the conventional focus on singular “drainage systems” as in irrigation systems or polders. This larger unit should be coextensive with the area affected by the various functions of drainage. This can be a river basin, subbasin, landscape unit, command area, or a combination of these. A framework for an integrated approach to drainage is the subject of the next chapter.

3. Functions, Values, and Participatory Planning at Landscape Level

A new definition of drainage was proposed in chapter 2 as the basis for an integrated perspective on drainage. This integrated approach to drainage requires new tools for analysis and planning. This chapter describes the contours of an integrated approach to drainage, which we have called DRAINFRAME (Drainage Integrated Analytical Framework).⁸ DRAINFRAME is a procedure for analyzing and assessing functions and values embedded in a participatory planning process. The systematic mapping of the functions of (the goods and services provided by) natural resources systems and the values attributed to these functions by people, and the exploration of the implications of particular drainage interventions, are the analytical component of the tool. DRAINFRAME also provides a framework for discussing and negotiating tradeoffs related to the different functions and values directly related to and influenced by drainage. This is the communication, planning, and decisionmaking support component of the tool.

DRAINFRAME combines and applies to drainage two sets of theory and practice:

- Recent work on environmental and social impact assessment that allows systematic and comprehensive analysis of the effects and impacts of interventions in natural resources systems
- Recent work on the process dimensions of participatory planning, adaptive management, comanagement, and other participatory

approaches for natural resources management and sustainable human development.⁹

While the first component (effect and impact analysis of an intervention) provides the substance for the second, the second component (participatory planning) is required to allow effective application of the first. The two components thus have to go together. The elaboration of DRAINFRAME as a tool therefore requires answers to two questions:

- How can a functions and values analysis and assessment be done in the context of drainage?
- How can this exercise be incorporated in a participatory planning process?
- A third question arises from the answers to the first two: At which scale or level can or should DRAINFRAME be applied?

Functions and Values Analysis and Assessment

This section describes an analytical tool that provides guidance in identifying the multiple functions of natural resources, helps with assessing the way in which drainage interventions affect these functions, shows which economic, social, and ecological values these functions represent, and identifies which stakeholders are involved. The latter element provides the bridge to the second dimension of the DRAINFRAME tool, participatory planning, discussed in the next section.

⁸ The best acronym would be DRAIN-IN-A-FRAME, which conveys the gist of the approach nicely but is somewhat unwieldy. We shortened it to DRAINFRAME.

⁹ Our shorthand “participatory planning” thus refers to the whole policy and intervention process, not just to one phase of it, as “planning” would suggest to some.

Box 3.1 Environmental functions—the supply of goods and services

Nature provides many functions, representing goods and services that humans can exploit. Four categories of environmental functions can be distinguished.

Processing and regulation functions. These functions relate to the maintenance of life support systems on Earth. These functions are often not recognized until they are disturbed. Some examples linked to drainage are: buffering of flood peaks in wetland systems, recharge of groundwater reservoirs by infiltration, recycling of organic matter and pollutants as a natural water-cleaning mechanism, maintenance of migration and nursery habitats for fish, maintenance of biological diversity, trapping of sediments in floodplains, regulation of fresh and saltwater balance in estuaries, river mouths, and coastal aquifers, and regulation of biological control mechanisms.

Carrying functions. The availability of space together with a particular set of environmental conditions associated with that space make an area suitable for performing certain functions for nature or for humans. Examples include: suitability of an area for human habitation and settlement, waterways for navigation, sites for energy conversion (e.g., hydropower reservoirs), sites for recreational activities.

Production functions. These functions are goods generated by nature, which, by investing time and energy, man can harvest (natural production functions), or biological products (animal or plant) produced in ways that involve active management and inputs by people (nature-based human production functions). Examples include: soil productivity for cultivation of crops, water as a harvestable resource, fisheries, animal husbandry, aquaculture, timber, and firewood.

Significance functions. Nature provides opportunities for spiritual enrichment, cognitive development, and recreation. Examples include: esthetic information (scenery, landscape), spiritual and religious information (religious sites, emotional attachment), historic information (historic and archaeological elements), cultural and artistic information (inspiration for folklore, music, dance, art), educational and scientific information (natural science classes, research, environmental indicators).

Source: Adapted from de Groot 1991.

Functions and values

Functions is a concept that summarizes what the goods and services are that natural resources systems provide and perform. These functions include production functions, processing and regulation functions, carrying functions, and significance functions (box 3.1). *Values* is the concept through which societal preferences, perceptions, and interests with regard to functions provided by natural resources are summarized. These values are social, economic, and (temporal and spatial) ecological values (box 3.2).

Detailed examples, based on the country case studies, of the effects of drainage interventions on functions of the water resources system, and of the respective impacts on values for different stakeholders are included in appendix D.

A systemic perspective

A systemic perspective is necessary for analysis and assessment of functions and values pertinent to drainage. Functions and values are properties and attributes of combined natural resources and social systems. Drainage is a distinct activity, a specific land and water control subsystem through which natural

resources and social relations are concretely managed. The interaction among the three subsystems is graphically represented in figure 3.1.

- The *resources subsystem* performs functions that provide multiple goods and services used by society. In river valleys, for example, nature provides appreciated functions such as productive soils and water for farming but may also provide less appreciated functions such as floodwater storage when it leads to flood-related damage. Agricultural drainage is intended to enhance the productivity functions, while flood control and open drainage channels may counteract flood damage. Natural resources systems are thus multifunctional.
- In the *societal subsystem*, groups of people value the goods and services provided by the natural resources subsystem and thus become stakeholders¹⁰ in natural resources management.

¹⁰ *Stakeholders* are direct beneficiaries of functions such as farmers (soil productivity) or fisherfolk (productivity of aquatic resources), but also include distant beneficiaries (e.g., foreign tourists or urban inhabitants dependent on water supply from elsewhere or

Box 3.2 Values—the demand for goods and services

Social values refer to the quality of life in its broadest sense and can be expressed in many different terms such as health and safety, housing and living conditions, and the value of the environment as a source of in-kind income, religious, and cultural values.

Economic values are related to both the direct values (such as the monetary value of agricultural produce) and the inputs in the production of other goods and services (such as water for irrigation; water storage in floodplains reducing downstream flood damage).

Environmental values refer to the value that society places on or derives from the maintenance of the Earth's life support systems. They come in two forms. Temporal environmental values refer to the potential future benefits that can be derived from biological diversity and key ecological processes that maintain the world's life support systems for future generations. Spatial environmental values refer to the interactions of ecosystems with other systems, performing functions for their maintenance. Examples of spatial values include: coastal lagoons and mangroves that serve as breeding grounds for marine fish, thus supporting an economic activity elsewhere; wintering areas for migratory birds; flood plains that recharge groundwater aquifers for neighboring dry lands or act as a silt trap, preventing downstream siltation of rivers and reservoirs.

Source: Adapted from Slootweg et al. 2001.

A function of a landscape is not recognized (i.e., valued) by society as long as it does not have stakeholders. The value these goods and services represent for society can be expressed in economic, sociocultural, or ecological terms.

- The specific *land and water control subsystem*, including drainage, consists of: institutional arrangements (laws and regulations; policy instruments—like permits, subsidies, and quotas; financial and administrative arrangements; and functional organizations); technology and infrastructure (like dikes, drainage canals, and pipes); and knowledge and human resources capacity (scientific and local).

Figure 3.1 Linkages and interactions of the three subsystems of the socioecological system

Figure 3.1 shows, in economic terminology, that society constitutes the *demand side*, and the resources constitute the *supply side*. Sustainability refers to an

equilibrium in supply and demand, now and in the future. Perceived imbalances in this equilibrium prompt individuals and organizations to act by managing either the supply from nature or the demand from society.¹¹

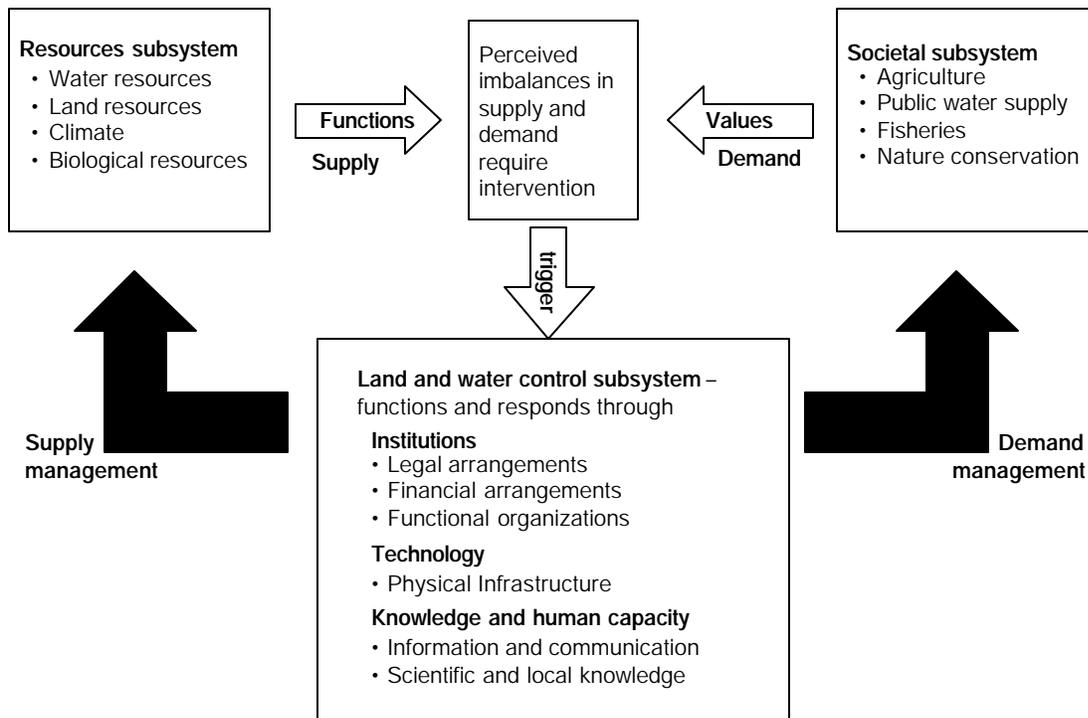
Threats and opportunities for development

Figure 3.1 depicts how the need for institutional arrangements, technology, and infrastructure and for knowledge and human resources capacity is triggered by a perceived disequilibrium in the relation between supply and demand. The demand for goods and services from nature may surpass the available supply, leading to a present or expected future problem (e.g., overexploitation or degradation of resources or insufficient supply), or the potential supply may be larger than what is actually being used, constituting a development potential. Perceived imbalances thus include both threats and opportunities for development.

discharge effluent to go somewhere), or indirect beneficiaries such as nature conservation nongovernmental organizations. We do not enter into the nomenclature of stakeholders and interest groups in this report. For this, see the literature on “participation.”

¹¹ We are aware that both equilibrium and sustainability are contested concepts. However, for our purposes, the exact meaning is not crucial. The central point is the dynamics: action triggered by *perceived* imbalances and unsustainability.

Figure 3.1 Linkages and interactions of the three subsystems of the socioecological system



Source: Adapted from Slootweg, Vanclay and van Schooten 2001.

An example of a *threat* is that waterlogging and salinity in irrigated systems in semi-arid regions like Egypt and Pakistan can reduce soil productivity and the supply of agricultural products. Decreasing the supply of agricultural products can trigger responses by individual producers, policymakers, and line agencies. Drainage interventions in the resources subsystem can enhance soil productivity to increase agricultural output. An example of an *opportunity* is the lack of exploitation of some functions of the natural environment, as is the case with the agricultural potential of the humid tropical regions of Mexico and the outer islands of Indonesia. Agricultural drainage interventions can enhance soil productivity by reducing flood damage in Mexico and by soil ripening in Indonesia.

In both examples, agricultural drainage is a management intervention in the resources subsystem. As depicted in figure 3.1, the land and water control subsystem can also intervene in the societal subsystem by managing the demand for goods and services. For example, the creation of water user organizations can further effective water distribution, thus reducing the risk of overirrigation, waterlogging, and excess salinity.

Other demand management interventions include water pricing, policies and regulations for pollution control, and tax measures. Management organizations can be national, regional, or local authorities using their formal instruments and regulations, or they can be traditional chieftains or village elders using traditional techniques and customary laws. In a globalized world, international agencies that exert effective control over human activities could also be included such as the Framework Convention on Climate Change or the Convention on Biological Diversity. (See chapter 4 for further discussion of the institutional dimensions of drainage.)

Multifunctionality and optimization of drainage interventions

Planning drainage interventions requires awareness of the diversity of functions of the intervention area and the multiple stakeholders who may directly or indirectly, positively or negatively, be affected by the intervention, “on-site” and “off-site.” The methodology proposed is systematic mapping of the effects and impacts of drainage interventions.

The conceptual difference between “effect” and “impact” is that an *effect* can be predicted, modeled, and measured and does not depend on society’s recognition or appreciation. Biophysical effects (resulting from changes in the biophysical resources induced by human intervention or otherwise) affect functions of a resources system, thus changing the quantity and quality of goods and services provided by that system. If stakeholders benefit from these goods and services, the impact that is “felt” (recognized and valued). *Impacts*, in contrast to effects, depend on the context. The impact cannot be determined without identifying and consulting stakeholders. This differentiation in the meaning of the terms “effect” and “impact” is not widely used, but it is important for functions and values assessment.

This report focuses on the assessment of effects and impacts of *physical* drainage interventions. The method derives from environmental impact assessment. Slootweg, Vanclay, and van Schooten (2001 and 2003) describe the underlying theoretical framework. Slootweg, van Schooten, and Vanclay (2003) describe the methodology for assessing potential change processes and impacts that may result from (proposed) *social or institutional* interventions. However, this potential of the tool still needs to be fully elaborated to allow practical use in drainage contexts.

For the assessment of the effects and impacts of drainage interventions, some questions, derived from environmental impact assessment methodology, must be answered.

- Which chain of events leads from the proposed drainage activity to positive or negative, intended or unintended, biophysical effects and societal impacts? Can these be predicted?
- Can second and higher order effects be identified?
- Apart from on-site effects in the drainage intervention area, may off-site effects outside the area also be expected?
- Which stakeholders are affected and how? What role do they play in the analysis (participation) and how are their preferences and interests taken into account?
- Within the objectives of the drainage intervention, can alternative solutions be identified that result in reduction of negative impacts or enhancement of positive impacts?

- Which measures are taken to prevent, mitigate, or compensate negative consequences and enhance potential positive impacts?

Figure 3.2 presents a series of analytical steps that provides relevant information to answer the first four questions (steps 1 to 6).

Step 1. Each analysis starts with a description of a (proposed) drainage intervention, a physical intervention in a landscape, to remedy a problem or capture an opportunity.

Two examples from case studies are given in appendix D: subsurface drainage for waterlogging and salinity control, and conveyance of drainage water in Egypt (example 1), and embankments for flood protection in Bangladesh (example 2).

Step 2. Drainage intervention results in physical or biological changes in the natural resources of an area. These biophysical changes may influence soils, water, air, flora, and fauna (first question).

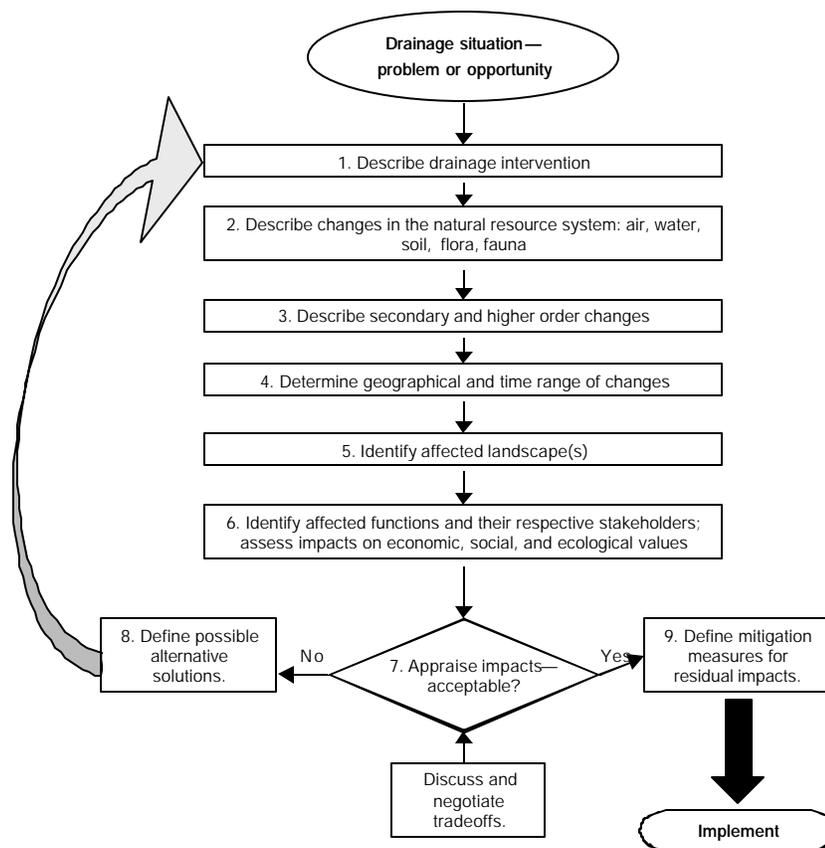
For example, subsurface drainage leads to a lowering of the groundwater table; embankments reduce or eliminate floods in the embanked area.

Step 3. Each (biophysical) change can lead to secondary and higher order biophysical changes (second question).

Lowering of groundwater tables can lead to reduced salinity, improved aeration and soil fertility, and better accessibility of soils for heavy equipment. Increased moisture capacity in the soil profile can dampen flood peaks. Reduced flooding in an embanked area can lead to increased flooding downstream of the embanked area.

Step 4. Biophysical effects have a geographical range in which their influence is noticeable. The effects may extend beyond the boundaries of the drained area (third question).

Many effects can be noticed only in the area where drainage is carried out (on-site effects; for example soil quality improvement). Effects related to water flows often go beyond the boundaries of a system (“off-site effects”). Examples of off-site changes are lowering of groundwater tables in agricultural land that leads to lowering of water tables in neighboring settlement areas; discharge of saline drainage effluent that affects areas at the outfall of the drainage system; and transport and disposal of agrochemicals into water-receiving bodies. Biophysical changes and

Figure 3.2 Stepwise, iterative analysis of (proposed) drainage interventions

Source: Authors.

effects can be predicted and modeled by experts like hydrologists, soil scientists, ecologists, and others (chapter 5). Biophysical effects take a long time to build up and develop impacts. Groundwater rise under irrigation schemes may proceed for many years before it affects crop yields and farmers' livelihoods. These time-bound processes also have to be analyzed.

Step 5. After assessing the biophysical changes and their range of influence, the areas and systems influenced and shaped by these effects can be identified (third question).

In Egypt the saline drainage water reused for irrigation affects agricultural areas outside the drained area. The quality of drainage water conveyed to coastal lagoons affects their functions. In Bangladesh, floodwater affects downstream areas. In Pakistan, seepage from evaporation ponds affects underlying groundwater reservoirs. Water in the downstream reaches of the Amu Darya River (Uzbekistan)

becomes heavily polluted from drainage water pumped in upstream.

Step 6. after identifying the areas and resources systems that may be affected, their functions can be identified. Subsequently, stakeholders of these functions can be identified, and positive and negative impacts for society at large can be assessed (fourth question).

In Egypt, the improved soil fertility through drainage that resulted in increased agricultural productivity (function) and higher incomes for producers (value), has farmers as direct stakeholders, but also perhaps, indirectly, urban food consumers when productivity increases reduce unit prices. A lower groundwater table in neighboring settlement areas that resulted in better living conditions and reduced transmission of diseases (both functions), leading to reduced damage to properties (economic value) and better health for people (social and economic value), has rural inhabitants in general or particular segments as main

stakeholders, depending on how the effects are distributed spatially and socially. In Bangladesh, the reduction of local floods that leads to higher productivity (function) and higher farmer income (value) but which also results in lower fisheries potential (function) and a consequent loss of fisheries income (value) has farmers and fisherfolk as main stakeholders with conflicting interests. Downstream the stakeholder antagonism is reversed, as the opposite impact occurs where increased floods lead to agricultural damage and reduced farmer income, but increases in fisheries income.

This assessment of functions and values by stakeholders requires an institutional framework and process. (This is discussed below under participatory planning). The results of this analysis help to answer the fifth and sixth questions on the development of alternative solutions and the design of mitigation measures (steps 7 to 9).

Step 7. After the assessment of steps 1 to 6, a decision has to be reached through discussion and negotiation among stakeholders.

Stakeholders will agree on which positive impacts are desirable and may need further enhancement, which negative impacts are acceptable, and which impacts need to be avoided or mitigated.

Step 8. In case of severe or unacceptable outcomes or impacts, alternative solutions can be sought.

This implies that an iterative process will start in which the analytical steps above are repeated as depicted in figure 3.2, for alternative intervention designs, trying to find an alternative with impacts more acceptable to the stakeholders.

Step 9. In a careful project design, many negative impacts may be avoided or reduced.

However, in actuality, drainage interventions usually have some unavoidable negative impacts. If their consequences are unacceptable, they have to be mitigated or compensated (box 3.3).

The Process Dimension of DRAINFRAME: Participatory Planning

The description above of the functions and values analysis and assessment methodology makes reference to the need to involve the different stakeholders, as

these are the carriers of the different values, and to the iterative character of the process. The latter implies that the process requires interaction, communication, and negotiation by the different stakeholders regarding the planned interventions. The idea of participatory planning is thus implicit in the methodology.

Participation and planning

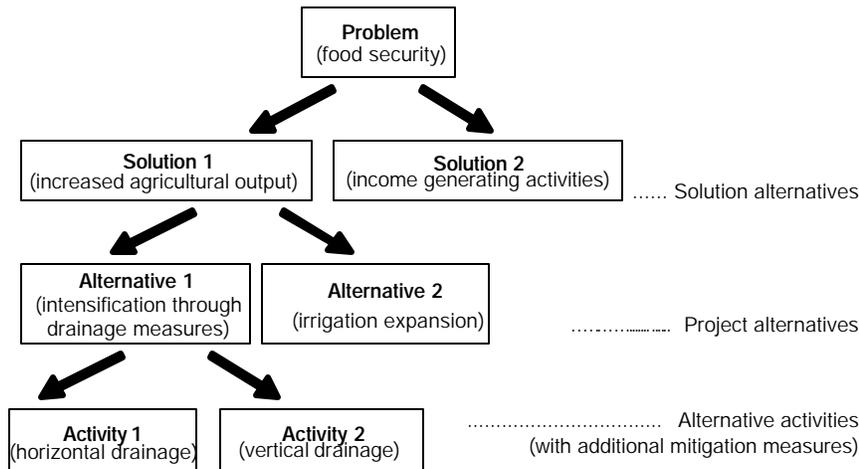
We have chosen the term “participatory planning” to refer to a series of approaches that emphasize stakeholder involvement in decisionmaking for natural resources development and management. Without advocating any particular approach, we focus on the central features of participatory planning processes. The precise features of a process are context specific and need to be designed on site. Implicit, and often explicit, in many participatory planning approaches is the adoption of the *subsidiarity principle*, that governance and management of natural resources should be done at the lowest appropriate level. The two—stakeholder participation and subsidiarity—come together in Dublin Principle No. 2.¹² Box 3.4 briefly discusses the evolution of the concept of participation as a background to what follows.

To describe its features, participatory planning can usefully be contrasted with traditional planning approaches. Some of the main characteristics of participatory planning are decentralization, inclusiveness, situation specificity, and dialogue-based negotiation, while traditional planning is characterized by centralization, exclusion, standardization, and expert-controlled decisionmaking (appendix F). Such dichotomous descriptions tend toward caricature and bad vs. good positions, but nevertheless the contrast adequately suggests the overall features of participatory planning. In the context of DRAINFRAME, the main point is the involvement of multiple stakeholders in an iterative learning and decisionmaking process.

¹² The Dublin Principles can be found on the Global Water Partnership website (www.gwp.org).

Box 3.3 Dealing with alternatives

The first step after problem definition is usually the best place to develop alternatives—thinking in terms of solving the problem. In practice, however, a ministry usually defines a solution, and proposes a plan with a set of activities, in line with its sector mandate (such as increase in agricultural output formulated by the ministry of irrigation). At best, a few alternatives to the *project* are proposed. More commonly, only one project alternative is proposed, whose assessment can only suggest alternative *activities* or *mitigating measures*. The figure below shows levels at which alternatives can be defined, with *examples* in parentheses.



The following levels of options can be distinguished:

- Problem solutions. An intersectoral approach is needed.
- Project alternatives. Within the same solution (sector) different projects can be envisaged.
- Alternative activities. Different activities can be envisaged to obtain the same results, for example, an alternative location or technology.
- Mitigation measures. Activities cannot be changed, but remedial measures can be taken to counteract negative impacts of these activities.

Thinking in terms of alternative problem solutions is rare in practice.

Source: Authors.

A good starting point for designing a methodology for participatory drainage planning is to follow the detailed procedure for achieving *comanagement* of natural resources (appendix G) as described by Borrini-Feyerabend and others (2000).¹³ Central to the *comanagement* approach, from an institutional or planning perspective, is the *negotiation* of options and strategies by the stakeholders.¹⁴ This approach

assumes a “level playing field,” in which all groups and individuals within a territory understand that cooperation is in the interest of all, needs to be achieved, and may require great effort. However, it may not always be possible. Participatory planning is not just a methodology but a political process in which different interests have to be balanced. This requires a repertoire of conflict-resolution methods and strategies for empowering excluded and underprivileged stakeholder groups.¹⁵

¹³ The document can be downloaded from www.ecoregen.com/com/share_ex/uploaded/man_Nat.pdf.

¹⁴ The theoretical basis for the centrality of negotiation lies in the fact that the resources and people systems under discussion are inherently *open* systems. “In open systems, the lack of a sovereign arbiter means that questions of due process must be solved by negotiation, rules and procedures, case precedent, etc.” (Star 1989:43, referring to Hewitt 1988).

¹⁵ Borrini-Feyerabend and others (2000:13) specify the basic conditions under which comanagement can work and, by implication, participatory planning generally. These conditions include “full access to information on relevant issues and topics, freedom and capacity to organize, freedom to express needs and concerns, a nondiscriminatory social environment, the will of

Box 3.4 Participation

The “participation” debate and practice has come a long way since the 1970s, when Rapid Rural Appraisal (RRA) marked the beginning of the participatory development paradigm. (RRA approaches were preceded by community development approaches in the 1960s (Esman and Uphoff 1984). RRA was mainly a consultative data-collection exercise, focusing on expert-driven changes in the physical environment. It was overtaken by the concept of Participatory Rural Appraisal (PRA) which sought to develop practical ways to support decentralized planning and democratic decisionmaking, to value social diversity, to work toward sustainability, and to enhance community participation and empowerment. This evolved into emphasis on collaborative learning and empowerment and became critical of the “project mode.” It was also realized that totally “bottom-up” approaches have limitations. Still, Allen (2001: chapter 2) states “in the main, application of contemporary approaches to improve participation still fails to grasp the nature of the rapidly evolving social forces that are driving natural resources management systems today.” In recent years fundamental questions have been asked about the participation paradigm (for a short overview, see Cornwall 2002; Cooke and Kothari 2000; and Mosse, Farrington, and Rew 2001). This particularly means that the issues of power, politics, and rights take center stage. In a recent strategy paper, the U.K. development agency (DfID), for example, recasts *development* as “a process of political struggle over priorities and access to resources” (Cornwall 2002: 7). Thus, embarking on a participatory planning trajectory cannot responsibly be done without an awareness of the many ambiguities of the “formulaic approaches” to “invited participation.”

Source: Authors

Participatory planning for drainage

The irrigation and drainage sector has produced methodologies for participatory approaches at the local level, particularly regarding water user associations. These focus mostly on irrigation. Examples looking specifically at drainage are rare, but some are discussed in chapter 4. In developing

partners to negotiate, and confidence in the respect of agreements.” In few situations, if any, are these conditions completely fulfilled. Acknowledging that many societies have large power disparities, the authors therefore also suggest, “Whether an above-board dialogue and confrontation is the best strategy to protect the interests of the less privileged groups can be assessed only within a specific context” (ibid.:14).

countries, the irrigation and drainage sector hardly has a practice of “change management”¹⁶ at the level of water resources agencies and ministries through designed social and institutional learning processes.¹⁷ Most attempts at institutional transformation have taken linear approaches to planning, particularly through the instrument of conditions attached to loans, and have focused more on outcomes than on process. An example is the considerable energy invested in the development of (normative) models of river basin organizations but the limited attention given to the process of how to move toward such organizations, given the sector’s institutional setup. Nevertheless, the interest in basin-level organization and initiatives for multistakeholder dialogues, platforms, and institutions for governance and management of water resources may signal an increasing focus on participatory forms of water resources planning. After all, participatory planning fits seamlessly into the notion of integrated water resources management (box 3.5).

To design participatory planning approaches for the DRAINFRAME tool, the following questions have to be answered:

- Which methodology (phases, steps, techniques) will be adopted for participatory planning of drainage interventions?
- How will civic engagement in the different phases of the planning and management cycle be enhanced and how will excluded and underprivileged groups be empowered or empower themselves for participation on reasonable terms?¹⁸
- Which locations and situations would allow experimentation with such an approach with a reasonable chance of success (i.e., are there situations with a favorable or enabling environment for participatory drainage planning)?

¹⁶ On change management, see de Caluwé and Vermaak (2002). For the example of a *Change Management Forum* for sustainable urban water and sanitation in India, see www.silsoe.cranfield.ac.uk/iwe/projects/cmf/.

¹⁷ For examples of contested irrigation reform, policy formulation and implementation, and the associated institutional transformations, see Mollinga and Bolding (forthcoming). On the effort in Egypt by the International Water Management Institute, see Merrey (1998).

¹⁸ The case of participatory budgeting is an interesting one to illustrate the importance of organized civic engagement (Wagle and Shah 2002).

Box 3.5 Participatory planning in the water sector

In many industrial countries, “change management” in the water sector is a rare and new phenomenon but does exist. Examples of tools for participatory planning and decisionmaking developed in the United States are the *Decision Process Guidebook: How to Get Things Done* on the web site of the U.S. Department of the Interior, Bureau of Reclamation (www.usbr.gov/pmts/guide) and the 200-page “how-to” guide of the Army Corps of Engineers, Institute for Water Resources, for “shared vision planning” applied to “Managing Water for Drought” (www.drought.unl.edu/plan/handbook/nds8.pdf). From a developing-country perspective, these guides may read like highly idealized and unrealistic proposals for planning processes, but they do contain useful material for designing locally specific approaches.

- Such methodologies are not necessarily implemented unproblematically, however, in the countries where they are designed. The U.S. *Decision Process Guidebook* puts politics at the center of the decision process, and the emergence of such guidebooks is at least partially the product of a conflict-ridden water resources history. There are also examples of highly institutionalized and regulated forms of consultative and participatory approaches, like land and water resources planning in the Netherlands, which local stakeholder groups find too constrictive, inflexible, and needing more room for local initiative. The Overdiep polder (Netherlands) provides such a case. Anticipating the implications of new national water management policies but years ahead of the formal procedures, farmers collectively and on their own initiative designed a plan for flood retention in their polder in an attempt to bypass years of bureaucratic deadlock. “Official” participation has become too bureaucratized in the perception of the direct stakeholders.
- The elements or phases of the participatory drainage planning and management cycle could, for example, be modeled after Scheumann’s work on waterlogging and salinization (Scheumann 1997). She distinguishes five “action arenas” (*ibid.*:214–20): planning and design; investment decisions; executing investments; operation and maintenance; and groundwater and salinization control at farm level. This is specific to situations with irrigation-induced waterlogging and salinity and would have to be adapted for cases where drainage serves other purposes. For each of these “arenas,” participatory planning and civic engagement methodologies could be developed. Performance monitoring should be part of each of them.

Source: Authors.

These three questions require locally specific answers. A more general, fourth, question is “At which scale level should participatory planning for drainage be pitched?” or “What is the logical unit for participatory planning of integrated drainage interventions?” Although the DRAINFRAME tool can theoretically be applied at any level, we suggest that the landscape level is the most appropriate one.

The Issue of Scale for Analysis and Planning

The analysis of the country case studies suggests that drainage situations can be defined at four different scale levels: the *basin*, the *hydroecological region*, the *landscape*, and the *drainage system* (table 3.1).¹⁹

¹⁹ At each of these levels, typologies of drainage situations can be developed, identifying the different types of situations that occur

Large river basins

River basins are delineated by hydrological boundaries. Water is the dominant resource, and water-related functions are the subject of national and international negotiations and treaties. In the context of a basin or similar hydrological units, interrelated issues can be addressed of both quantity and quality of surface water and groundwater, its extraction and use, and the disposal and reuse of drainage effluents. The basin might be the appropriate planning level for the highly interconnected tasks of land drainage (main

in the large diversity of drainage situations (chapter 2). The development of typologies of drainage situations was a stated objective in the terms of reference for this study. However, to avoid overcomplicating the main text, we do not elaborate here. We wanted to arrive at combined, sociotechnical typologies of drainage situations that would allow identification of the basic dynamics of different situations. On this analytical part of the study more research needs to be done.

Table 3.1 Four scale levels for analysis and planning of drainage

Resources system	Composition/unit	Dominant functions	Management focus
Large river basin	Several hydroecological regions ^a	Water functions	Allocation issues; quantity and quality monitoring; database management; sharing costs and benefits
Hydroecological region	Family of landscapes belonging together, but with different characteristics	A few functions giving rise to particular issues	Policymaking on these issues
Landscape	“Homogeneous” resources base	Typical set of functions	Planning of optimal mix of benefits
Drainage system	Parts of landscapes	Few target functions	Interventions; daily operation and maintenance

a. Given the enormous diversity of water resources situations, there are bound to be exceptions to this neat formula where “a river basin consists of several hydroecological regions.” Several small or very small river basins may form a single hydroecological region (e.g., parts of the Kerala coast in India and the island of Bali). In very flat areas where several rivers form and occupy a delta or plain, and where the basin concept loses some of its applicability, a hydroecological region may cover parts of several large river basins (e.g., Bangladesh and the Indo-Gangetic plain). As emphasized below, the determination of useful units is part of the participatory planning process.

Source: Authors.

drainage systems and regional outlets), drainage and flood control, and for its coordination with relevant sectors for water quality control or infrastructure planning. The great appeal of river basin management has been the focus on either a hydrologically or hydraulically coherent area encompassing all actors physically dependent on each other through the water system (Alaerts and Le Moigne 2003). A basin typically covers a large area, and drainage units do not always fit neatly into a river basin unit. For example, lowland drainage in Indonesia occurs in a long belt along the coast crossing several basins. In Bangladesh, Pakistan, and the Netherlands, the landscape is manmade to the point where a basin perspective is not always relevant. (see also chapter 4).

Hydroecological region: macro level for policy formulation

The hydroecological region is a macro-scale characterization focused on a region’s physical characteristics. Hydroecological regions, a specific case of the broader concept of agroecological zones, are defined by the combination of human intervention in the water resources system and natural or created hydrological boundaries.

The natural resources system can be divided (on a continuous scale) into natural ecosystems,²⁰ semi-

natural or exploited ecosystems, and completely manmade natural resources systems, depending on the level of human intervention. Over the centuries, agricultural activities have resulted in agroecological zones, which often follow the boundaries of the original ecosystem. Where water and drainage play a prominent role in the creation of an agroecological zone, the boundaries of the zones can be drawn around a hydroecological region. Under natural conditions, these regions usually coincide with natural flow patterns of water such as river basins. However, drainage interventions can be of such magnitude that completely manmade drainage basins are created with totally artificial boundaries (e.g., coastal polder systems in Bangladesh and the Netherlands). Similarly, a hydroecological region can coincide with a manmade water management system such as irrigation schemes (e.g., irrigation systems in Pakistan and Egypt covering large parts of these countries).

Box 3.6 shows that, in Bangladesh, water resources and portfolio planning at macro level is done on the basis of eight hydrological regions, each representing a specific catchment area with typical drainage and

evolution). It comprises a community of organisms and their physical environment that interact as a unit. Systems cannot be defined precisely and can be described at various levels of detail. Ecosystems are open systems in the sense that they are characterized by an exchange of both mass and energy with their surroundings (water).

²⁰ An *ecosystem* is an ensemble of components (soil, water, air, plants, and animals) and processes (such as photosynthesis and

environmental issues. In the Netherlands case study, six hydroecological regions are distinguished. Their different dominant resources characteristics have determined agricultural development, and they typically have different drainage issues to be addressed. The characteristics of the hydroecological region thus broadly define the kind of drainage issues that can be expected and the type of drainage interventions that may be appropriate. Descriptions at the level of the hydroecological zone serve overall water resources policy development. Such policy usually focuses on the (problematic features of) water in the region, that is, tends to be hydrocentric.

In summary, a hydroecological region has the following characteristics.

- It is delimited by natural hydrological boundaries or by manmade water management measures, or by a combination of both.
- It broadly defines the drainage issues to be solved and the types of technical drainage interventions that may be needed.

From the case studies, the hydroecological region appears to be the best level for policy formulation and implementation for natural resources-based development.

Landscape level: meso level for planning of drainage strategies

A *landscape* is a unit of land with homogeneous natural resources (soil, water, climate, vegetation) that performs a homogenous set of functions.

The concept of hydroecological region is too broad for concrete planning of drainage interventions, as it combines different natural resources systems with different combinations of functions. For example, the hydroecological region of the sandy uplands of the Netherlands can be subdivided into three landscapes: uplands, slopes, and valley bottoms. Valley bottoms have the designated functions of floodwater regulation, nature conservation, recreation, and agriculture. Because these functions cannot be developed in isolation for obvious reasons, a coherent strategy has to be devised, taking the whole landscape unit into consideration. In the adjacent sloping lands, the emphasis is more on dairy farming and water retention, whereas the uplands provide better conditions for settlements and arable cropping. The three landscapes of the sandy upland also have (bio-) physical relations, for example, the exchange of water. Policies are needed to address the problems

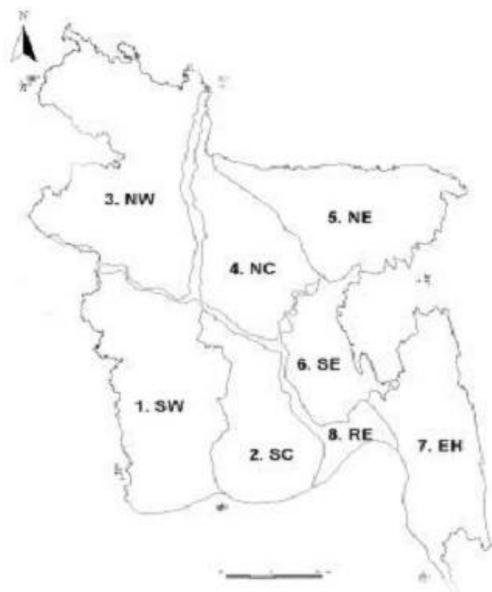
accompanying this exchange, for example, the limitation of pollutants.

Bangladesh needs a much finer characterization of drainage situations than the hydroecological region concept provides for planning physical improvements and development of institutions at the local or subregional levels. The diversity of drainage conditions, the multipurpose nature of flood control and drainage (FCD) systems, and the variety in technologies, are among the reasons a hydroecological region-based classification is bound to overlook local and subregional differences. A classification is needed, combining the physical and engineering features of FCD systems and those of the landforms they are part of. Landforms are the product of human interventions in the natural environment through both informal adaptations by resources users and formal “rehabilitation” or “remodeling” exercises for drainage, irrigation, navigation, flood control, and other purposes. A landform-FCD system typology is the way in which the landscape concept can be made operational in Bangladesh.

This lower level of aggregation we call the “landscape” provides a coherent set of functions that deliver goods and services for society (e.g., agricultural production, water supply and sanitation, tourism, navigation, fisheries). Groups in society value these good and services and become stakeholders. Drainage interventions are intended to enhance certain functions for the benefit of these stakeholders. Institutional arrangements are created to manage these interventions. Thus, a landscape provides the consistent set of functions that form the basis of concrete planning. It provides the proper level of analysis for understanding the dynamics of a drainage situation and for assessing the potential environmental and social consequences of an intervention. Within the landscape, the main planning and management challenge is the (in-)compatibility of function development. Because functions of a landscape are interconnected, the whole unit has to be considered when preparing strategies for interventions (*strategies* are coherent packages of measures). Landscape-level

Box 3.6 Hydroecological regions in the country case studies: Bangladesh and the Netherlands

In *Bangladesh*, water resources and portfolio planning at macro level is based on eight hydrological regions, each representing a specific area with typical drainage and environmental issues.



Region	Gross area (km ²)	Average rainfall (mm)
Southwest (SW)	26,226	1,655
South Central (SC)	15,436	2,307
Northwest (NW)	31,606	1,739
North Central (NC)	15,949	1,956
Northeast (NE)	20,061	3,194
Southeast (SE)	10,284	2,271
Eastern Hills (EH)	19,956	2,445
Rivers and Estuaries (RE)	8,607	2,318
Total	148,125	2,360

The hydrological regions are characterized by the occurrence of different combinations of eight different kinds of flood control, drainage, and irrigation systems (irrigation drainage only; combined irrigation and drainage; flood control and drainage schemes excluding coastal systems; flood control, drainage schemes with measures for the supply of irrigation water; coastal flood control and drainage schemes; coastal flood control, drainage schemes with measures for the supply of irrigation water; and shrimp culture polders)

In the *Netherlands* case study, six different hydro-ecological regions were identified. These hydroecological regions have dominant resources characteristics that require specific water management measures:

- **South Limburg hills.** Hilly aeoline loam uplands, natural drainage by gravity largely overland, and deep groundwater. Water management issues: peakflow management, surface drainage, and erosion control
- **Sandy upland.** Sandy soils with local impervious layers; slow infiltration, shallow to deep fluctuating groundwater, and drainage through natural streams and manmade ditches by gravity. Management issues: peak flow management, ground and surface water quality, agricultural drainage, and public water supply
- **Major river plains.** Flat, heavy clays, slow infiltration, shallow groundwater, temporary flooding of valleys, imperfect gravity drainage, and lateral seepage. Management issues: flood protection, agricultural drainage and water supply, and nature restoration
- **Coastal polders.** Flat, marine clays or organic peatsoils, shallow to very shallow groundwater, eutrophic freshwater overlying saline water, and manmade pumped drainage. Management issues: pumped drainage, sea flooding, salt water intrusion, and peak discharge control
- **Dunes.** Sandy, rolling dunes and deep groundwater. Management issues: nature conservation, recreation, coastal protection, and public water supply
- **Glacial formations.** Undulating sandy soils, deep ground water, and no surface waters. Management issues: water conservation and public water supply

Source: Bangladesh and the Netherlands case studies.

characterizations serve the planning of such drainage strategies.

The features of a landscape are thus the following:

- It combines a uniform set of natural resources and functions.
- It provides goods and services for society.
- It represents values for societal groups (stakeholders) that are not necessarily confined geographically to the landscape.
- It is the logical level at which drainage strategies are planned.
- In large-scale landscapes, subdivision may be required for practical institutional and management reasons.

The physical size of landscapes can vary enormously. Tidal drainage systems will be small (if not, they are likely to be failures, as shown by several resettlement schemes in Indonesia), while the interconnected drainage system of the Nile Valley and Delta has become country-sized. The irrigation system of Pakistan, the size of a country, is an interesting case. The question is whether this system, from a drainage perspective, is one landscape where similar drainage technologies can be applied. Indeed, vertical drainage has been applied nationwide. However, from the multifunctional perspective, the system contains different landscapes needing different drainage technologies. In fresh groundwater areas, vertical drainage has created an extra supply of water that is inevitably used for various purposes (functions), irrigation the most important. In saline groundwater areas, however, this function is perverse, for it contributes to secondary salinity.

Our focus on the landscape does not imply that planning a drainage intervention requires only the study of the landscape in which the drainage intervention is located. Landscapes are usually interconnected by flows of mass, energy, and organisms. The key message is that a landscape, as a geographical stretch of land with a homogenous set of resources and functions, is the preferred unit of analysis, but one that includes its relations with other landscapes. The DRAINFRAME tool is not scale-specific and could be applied at any level. However, we suggest that it is most usefully applied at the landscape level, because this is where the configuration of functions and values defines systemic properties. The approach invites its users to identify

the relevant levels of aggregation in any given situation and to define the appropriate level for application of the tool. This decision is part of the analysis.

This elaboration of the landscape concept for analysis of drainage situations, and the description of drainage types, closely resembles the ecosystem approach adopted by 187 parties to the Convention on Biological Diversity. The present document is an early attempt to make operational the generic principles of the ecosystem approach adopted by the biodiversity convention. In this sense, this report is on the cutting edge of evolving ideas on sustainable and equitable use of natural resources (appendix E).

Drainage system level: micro level for implementation of drainage interventions at field level

A drainage system-level characterization provides detailed and locally specific descriptions of drainage systems. Characterizations at this level serve field-level design and implementation of drainage interventions, in particular land and water resources control systems, for a limited number of precisely defined functions.

The system level is the level of concrete drainage interventions, where technical and operational design has to take place within the framework set by policies at hydroecological level and planning at landscape level. For example, in a landscape, a number of farmer groups may share a collector drain that ends in a natural drainage channel. These small drainage systems may be independently constructed and managed. There may be additional separate systems for wastewater treatment and for urban drainage, a program for main drain maintenance for flood control, and so forth.

The Mexico country case study provides a concrete example. For an irrigation system in the arid zone of Mexico, a micro-level typology of drainage situations was created to establish the drainage needs of three irrigation districts covering 10,000 ha. Excessively saline zones were characterized, and reclamation alternatives with subsurface drainage were identified. This typology was created for the practical purpose of identifying drainage needs and possible solutions. Yet, microtypologies in Mexico are considered a function of a wide range of variables: geographical and climatological conditions, flood control infrastructure, soil and water quality, agricultural development (present and future), users' long-term objectives, user

organization relations with other sectors, and available equipment and materials.

The Mexico example shows that distinctness of systems does not necessarily represent fragmentation or lack of integration, as system-level characterizations can also take into consideration a broad range of factors. Projects are implemented in small, manageable subdivisions of a large landscape to facilitate construction contracting and supervision. They may be convenient units for day-to-day operation and maintenance and may enable workable group sizes of local organizations. They are limited in scope but should be designed from a broader, integrated perspective.

What's New?

The major feature of this chapter is the introduction of the functions and values analysis and assessment at the landscape level by means of the DRAINFRAME tool. The tool is specifically designed as a framework for assessing the multifunctionality of natural resources at landscape level and the effects of any drainage intervention on the water resources system and for identifying impacts in the social context, all embedded in a participatory planning process.

DRAINFRAME brings together in one conceptual framework elements of a variety of scientific disciplines and development intervention approaches. Through the concept of “functions,” it mobilizes the knowledge of physical and ecological science disciplines to understand the behavior of natural resources systems and approaches for physical and technological interventions in these systems. Through the concept of “values,” it mobilizes knowledge from the social sciences and humanities to understand the dynamics of society and the way individuals and groups relate to and engage with the natural resources systems. Through the notion of “participatory planning,” DRAINFRAME mobilizes knowledge and methodologies for social transformation and learning from a perspective of democratic, equitable, and sustainable governance and management of natural resources. None of this knowledge and methodologies are new in themselves. What is innovative is the attempt to incorporate them in a single framework.

DRAINFRAME is a typical example of a *boundary object*: it is a device through which the differences between different “communities of development practice” involved in drainage and water resources

management become communicable and negotiable across the boundaries of disciplines, perspectives, and interests.²¹ Although a lot of science goes into this process as an input, the tool suggests that this “optimization” is not a straightforward calculating procedure but a social process in which meanings and interests are negotiated.

The concept of “landscape” further adds to this property of DRAINFRAME as a boundary object. “Landscape” is a typical example of what has been called a “loose concept.” Loose concepts are imprecisely defined ideas that can play an important role in disciplinary integration.²² Their imprecision invites different groups and individuals involved in a particular problem area to negotiate their meaning, while simultaneously allowing space for adopting specific meanings in each particular domain. Loose concepts can thus be strong tools for integration.²³

This chapter has also made clear that making DRAINFRAME operational requires further work, preferably set in the context of actual drainage intervention through integrated and participatory planning. Application of DRAINFRAME in real contexts and proposing and implementing feasible institutional and technological innovations requires an

²¹ “Boundary objects are objects that are both plastic enough to adapt to local needs and constraints of the several parties employing them, yet robust enough to maintain a common identity across sites. They are weakly structured in common use, and become strongly structured in individual-site use” (Star 1989: 46; Star and Griesemer 1989). The individual site is a particular discipline, professional domain, or other community of practice. There is a broad literature on the issues of both boundary setting and guarding and boundary crossing within science, at the interface of science and society, and within societal domains such as, for example, factories or development projects. The term “community of practice” also derives from this literature. It means that knowledge communities, like disciplines or professional fields, share not only a knowledge base but also a culture, worldview, and set of institutional interests.

²² On “loose concepts,” see Löwy (1992).

²³ One interesting addition to the definition of landscapes as the units for planning drainage strategies would be to combine it with the notion of “problemshed,” as used in discussions of “virtual water” and in participatory decisionmaking approaches in environmental and water resources planning in the United States (Allan n.d.; Earle n.d.; Viessman 1998; Western Governors’ Association 2001). The notion of “problemshed” invites researchers and practitioners to be less resources-centric (water-centric in our case) and to realize that both causes and solutions of water problems may lie outside the physical boundaries of the basin or landscape and outside the domain of water resources management. Defining the “boundaries” of a problem is complex but necessary and involves negotiation of perspectives, interests, inclusion and exclusion, and the practicalities of intervention.

understanding of the existing institutional and technical situation and approaches and some guidance on the direction of more integrated interventions. This is discussed in chapters 4 and 5. Chapter 6 then describes the kind of initiatives required at the policy level to facilitate the emergence of more integrated approaches to drainage.

4. Governance, Management, and Finance in Drainage

In this chapter we explore, on the basis of the country case studies, the implications of an integrated perspective for the governance, management, and financing of drainage systems.

Governance in Drainage

Governance is increasingly presented as a key theme and solution area in natural resources management. The summary reasoning is that “the water crisis is often a crisis of governance” (Global Water Partnership 2003: 2). The centrality of governance is not difficult to see in drainage, where agricultural interests have prevailed and foreclosed opportunities for integrated management. In the DRAINFRAME approach presented in chapter 3, governance is about who responds to perceived imbalances between societal values and functions of the resources systems and who assigns values to the functions of these different resources. Governance systems define drainage institutions, and financial arrangements follow.

In all countries, the governance system in drainage is closely linked to the overall political-administrative system in that country and to the particular route that drainage development has taken. Broadly speaking, drainage development follows three trajectories: government-initiated drainage development, user-initiated drainage development, and the absence of drainage development. Each trajectory translates into different roles for the major players and different challenges and possibilities for improved governance.

Government-initiated drainage development

In several of the country case studies (Egypt, Pakistan, Bangladesh, and Indonesia), governments have taken the lead in drainage development, motivated usually by concerns over national food security and social development objectives of national importance

(appendix H). Other governments have done the same (box 4.1). The engagement and coordination of the public sector made sure that a critical mass of activities was reached and that drainage problems could be tackled on a large scale. A typical outcome of this trajectory is monocentric governance in the shape of strong central government organizations as a part of either Ministries of Public Works or Agriculture, implementing large drainage development programs. Another feature is that the scale of these programs has often resulted in standardization of designs and implementation procedures with little sensitivity to local issues. The case studies undertaken as part of this study, however, suggest large differences between countries in the effectiveness of local planning and consultation procedures, quality control in implementation, or land compensation, for instance. Post-construction care and water management also received less attention in several of the large programs. Examples are the Salinity Control and Reclamation projects (SCARPs) in Pakistan using deep tubewells and transmigration-related lowland development in Indonesia. The salient point is that the transfer of operational responsibilities after construction from central bodies to local organizations has often been problematic.

In this trajectory of government-initiated drainage development, the role of the private sector, civil society groups, and other players has been defined by how much public sector organizations do in-house and how much they contract out. In Egypt, design and maintenance of pipe field systems are done in-house by the Egyptian Public Authority for Land Drainage Projects (EPADP). This made possible great headway in implementing the national drainage program. The downside was that no private sector developed that could service private clients with designs or field system maintenance. In contrast, construction in general and main open drains maintenance are implemented through contracts, and

Box 4.1 Government-initiated drainage development

The *Malaysian* government was firmly committed to developing agriculture to provide fiber and food. From 1951 to 1995, large allocations were made to integrated agricultural development projects that included drainage, and the Drainage Division under the Ministry of Agriculture installed facilities to mitigate flood damage and enable cultivation of commercial crops like oil palm and rubber. Meanwhile, 600,000 hectares have been reclaimed, largely to the benefit of smallholdings. Not even the declining relevance of the agricultural sector has negatively affected drainage development because of its positive effects on poverty eradication (Keizrul 2000).

A different event triggered the large-scale land reclamation program in *Latvia*. Prior to 1940, small family farms characterized the traditional rural landscape in Latvia. They used simple drainage technology and had introduced independent “melioration” systems. When the country came under the rule of the Soviet Union, it was decided that Latvia would be the dairy production center of supply for Moscow and nearby regional cities. Family farms were liquidated and collective dairy farms established, which allowed large-scale, standardized land reclamation (1.5 million ha). The land-privatization process started in 1990 resulted in new land ownership patterns. Because there is no authoritative body to induce joint maintenance, drainage systems deteriorated. Due to this and the collapse of agricultural markets, about 19 percent of the formerly cultivated agricultural lands have been abandoned (Busmanis et al. 2002).

Source

a strong private sector has sprung up to provide these services.

User-initiated drainage development

In several hydroecological regions, considerable drainage development has occurred spontaneously, but it is often not well documented because of its informal nature. In arid regions, user-developed drainage tends to be limited to on-farm drainage, but countless examples of user-initiated drainage come from low-lying areas in temperate and humid zones. Pioneer groups, for instance, have driven most of the conversion of lowland swamps into agricultural land in Indonesia’s outer islands. The most recent estimate of the extent of spontaneous lowland development is 2.6 million ha. Similarly in coastal Kerala (India) and in Northeast Bangladesh, user groups manage low-lying areas (Duyne 1998). In Sub-Saharan Africa, little drainage development by governments has taken place, but farmers in some places are known to have constructed open ditches to drain valley bottoms and, in West Africa’s coastal mangrove swamps, to have built and managed polders (Beltran and Kielen 2000). Most of these local organizations are independent of formal government, and their work is organized as a collective effort or with the help of small-scale local contractors. Similarly, in Northern Europe, much of the land reclamation was initiated by groups of local land users and private investors. This gave rise to local organizations such as the Dutch water boards

(Dolfing and Snellen 1999), the English internal drainage boards,²⁴ and the German water and soil associations (Monsees 2002). Right from the beginning, they were membership organizations with internal autonomy and financial independence, but, unlike local initiatives in most developing countries, local organizations in the European countries have become an integral part of the national institutional framework for water management. They are statutory bodies under public law, and their formation, tasks, membership, governing boards, and finances are regulated by law. Historically, agricultural interests dominated their programs, but recently other groups—including civil society organizations with an environmental agenda—have acquired a voice and seats on the governing bodies. A process of water board mergers is underway in Northern Europe, impelled by the need to cut overhead and the intention to manage the different water functions in a more integrated way. This scaling up is making the water boards more “governmental.” Because of the size of the farms, a relatively mature private drainage services sector has developed in Northern Europe, with private companies providing services in on-field drainage development, larger scale construction, maintenance, design, and water management.

²⁴ Web site of the Association of Drainage Authorities at <http://www.ada.org.uk/>

None or limited drainage development

A third trajectory—a nondevelopment trajectory—is represented by many countries where drainage development has received scant attention. The dearth of development may not derive from limited drainage needs in the area. As the new Rural Development Strategy of the World Bank states, “The declining investments in drainage can hardly be justified while many countries (e.g., India, Central Asia, East Asia’s humid tropics and some countries in Latin America) have a great potential to enhance their productivity through improved drainage” (World Bank 2003b: 144). India is a major example, with an estimated 2,464,000 ha of waterlogged land in irrigation commands and 3,302,000 ha of salt-affected areas. Yet the drainage program in India is negligible—neither the central nor state governments have given it budget priority. As a result, there is no service industry, no easy access to know-how, and systems for developing or managing drainage hardly exist—either through government or private initiative. The magnitude of the drainage problem may explain this—it requires a coordinated government response to solve main system problems and create a drainage program with a minimum critical mass. In the absence of this in several areas, local interventions—either in construction or water resources management—will not work.

Governance themes

Different as these three trajectories are, a number of recurrent themes characterize governance in drainage. The *first* theme is that, in many countries, the agricultural community has been the main constituency. Other constituencies, be they environment, health, or the protection of buildings and roads, have been less articulate. In user-initiated drainage, land developers have generally taken the lead. Government-initiated programs have often strongly identified with agricultural objectives—food security or agricultural land settlement. The nonagricultural functions of drainage have received little institutional attention, and the know-how to serve other functions is poorly developed. The emphasis has been on system development rather than water resources management. Governance has been monocentric rather than polycentric with limited roles for other players from other sectors, local government, or civil society.

A *second* theme is that, in many countries, a strong drainage sector has not developed. This also applies to countries that have had considerable drainage investment, either public or private. In countries where the government has taken the lead, much has been done in-house, and no service sector has emerged outside the public sector. In several countries in Asia and Africa where users have developed drainage systems, the public sector has neither regulated nor supported user-initiated drainage. Private service activities or the role that civil society plays are often weak.

A final theme is that—with the exception of a few counties—managing drainage through improved overall water resources management is anything but mainstreamed. Similarly, drainage finance has received little attention. This neglect is most obvious in countries where the management of shallow water tables and removal of surface water has not gotten off the ground at all. Even where substantial development of drainage infrastructure has occurred, the low budget priority given to operation and maintenance of drainage systems has undone many of the positive effects and created environmental or health hazards instead.

Handing over responsibilities to local governments in the post-construction phase often complicates things. In Pakistan, for instance, the Provincial Irrigation Departments complained that they inherited badly designed and executed projects, with a technology that was costly to manage. In Indonesia, lowland schemes once constructed fell into a kind of no man’s land. The schemes were transferred to the provinces, which in turn considered the districts responsible. Virtually no financial resources and manpower were dedicated to manage the systems. In fact, nobody has taken over management.

Management of Drainage at Higher Levels

Chapter 3 argued that drainage should be planned at landscape level rather than at system level only, the common practice today. This point is consistent with the emphasis in current policy discourse on water resources management at higher levels than the individual water control system, that is, at the subbasin or basin level. In this section, we explore drainage management above the system level (landscape, hydroecological region, basin) and the

institutions involved. Chapter 5 looks at drainage management at system level and the technologies required. With attention historically focused on construction and development rather than management, management structures have often revolved around a single strong organization—the construction agency. The roles of other players in management, like local government, private players, or user groups, has been disjointed or weak. This section explores the scope for plurality in drainage management.

Landscape or basin level drainage management

In the case of drainage, it is easy to see the value-added of natural resources management at landscape, hydroecological region, subbasin, or basin level—whatever unit is appropriate in a given situation. Several processes can be managed only at these higher levels. The following are situations in which drainage linkages with other components of the water resources management require management at higher levels.

Drainage and Flood Management. Flood management is an example of water resources management that requires a higher level. Drainage and flood management are strongly linked at basin level. Drainage congestion is a major cause of local flooding, stagnating water, and high water tables. The impact on drainage patterns of the construction of roads, residential areas, polder embankments, and other infrastructure is often underestimated and not addressed. In Pakistan, insufficient cross-drainage during the construction of the motorway between Lahore and Islamabad caused widespread flooding in Punjab in 1997. In Mexico, the development of aquaculture in the coastal lagoons has distorted natural drainage paths, causing upstream flooding. On Java, river sedimentation made it more difficult for main drains to discharge into rivers and for smaller drains to discharge into main drains. River sedimentation is a natural phenomenon, but as rivers lose floodplains that once trapped these sediments, the narrow river courses collect these loads, leading to drainage congestion. Upland deforestation and soil erosion worsen the problem. Far wider integration is needed between the different types of land use planning—be it municipal planning, road development, or upland protection—and basin water management, including drainage planning.

Drainage And Irrigation. A second relation between drainage and water resources management at landscape or basin level concerns irrigation. In arid areas such as Pakistan and India, drainage problems are often stereotyped as “irrigation-induced.” Yet, for all the attention to water scarcity in recent years, little systematic effort has been devoted to improving irrigation efficiency at command area or landscape level. In the irrigation commands of South Asia, irrigation allowances can be too high or distribution skewed, causing waterlogging and low yields.

One example of the effect of improved command-level water management is the introduction of rotational water supplies in Layyah District in Pakistan (van Steenberg and Oliemans 2002). Layyah was generously supplied from the Thal Canal until 1980. Waterlogging was widespread. After upstream irrigation developed, volumes supplied to Layyah were reduced, and a rotation was introduced whereby the area was provided with irrigation for two weeks out of three. This caused a sharp increase in private shallow tubewell development, and, by and large, waterlogging disappeared from the area. The prolonged drought of 2000–02 in India and Pakistan brought main system water management back into the limelight. In Pakistan, canal diversions fell from 128 billion cubic meters (BCM) in 1975–2000 to 97 BCM in 2000–01 and 88 BCM in 2001–02. Yet agricultural production, instead of falling, increased slightly, because there was less waterlogging in previously oversupplied command areas. Similar reports come from Andhra Pradesh (India). During the recent drought, irrigation allowances were reduced by 35 percent in the Krishna Delta, but agricultural production remained stable. Main canal water management allows much scope to develop improved water supply strategies at command area level by avoiding overirrigation and waterlogging in times of scarcity but also by promoting recharge in times of excess flows.

Drainage and Ecology. A third interaction at basin level is the role of drainage in managing key ecological processes. Drainage can provide opportunities for maintenance or restoration of essential processes for the functioning of certain landscapes when it is considered a tool for shallow water table management and removal of excess surface water (the new definition of drainage in chapter 1). Restoration of the hydrological dynamics of former floodplain depressions in Northern Cameroon provides an example. In 1982 the Benue River was dammed for hydroelectricity and irrigated

agriculture. Large parts of the downstream floodplains could no longer be used. However, after a long rainy season, the dam had to release water. Former floodplain depressions were reconnected with the river and in several weeks were packed with fish. The restoration of fisheries potential was so impressive that experiments began with management of floodplain depressions, now being filled with drainage water from the irrigation scheme. An additional element was that, at the end of the dry season, fish were taken out and the entire depression was drained and left to dry until the next rains as an effective means of vector control (schistosomiasis snails).

Drainage and Water Quality. Finally, drainage management at landscape, hydroecological region, subbasin, or basin level has a heavy bearing on water quality. The cleansing capacities of wetlands may be undermined or protected, depending on the way shallow water tables are managed. A study of the wetlands around Lake Victoria established their importance in removing phosphorus and sediment. High phosphorus and sediment loads contributed to low visibility in the lake, the exponential growth of water hyacinth, decline in fish stock, and decreased accessibility of ports. The Kolkata (Calcutta) wetlands in India are another example. These have been characterized as the kidneys of the mega-city, although their function is under duress as the quantity of effluent channeled to the wetlands exceeds their cleansing capacity. Maintaining, protecting, and even constructing wetlands in some locations can contribute to overall water quality. Taking due notice of the potentially negative effects and impacts of drainage, through its transport of salt and effluent-loaded water to wetlands, might have repercussions on land and irrigation management at landscape, if not at basin level.

The main point, however, is not so much what is possible but why so little of what is possible is happening. The development trajectories discussed above are part of the explanation. In the case of government-initiated drainage programs in, for instance, Indonesia, Pakistan, and Egypt, the emphasis has been on construction and on the maintenance of drainage infrastructure (though to a lesser degree in Indonesia and Pakistan). Central government bodies have played the main role, strongly identified with agricultural agendas. Integrated natural resources management at landscape level has remained a blind spot—institutionally, politically, and cognitively. Similarly, in the user-initiated trajectory as found in

Asia and Africa, the focus has been on local organizations that are not connected with resources management at landscape or basin level.

River basin management or river basin organizations

River basins have been promoted as an appropriate level for planning and managing water resources in an integrated water resources management framework. Some of the main issues in the governance and management of river basins, particularly the larger ones (like the Nile, Rhine, Indus, and many others), are: the allocation of water among different geopolitical units (be they countries, states within countries, provinces, districts, valleys and hill areas, upstream and downstream parts, or combinations of these) and among sectors and use(r)s; the monitoring and adjudication of water quantity and water quality; and keeping a basin-level hydrological database, basin-level natural resources planning for ecological sustainability and other purposes and for cost and investment sharing. River basins are rarely governed and managed by single organizations. More typically, a plurality of organizations carries out responsibility for different elements (polycentrism). However, as stated in chapter 3, a basin typically covers a large area. Many basins comprise several local and regional administrations and multiple actors who are often weakly connected to each other. In several countries, the call for river basin management has translated into a call for river basin organizations. Prominent examples of river basin- or catchment-related organizations are the Australian interstate Murray-Darling Basin Ministerial Council, the regional and local flood defense committees in England, and the river basin agencies in France and Spain. Despite differences in their organizational structure and competencies, they combine irrigation and drainage (Langford, Forster, and Malcolm 1999) and integrate drainage and flood control (Correia and Kraemer 1997a, 1997b; Mody 2001). In several provinces in Indonesia, provincial basin management units and river basin management units are being established.

However, caution is required in equating the need for integrated water resources management at the basin level with a recommendation to establish river basin organizations. Equal caution is required in recommending “leapfrogging” to river basin management organizations in the contexts prevailing in many developing countries. As Shah and others (2002) show, there are limits to jumpstarting river

basin management. The river basin organizations as they exist in rich economies address different problems, priorities, and values from those prevalent in most developing countries (table 4.1).

Indonesia's early experience with drainage suggests that river basin organizations may in theory create a framework for managing the many functions of drainage. Yet precisely because of the broad mandate of river basin organizations drainage may still take a backseat, not because it is not relevant but because nobody specifically identifies with it. In Java, for instance, where river basin organizations have been established, no evidence suggests that drainage and flood management is handled any differently now than in the past.

Instead of opting routinely for management at the river basin level, every country will have to follow its own route to improve resources management at the middle level. River basin agencies may be appropriate organizations in some circumstances, but they are not the only form. A process that promotes communication and negotiation among sectors and interests will eventually lead to appropriate organizational structures.

Polycentric Governance and Multistakeholder Management

A polycentric governance structure generally offers great promise for drainage development and management. Instead of a sole, ultimate center of authority, players with clearly differentiated functions and roles would each exercise authority circumscribed by rules (Ostrom, Schroeder, and Wynne 1993). Groups that spontaneously developed drainage schemes require recognition to play their part. In the countries covered by the case studies, a process toward decentralization, both in the general administration and in the water sector, is unfolding. Reform of drainage governance and management should be linked to this. While moving from drainage development to integrated natural resources management, the role of public sector organizations would need to be revisited.

Governments or public organizations may be involved at different levels of services provision (national, provincial, district, municipality). Arrangements should allow room to support water users planning and implementing their own schemes. For instance, some observers maintain that the public

Table 4.1 River basin organizations: different priorities

Focus and performance of river basin management institutions in developed countries	Current priorities in developing-country water management
Problems addressed effectively	
▪ Wetland preservation	Low
▪ Water pollution	Low
▪ Water quality	Low
▪ Scenic beauty	Low
▪ Financial viability of water sector	High
▪ Farmer management of irrigation	High
▪ Urban water supply	High
Problems unresolved or irrelevant	
▪ Regulating groundwater overdraft	Low
▪ Using water to create livelihoods for poor people	High
▪ Safeguarding water and food supplies	High
▪ Protecting against drought	High
▪ Providing domestic water supply to poor rural people dispersed over a vast region	High
▪ Regulating groundwater	High

Source: Adapted from Shah, Molden, and Sakthivadivel (n.d.).

sector should provide the main drainage infrastructure in arid areas and that diverse local units (e.g., water boards, irrigation associations, farmer organizations, associations for flood control, drainage, and irrigation) may develop and manage drainage basins or subbasins, polders, main or secondary canal commands, and artificially created or natural landscapes. Which tier of government or which organizations provide what kind of service would have to be decided after consideration of revenue sources, the need to redistribute revenues due to unequally spread income, strategies for developing technical and administrative capacities, and ways of preventing elite groups from capturing local institutions.

Polycentric governance and multistakeholder management require an enabling strategy at national level. The current discussion on enabling frameworks strongly emphasizes legislation and regulatory agencies, but the enforcement power of these mechanisms is sometimes limited. There is a case for developing a much broader repertoire of enabling strategies. In strengthening the role of local governments, the private sector, and user organizations in natural resources management, a close look at operational processes may be worthwhile: how planning and budgeting processes work, how public investment programs in the water sector are set up, how procurement is being done, how mechanisms that support private and local investment function, and how local governments, user organizations, and private service providers build capacity.

Establishing user organizations in drainage

Strengthening user organizations is a recurrent theme in water resources management, particularly in countries where drainage programs were initiated primarily by governments. As discussed above, the new user organizations are expected to bundle the interests of the drainage users and take over operational tasks. Following in the footsteps of the move to irrigation-management transfer, efforts have been made to transfer responsibilities to drainage user groups. This section explores this experience, particularly with regard to the scale and organization appropriate to an integrated approach.

Several initiatives to establish drainage user groups were undertaken in Egypt, Indonesia, and Pakistan. These focused on the transfer of operation and

maintenance of the tertiary part of the drainage system. The results have generally been disappointing (appendix H). They suggest that the area of jurisdiction for user organizations should be of a size that covers a manageable and cost-efficient unit, be it a drainage basin, subbasin, canal command, or any other convenient unit. Establishing local organizations on a scale similar to water user associations in participatory irrigation management programs²⁵ is pitching too small an organizational unit. Logic seems to suggest a medium-size organization. The service area must be large enough to generate revenues, and the management tasks must legitimize the cost of running an organization. At this level, irrigation with drainage or flood control with drainage could be managed by the same organization.

Private sector involvement

Many governments wanting to allow, facilitate, and strengthen private sector involvement transfer or subcontract services provision. The private sector may furnish construction and maintenance services under the supervision of the respective governing organizations; it may provide consultancy services for surveys and design, bid preparation, implementation supervision, materials production, and machinery leasing as well as other services under management and performance contracts. At present, the private sector is involved in only some of these aspects in the drainage sector. A more diversified governance and management structure might benefit from diverse private sector services delivery.

Jurisdiction and coordination

Assigning responsibility for management requires the definition, and the legal recognition, of the jurisdiction over which units exercise authority. The jurisdiction should ensure that all beneficiaries of the services pay, or that binding commitments, including financial transfers, are made if benefits spill over boundaries. Such user organizations should coincide or at least relate to efforts at drainage management at basin or landscape level. This also raises the question of the relation of these organizations to local governments. In South Africa, district councils—the third government level—are responsible for developing and implementing infrastructure projects in local communities, including irrigation and drainage. In

²⁵ From which the organizational models for local drainage organization are sometimes derived.

Bangladesh, discussion is ongoing whether the union parishads, the lowest politically elected level, should manage small and medium-size flood control, drainage, and irrigation schemes. It is expected that both can play a role in realizing social and economic objectives through infrastructure development by using resources allocated by the central governments and generated by themselves. Coordination with other functions assigned to local governments (roads, sewerage collection and disposal) could improve as well, but coordination with neighboring jurisdictions may be needed if administrative and hydrological boundaries do not match. Local government institutions may also lack the skills for water management, and closer links are needed between service providers and clients than those provided by the political process. There is no uniform answer as to what role local governments can play, but decisions would also have to come to terms with the issue of weak mechanisms of political accountability, the need for improving the technical and administrative capacity, and for financial transactions from the central government to local institutions (Bardhan 2002; Calvo 1998).

Broadening the Financial Basis

Financing is a major issue in drainage, as in other water sectors. The development and maintenance of drainage systems is often underfunded, and conventional funding mechanisms prevail, particularly central budget allocations. In Indonesia, for instance, allocations to maintain lowland flood control and drainage schemes have dropped close to zero. Earlier, when the provincial governments in Indonesia provided block grants for maintenance, irrigation systems typically got the major share to the detriment of drainage infrastructure. Even in the economic heydays of the 1970s and 1980s, the operation and maintenance budget was only half of what was reasonably needed for flood management and drainage. Similarly, in Pakistan, Bangladesh, and Egypt, most of the expenditure for maintenance comes from tight provincial or central government budgets. In Egypt, the public sector is still able to furnish these costs, but in Pakistan and Bangladesh it is not. For instance, the maintenance of the Left Bank Outfall Drain in Pakistan, draining more than 600,000 ha, has been financed from international loans since its completion.

Better cost recovery

In the light of governance discussions, a fresh look should be taken at financing drainage. Acknowledging the role of many different players in many different drainage sectors allows the identification of a number of new financing strategies. In recent years, discussion of financing water services—including drainage—has been dominated by the debate on cost recovery. This debate is typically part of discussions about the future of government-initiated programs.

The thrust of this debate is that a substantial part of the capital charges and running costs should be recovered from primary users of irrigation and drainage services. Cost recovery received further impetus by the argument that realistic water prices would also encourage water users to use water judiciously. This last argument cannot always be upheld. Water charges are generally a small part of total farm production costs, and farmers often pay high transaction costs to acquire the volume of water they consume.

In some areas, however, economic incentives have made water use more efficient and sustainable. The best documented example is the San Joaquin Valley, the southern part of the Central Valley of California. When farmers in this area were no longer allowed to discharge excess water into the Kesterson Reservoir because of its high salt and selenium loads, drastic measures were in the cards, and subsurface drains were sealed. The district water board imposed a two-tier tariff with a substantially higher tariff for the water consumed in excess of crop water requirements. Farmers responded by adjusting cropping patterns, inventing water-saving technology, and improving irrigation-system management. Drainage outflows from the area fell dramatically. San Joaquin is a good example of the use of pricing as an economic instrument in drainage management, but the case was helped by a strong regulatory environment, the existence of water districts capable of taking measures, the presence of large farmers (making it numerically easier to manage), and the fact that, to survive, the San Joaquin farming system had no alternative. All of these factors make the case unique (Wichelns 1991, 2003).

Elsewhere the record of cost recovery in drainage is mixed. In Pakistan a special drainage cess is levied in some but not all areas served by public drainage systems. The cess has never been at par with operation and maintenance costs. Collection

increasingly suffers from problematic assessment and revenue collection. In Indonesia, an attempt to introduce a drainage service fee was short lived, because settlers in newly developed lowland schemes could not spare the cash. One of the more encouraging examples of cost recovery comes from Egypt. The Egyptian Law 12/1984 requires full recovery of the tile drainage investment costs without interest over a period of 20 years, which comes down to an effective contribution of close to 50 percent. The capital costs are collected as a surcharge on the land tax. As a result, the transaction costs of collection are almost nil, and recovery rates are high. In the South African irrigation board schemes, farmers finance two thirds of the capital costs. In the national irrigation systems in the Philippines, farmers contribute labor and material, donate land, and cover 10 percent of the costs of constructing drainage works.

There is room for reviving efforts at cost recovery, particularly by working on willingness to pay. Low recovery is often related to users' disillusionment with the quality of service. Elements of a strategy to improve cost recovery are improved service, low administrative costs for levying the fee (making assessments and billings), low collection and enforcement costs, rewards for prompt payments, enforcement of fines for nonpayment, and transparent procedures. With respect to transparency, users' approval of budgets is one option, as in the benefit-pay-say system of the Dutch water boards. In this system, every party with an interest in water management contributes to and is represented on the governing board (box 4.2). There may also be room for innovative collection mechanisms. An example comes from some of the regulators in Bangladesh. These regulators maintain or increase water levels for irrigation, fisheries, and domestic purposes. Intricate management arrangements operate these structures. Services are auctioned or tendered to small private contractors (often farmers from the area), who take care of the inlet of irrigation water from outside the embankment, distribute water, and collect fees.

Which costs to recover and how to avoid inefficiency are other elements of the cost-recovery debate that deserve more prominence. Particularly in centrally funded drainage development programs, insufficient consideration has been given to keeping running costs within reasonable limits. The main example in this regard is probably the electricity bill charged to the drainage tubewells in Punjab and Sindh provinces. A

large part the charges were fictive or unnecessary, but the bills were enormous and amounted to 50 percent of the overall budget for irrigation and drainage in both provinces.

Box 4.2 "Benefit-pay-say" in Dutch water boards

The Dutch water boards are autonomous and self-financing. The boards plan and budget for a year and, in the case of shortages, levies are increased the next year. The boards define the level of services within the margins set by the national and provincial policies.

The costs are charged to different categories of beneficiaries (landowners, property owners, residents) and are differentiated according to the benefit derived. The value of land and assets (residents, building owners, industry) and land size (farmers) are taken into account. In the governing council of the water board the different categories of interests are represented, each according to its financial contribution. This is the "benefit-pay-say" system.

Charge collection is delegated to the Central Tax Collection Office (which means low administration costs). If dues are not paid, the water boards, via the bailiff, have the right of confiscation to generate the dues from the proceeds of an auction.

Source: The Netherlands case study.

New financing mechanisms

Several other strategies exist to broaden the financial basis for drainage investment and management in addition to improving water charge collection. Three of these are worth exploring further: charging against nonagricultural functions, making use of increased land values, and promoting private investments.

Charging against Nonagricultural Functions. As argued throughout this report, drainage serves both agricultural and nonagricultural functions. The many groups of beneficiaries may include shrimp farmers, rice growers, other agriculturalists, fisherfolk, urban and rural residents, industry, and municipalities. A case can be made for charging part of the cost of drainage management against these nonagricultural functions, but it is not always done. In some cases, charging nonagricultural users directly may be possible. To generate revenue in the flood control and drainage schemes of Bangladesh, maintenance service fees are levied per hectare and fishing rights are leased. The challenge is to find acceptable formulas for dividing costs among different interests. Ideally, this is done in negotiations with the different parties,

but a negotiation process requires a workable mechanism to conclude the bargaining and a relatively “level playing field.” The method followed in the land consolidation programs in the Netherlands is an example of such controlled negotiation. In these programs, landowners contribute in proportion to the estimated increase in the value of their land. The increase depends on improvements in access to land and in water management. A standard, well-described categorization exists, classifying improvements in different categories. A board of users is asked to apply this classification and fill in the necessary blanks.

Some effects and impacts of drainage on the functions of the natural resources system are of general interest by nature. Ecological functions are in the interest of living people but even more in the interest of future generations. The same applies to public health, flood control, and protection against dampness. On this basis, it can be argued that governments should contribute to the (incremental) cost of drainage or, alternatively, charge all residents or landowners equally (box 4.3).

Box 4.3 Funding drainage services in Europe

In drainage organizations in the Netherlands, Germany, and the United Kingdom, a mix of specific and general interest funding is in practice. Drainage service charges relate either to the size of the area drained (owners' rate, occupants' rate), or to property value. The English internal drainage boards, for instance, raise income through the direct rating of agricultural land and buildings in their jurisdiction (drainage district) and recover income through a special levy on constituent district councils in recognition of the benefit to all nonagricultural land and property from their work. Funding sources are diverse, however, and budget lines exist for performing public functions, which is subject to political definition. Large-scale infrastructure that protects residential and commercial land use is supported by property-related taxes, general local taxes, and central government subsidies. The German water and soil associations receive, in addition, high subsidies for maintenance from the European Union and the federal state. Grants for maintenance from the Ministry of Agriculture to the English internal drainage boards may be as high as 50 percent.

Source: Correira, and Kraemer 1997.

Capturing Added Value. The DRAINFRAME approach suggests that drainage is best looked at not merely as a service that has to be reproduced but as a central component of a resources management system that requires inputs and produces value. Part of this increased value may be captured to pay for investment, operation, or water management costs. Annual land lease values in Nawabshah, Pakistan, for instance, increased by US\$120/ha after the Left Bank Outfall Drain infrastructure became operational. This increase in land values justifies capital cost contributions. Similar increases in land value followed drainage improvement in Mexico.

Improved use of drainage infrastructure may also create economic value, which can be used to pay for essential maintenance services. An example is the Dampara Water Management project in Northeast Bangladesh. The planting of vetiver grass was encouraged as an income-generating activity, thus giving the inhabitants an incentive to maintain their embankments. Similarly, some water boards in the Netherlands raise a substantial part of their revenue from long-term land leases on the dikes. The use of such financing mechanisms to pay for operating costs appears to be rare. In cost recovery for capital investment, they are even less common. During the reform of the irrigation and drainage sector in Sindh, Pakistan, several alternatives were discussed to raise revenue—leasing or selling land on lake banks, leasing canal and drain banks for forestry, auctioning fishing rights—but so far they have not been put into practice.

Promoting Private Investment. A third mechanism requiring more attention is the promotion of private investment. Due to the disjointed nature of governance in drainage, the public and private sectors are often worlds apart. Yet some regions have seen substantial spontaneous investment in local drainage. A prime example is the (often unregulated) land user-driven development of lowlands, the development of farm-level pipe drainage in the Netherlands, and the reclamation of sodic soils in Uttar Pradesh, India. There is room to rethink drainage development strategies in this case and to look at the development of local private capacity to serve individual farmers and to concentrate public investments on main systems.

Challenges

Country- and site-specific polycentric and multistakeholder governance and management structures for drainage offer the promise of combining the potential of the public sector, local and user groups, and the private sector. The challenges are manifold. Organizational structures, procedures, or both are needed in which drainage is not separated from other forms of land and water management and related objectives are coordinated—such as flood control, public health, and the conservation of natural areas and water bodies (wetlands). This also applies to residential and agricultural land use and infrastructure planning. River basin organizations may provide a forum for coordination and planning, but other organizational forms may better fit the countries' political and administrative systems. Because such a structure has no single, ultimate center of authority, functions have to be clearly assigned, responsibilities

circumscribed by rules, and procedures established for cooperation, coordination, and structured decisionmaking. This integration has a financial dimension in that the introduction of the benefit-pay (-say) principle would bring all stakeholders into the fold.

This is a tall order for a sector in which discussion of institutions is in its infancy. A prudent approach might be to start with existing situations and identify small, possible steps toward change (chapter 6). Returning to the introduction of this chapter, governance challenges could be mapped on a matrix with the three trajectories of institutional development on one axis, and the governance, management, and finance issues on the other. Examples of issues that would emerge from such an exercise are given in table 4.2. The mapping is not exhaustive but illustrates the kind of opportunities ahead.

Table 4.2 Drainage development trajectories and institutional challenges: some examples

Issues	Trajectories		
	Government-initiated drainage	User-initiated development	Limited or no development
Governance	Transform highly centralized drainage/irrigation agencies into less centralized ones (implement principle of subsidiarity).	Create an appropriate regulatory structure within which local organizations can operate with sufficient autonomy.	Define the institutional space(s) for drainage governance.
	Redefine the “ownership” of drainage across sectors and include other constituencies besides farmers in the planning and decisionmaking process.	Develop constitutional and collective choice rules for local organizations (representation of different stakeholder groups and charter).	Align different constituencies to magnify attention to drainage.
Management	Transform upwardly accountable public officials and poor maintenance into managers responsive to local needs with incentives for better performance.	Professionalize management and consider appropriate scale level of different activities.	Support and mainstream local initiatives and practices for drainage management.
	Create workable modes of collaboration between agriculture and other relevant departments for addressing multifunctionality.	Define and create support services for local organizations.	
Finance	Change centralized, highly subsidized into cost-sharing between government and multiple drainage beneficiaries.	Define cofinancing arrangements between government and local organizations for different aspects of drainage investment and maintenance.	To mobilize resources, lobby for allocations in government budgets; attract private investment capital and resources from beneficiaries.
	Include other constituencies besides farmers in revenue generation.	Promote private sector capacity to support local investment	

Source: Authors.

5. Drainage Infrastructure and Operation for Multifunctionality

This chapter explores the implications of an integrated perspective on drainage for the (re)design of drainage infrastructure. The premise of this chapter is that an integrated perspective has implications for the drainage technology that should be deployed and the operational procedures that should be adopted to use it.

Multipurpose Drainage Systems

The physical design and operation of many drainage systems has a long-standing bias toward agricultural productivity—for example, improving soil aeration and land practicability and converting lowland into farmland. Drainage techniques have also been geared to this purpose. Multipurpose design and operation is the exception rather than the rule in drainage, nor is it mainstreamed in the operation of other water infrastructure—be it irrigation, water supply, or sewerage. Yet if drainage systems are to serve a variety of objectives, from improving land productivity and water quality to protecting buildings and safeguarding public health, technology design and operation have to be handled differently. Often such technology and operating procedures are unavailable, even in a country generally considered advanced in drainage technology like the Netherlands (box 5.1).

A “technological lock-in” has occurred in many countries. Equipment supplies, spare parts availability, design schools, research capacity, and financing mechanisms are all geared to a certain way of doing things, in this case for optimum agricultural productivity. Changing institutions to improve water resources management is gaining attention, but the extent of the effort required to change the prevailing technologies should not be underestimated.

In several countries, openings exist to make drainage serve multiple objectives and also address flood management, public health, and environmental sustainability. This requires different designs and

operation practices (table 5.1). It may also involve retrofitting drainage infrastructure, for example, to improve water-retention capacity and water-level control, environmental management of disease vectors, and management of drainage effluent quality.

Box 5.1 New technology needed for integrated water resources management

The skill of farmers and the available technology for on-farm water management in the Netherlands are one-sidedly developed in the direction of optimum agricultural drainage. Pipe drainage systems, equipment to clean them, open field ditches and the mowers used for maintenance, timing of maintenance farming activities; selection of varieties, application of fertilizers and manure, and so on are unilaterally fine-tuned to optimum agricultural drainage. Under a new, integrated water regime, completely new farming systems and new farming skills have to be developed to make a new optimum possible. A simple example is a farmer who wants to take a first step by integrating field drainage with field irrigation and groundwater conservation—s/he cannot draw on reliable scientific trials and economic evaluations. There are no devices on the market for automated closing of pipe drains. Mowing ditches full of water requires different machines, and few contractors have them.

Source: Netherlands country case study.

Our discussion of “technology for multifunctionality” is tentative and exploratory. We report a number of examples of rethinking technological designs and technical operation procedures from the perspective of multifunctionality. The main point the chapter seeks to establish is that further work in this domain is urgently needed. The question of matching technologies with institutions and vice versa is an issue we only raise without discussing. No debate has yet developed on, for instance, design-management relations in the field of drainage technology. Again, this is an issue that requires further work.

Table 5.1 Instruments in the multipurpose management of drainage

Water table management	Stormwater removal and retention	Effluent quality and reuse	Public health
Controlled subsurface drainage	Pumping and removal strategies	Depth of water removal Mixing strategies	Adequate maintenance (vegetation clearing)
Control gates on open drains	System capacity Retention structures	Protection against inflow of contaminants	Intermittent flow, flushing and drying strategies Lining, coverage, subsurface drains Distance from settlements to drainage infrastructure

Source: Authors.

Water retention, water table management, and controlled drainage

If the prime meaning of drainage is redefined as comprising the management of shallow water tables (chapter 2), the ability to control water table depth and drainage canal water levels becomes very important. It allows regulation of soil moisture for both irrigated and rainfed crops and enables maintenance of water levels for fisheries and other uses. A control structure is provided at the drainage outlet to reduce drainage intensity. The concept of controlled drainage has several advantages over free flow in a variety of drainage conditions (appendix I). It has been applied on both field and watershed scale to conserve water and increase crop yield. It has also been found an effective method for reducing losses of plant nutrients and other surface water pollutants (box 5.2).

Key to the development of controlled drainage is the understanding of hydrological regimes, as this will allow the best balance to be struck between water removal and water retention and identification of suitable locations and times for drainage outflow

interventions (photo 5.1). It is particularly sensitive under arid climate conditions and requires careful management. The challenge is to develop appropriate low-cost, easily manageable water conservation technology. However, in many drainage systems and infrastructure, this ability to control water tables is missing. Areas where controlled drainage should be more widely applied include Algeria, Egypt, Israel, Syria, Iraq, Bahrain, India, Pakistan, Northern China, and Central Asian states (Abbott et al. 2002).

Flood management

The capacity of the drainage infrastructure to retain water is closely related to its function in flood management. Drainage and flood management should be brought closer together at the level of (sub)basin management (chapter 4), but also at the level of drainage infrastructure design and operation. The capacity to store excess rainfall in a shallow aquifer is an important asset in flood management. A lowered water table before the main rainy season will help absorb peak rainfall. Drainage design and operation may be harmonized to provide such flood buffers. In many cases, investment in drainage infrastructure will complement flood mitigation strategies.

Box 5.2 Benefits of controlled drainage

Yield response to controlled drainage varies with the drainage intensity and the variability of rainfall. In the case of the Conetoe Creek project, raising the water table increased corn yields by 25 percent in nonirrigated fields and by 15 percent in irrigated fields. Data from 125 site-years with controlled drainage in North Carolina, United States, showed an average decrease of 30 percent in drainage outflows as compared to uncontrolled drainage systems. Average reduction of nitrogen and phosphate losses to surface water were 55 percent and 35 percent, respectively.

Source: Skaggs 1999.

Photo 5.1 Controlled drainage

A weir with movable crest to remove excess water in winter (left) and retain water in summer (right) at Chaam, province North Brabant, the Netherlands (Pictures courtesy of Jan Hoevenaar)

In some cases, drainage infrastructure has aggravated floods. This happens when the network of drainage pipes and canals without a facility to store or slow down the runoff quickly transports stormwater to watercourses and rivers. This has been the downside of widespread farmer-driven private investment in subsurface drainage in the Netherlands and North America. This largely unregulated phenomenon has resulted in rainfall events that quickly lead to peak discharges, increasing the risk of flooding and forgoing opportunities for recharge. Something roughly similar happened in the Left Bank Outfall Drain in Pakistan. During the rare event of severe rainfall, unauthorized “cuts” were made by landowners to drain excess water from fields into surface drains. Disposals exceeded the capacity of the drains, and downstream flooding occurred. In the original design of the system, this dual function of conveying drainage effluent and removing stormwater was not considered. In a redesign of the system, the dilemma of whether to accommodate such unusual but potentially damaging events was looked at. Options considered were increasing capacity and creating spill areas. For various reasons, none of this materialized. However, the case is strong for taking into account, right from the beginning, stormwater functions and the effect of unregulated cuts of private drainage facilities.

Reuse and the management of effluent quality

The design of drainage infrastructure affects the quality of the drainage effluent. The water produced

by drainage systems can be an important additional source of water, yet it can equally be a major liability if the water is of poor quality. Examples are the cases of irrigation-induced river salinity in the Colorado Basin and the Murray-Darling Basin, where fossil salts mobilized by irrigation impaired river water quality. When water is reused, for example in homes, irrigation, or fisheries, a minimum quality is required. It makes sense to base this assessment of desired water quality on the local water management system and uses. Local operational norms may be more useful than a national standard that is not sensitive to the specific local interplay of supply and demand.

The quality of drainage water may be impaired by high salinity, acidity, sodicity, or chemical or bacteriological contamination (appendix J). In the design or operation of drainage facilities, the quality of the effluent and the possibility of mixing it or neutralizing it should be given a prominent place. Often this has been neglected. Proper investigations into the quality of the drainage effluent are essential. In some cases, irrigation and drainage will mobilize and transport trace elements from the soil to the point where they become hazardous to wildlife and possibly to public health.²⁶ Water quality is thus crucial and often problematic in drainage. There are several possibilities for improving water quality and reducing the damage caused by low-quality effluents by better design and operation of infrastructure for flexibility in managing

²⁶ The most infamous case is the Kesterson Reservoir in San Joaquin Valley in California (chapter 4).

the water table. In many cases, alternatives have been discovered by trial and error, and knowledge about managing drainage water quality has developed along the way. These lessons should be systematically incorporated in designs for new drainage infrastructure and retrofitting of existing systems.

Vector control

Drainage infrastructure can have significant effects on vector organisms and improve local sanitary conditions. Yet poorly maintained drainage has only added to health problems, with stagnant water a main source of disease transmission. Over the years, guidelines and good practices have been formulated that improve the positive impact of drainage on public health, but it is testimony to the isolated position of drainage that these have not been mainstreamed. The environmental management approach to disease prevention was developed before World War II. It regained popularity in the mid-1980s, when the limits on the use of DDT for vector control were increasingly recognized. Substantial work was done by the World Health Organization and others.²⁷ Despite these efforts, uptake within the drainage community is limited. The increasing resistance of, for example, malaria vectors to pesticides and malaria parasites to conventional treatment, the continuous high incidence of malaria particularly in Sub-Saharan Africa, and the persistence of other vector-borne diseases warrant a second look at the impacts of both drainage and irrigation management on public health.

Despite the complexity of the matter, some generally applicable rules can be identified in relation to drainage. Mosquitoes breed in water—clean or polluted. Many anopheline, malaria-transmitting mosquitoes breed in clean water in rainwater pools, seepage pools, and recently submerged irrigation fields. Many culicine mosquitoes, transmitting yellow fever, dengue, encephalitis, and filaria, breed in stagnant polluted (urban) waters. Effective drainage of stormwater and the timely removal of waterlogging has been an effective measure for controlling the breeding of these mosquito species, as it reduces the number of breeding habitats. Standing water has to be removed before mosquito larvae have time to mature.

Schistosomiasis-transmitting snails breed in semi-permanent waters. Drainage canals are notorious in

this respect, especially if maintenance is neglected, consequently reducing flow velocities and impeding the regular drying of canals. Contact with snail-infested water infects people. The simplest measures to reduce transmission risk are public water supply and provision of latrines so that people do not need to use infested waters for domestic purposes, and reinfection of water by urine and stool is interrupted (Slootweg and Keyzer 1993; Slootweg et al. 1993). As shown in Egypt, subsurface tile drainage is most effective in preventing snails from breeding as well as reducing people's contact with water.

Some general drainage principles reduce both snail and mosquito breeding:

- Subsurface tile drainage prevents breeding of snails and mosquitoes and avoids human contact with water.
- Periodic drying of canals kills most vector organisms (although a few snail species are known to survive long periods of drought).
- A sudden drop in water level leaves mosquito larvae behind on dry stream banks but is less effective for snails, as many will manage to crawl back into the water.
- Flushing with high water velocities (0.6 m/s) reduces vector breeding.
- Lining drains leads to higher flow velocities that will reduce vector populations.
- Removing vegetation deprives vectors of breeding places.

Apart from the above-mentioned drainage measures, a vigilant primary health care system (addressing prevention as well as treatment) and a safe public water supply and sanitation system are of overwhelming importance in the control of vector-borne diseases. Recently, health impact assessment is getting increased attention as a tool for gauging the potential health effects of proposed projects, programs, and policies. A rapidly developing suite of tools and procedures are also relevant to the drainage sector.

Compartmentalization

Multipurpose drainage management raises the question of the appropriate unit size (see chapters 2 and 4). Compartmentalization into smaller units allows more or less tailor-made solutions to local water

²⁷ Good examples are ADB (1992); Birley (1991); Oomen, de Wolf, and Jobin (1990); Pike (1987); and Rozendaal (1997).

Box 5.3 Local compartmentalization in Bangladesh

An interesting example of local flood control with drainage is found in a 3,000-hectare, farmer-operated mini-polder in one corner of a larger polder in Bangladesh. By raising the height of a road embankment, the local community has made its mini-polder independent of the main polder. Each of four local committees looks after its own oxbow lake (beel) and stretch of embankment. These committees work closely together when necessary. The one drainage regulator is operated for drainage or irrigation storage, as desired. Maintenance is funded by a US\$3/ha farmers' contribution, a five-year fishing lease for US\$4,000, and emergency contributions by big landowners when needed. The mini-polder escaped damage in the 1998 flood. The mini-polder farmers have essentially adopted a "living with floods" approach, with a form of controlled flooding. Instead of attempting to replace the original deep-water rice with high yielding varieties, they have reduced flood depths, which are maintained at levels not much below those outside the polder. This adds to embankment safety. The traditional rainfed paddy remains the dominant monsoon crop, but fish production is maintained.

Source: Bangladesh country case study.

issues. This is particularly useful in localities with large differences in drainage conditions and drainage interests. An example of spontaneous compartmentalization comes from Bangladesh (box 5.3). Compartmentalization has been used in the Netherlands to create buffers around nature areas. However, the downside is that, as management becomes more tailormade and fragmented, management costs increase. This touches upon a larger discussion—whether the public sector should provide only the main drainage infrastructure or a complete package. In the first option, landowners themselves would undertake downstream drainage development. The challenge in this option is to ensure a minimum level of organization for local drainage initiatives to come about while avoiding the threat of overdrainage.

Planning, Design, and Evaluation Technologies

Integrated water resources management attempts to link land and water resources within the regional and river basin context and deal with the multifunctionality of the resources system (crop production, fisheries, water quality, landscape, environment), as well as conflicting interests of user groups (farmers, fisherfolk, industries, and municipalities). These concepts are novel, and their implementation is not straightforward. Data to help make these concepts operational are not always available, and the number of variables and interactions would be far too great to capture by conventional methods and simple analysis. New tools are needed to capture enough information and simulate complex

hydrological and environmental processes as well as social processes and responses.

The problem of data shortage grows with increasing scale. For large catchments and river basins such as the Indus System, Aral Sea Basin, Nile Delta, collecting all data through field surveys is a big job. Remote sensing techniques can be used to infer some key data related to planning and operating irrigation and drainage schemes. Information related to water management including drainage can nowadays be remotely obtained at a spatial range of 5 meters to 5,000 m and with temporal resolutions from 0.5 to 24 days. Remote sensing has been able to provide information with varying degrees of success and accuracy on irrigated area, crop type, biomass development, crop yield, crop water requirements, crop evapotranspiration, soil moisture, soil salinity, and water logging (World Bank 2001).

Remote sensing is receiving increased attention as a reliable and cost-effective technology applicable to the needs of integrated water resources management. When combined with geographical information systems, remote sensing is a powerful tool for planning, monitoring, and managing water resources systems, including drainage. The technology has been used in recent World Bank-related water resources management studies in Pakistan, Egypt, China, and Karnataka, India.

System analysis, information systems, and simulation models are useful tools in this situation. Several water management simulation models with drainage and drainage water management focus have been extensively developed over the past few decades for multifunctional purposes (Feddes and van Wijk 1977; Skaggs 1978).

The introduction of an integrated perspective illustrates the many remaining unknowns about developing and operating drainage infrastructure. Some knowns have also been around for some time but have not yet made it into the standard repertoire of drainage design or system operation. An example is the relation between drainage investment and soil and water chemistry with subsurface and surface systems (box 5.4). Although much is on record about the effects of surface and subsurface systems on the availability of nutrients, this knowledge is rarely incorporated in drainage design.

Box 5.4 Drainage impact on agricultural nutrients

Increased subsurface drainage intensity generally reduces loss of phosphorus and organic nitrogen and increases the loss of nitrate-nitrogen and soluble salts. Conversely, increasing surface drainage intensity increases phosphorus loss and reduces nitrate-nitrogen outflows. Although exceptions for nearly all cases have been reported in the literature, most investigations have supported these general conclusions.

Source: Skaggs, Breve, and Gillam 1994.

Knowledge Management

Far greater sophistication is needed in the development of drainage infrastructure and the management of drainage systems. The question is, how to bring it about? As described in chapter 4, several countries that developed ambitious drainage programs also developed capacity in system design and the physical implementation—EPADP in Egypt, WAPDA in Pakistan, and the Directorate of Swamps in Indonesia. This created a core of practitioners. In Egypt and Pakistan, specialized in-house research institutes grew up.²⁸ This has had the effect of creating an environment where knowledge was developed, based on practical questions and feedback, and much of it was incorporated in mainstream operations. Research programs in large-scale investments paid off, particularly when the technologies used were sensitive to improvements and gains in cost-effectiveness achieved. Meanwhile, it

narrowed the focus of knowledge development. This helps explain why most of the advances in drainage technology has been in materials and methods for constructing pipe drainage systems (e.g., plastic drain pipes, trenching and trenchless machines, synthetic envelope materials). Less research has gone into open drains, even though they are more common. World Bank lending for drainage, for instance, shows that 92 percent of the drainage projects supported between 1973 and 2000 included open drainage, while only 15 percent included pipe drains, and less than 5 percent tubewells (Abdel-Dayem 2000). Even less research has been devoted to the practical management of drainage systems or to supporting the spontaneous development of drainage systems. This bias in research programs toward public investment rather than overall relevance is also common in other natural resources research programs.

Thus, a fresh look at research agendas is necessary, with far closer attention to technologies and water management strategies that serve multifunctional resources use. The emphasis is also changing in water governance, incorporating more sectors, shifting from construction to water management, capitalizing on decentralization, engaging a far larger range of players, including local government, user organizations, and the private sector. In research and knowledge development, this means that clients should also change. In water management research programs, clear definitions are needed for who will be the natural recipients of the knowledge (a specification now often missing) and how to disseminate it effectively. At the same time, more could be learned from ongoing practices, and more practitioners could be allowed to innovate and upgrade their knowledge. In practice, this means making room for experimentation in water investment programs and forging a much stronger link between research organizations and training institutes. In developing new drainage technology, there seems to be little place for the classic field experiments used in agricultural drainage and other types of single-purpose water management.

Partnerships between research and development organizations within the same country and between different countries have great potential for making a change toward a more interdisciplinary approach. The legendary Egyptian-Dutch Advisory Panel that has been functioning since the 1970s has had a great impact on drainage and water management in Egypt. It brings policymakers and practitioners from both countries together to trade experiences and advise the

²⁸ International Institute for Land Reclamation and Improvement (ILRI) in the Netherlands, the Drainage Research Institute (DRI) in Egypt, and the International Waterlogging and Salinity Institute (IWASRI) in Pakistan.

government of Egypt on its development plans. The evolution of the panel's mandate is striking—from a purely drainage technology focus in the 1970s to policy and planning of integrated water resources management in the 1990s.

To conclude, a shift toward an integrated approach to drainage offers a major technical and professional challenge. This challenge includes topics like

controlled drainage, flood management, management of effluent quality, vector control, and compartmentalization. To address these challenges, innovative research should be mainstreamed in operations. Reform of the knowledge system is required, and long-term investment in capacity building is necessary.

6. Toward Policy Changes for Integrated Drainage

The lessons and ideas generated by this study have to be translated into policies and actions that promote an integrated approach to drainage. This chapter discusses the opportunities and requirements for that translation. It describes what would make a good drainage policy and how to move toward it. Specifically, the chapter discusses how to move from a conceptual to an operational framework.

Policy: Constraint or Drive?

As we have seen in chapters 1 through 5, a new approach is needed to reclaim the position of drainage in integrated resources management and sustainable development. DRAINFRAME is presented in this report as a framework for thinking through and acting upon drainage from an integrated perspective (chapter 3). The main message is that drainage should be perceived as an intervention in a physical resources system, and that it changes this system not only for the benefit of one economic sector—agriculture—but also the functioning of the physical system for other use(r)s. The notion that biophysical resources form integrated and finite systems leads to the conclusion that proper management of these resources should follow an integrated route. For water resources in general, this conclusion was already drawn at the Dublin Conference in 1992. For drainage, it remains to be systematically implemented.

Agricultural drainage is an independent water management sector in only a few countries (chapter 4). In most cases, the public works, irrigation, or agriculture department looks after agricultural drainage. The policies of these sector institutions therefore determine the way agricultural drainage is shaped and used. Usually, however, the ambitions of these sector institutions do not represent the ambitions of society as a whole. They use drainage to promote the particular objectives of their sectors. The disadvantageous effects of agricultural drainage can be

traced back to the one-sidedness of these policies, but in most countries to the absence of drainage policies.

Efforts to reform water policies are usually ambiguous when it comes to drainage. A main constraint is the lack of vision or awareness regarding the opportunities and challenges involved in sustainable drainage development. This report and the country case studies on which it rests show that increasing crop productivity, though important, is today too narrow an objective to convince people outside the drainage sector to support drainage development. This report takes an integrated approach, as outlined in DRAINFRAME, that incorporates all effects and impacts of drainage (cost and benefit) and involves all stakeholders who could make a difference in decisionmaking and planning. The forces driving policy transformation are based in the vested interests of a wider group of stakeholders who want balance between productivity, resources conservation, environmental protection, and improved livelihoods.

World Bank Policy Statements

Three recent World Bank strategy papers reflect a new way of thinking about the development of land and water resources:

- Water Resources Sector Strategy: Strategic Directions for World Bank Engagement (2003)
- Reaching the Rural Poor I: Strategy and Business Plan (2002a)
- Making Sustainable Commitments: An Environment Strategy for the World Bank (2001a).

All three strategies recognize the holistic nature of our natural resources and draw lessons on their use for the benefit of all.

Sector strategy for water resources

The World Bank's *Water Resources Sector Strategy* paper (2003a) is a strategic elaboration of its *Water Resources Management Policy* paper (1993). The policy paper in turn was the World Bank's answer to the recommendations of the 1992 Rio and Dublin conferences on sustainable development. The strategy stresses that it is time for a *pragmatic* but *principled* approach (efficient, equitable, and sustainable). This intention is founded on the finding by the Bank's Operations Evaluation Department that "while it is essential to plan comprehensively, greater success can be achieved through discrete, manageable sequenced development," that is, by following an "unbalanced approach" (World Bank 2002). Such an approach would include a strong "learning by doing" component. The water management principles adopted in the 2003 strategy are summarized in box 6.1.

The major challenge is to develop *context-specific, prioritized, sequenced, realistic, and patient approaches* for implementation. Meanwhile, any involvement of the World Bank in water management development should adhere to the two main Millennium Development Goals: *poverty reduction and sustainable growth*. This study shows the important role drainage can play in achieving these goals, when it is planned and managed to deal with the multifunctional resources system and the values attributed to these functions by society, particularly the poor, the most vulnerable group.

Rural development strategy

In its strategic objectives for rural development, the World Bank chooses to accelerate broad-based rural growth by enhancing agricultural productivity and competitiveness and enhancing sustainability of natural resources management (World Bank 2003b: 39). This study shows that agricultural drainage is one of the important instruments for enhancing agricultural productivity and improving health and livelihoods but that it could also be a disadvantageous practice for other water use sectors if poorly planned and managed. Throughout, principles of integrated natural resources management are stressed to safeguard sustainable use of resources. In *Re-Visioning Irrigation*, the rural strategy set the priority issues for sustainable irrigation (and drainage) as waterlogging and salinity control, managing the disposal of drainage water, managing sufficient river base-flow, regulating reuse of water, anticipating climate change, and adopting environmental planning for new and modernizing projects (ibid:141). The need is obvious for a consistent analytical framework that leads to an integrated resources management model to address these issues.

Environment strategy

The World Bank's environment strategy (2001a) sets a direction for the Bank's long-term activities in that area and specific actions for the next five years. The strategy recognizes the diversity of the environment as well as the differences in institutional development

Box 6.1 World Bank principles for water management

The World Bank's 1993 policy paper reflected the broad global consensus that modern water resources management should be based on

ECOLOGICAL PRINCIPLE

- Independent sector-based water management is not appropriate.
- The river basin is the unit of analysis.
- Land and water should be managed together.
- Much more attention is needed for the environment.

INSTITUTIONAL PRINCIPLE

- All stakeholders participate in water management.
- Women must be included.
- The principle of subsidiarity should be adhered to.

INSTRUMENT PRINCIPLE

- Recognize water as a scarce resource.
- Make use of economic principles for water allocation and quality control.

Source: World Bank 2003a: v.

and environmental management capacity in client countries and calls for an assistance approach tailored to these diversities. Environmental management is not seen as a separate sector but as a particular dimension of development management, which covers all sectors. At several points, the importance of “learning before doing” is stressed. The environment strategy does not deal with individual sectors in detail. Nevertheless, it is not difficult to situate drainage within it, because drainage is both a cause of *and* a solution for environmental problems of land and water and of poverty.

These general policy statements by the World Bank on water resources management, rural development, and the environment strongly support the idea of an “integrated drainage” perspective. Conversely, an integrated approach to drainage is a way to implement the principles promoted by these strategies. The art will be to translate such general strategic principles into practical “how-to” approaches for drainage situations.

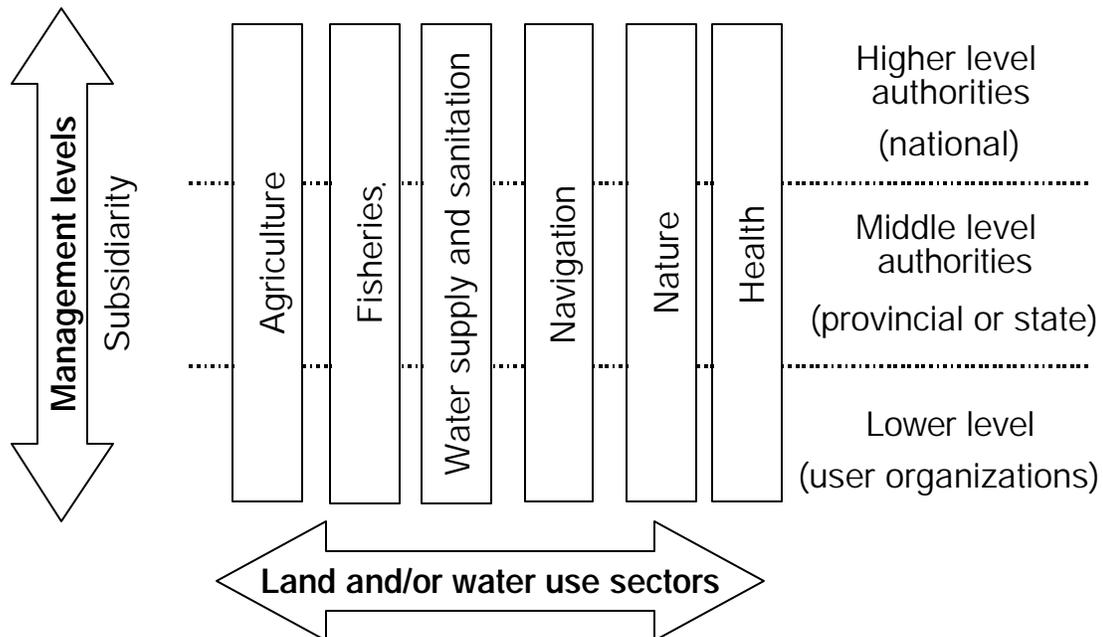
Critical Issues for Integrated Drainage

This section briefly analyzes the issues that need to be addressed when new policy and actions are considered to promote integrated agricultural drainage: governance and power, policy and legislation, critical issues for integrated drainage, functional organizations, financial and funding arrangements, education and knowledge systems, and drainage technology

Governance and power

The opportunities for policy transformation will, to a large extent, be determined by the distribution of decisionmaking power. This power has to be distributed in two directions: vertically and horizontally (figure 6.1). Vertically, higher level authorities exert power over lower echelon authorities. The subsidiarity principle is the key to vertical devolution of power by moving decisionmaking to the lowest appropriate level. Horizontally, or in parallel, the users of different functions of the same water (and land) have different power positions in the management of drainage. Sharing power between agriculture, often the predominant user sector, and other user sectors is the condition for balanced

Figure 6.1 Vertical and horizontal distribution of power



Source: Authors.

decisionmaking and management in the horizontal direction. To be effective, changes for reform of the decisionmaking structure have to be made simultaneously in both directions.

Any hydrocracies that claim responsibility for drainage usually want to retain their power and thus pose an important hurdle for reformers to negotiate. Worldwide, the engineers' fortresses are well known. Authority over policymaking, planning, decisionmaking, implementation, and operation of agricultural drainage often resides in these governmental institutions. Strong formal (legally sanctioned) and informal alliances sometimes exist between these departmental organizations and the predominant drainage user sector. This has long been the pattern in the Netherlands. There are few examples available to suggest that monopolists will share power of their own free will. Any change in this kind of monopolist management situation will be impelled by broad societal and bureaucratic developments. Such developments may be a gradual change of values regarding functions of the environment in society as a whole, resulting in reduced leverage for agricultural stakeholders or triggered by a government financial or budget crisis.

Thus, there are three important entry points for reforming decisionmaking in the agricultural drainage sector:

- Work on the principle of subsidiarity.
- Create platforms for stakeholder representation and empowerment of user groups.
- Reduce the influence of state departmental organizations on decisionmaking.

Policy and legislation

Relevant legislation has to be changed to create legal security in the right to use natural resources and to give disadvantaged groups access to these resources. By Law 35/1949 the Egyptian state, for example, unambiguously established that the provision of drainage is a public responsibility and that drainage projects would be undertaken on all agricultural lands. The law also established that farmers would be charged with the capital costs (though on soft terms). This was the start of a large-scale drainage construction program in the Nile Delta and the Valley. With the recent introduction of elected water boards to manage the water control systems (irrigation and drainage) at district or branch canal level, the

necessary changes in the water law are being discussed.

If policy change from a monofunctional agricultural drainage model to a multifunctional one is considered, basic changes have to be made in legislation. Sometimes even constitutions may have to be revised to create space for devolution and decentralization of authority. The reverse may also be true. Changes in the law or the constitution may have serious consequences for agricultural drainage policy and take time to accomplish (box 6.2).

Box 6.2 Constitutional Amendment Seventy-three in India

The Constitution of India was changed in 1992 through the Seventy-third Amendment Act to devolve powers from state governments to *panchayats* (elected bodies) at three levels. This created the legal environment for devolution of water management powers to the lowest appropriate level (subsidiarity principle). It took until 2001 to incorporate these principles in a new National Water Policy for India. The policy states, "Management of the water resources for diverse uses should be done by adopting a participatory approach; by involving not only the various governmental agencies but also the users and other stakeholders in an effective and decisive way in various aspects of the water resources schemes....Water Users' Associations and the local bodies such as municipalities and gram panchayats should particularly be involved" (Statement 12).

There is a dilemma regarding existing legislation on one hand and new approaches and initiatives to reform agricultural drainage on the other. The important effects and impacts of drainage on health and environment (both positive and negative) make the formulation and enforcement of regulatory frameworks and operational standards essential. Experimentation and piloting are often needed to find the best modalities for a new drainage concept, but existing legislation does not always allow it.²⁹ The legislation therefore has to be reviewed and changed to make room for experimentation.

²⁹ In the Netherlands, experimentation with water levels in polders is necessary to find new optimums between agricultural and ecological requirements. However, in the past, water levels were set by law, and the water boards were obliged to maintain them or incur penalties.

Functional organizations

Egypt is the only country that has a semi-autonomous drainage organization. Elsewhere, drainage is institutionalized through irrigation, flood control, or agriculture departments. The urgency of water supply, irrigation, and protection of life and property from floods pushes drainage to the lowest institutional priority in terms of both management and funding (chapter 4). This situation is a disadvantage now but can be turned into an opportunity for policy development and transformation. The germs for integrating more than one water function are already present institutionally in most countries. This raises the important question of whether the management organizations for the water sector should be dismantled and replaced by a new organization encompassing all land and water management so as to achieve integrated water management. Chapter 4 suggested caution with regard to the establishment of river basin organizations and argued for the appropriate structures for polycentric and multistakeholder governance and management structures.

When an organization in charge of agricultural drainage starts to follow integration principles, it will impinge on other organizations' areas of competency. In these cases, good procedures have to be available to arrange for:

- Final competency (which organization is in the lead position)
- Budget provisions and allocation
- Leading and subordinate roles
- Modalities of coordination
- Sanctions for noncooperation
- Accountability to users.

Financial and funding arrangements

Cost recovery for drainage development and management expenditure in general is notoriously low (chapter 4). It presents both a challenge and an opportunity when drainage is managed in a way that recognizes the multiple functions of the water resources system with a cost-recovery mechanism, negotiated among the different stakeholders, to allocate costs and benefits among them.

Because integrated drainage has to address more than one function, the beneficiaries of each function should logically contribute to cost recovery in

proportion to their interest. However, if agriculture is to relinquish part of its production potential because drainage is operated suboptimally from an agricultural perspective to enhance other functions, the sector will insist on spreading around the cost of lost benefits. An equitable cost-sharing model has to be found—fair and acceptable to everybody—but the financial quantification of intangible goods and services provided by water is difficult and somewhat arbitrary. Financially balancing an area's increase in biodiversity against a loss of X tons of wheat is problematic, even disregarding the question of who exactly benefits from biodiversity and therefore has to be charged.

Recognition of the multifunctionality of drainage provides a strong impetus for cost sharing by governments. They may contribute in the interest of future generations and for public goods and services such as maintenance of ecosystems, public health, and flood protection. However, it will take time for local value and norm systems to absorb the guiding principles for cost sharing in drainage. At the same time, there is also considerable scope to look at the cost-efficiency of drainage operations. In several drainage systems, cost saving measures are possible that would bring drainage within spending capacity of public sector and individual users.

Education and knowledge systems

Education in agricultural drainage at universities and polytechnics is often purely technical and focused on agricultural production. Leading researchers, whose careers have been shaped by monodisciplinary thinking, have great influence over decisionmakers, including those who determine research programs. As advisers to politicians and senior administrators, researchers, too, can substantially influence policymaking.

A new policy for drainage, based on an integrated water resources management approach, should therefore also aim at a long-term but consistent transformation of the educational and research and development institutions. This would involve adaptations in student curriculums, teaching by open-minded instructors, and research programs oriented to integrated water resources management. Existing innovative approaches in drainage teaching and research should be identified and supported.

At the international level, several organizations could play a role in the expansion and transformation of the drainage knowledge system. Among these are the

International Commission on Irrigation and Drainage, the International Program for Technology and Research in Irrigation and Drainage, the International Institute for Land Reclamation and Improvement, and the network of institutions under the Consultative Group on International Agricultural Research. Training and capacity-building institutions at the national level can play an equally important role. They help professionals who work in drainage planning and management and can therefore provide context-specific solutions and training.

Drainage technology

Part of the resistance to an integrated approach to drainage, emphasizing multifunctionality of resources systems, could stem from the lack of mature technological solutions and adequate management capacity for “integration.” Some of the country case studies show that initial resistance disappears once a new drainage technology situation is established and proper ways are found to deal with it (chapter 5).

If agricultural drainage is to become receptive to other functions of the environment, a series of techniques and technological solutions has to be developed to facilitate the shift to multifunctionality. Most drainage technology in use was developed for the agricultural production function. It is therefore not automatically suitable for more integrated forms of drainage. Chapter 5 provides more discussion on technological options and opportunities for integrated drainage management. Research is needed to find technology and management options that help optimize the diversity of the system’s functions.

Policies are needed to stimulate the development of new technical drainage solutions that facilitate multifunctional drainage management. The role of government and private parties in promoting research and technology for integrated management needs rethinking.

A Pragmatic Approach to Policy for Sector Reform

Policies tend to be generic and prescriptive, but they should be enabling and give guidance. When drainage is to address the multiple functions of resources systems in a highly diverse environment, sound policy should allow the change agents to find out how the transformation should be done instead of telling them from the beginning exactly what should be changed.

Because drainage policies at different levels are nested, one might believe that new policy has to come from the top to be legitimate. However, the problems caused by agricultural drainage, as well as most opportunities for improvement, occur at grassroots. These problems and opportunities provide important ingredients for a responsive policy (box 6.3). The drivers of policy transformation are often located at the practical level and in specific situations. A balanced approach would be to adopt an enabling policy at the top, one that enables and promotes initiatives, experiments, and pilot projects for integrated forms of drainage. More clear-cut policies can be developed at the lower, practical levels and in particular situations.

Policies are nested in a variety of ways. There are different levels of legislation and governance, and different hydro(-ecological) levels (chapters 3 and 4). Also, policies from different domains are interrelated, and their ownership may be located in different groups and organizations. Policies cannot, therefore, be conceived in isolation. Designing a new drainage policy for all times is neither wise nor possible. Policies, including drainage policy, should be continuously “under reconstruction.”³⁰

Logical Steps toward Change

This report advocates a careful, multilevel approach to (interim) policy changes to promote an integrated approach to drainage. The main steps in a logical sequence are the following.

Step 1. Understanding is the basis for a new drainage policy.

The first step toward a new policy is a thorough analysis of the existing situation, for which DRAINFRAME has been developed (chapter 3). This

³⁰ The underlying theoretical framework is a “policy as process” perspective, instead of a “policy as prescription” perspective (Mackintosh 1992). This approach shows that policy formulation and implementation are social processes in which different interest groups struggle, negotiate, compromise, or otherwise interact to shape policy and “what it does” (e.g., Grindle 1977; Lipsky 1980; Keeley and Scoones 1999). Alignment of interests is the core process in making policies work. Understanding and intervening in alignment processes requires understanding the way social power works in policy processes. (Mollinga and Bolding, forthcoming). Strategic behavior involving incremental social and institutional transformation and decisionmaking in multistakeholder institutions also fits this perspective.

Box 6.3 Example of friction between policy and management

Somewhere in the Netherlands, a group of six farmers, with contiguous tracts of land in the head reaches of a drainage system, wanted to improve the productivity of their land through water conservation. Part of their policy was to act together and pay for the investments themselves. Their strategy was to build small movable weirs in the main drain to raise the groundwater level and to operate and maintain the weirs themselves so they could respond as quickly as possible to changing weather conditions and changing requirements for land cultivation. Initially, a third element of their strategy was to get permission from the local water board that owns and operates the main drain. Although it was national, provincial, and water board policy to conserve water (not only for agriculture, but also for the restoration of nature), this kind of public-private cooperation was not anticipated in the respective policies and management strategies. Therefore, permission was not given. So, the farmers changed their strategy and built the weirs without the board's permission. After the first year, while cleaning the drain, the board removed the weirs.

The next year, discussions started between the group of farmers and the water board. It turned out that it was within the board's power to decide who would operate the weirs (within certain water-level boundaries indicated by the provincial government). However, as a matter of legal principle, the ownership of any structure in the drain would have to stay with the board, and so the board also had to pay for the construction.

This simple example shows that understanding a particular local drainage situation resulted in a particular solution that satisfied a declared policy—that bottom-up action can change things. However, it also shows a case of conflict between policies and lower management levels driven by institutional and legal factors. Time and effort would have been saved if different levels of management had worked together in harmony and with better understanding.

Source: Personal communication Jan Hoevenaars (2003).

includes understanding all functions of the resources system (land and water), their stakeholders, and the values stakeholders attribute to these functions. Lowland development in Indonesia shows that, when policy is not based on an understanding of the diversity of the resources system, development opportunities are missed (Indonesia country case study).

Step 2. Identify ambitions, problems, and opportunities for policy reform.

The second step toward a new drainage policy would be an iterative process of formulating ambitions, identifying problems, and searching for opportunities to realize the ambitions. If integrated drainage is one ambition, this iterative process requires multistakeholder involvement, participatory planning (chapter 3).

Problems and opportunities for change are identified by answering three main questions:

- What are the inconsistencies or gaps in the present drainage policies with regard to the sustainability of the different functions of the water resources system?
- What are the main weaknesses of the governance and management system (internally and in dealing with multifunctional resource system)?

- Which external and internal drivers of change exist (increasing complexity; serious conflicts of interest; changing values regarding drainage impacts; loss of luster, chapter 2)?

Step 3. Get a common ambition for a new policy.

Four strategic issues are central for a new drainage policy:

- Differences in interest between societal groups
- Differences in decisionmaking power between interest groups
- Limited availability of resources
- Resistance by established organizations and bureaucracies.

In such an environment, reform ambitions should be modest. The World Bank *Water Resources Sector Strategy* paper states, "The major challenge is developing context-specific, prioritized, sequenced, realistic and patient approaches to implementation." (World Bank 2003a: v). And on pricing and water rights, the strategy promotes the approach of: "*Principled pragmatism* because economic principles are very important and solutions need to be tailored to specific, widely varying natural, cultural, economic and political circumstances, in which the art of reform is the art of the possible" (ibid.: 22). To overcome built-

in resistance, considering the complexity of the subject, it seems wise to be pragmatic, but this pragmatism should be guided by a vision based on the principles of integrated resources management.

Developing a vision entails identifying feasible shared ambitions or objectives and enrolling as many stakeholders as possible through an adequate communication and information process. Apart from contextual drivers (chapter 2), this requires political entrepreneurship of the main agents of policy transformation.

Guidelines for action

The DRAINFRAME formulation derives from a set of conceptual frameworks and a limited amount of practical experience (chapter 3). However, DRAINFRAME still needs to move from concepts to action. Methodologies, scientific research, and field-level how-to's are available only in a fragmented and incomplete way within current practices. A phase of experimentation and learning is needed to collect evidence, gain experience, and develop a practical set of instruments. This would require an enabling policy that allows experimentation in the context of actual drainage intervention situations.

The following recommended actions could lead to the required policy changes. They could be taken one or more at a time.

- Conduct experiments or pilots projects.
- Concentrate first on quickly rewarding activities: “pick the lowest hanging fruit.”
- Build awareness and information; enhance transparency; start public debates on the multifunctionality of the resources system.
- Underline gains.
- Recognize, mobilize, and empower other stakeholders besides agricultural producers.
- Make financial resources available for dedicated activities

Learning about and assessing the need for implementing an integrated approach include improving knowledge in the following areas:

- Nature provides many functions: detect those functions.
- Agricultural drainage has an impact on natural resources: know the changes.

- Changing resources affect all functions: understand the effects.
- Functions have stakeholders: identify and involve them.
- Stakeholders assign values to functions: assess those values.
- Stakeholders have different says in decisionmaking: analyze and reform it.
- Policies and institutions lag behind requirements for needed services: make an audit and put pressure on policymakers and practitioners.

Concluding Messages

Five main messages emerge from the analysis presented in this report. Some of these messages target the broad audience of professionals in the drainage and water management sector, planners, decisionmakers, governments, and the international development community at large. Some are specific to a particular group. These messages may help in rethinking drainage policy and induce these different groups to take up their responsibilities in the drive to integration.

Message 1. Dare to Look at All Costs and Benefits.

A general lesson from the case studies behind this report is that there is a dire need for effective approaches that acknowledge all *positive* and *negative effects* of drainage and ensure multifunctional (re-) design and operation of systems, apply fair cost allocation, and offer mitigation or compensation for all parties who experience negative impacts from drainage.

Expanding and balancing the assessment of drainage, and the management of water resources generally, to include both positive and negative effects would provide incentives for mobilization of resources for investment in “integrated” drainage—drainage systems that consciously address the multifunctionality of the resources system and the plurality of stakeholders and their values.

Message 2. Emphasize the Potential for Poverty Reduction in the Integrated Approach.

Ignorance about many functions of water and land, and the interests at stake, are among the root causes of unsustainable drainage and a cause of poverty for many people. Increased costs because of the loss of

functions of the natural resources system reflect the potentially poverty-deepening effects of having or not having drainage. The two-sided effects of agricultural drainage on poverty make it imperative that planning simultaneously address both sides of drainage. The proposed integrated approach fosters the poverty-reducing effects of agricultural drainage.

Message 3. Move Toward an Integrated Approach with Pragmatism and Vision.

Change is difficult and slow everywhere, including the transformation of policies that govern drainage management and development. Moreover, vested interests may resist changes that affect the economic position of agriculture. There is little experience with the implementation of drainage based on multifunctionality, especially in developing countries. This makes it difficult to make big steps toward a significant paradigm shift. As stated, a steady, step-by-step approach to change is preferred as a pragmatic way for achieving change. Nevertheless, a paradigm shift toward integrated drainage is required and offers an opportunity not only to address the well-known side effects of the technology but also to overcome major problems of classic agricultural drainage. Pragmatism should be pursued within a visionary framework that fosters the main direction of transformation.

Message 4. Learn before Doing.

Change should start by improving knowledge. For the first critical steps toward new policy, in a scene of diversity in all respects and little experience with new approaches, understanding each drainage situation and its specific needs is indispensable and must come before action. Experimentation and piloting the integrated approach such as the one presented by DRAINFRAME in the context of local diversity is a crucial first step toward formulating policies and guidelines and for planning drainage interventions.

Message 5. Governments and the international development community must play an important role in promoting an integrated approach to drainage.

Part of governments' mandate is to promote development and change and to provide the instruments and enabling environment to make it happen. The international community comprises important players in the fields of water management, agriculture and rural development, water supply and sanitation, social development, and environment. They manage strong knowledge bases and many research centers. They could open many doors to promote the proposed changes in drainage. As change agents, governments and the international community can push policy development and innovation processes in drainage. Specifically, they could

- Promote a long-term vision of integrated drainage.
- Promote, and make resources available for, the learning processes necessary to help along the transformation process in drainage.
- Work to develop a portfolio of projects and programs that encompass the features of the proposed changes.
- Introduce the principle of full understanding of drainage situations as a part of new projects for restructuring the water resources sector.
- Recognize the effects of drainage on poverty, and the distribution of poverty, over different societal groups.

And finally, all individuals, organizations, and agencies with the power to act, should act now—no need to wait. The challenge is clear, but the rewards can be enormous.

Appendix A Selected Primary and Secondary Function Changes due to Agricultural Drainage

Main agricultural drainage interventions	Primary physical changes	Primary change in function	Secondary changes	Affected landscape	Other affected functions
Prevent or reduce waterlogging (Pakistan, Egypt, Mexico)	Lowering of soil water table	Improved soil productivity and workability (mechanization)	Lowering of water table in adjacent lands	Adjacent inhabited land	Improved living conditions due to less damage to buildings and public infrastructure
				Adjacent natural wetlands	Maintenance of biodiversity threatened, including productive resources (fish)
Reduce or prevent soil salinization (Pakistan, Egypt, Mexico)	Leaching and lowering of soil water table		Reduction in snail and mosquito breeding	On site	Improved living conditions due to improved public health
			Increased flood buffer	On site and downstream	Reduced risks of prolonged inundation
Flood control (Bangladesh, Java)	Hydrological changes in flood regime	Prevention of crop damage, prolongation of growing season	Reduced high-level inundation	On site	Less flood damage to built-up property, but also diminished fish production (in coastal areas diminished shrimp or salt production)
			Reduced field sedimentation	On site	Reduced soil fertility
			Increased downstream inundation and sedimentation in water ways	Downstream waterways, unprotected areas	Downstream flood risks and drainage congestion
			Increased ability to retain water on site	On site	Increased ability to balance water use for different purposes in command areas
Conveyance and discharge of drainage	Transportation of water elsewhere	Disposal of excess water	Reuse	Downstream	Additional water supply for agriculture and aquaculture provided quality is acceptable

Main agricultural drainage interventions	Primary physical changes	Primary change in function	Secondary changes	Affected landscape	Other affected functions
waters (Egypt)			Disposal of liquid waste from urban and industrial sources	Canals and waterways	When uncontrolled, contributing to pollution problems of large water systems
			Ecosystems receiving drainage waters	Wetlands	Affects and possible threatens natural productivity (fish, shellfish) by pollution or changing system hydrology
					Natural water purification processes and biological diversity affected by inflow of contaminated water – on other hand also new wetlands created by excess flows
Reclamation of waterlogged organic, acid-sulphate soils in natural lowland areas (Indonesia)	Clearing of natural ecosystems	Turn into agricultural lands	Loss of local biodiversity	Local	Reduced biotic pressure on surrounding areas—particularly if new areas fully developed. Risk of opening pristine areas. Local loss of regulation, carrier, and significance functions of ecosystems
	Lowering of water table and regular flushing	Increased agricultural productivity	Land subsidence	Local	If areas inadequately selected or developed, abandoning of land
			Changes in soil and water quality	Local and downstream lands (natural and agricultural)	Wrong practices may lead to degradation and domestic water problems Importance of second-stage lowland development

Source: Country case study reports.

Appendix B The Multiple Impacts of Drainage

Agricultural Impacts

Drainage interventions were often undertaken primarily to improve agricultural production. Agricultural benefits of drainage in selected areas have been considerable and on a similar magnitude to irrigation investments. The impact of well-planned drainage investments on farm productivity can be large. Moreover, drainage investments usually do not require scarce water.

Drainage development depends on the stage of agricultural development (Smedema, Abdel-Dayem, and Ochs 2000). In subsistence agriculture and initial stages of agricultural development, basic types of drainage are economically justified. When agricultural development takes off and yield, intensity, and diversity of crops become important issues, investment in more intensive drainage systems becomes justified.

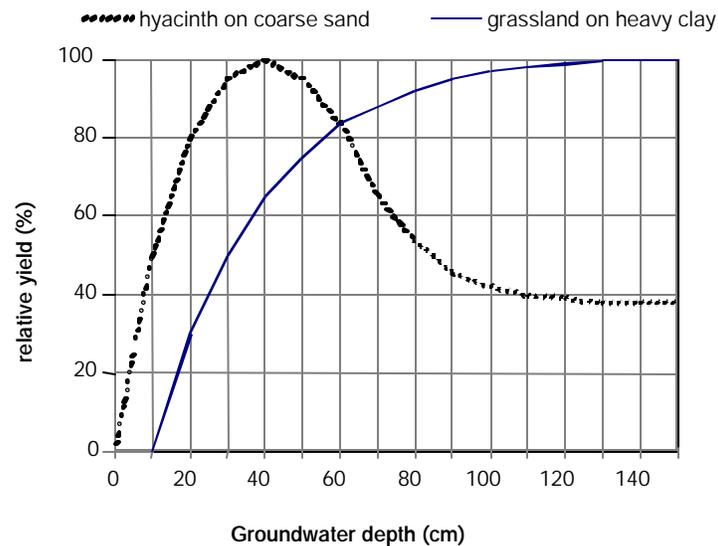
The impacts of drainage improvements have been less systematically reviewed than the impacts of irrigation projects. One reason is related to the difficulty of establishing drainage impacts per se, because of the large sensitivity of drainage programs to external variables such as the occurrence or nonoccurrence of rainfall in a number of years, sufficient irrigation supply, soil fertility, plant protection, or the state of operation and maintenance of drainage works.

Crop yields and water table depth are strongly related. In the Netherlands, considerable research has been done on this. The relation is influenced by soil type, crop (particularly its rooting depth), and rainfall distribution during growing season. An example of different responses to groundwater depth of two crops on different soils is shown in figure B1.

Drainage theoretically results in better root aeration and changes the environment for soil chemical processes and the development of soil bacteria. For example, water table control enhances denitrification.³¹ Drainage also has other effects that support farm operations and create opportunities for crop diversification. Drainage improves land access, allowing farm mechanization for timely soil preparation and early sowing. In temperate climates it can advance and prolong the farming season. It also enables double or triple cropping. Such gains have triggered spontaneous farmer-managed drainage development in areas as diverse as the coastal mangrove swamps in West Africa, the lowlands of Indonesia, and coastal Kerala, India. Drainage increases soil temperatures during spring, which improves germination and inhibits plant diseases. In lowlands in the humid tropics such as Indonesia, drainage plays a complex role in ripening acid sulphate soils through the oxidization of pyrite and the flushing of acidity.

Most drainage development has been based on free flow that lowered the water table to the drain level, rather than managing it for moisture content in the root zone. An important factor in managing shallow groundwater is the impact of capillary supply. When water tables are relatively shallow, capillary supply replenishes soil moisture, which is of particular importance during dry spells or peak growing periods. Active capillary supply is an example of the management of “green water,” the water stored in the soil (Falkenmark 1995). Drainage systems that have no facility to control the depth of water tables (systems with free gravity outlets) may lose the

³¹ *Denitrification* is the process whereby $\text{NO}_3\text{-N}$ is broken down to N and NO_x , making the nitrates retained in the soils available for plant use.

Figure B1 Relative yield and groundwater depth: an example

Source: Adapted from Van der Molen 1968.

subirrigation effect, resulting in overdrainage and undoing gains in farm productivity.

Economic impact studies on drainage are few and far between (Umali 1993; Datta, de Jong and Singh 2002). Where undertaken, such studies have usually looked at agricultural impacts. One of the most recent and elaborate efforts was undertaken in the National Drainage Program in Egypt. An intensive network of subsurface pipe drains and surface drains has been constructed in the “old lands” in Egypt to reduce salinity and overcome waterlogging in this arid environment. A multiyear evaluation based on 15 large sample areas established that the gross agricultural production value typically improved by about US\$500 to US\$550/hectare. The annual net farm income of the traditional farm increased by US\$375/ha in nonsaline areas and by about US\$200/ha in saline areas. The overall cost of installation of drainage (construction of subsurface network, remodeling of open drains, planning, design and supervision) was estimated at US\$750/ha and US\$550/ha for rehabilitation. Maintenance costs were about US\$10/ha/year. Assuming that two-thirds of the incremental income could be attributed to drainage, the pay-back period of the drainage investments in Egypt is short—i.e. less than 4 years (Ali et al. 2001).

Another comprehensive assessment of the impact of drainage improvement in arid areas was done in the Mardan Salinity Control and Reclamation project (SCARP) in Pakistan (Freedman and Akram-Lodhi 2001). It compares the before and after project situation in both impact and control areas. In the 10 years in which the project was completed, crop yields increased between 27 percent and 150 percent in the project area. Real household income increased by a mere 5 percent (corrected for inflation). However, this was still a boon compared to the 32 percent drop in real income in the control area. In both areas, the importance of farm income declined, but the drop was pronounced outside the project area. This showed a steep increase in the importance of wage income. The study ascribes the stagnating incomes in the project area to the worsening terms of trade for agriculture, the persistence of subsistence farming, and inequity in access to resources—related to a tenure system dominated by large landowners.

Mexico reports short payback periods, particularly for drainage investment that enabled water table management in the humid parts of the country. This allowed the introduction of sustainable soil and water conservation practices, including the expansion of tropical fruit cultivation and

improvement of field crops (doubled corn yields) and pastureland. In the different subprojects in the Program for Integrated Rural Development in the Tropical Wetlands (PRODERITH), the economic rates of return, calculated only on the basis of changes in agricultural yields, were decent, varying between 14.7 percent in Zanapa Tonalá in Tabasco state to 21.5 percent in Centro de Veracruz.

Comparable analysis of flood control with drainage projects in Bangladesh shows a large variation. The impact of investments in coastal regions was generally higher than inland investments. Saline flooding is far more damaging than freshwater flooding, especially for agriculture. Economic analysis of flood control and drainage benefits undertaken in Flood Action Program 12, a component of the larger Flood Action Program, concluded that, out of 17 inland flood control and drainage projects, 9 projects were, in retrospect, economically viable, with economic internal rates of return between 22 percent and 96 percent (median 54 percent). The performance of 8 other projects was marginal. In two cases, the economic returns were negative. Smaller projects did somewhat better than larger projects, while pumped drainage appeared to be uneconomic (Government of Bangladesh 2001: annex B-34).

Finally, drainage investments in Europe and the United States show a mixed picture. There were substantial farmer investments, often aided by public subsidies, but interest declined once the subsidies were phased out and agriculture had become less profitable.

The agricultural impacts of drainage investment have thus been mixed, but in several instances they have equaled or surpassed productivity gains through investment in irrigation infrastructure. Drainage is sometimes regarded as the necessary evil accompanying irrigation investments, but the studies referred to above suggest that drainage investments are justified on their own merits. The impact of drainage is, however, very much dependent on the state and maintenance of the system. This may state the obvious, but maintenance of drainage infrastructure, particularly open drains and pumping facilities, has often been neglected.

Public Health, Drinking Water Supply and Sanitation

Drainage plays a crucial but often underexposed role in public health. Excessive moisture and stagnant water are breeding places for vectors (e.g., mosquitoes, flies, and snails) of parasitical and viral diseases. An important side effect of drainage has been the reduction of the incidence of killer diseases such as malaria, schistosomiasis (bilharzias), Japanese encephalitis (brain fever), yellow fever, and various forms of filariasis, but all depends on the quality and continuity of the drainage services. Combating malaria is explicitly mentioned in the Millennium Development Goals, and the importance of vector control therefore needs emphasis.

Other positive health impacts include reduction in dankness. Rheumatism was endemic in many farm areas in the Netherlands, but lower water tables improved living conditions. What applies to human health also applies to animal health. Kamal et al. (1999) found a remarkable reduction in animal diseases after the completion of drainage projects in Sindh, Pakistan. Diseases such as lungworms and West Nile virus are positively correlated with humid subsoil and standing water. However, the effective contribution to public health depends on proper design, operation, and maintenance of the drainage systems. Malfunctioning drains can easily turn into major problem spots and become a public health risk.

Drainage has a major impact on diarrhea and gastroenteric disorders. A lowered water table is often a precondition for a minimum sanitation environment. It is impossible to construct inexpensive latrines in waterlogged areas—often the most convenient and cost-effective technology cannot be used. The provision of such facilities is standard practice in drainage programs in Japan. Rain washes contaminants into shallow wells, often the major source of drinking water. Reducing the number of persons without access to adequate sanitation (by 50 percent of an estimated 2.6 billion people by 2015) received new impetus in the targets set at the World Summit on Sustainable Development in Johannesburg in 2003. Unfortunately, agricultural drainage projects have often ignored these public health effects and have

neglected to extend drainage networks to local settlements. There are few examples of joint programs between agricultural and public health departments.

Drainage may affect domestic water supply. In some saline groundwater zones in Pakistan, where waterlogging is most widespread, lowering water tables allowed a thin lens of freshwater to develop on top of the saline groundwater, recharged by rain and canal seepage. An example is the Drainage IV area near Faisalabad. Freshwater lenses under farm ponds are also widely used for drinking water supply in coastal Bangladesh. Though far from excellent, these thin layers are often the best locally available source of drinking water. In the lowlands in Indonesia, domestic water supply is equally problematic. At the end of the dry season, water quality in lowland areas usually deteriorates to the point that it becomes unfit for human consumption due to high suspended-solid and high sulphate content and bacteriological contamination. A range of measures is used to provide drinking water of reasonable quality: filtration, sedimentation, addition of coagulant and disinfectant, boiling, and roof-top rainfall harvesting. Controlled drainage, in particular flushing the system with river water to remove acidity and organic pollutants, ensures that the water in canals will remain suitable for other domestic uses such as bathing and washing.

Reduced Damage to Buildings and Roads

Less damage will be done to buildings and other rural infrastructure when shallow water tables are under control. First, lower water tables can reduce the possibility of uncontrolled flooding because they act as a buffer to excess rainfall. Drainage also ensures the removal of stormwater. The deteriorated condition of the drainage system in the Mahanadi Delta in Orissa state, India, was responsible for the persistent flooding after the 1999 cyclone—multiplying the woes of a society already devastated by the storm surges. The balance is delicate, because an overdeveloped drainage system can also lead to sharp flood peaks, as rainfall very rapidly finds its way to the rivers.

Second, drainage reduces damage to buildings because, when water tables are managed, less

damage occurs from excessive moisture. This is particularly important when houses are made of adobe, as in large parts of rural Pakistan, India, and Mexico. Low-income mud houses are badly damaged by humid soil conditions and have to be rebuilt frequently, as do earth roads. In the Netherlands, for instance, many roads in badly drained areas used to be little more than mud tracks, difficult to travel on, isolating communities from markets and civic amenities. Power and communication lines also collapse under wet conditions in rural areas. Leaning or fallen telephone and power lines are a common sight in waterlogged areas. Maintaining a balance in the control of shallow water tables is also important to avoid land subsidence. Overuse of groundwater and overdrainage can result in a lowering of land levels with dramatic effects on buildings. Better water retention can mitigate these effects.

Up-to-the-mark drainage management has translated into increased property and land prices in several cases. For instance, some scenic land in areas near the rivers close to the Port of Veracruz was no longer waterlogged and threatened by floods after the construction of drainage systems in the humid part of Mexico under the PRODERITH program. Values increased from US\$7,000 to US\$200,000/ha. Such impacts are usually forgotten in the calculation of returns on investment. Moreover, they are typically not recovered and become a windfall for landowners. In urban development, investment in public infrastructure is usually recouped directly from new landowners. But it is uncommon in rural water management projects, where capital cost recovery, if any, is usually tried through the painful route of recurrent charges. The appreciation of land value and the introduction of “sites-and-services” approaches might be considered in drainage evaluation and planning.

Effects on Environmental Functions

Drainage development has several effects on the environmental functions of the natural resources system. Drainage development focused exclusively on agricultural development often did damage. It did not look at what was lost in the developed areas or at the external consequences. Conversion of swamps into agricultural or residential land

inevitably leads to loss of wetlands. Although wetlands have been a source of disease vectors, they may shelter unique species or valuable ecosystems, serve as water buffers or sediment traps, or have important production functions such as fisheries or the collection of wetland products (e.g., reeds, sago, and honey).

Wetlands may have cleaning properties and serve to maintain water quality in the basins of which they are part. One example is the Pripyat River between Ukraine and Belarus. About 25 percent of the basin used to be under peatland, but when a large part of it was cleared under the “amelioration” program of the Soviet era, water quality in the river declined. The conversion of wetlands into agricultural land may also affect microclimates. In Indonesia, for instance, the presence of peat swamp forest and the large mass of freshwater acts as a windbreak and absorbs heat. This causes more rain to fall on forested lowlands than in stripped areas, which have a higher albedo. Rainfall in Southern Florida has seriously diminished due to drainage and drying of large portions of the wetland system (of which the Everglades is the best known part). Florida is now executing a multibillion dollar wetland restoration program.

The transport of contaminants and toxicants has also made drainage controversial. Toxicants may originate from the drained areas. Examples are the saline effluent from arid area drainage systems such as in Egypt and Pakistan or acid releases from the decomposition of acid sulphate soils in the early days of lowland development in Indonesia. Adequate disposal and mixing with better quality water is required. This has been the lesson from Indonesia, where controlled drainage now helps the flushing of acid and toxic effluents by river water. This, however, is difficult when drainage basins are closed, or no outfall to the sea is feasible, as in

Punjab in Pakistan and India. In those areas, the interests of upstream and downstream areas—the latter receiving the contaminated effluent—may be miles apart.

Contaminants may also originate elsewhere, and the drainage systems may accelerate their transport and spread. A prime example is Egypt where parts of the drainage network serve as sewers and an integrated perspective on water-quality management is needed. Drainage management may either cause or delay the washing of agrochemicals into the groundwater table. In intensively cultivated parts of the Netherlands, this has been a major problem.

The effects of drainage on the environment can be positive, too. Where soils are adequately drained, there is less surface runoff and less erosion. This is particularly important in uplands or areas with unstable soils. In plains, water retention by bunds and gully plugs will reduce the force of sheet flow and prevent the development of erosion rills and deep gullies (Mahapatra 2003).

Another example of a positive impact is the creation of new wetlands supplied by drainage flows. Lake Sarykamysh near the Aral Sea is an example. The disposal of drainage water in evaporation ponds has created wildlife refuge areas of great biodiversity value. The Aral Sea and its adjoining deltas always served as an important refuge area for migrating bird life. The Aral Sea crises made its wetlands virtually disappear. Many birds have moved toward Lake Sarykamysh, a large desert lake, permanently filled by a constant supply of drainage water. In time, however, the lake is expected to become hypersaline because of rapid salinization, similar to what happened to the Aral Sea. In other cases, drainage development may lead to the loss of wetlands, but it may also promote the intensification of agriculture, which can slow down the opening of pristine areas.

Appendix C Diversity in Drainage Situations

Diversity in Agriculture

In many landscapes, the cropping pattern and calendar are big hurdles for adequate agricultural drainage. Different crops require different optimum groundwater levels, which vary throughout the season. Orchards need a stable, not too shallow groundwater level. Rice needs standing water for most of the growing season, but for ripening and harvest all water has to be drained and the soil has to dry. Drainage often has no answer to this variety of needs. Therefore, there are few orchards in between rice fields. When a rice farmer is too late to join his neighbors' calendar, s/he risks falling dry well before the crop ripens. Strategies to cope with these inconveniences are compartmentalization and fine-tuning the system (establishing smaller hydrological control units) and segregation (splitting land into high and low parts by raising one part and excavating the other). Apart from this, acceptance of a compromise between optimums is what remains.

Multiple functions, Multiple sectors

Drainage can influence the many functions of land and water resources systems. Which combination of functions is influenced differs from place to place, as seen in Bangladesh and Egypt. The exact set of relevant functions for drainage development therefore has to be identified in each situation.

In Bangladesh, interventions to maximize agricultural production interfere with other functions. The construction of riverbanks to protect agricultural land from flooding has led to reduction in fisheries and increased sedimentation in waterways. Consequently, drainage flows are obstructed and problems with navigation occur.

Drainage infrastructure in Egypt, designed from a single-sector perspective, has contributed to a significant increase in agricultural production. Drainage intervention has also had positive impacts on public health (reduction in schistosomiasis transmission), reduced damage to buildings, and created a highly suitable canal system for the disposal of urban and industrial waste. Improper disposal of these wastes causes serious environmental problems. Drainage influences several natural resources functions and serves the interests of multiple sectors.

Small, medium, and large scale

Drainage systems show immense variation in size. Tidal drainage systems in Sumatra measure several hundreds of meters parallel to the coastline. Boundaries are defined by the difference between high and low tide. High tides raise the water level in rivers, allowing irrigation of fields along the rivers. At low tide, the water level in the river drops, and fields can be drained. The size of these drainage systems ranges between hundreds and thousands of hectares. In the Kuttanad backwaters of Kerala, India, pumping drains individual polders of similar size directly into the backwaters. However, in polder landscapes in the Netherlands, draining one polder always interferes with drainage of other polders. More complex organizations are necessary to deal with the interests of all polders in one "drainage basin." These polder landscapes measure from thousands to tens of thousand of hectares, as do individual irrigation systems in, for example, Northern Mexico, or rainfed agriculture in microcatchments in Southern Mexico and Java. The irrigation and drainage systems of Egypt and Pakistan are the largest and most complex systems, covering country-sized areas that run well into hundreds of thousands or millions of hectares.

Historical evolution of systems

The layout and functioning of present day drainage systems is a result of historical development. Their features often represent development ideologies or economic emphases at the time of planning and design of a scheme. The Tungabhadra Irrigation project (Karnataka, India) was constructed in the 1950s to increase coarse grain and cotton production by supplementary irrigation and to irrigate a small area under rice. Natural streams and small lateral surface drains were assumed to be sufficient to drain the undulating landscape and send the effluent back into the Tungabhadra River. In the early years, production levels were satisfactory, but fifty years later, the scene has completely changed. Economic problems, crop disease, and pests have heavily reduced cotton production, while rice cultivation has dramatically expanded in the head reaches, causing waterlogging and salinization problems in the lower parts. Natural drains are silted up and overgrown. Villages located along these streams have more drinking water but experience health and accessibility problems due to stagnating water.

The Netherlands created a successful flood control and agricultural drainage system that performed well for all stakeholders: it improved soil quality for farmers, gave protection from floods for all, and provided efficient waterways for shipping. But industrialization has created a wealthy, urban society in a densely populated country that is in desperate need of open rural space for housing, recreational activities, and maintenance of scarce biological diversity. Due to changing physical parameters (sea level rise, soil subsidence, river discharges) and changes in the value society attaches to functions of the natural resources system, the drainage system that worked so well for agriculture has been redirected into a costly operation to restore some of the lost functions such as flood retention and conservation of biological and landscape diversity. The Netherlands case provides a lesson about long-term functional changes and shifts in the values of stakeholders that is rarely addressed in planning and design of drainage interventions.

Irrigation schemes in arid areas may develop waterlogging and salinity problems only after several decades. Drainage interventions are thus usually

postponed and lag behind irrigation interventions. In many cases, the interventions reflect prevailing views on a desired path of development at that point in time. A simple drainage typology in Egypt would distinguish three broad categories of drained lands: the old lands (Nile Valley and Delta, containing pipe and open drains and managed by one government body); the old new lands (fringes of the old lands and along the coast, with limited open drains governed by mixed institutions); and the new lands (desert land, where drainage is absent or underdeveloped, governed by private initiative). The change in perspective from a highly centralized organization to a liberalized market-oriented approach can easily be traced in this categorization.

Diversity in Environmental Factors

Many different environmental factors influence drainage, including climate, topography, soil characteristics, groundwater characteristics, natural drainage, and biological diversity and ecological processes.

Climate. Important climate parameters that influence a drainage situation are rainfall, evaporation surplus or deficit, and seasonality. The objectives of any drainage intervention are to largely determined by the amount of rainfall. In arid regions like Egypt, Pakistan, and Northern Mexico, drainage systems are designed mainly to combat irrigation-induced waterlogging and soil salinity. In wet regions like Bangladesh, Southern Mexico, and Indonesia, drainage interventions are usually designed to prevent flooding. Some drainage schemes in Bangladesh have multiple objectives and uses, varying with the seasons: crops need protection from premonsoon flash floods, water is stored for fish production during the monsoon rainy period, and crops need irrigation water during the post-monsoon dry period. In the Netherlands' temperate climate, rainfall is moderate, but low temperatures and a consequent lack of evaporation (and lack of gradient) necessitate artificial drainage interventions. Drainage systems in arid Mexico and Pakistan have to deal with sporadic torrential rains and the resulting flash floods.

Elevation. The land elevation has to be considered in relation to the water body that receives its drainage

waters. Most of the Netherlands lies below river and open seawater levels. Excess water has to be drained by pumping. In Sumatra, tidal irrigation and drainage systems in coastal areas lie between the range of high and low tides. Seasonal differences in range, frequency, and tide, caused by changes in the direction of trade winds and fluctuating river discharges, create complex and highly localized conditions for drainage (as well as irrigation). There are no generalized operational rules for tidal drainage systems. The microrelief in each drainage situation creates widely diverse conditions.

Slope. Flat terrain with small surface gradients, combined with composite drainage systems (laterals, collectors, secondary and main drains) as found in the Nile Delta, requires pumping at the outlet of the main drains. In the delta, pumping is necessary to maintain gravity flow in the field system, given the elevated water levels in the receiving water bodies. In the Netherlands, the Southern Limburg hills, which consist of aeoline loams with low permeability, are characterized by a heavy overland water runoff. Under such surface drainage conditions in hilly terrain, the removal of vegetation cover for agriculture leads to local erosion and sedimentation downhill. Conservation of contour strips of vegetation or construction of contour bunds are the drainage control measures. By catching eroded materials, bunds or contour strips may develop into seminatural terraces.

Soil characteristics. Heavy clay soils with low hydraulic conductivity in the Nile Valley and Delta need narrow drain spacing, leading to a 15 percent land loss in the case of open drains and fragmentation of properties into small units, thus hampering agricultural operations. Buried pipe drainage (horizontal drainage) provides an optimum solution under these circumstances. In large parts of India and Pakistan where clay content of the soils is much lower and permeability consequently higher, vertical drainage by tubewells is a good alternative in the case of fresh groundwater aquifers.

Mineral content of soils is an important characteristic for assessing the risk and type of primary salinity and alkalinity,³² the intensity of

drainage necessary, and the need for additional leaching and chemical amendments for reclamation (e.g., gypsum).

Groundwater characteristics. In dry climates, drainage activities in conjunction with irrigation create permanently available water in areas where water used to be (seasonally) scarce. This creates new water functions for man, nature, or both. Water quality largely determines whether these functions can be exploited sustainably or whether they are harmful. Naturally occurring concentrations of salts or harmful elements (arsenic, fluoride) in deep groundwater reservoirs are a cause of concern in Pakistan and Bangladesh. Deep tubewells in Pakistan have been used successfully for drainage in areas with naturally occurring saline groundwater. By pumping up this water, new possibilities for irrigation were created. However, this introduced large quantities of salt into the irrigation systems, leading to secondary salinity of soils, which is now considered a major problem. In areas with good quality, shallow groundwater, sustainable reuse of drainage water is possible.

Natural drainage system. The characteristics of the natural drainage system derive from the above primary factors and natural vegetation. The natural drainage system determines the natural state of dryness or waterlogging of landscapes. In water surplus areas, humans have invariably extended and intensified the natural drainage system. The drainage situation is strongly determined by the original natural hydrological system. In many arid regions, irrigation schemes have been developed. The absence of a dense network of natural drains has often led to the creation of a manmade drainage system. Another dimension of the natural drainage system is the aquifer characteristics. The presence of impervious layers, the depth of the aquifer below surface, the upward movement of groundwater in certain zones, and the occurrence of springs are all related to the natural subsurface drainage system.

Biological diversity and ecological processes. Coastal swamplands in Indonesia have great potential as a source of food, cash crops, and livelihoods for growing populations. However, these lowlands support rich productive swamp and mangrove forests, together with abundant and varied aquatic life, performing many functions for the larger area

³² *Secondary salinity* results when irrigation water deposits minerals in the soil.

(fish reproduction, wood production, coastal protection, soil protection, water storage, maintenance of biodiversity and genetic resources). The validity of drainage development is called into question by the potential loss of unique and irreplaceable, multifunctional, natural ecosystems. To protect these systems, a detailed assessment of their many functions and the values attributed to them and careful, well-documented experiments should be done to determine whether and how development for a growing population can be combined with protection of ecological processes and biological diversity.

Agricultural development in the Netherlands has created a rich habitat for bird life over the centuries. Large proportions of the world population of several species of meadow bird depend on these manmade land use types. Optimization of drainage and subsequent intensification of agriculture over the last decades has dramatically reduced the number of birds. The Netherlands now has legal problems with respect to the European Union's directive for the protection of birds. In the most valuable areas, drainage interventions are being reversed.

Key environmental processes have to be taken into account when drainage interventions are planned in coastal swamplands. Vegetation cover develops under the influence of physical (abiotic) conditions. Although vegetation on barren land (pioneer vegetation) is totally determined by these external variables (soil, hydrology, climate, tidal rhythms, and so forth), natural vegetation develops into more complex systems that increasingly create their own conditions for growth. Peat swamps provide a good example. Due to poor internal drainage, peat develops on poor, sandy soils. By retaining rainwater in layers of dead plant material, these systems create their own specific hydrological conditions. Due to the anaerobic circumstances, plants hardly decay and develop into thick layers of peat. Drainage of the system will lead to aerobic soil conditions, thus starting the process of decay of organic materials (oxidation). This natural "burning" of peat layers leads to soil subsidence. Bad planning of drainage canals in deep layers of peat in Kalimantan (the "peat domes") has caused deep depressions that cannot be drained with gravity systems. However,

shallow peat layers can be successfully developed, especially when a staged process is followed.

Vegetation cover. In the Banaue Valley of Northern Luzon in the Philippines, a system of terraces has been functioning for centuries. The necessary supply of water for paddy cultivation is guaranteed by maintaining uphill rainforests that absorb the heavy tropical rainfall and release it gradually to the lower terraces. Customary regulations prohibited the cutting of these forests. Nowadays, squatters from densely populated central Luzon that have no knowledge of these regulations cut down forests, leading to increased runoff (surface drainage), landslides, and water supply problems for the lower terraces. Vegetation cover in this case is a management tool to control surface drainage as well as irrigation water supply.

Table C1 summarizes the diversity of drainage situations in the six countries studied, based on environmental characteristics and technical drainage solutions. This presentation, which does not take into account historical, institutional, and environmental aspects, already results in 17 broadly defined drainage situations. Every drainage situation is unique, because all these key parameters vary from country to country and from place to place. The development of each drainage situation makes them even more diverse over time.

Social and Economic Diversity

Apart from the spatial and time-related factors discussed above, diversity in the social and economic environment also influences drainage characteristics, as seen in the examples below.

Prosperity and values. A comparison of the U.S. state of California and Haryana, India, shows that drainage situations can develop in similar directions but through totally different driving forces. In both cases, drainage was introduced when irrigation-induced salinization and waterlogging became problematic. In both cases, subsurface drainage systems were installed that improved agricultural production. In both cases, drainage proved unsustainable, but for completely different reasons, stemming from socioeconomic differences.

In California, drainage mobilized selenium, which accumulated in the Kesterton Reservoir, used as an evaporation pond. After some years, the many birds attracted to this water body from a nearby bird sanctuary showed high death rates. The ecological function of this distant landscape had been negatively affected by the agricultural drainage. In the United States, ecological functions have influential stakeholders, represented by environmentalist nongovernmental organizations, and the legal system recognizes these functions. A court decided that Kesterton Reservoir had to be closed for evaporation of drainage water. Expensive measures had to be taken to either safely dispose the drainage water elsewhere or retire irrigation schemes in the area and compensate the farmers.

In Haryana, drainage system effluent runs to the lowest point in the region. Water, salts, and pollutants are accumulating, and the disposal of saline drainage water is severely constrained. A possible drainage outlet is provided by the Yamuna River, which also provides drinking water to New Delhi, the capital city. Transfer of saline drainage waters to this river pose a threat to the public water supply in a city with large groups of influential stakeholders. Legal restrictions apply to drainage on this river. It is only a matter of time before some rigorous measures, comparable to the California case, will have to be taken to improve the drainage situation in Haryana, but the costs are a major constraint. Agriculture is the driving force behind the need for a rigorous drainage solution in Haryana. The most straightforward solution, however, is opposed by a powerful urban interest in drinking water quality. In this case, whether wildlife values are threatened is unknown.

Distribution of power and cultural background. In the Tungabhadra Irrigation project (Karnataka and Andhra Pradesh, India) referred to above, farmers were a mix of colonists from the Andhra coast experienced in irrigated rice culture and local people who farmed rainfed coarse grains, oilseeds, and cotton. Rice farmers have become the economically dominant group that de facto rules the scheme by manipulating the irrigation and drainage authorities. Head reach farmers (with a high percentage of colonists) double-crop rice and have enough influence to claim more water than they need. Due to overirrigation, large amounts of water

have to be drained off. As a result, the tail end, largely local farmers get little irrigation water, and the drainage water from the head reaches is polluted, has an unreliable flow, and causes flooding. In this case, three functions are influenced by agricultural drainage: rice production in the head reaches of the scheme, domestic water supply along the tail end canals, and flow regulation in the downstream reaches of the natural streams in the valleys. The rice farmers are stakeholders of rice production. The downstream end has different categories of stakeholders. Farmers along the tail end canals do not get water for cropping, and households have to rely on poor quality drinking water. Women have more work fetching good water, and children are more vulnerable to health problems. In villages along natural drains, inhabitants experience flood damage. Head reach farmers give low priority to the system's drinking water function because they have access to piped water systems, and the irrigation water is of good quality. Irrigation water quality is of great importance for the downstream people along the canals, because they rely entirely on it for their drinking water. The different socioeconomic status of the two groups, colonist rice farmers from Andhra Pradesh and local farmers practicing rainfed agriculture, has had a strong impact on the development of the water management situation.

Sociopolitical structure. The transformation of the Netherlands' political system in the 1960s and 1970s, from a democracy with corporatist features to a more open democracy based on increased citizen consultation and participation at different levels, is one of four main developments that has changed water management in the Netherlands over the past 40 years, and agricultural drainage in particular. The more open political system allowed the strongly organized and very influential agricultural interest to be questioned. Several other processes facilitated this questioning.

- A large part of the population put higher value on a clean, biologically rich, and attractive environment, as articulated by the emerging environmental movement.
- An expanding and democratized higher education system stimulated a critical attitude among students and teachers and facilitated the

scientific development of new water management concepts.

A paradigm shift in water management was the result of a combination of these factors. The vested executive organizations were forced to change by parliamentary decisions, laid down in new acts concerning water boards, land consolidation, water quality management, and other issues. Fights

characterized the process of change in the early stages, and resistance of conservative powers and people, especially in the agricultural sector. After new elements were institutionalized, the process became less conflictual, and more cooperation between the new and the old interest groups emerged. Once the ideological fight was over, new ambitions had to be translated into plans.

Table C1 Drainage diversity in six countries, based on environmental characteristics and technical drainage solutions

Region	Climate	Seasons	Soil	Altitude in relation to receiving water body	Gradient	Groundwater	Drainage objectives	Drainage solutions and techniques	Remarks	
Egypt										
Irrigated old lands (Nile Valley and Delta)	Arid	Hot/cool	Heavy clay; low hydraulic conductivity	Gravity drainage to secondaries; pumped at outfall	Very slight	Saline groundwater toward the north in the delta	Water logging and salinity control, reuse	Narrow spacing pipe field drains and open main drains	Tubewells unsuitable due to low soil permeability	
Irrigated old new lands (fringes of old lands)	Arid	Hot/cool	Silt-clay; medium hydraulic conductivity	Gravity drainage to secondaries; pumped at outfall	None	n.a.	Water logging and salinity control	Limited open drains progressively coming under subsurface drainage.	Seepage to old lands	
Irrigated new lands (desert land)	Arid	Hot/cool	Light soils; high hydraulic conductivity	Gravity drainage	Little	n.a.	Water logging and salinity control	None or under development	Water saving technologies introduced; tubewells tested	
Pakistan										
Irrigated areas	Arid	Wet (monsoon)/dry	Light soils	Gravity drainage and pumped drainage	Little	Fresh groundwater	Flash flood, water logging, and salinity control; reuse	Open collectors/shallow and deep tubewells; pipe drains	Irrigation water also provided; groundwater quality deteriorated due to overpumping	
							Canal seepage capture and reuse	Interceptor drains at interface saline and fresh groundwater	n.a.	
							Saline groundwater	Water logging and salinity control	Mostly shallow but sometimes deep tubewells	No reuse of saline effluents intended (but not under control)
							Water loss prevention	Lining of water courses		
The Netherlands										
South Limburg hills	Temperate wet	Water shortage in summer	Aeoline loam; low	50m–300 m	Hilly	Deep	Erosion/sedimentation control	Surface drainage control by contour	Seminatural terraces created	

Table C1 Drainage diversity in six countries, based on environmental characteristics and technical drainage solutions

Region	Climate	Seasons	Soil	Altitude in relation to receiving water body	Gradient	Groundwater	Drainage objectives	Drainage solutions and techniques	Remarks
			permeability, surface drainage					strips	over longer periods
Sandy uplands	<i>Idem</i>	<i>Idem</i>	Sandy	2m–50 m	Gently sloping	Obstructed by impervious layers	Ground- and surface water management	Open drains (ditches) and collector canals; Beds and furrows in wet parts	Spring growing season advanced by lower soil moisture
Main river plains	<i>Idem</i>	<i>Idem</i>	(Heavy) clay	Below or at sea level	Flat	Fresh	Flood control; avoid waterlogging in embanked lands	Embankments; open drains with pumped drainage	Rising river forelands created by embankments, leading to seepage and increased need for pumped drainage
Coastal polders	<i>Idem</i>	<i>Idem</i>	Clay or peat	Below sea level	Flat	Brackish/saline	Balance rainfall, saline groundwater and land subsidence; flood protection	Embankments, canals, pumped drainage, artificial supply	Subsidence of 3 m from peat drainage; lower groundwater in clay polders

Bangladesh

Deltaic coastal polder	Humid monsoon	Tidal and river floods	n.a.	Tidal	Flat	n.a.	Water level control under tidal regime; salinity control, balancing interests shrimp and rice	Embankments, canals, regulators, flapgates, sluices, pipes	Three crops, shrimp, fish and salt production
Nondeltaic coastal polder	<i>Idem</i>	Rainfall and flashfloods	n.a.	Tidal surges and cyclones	Flat; surrounding hills	n.a.	Salinity, tidal surges, flashfloods, and water distribution control; balance interests	Embankments, parallel canals, flapgates and regulators	Up- and downstream use of irrigation water
Beel	<i>Idem</i>	Rainfall and river floods	n.a.	n.a.	Flat	n.a.	Balance fisheries and irrigation; flood and drought (groundwater) control; drainage congestion	One main embankment, regulators, closure, and excavation of canals. Beels connected.	Increased riverbed sedimentation due to creation of embankments, obstructing drainage and navigation
Flood plain	<i>Idem</i>	River and	n.a.	n.a.	Flat	n.a.	River flood control,	One or two main	Loss of soil

Table C1 Drainage diversity in six countries, based on environmental characteristics and technical drainage solutions

Region	Climate	Seasons	Soil	Altitude in relation to receiving water body	Gradient	Groundwater	Drainage objectives	Drainage solutions and techniques	Remarks
		rainfall floods					maintenance of fish migration routes, dry season water bodies, and groundwater	embankments in network of rivers, many canals.	productivity due to reduced sedimentation; increased flooding in unprotected areas
Haor	<i>Idem</i>	River, rainfall, flashfloods	n.a	n.a	Deep depression	n.a.	Premonsoon flashflood control, balance fisheries and agriculture	Submersible embankments; haors, beels, and khals	Deeply flooded for 6 to 8 months, managed by cutting banks
Mexico									
Northern	Arid	Hurricanes	Clay and loam	Above high tide	Coastal lowlands	Insufficient quality or quantity	Water logging, salinity; and flashflood control	Dams, surface and subsurface (limited) drains; tubewells	Aquaculture developing at tail end of drains
Subtropical	Humid	Dry spells	Clay and loam	Above high tide	Coastal lowlands	Fresh	Flood control; surface drainage	Dams, land leveling, surface drains	Drains used for subirrigation in dry spells
Indonesia									
Inner islands	Humid	n.a.	n.a.	Tidal floods caused by land subsidence in some areas	n.a.	n.a.	Flood control from rainfall, rivers, high tide and flashfloods	Flood plains, fuse plugs, spillways, and retarding basins obsolete; dikes and (pumped) drainage system needed	Degradation of watersheds from increased population and development pressures
Class A ,B, C, and D lowlands	Humid	Seasonal variations in tidal levels and rainfall	Differentiation between mineral and organic soils, acid sulphate layers, thickness of peat layers.	Elevation of coastal lowlands in relation to tidal water levels in lowlands creeks and rivers under influence of seasonal water level fluctuations	n.a.	n.a.	Maintenance of proper soil and water quality, flushing, drainage, irrigation. Ripening of acid sulphate soils.	Delicate management of microdiversity in tidal/ nontidal irrigation, and drainage, river regime, and seasonal floods	Severe impacts on local and surrounding forests, wetlands, wildlife, and local communities.

n.a.= information not available in the report.

Source: Country case study reports;.

Appendix D Landscapes, Functions, Values, and Drainage Activities: Two Examples from Country Case Studies

This appendix presents two examples of the effects and impacts of drainage interventions on natural resources functions—Egypt and Bangladesh—with summary narrative accounts and tables (D1 and D2).

Egypt

In Egypt, agricultural subsurface drainage resulted in lower groundwater tables and soil salinity as well as the disappearance of many open field drains. These physical changes improved soil properties, soil productivity, and accessibility for mechanized equipment, which raised Egypt's food self-sufficiency and farmer incomes. The productivity function of the soil was greatly enhanced, and with it, economic and social value for society at large and farmers in particular (income and food security).

Lower water tables also influenced adjacent areas. They improved the suitability of the area for housing (a carrying function) as water-related damage to buildings was reduced (an economic value). Disappearance of open drains eliminated their function as a breeding place for disease-transmitting freshwater snails. Consequently the prevalence of schistosomiasis (bilharzia) was reduced, and health conditions for domestic animals and people improved (economic and social value for stakeholders).

The conveyance of drainage water through open canals to coastal lagoons negatively affected fisheries productivity and the capacity of the lagoons to support large numbers of migratory water birds. These functions represent not only a significant economic value for local fishing communities, but also an ecological value for the international

community, as the lagoons are recognized as important bird areas under the Ramsar wetland convention. Local fisherfolk and the international nature conservation community bear the negative consequences of drainage, while completely different stakeholders receive the benefits.

The conveyance canals created a number of new functions. The canals are well suited for the disposal of urban and industrial liquid and solid waste, providing a value (though in a perverse sense) for industries and urban communities. The conveyance of drainage water also provides opportunities for reuse in agriculture. In Egypt, this is carried out by mixing drainage water with fresh irrigation water. This form of drainage water reuse in agriculture causes local problems to spread over large areas, potentially impairing functions of the resources system far away from where the activity is carried out.

Bangladesh

Embankment construction for flood protection along large rivers enables increased agricultural productivity through double cropping and better housing conditions (two functions). These lead to higher farmer income and better safety for inhabitants (economic and social values). Simultaneously, the reduction in flood intensity or frequency leads to lower fish productivity (a productivity function) and lower income for fisherfolk (an economic value). By preventing agricultural lands from flooding, large amounts of sediment carried by the river will no longer be deposited on the land but will instead be deposited elsewhere in the river system, leading to drainage

congestion and obstruction of navigation. Because rich sediment will no longer fertilize soils, fertilizers may be needed. In the longer term, lack of sediment deposition and land subsidence creates unsustainable conditions. Another effect of the embankment is the reduction of water storage capacity in the river system, which may result in increased floods in other parts of the river system.

Functions of the resources system directly or indirectly affected by the embankments thus are soil

productivity, living conditions, fish productivity, sediment deposition, soil fertility, water storage and flood protection (for other areas) in the wet season, and river navigability and drainage capacity. Multiple values and stakeholders in a densely populated and intensively used land are affected. Each intervention in the resources system of Bangladesh will change several functions and consequently affect multiple stakeholders in different ways.

Table D1 Egypt: agricultural drainage activities, biophysical changes in landscape functions, and related social values

Drainage activity	Biophysical change	Landscape under influence	Functions of landscapes	Values (stakeholders italicized)
Subsurface drainage	Lowering of soil water table combined with resulting reduction in soil salinity Improved soil structure	Agricultural land	Better soil properties lead to higher productivity	Food self-sufficiency of the <i>country</i> , higher <i>farmer</i> income, poverty reduction
		Agricultural land	Improved accessibility for mechanized equipment	Increased <i>farmer</i> income, poverty reduction through agricultural modernization
	Lowering of soil water table (off-site)	Built-up area (settlements) surrounding drained agricultural lands	Reduced damage to buildings; healthier indoor environment; improved sanitation	Increased property value for <i>house owners</i> ; reduced disease (<i>asthma patients</i>); improved conditions for human settlement (<i>rural development</i>)
	Disappearance of open field drains	Agricultural land	Reduction in breeding grounds for disease-transmitting snails and mosquitoes	Better health for humans and domestic animals (<i>social and economic</i> benefits)
Conveyance of drainage water through open drains and reuse by mixing in freshwater canals	Off-site: transport of drainage water (saline and polluted by agricultural chemicals and untreated municipal and industrial effluent) elsewhere	Open drains	Breeding grounds for disease transmitting snails and mosquitoes	Continued health risks for <i>humans and domestic animals</i>
		Fresh canal water	Public water supply impaired by pollution and salinity	Health problem for <i>people without access to safe drinking water</i>
		Fresh canal water	Agricultural water supply contaminated by salinity and pollution	Irrigated agriculture (<i>farmers</i>), receives <i>supplemental supplies against potential risk of sustainability</i>
		Open drains	Facility for disposal of liquid and solid waste from urban and industrial facilities	<i>Multiple values</i> , but perverse due to reuse of water re (see above)
		Ecosystems receiving drainage water (coastal wetlands, Nile River, Mediterranean)	Threat to production functions related to biodiversity (mainly fish)	<i>Fisheries communities</i> marginalized; health hazard for <i>consumers of fish</i>
			Stinking waters threat to landscape quality (signification function) Threat to natural water purification processes due to overload of pollutants	Threat to <i>tourism industry</i> , loss of leisure opportunities for <i>urban inhabitants</i> Replacement costs for <i>wastewater treatment facilities</i> to compensate loss of natural treatment capacity
Coastal wetlands	Threat to biological diversity	Ecological value for <i>future generations</i> and for <i>areas elsewhere</i> (migratory birds and fish)		

Source: Egypt country case study report.

Table D2 Bangladesh: impacts of embankment construction (illustrative, not exhaustive)

Biophysical change	Affected landscape	Functions	Values (stakeholders <i>italicized</i>)
Reduced floods and change in sediment deposition	Embanked area	Increased agricultural productivity	Increased <i>farmer_income</i>
	Embanked area	Improved living conditions	Increased safety for <i>inhabitants</i> , cattle and homesteads.
	Embanked areas	Reduced fish (re)production	Reduced income of <i>fisherfolk</i>
	Embanked area	No further deposition of sediment reduces soil fertility	Higher fertilizer input needed by <i>farmers</i>
	Increased sediment deposition in river	Obstruction of navigation	<i>Shipping</i>
	Increased sediment deposition in river	Congested waterways for drainage	<i>Farmers</i> in embanked area; <i>inhabitants</i> of other areas affected by reduced drainage
	Embanked area	Loss of other wetland functions (e.g., reproduction of migratory aquatic species, groundwater recharge)	<i>Future generations, people elsewhere</i>
Provision of elevated space	Embankments	Transport over embankment, flood shelter; better housing conditions	Improved communication between <i>communities</i> ; <i>personal safety</i> during floods; illegal housing for <i>squatters</i>
Increased water level in river (due to reduced storage capacity)	River	Navigation	<i>Adjacent communities</i> and others; depends on local characteristics
	Flood-prone areas downstream	Threat to existing land use due to increased flood risk	<i>People downstream</i> of embanked area (depends on local characteristics.)
Keeping water inside embankment (in khals)	Embanked area	Increased possibilities for fisheries	<i>Fish farmers</i>
		Increased possibilities for irrigated agriculture and reduced possibilities for rainfed agriculture?	<i>Farmers</i> . Complex, relates to water levels, length of inundation, physical features of polder, and so on

Source: Bangladesh country case study report.

Appendix E The Ecosystem Approach—Convention on Biological Diversity

The ecosystem approach is a strategy for the integrated management of land, water, and living resources that promotes conservation and equitable and sustainable use. An ecosystem approach is focused on levels of biological organization, encompassing the essential processes, functions, and interactions among organisms and their environment. It recognizes that humans, with their cultural diversity, are an integral component of ecosystems. The scale of analysis and action should be determined by the problem being addressed. The ecosystem approach requires adaptive management to deal with the complex and dynamic nature of ecosystems in the absence of complete knowledge or understanding of their functioning. Adaptive management must be able to respond to such uncertainties and contain elements of "learning by doing." As with the precautionary principle, measures may have to be taken even when some cause-effect relationships are not fully established scientifically.

Principles of the ecosystem approach

The ecosystem approach is governed by the following principles.

- The objectives of management of land, water and living resources are a matter of societal choice.
- Management should be decentralized to the lowest appropriate level (subsidiarity).
- Ecosystem managers should consider the effects (actual or potential) of their activities on adjacent and other ecosystems.
- Recognizing potential gains from management, the ecosystem must be understood in an economic context. Any ecosystem-management program should: reduce market distortions that

adversely affect biological diversity, align incentives to promote biodiversity conservation and sustainable uses, and internalize costs and benefits in an ecosystem to the extent feasible.

- A key feature of the ecosystem approach includes conservation of ecosystem structure and functioning.
- Ecosystems must be managed within the limits of their natural functions.
- The ecosystem approach should be undertaken on appropriate scales.
- Recognizing the varying temporal scales and lag effects that characterize ecosystem processes, objectives for ecosystem management should be set for the long term.
- Management should recognize that change is inevitable.
- The ecosystem approach should seek the appropriate balance between conservation and use of biological diversity.
- The ecosystem approach should consider all forms of relevant information, including indigenous and local knowledge, innovations, and practices as well as scientific knowledge.
- The ecosystem approach should involve all relevant sectors of society and scientific disciplines.

Operational guidance for application of the ecosystem approach:

- Focus on the functions of (biodiversity in) ecosystems.
- Promote the fair and equitable sharing of the benefits derived from the functions of (biological diversity in) ecosystems.

Reclaiming Drainage

- Use adaptive management practices.
- Carry out management practices on the scale appropriate for the issue being addressed, decentralizing to lowest feasible level.

- Ensure inter-sectoral cooperation.

Source: Convention on Biological Diversity 1999.

Appendix F Traditional Planning and Participatory Planning

The following table, taken from the website of The Communication Initiative, is No. 14 in a series of 87 (on October 9, 2003) planning models, which are all briefly presented with reference to the original source. Models for development communication are the focus. (See www.comminit.com/planning_models.html) Another interesting site is www.odi.org.uk/RAPID/Lessons/Theory/Theories_index.html, which presents 30 theoretical models on how research-based evidence can influence policy, collected by the Research and Policy in Development (RAPID) programme.

Table F1 Traditional vs. participatory planning

Traditional planning	Participatory planning
<ul style="list-style-type: none"> • Centralized (from the center to the periphery) • Vertical and imposed (from the top to the bottom) • Technical (done by experts) • Done by sector or industry • Short-term (focused on annual budgets) • Done to meet legal requirements (what matters is compliance) • Sets priorities for sector or industry investment • Designates the parties responsible for each task but does not assume responsibility • Homogenizing and unifying • Exclusive • Authoritarian • Distances state and civil society • Recognizes a certain population as an object that will benefit from the plan • Responds to an intervening and controlling state • Ignores conditions specific to each location • Creates lack of confidence in institutions • Promotes confrontation and the imposition of power • Decreases manageability 	<ul style="list-style-type: none"> • Decentralized (from the periphery to the center) • Horizontal and agreed upon (from the bottom to the top) • Dialogue-based (promoting discussion of different knowledges) • Integral, considers whole picture • Long term (focused on building a vision of the future) • Is seen as a real necessity (what matters is the content) • Sets priorities for social investment • Assigns responsibilities and social commitment • Recognizes diversity and respects differences • Inclusive • Democratic • Brings state and civil society closer together • Recognizes social actors as active subjects in their own development • Encourages a facilitating state • Is based on knowledge of concrete and particular conditions in a location • Builds relationships of confidence • Promotes tolerance and living together peacefully • Recovers manageability

Source: De la trocha al plan de desarrollo [From A Trail to A Plan for Development]—Consejo Nacional de Planeación (National Planning Council)—Colombia; www.comminit.com/pmodels/sld_708.html

Appendix G Comanagement

Comanagement is “a situation in which two or more social actors negotiate, define and guarantee amongst themselves a fair sharing of the management functions, entitlements and responsibilities for a given territory, area, or set of natural resources” (Borrini-Feyerabend and others (2000:13). The approach has three phases, preceded by a point of departure, and steps within these (box G1). The steps are not necessarily sequential; iteration is an important characteristic of the approach, as are joint analysis, design, and evaluation of project interventions.

Box G.1 Comanagement of natural resources

Point of departure

1. Assessing the need for comanagement and the process feasibility
2. Assessing available human and financial resources
3. Establishing a start-up team

Phase I: Preparing for the partnership

1. Gathering information and tools (such as maps) on the main ecological and social issues at stake
2. Identifying in a preliminary way the natural resources management unit(s) and institutional actors at stake
3. Launching and maintaining a social communication campaign on the need for, the objectives, and the expected process of comanagement
4. Contacting the institutional actors, facilitating appraisal exercises and continuing with them the ecological, social, and stakeholder analyses
5. Helping the institutional actors to organize and identify their own representatives, as necessary
6. Organizing the first meeting of institutional actors and proposing a set of rules and procedures for the negotiation phase, including explicit equity considerations

Phase II: Negotiating plans and agreements

1. Agreeing on the negotiation rules and procedures
2. Developing a common vision of the desired future for the natural resources management unit(s) at stake
3. Ritualizing the agreed common vision
4. Reviewing the current socioecological situation and trends, and agreeing upon a strategy toward the common vision
5. Negotiating specific comanagement plans and agreements for each component of the strategy (this includes identifying what will be done by whom and with what means; mediating conflicts; clarifying zoning arrangements and the sharing of natural resources management functions, rights and responsibilities among stakeholders, agreeing on follow-up protocols)
6. Agreeing upon comanagement organizations and initiatives to institutionalize comanagement
7. Legitimizing and publicizing the comanagement plans, agreements and organizations

Source: Borrini-Feyerabend et al. (2000)

The functions and values analysis and assessment procedure as described above would be part of steps I.1, I.2, I.4, II.2, II.3, II.4, II.5, III.3, and III.4 as indicated in box G1. It would thus be an integral part of the overall participatory planning approach.

Appendix H Governance and Institutions in the Country Case Studies

Government-Initiated Drainage Development

Land reclamation was crucial for *Indonesia's* transmigration programs of the 1970s and 1980s. These government-sponsored projects should improve the living standards of poor landless families from the inner islands, create employment opportunities, alleviate population pressure, promote regional development, and increase agricultural production. To this end, a powerful Directorate for Swamp Development came into being. It managed a substantial portfolio of lowland development, including planning, design, and construction. However, with the economic and political crisis of the late 1990s, attention for lowland development gradually faded away. In 1994, the directorate was abolished, and its responsibilities were absorbed within the organization for irrigation development, leaving a vacuum in the ongoing lowland schemes. When the once-powerful Ministry of Public Works was later folded into the Ministry of Settlements and Regional Development, lowland development was further diluted (*Indonesia country case study*).

Disastrous floods in the 1950s and 1960s triggered flood control and drainage projects on a national scale. These projects, initiated by the Government of (East) Pakistan before *Bangladesh* achieved independence in 1971, marked the start of a large-scale program for embankment construction on the major rivers and flood plains. After the country's independence, the Bangladesh Water Development Board was given responsibility for overall development and management of water sector projects (flood, irrigation, drainage). In the 1970s and 1980s, the board administered 85 percent of all investments in the water sector, a quarter of them designated for flood control and drainage, the key to

food self-sufficiency. These projects made cultivation of high-yield rice varieties possible, and rice production increased (*Bangladesh country case study*).

In *Pakistan*, the threat of water logging and salinity was recognized soon after the introduction of perennial irrigation in the Indus plain. However, central to in Pakistan's struggle to become economically independent were the development of new water resources, the expansion of irrigated lands, and combating water logging and salinity. In 1959, responsibility for planning, design, and implementation of all major water projects was transferred from the provinces to the federal government. Subsequently, planning and implementation of the Salinity Control and Reclamation projects (SCARP) was under the responsibility of the federal Water and Power Development Authority and financed out of development budgets. Emphasis on SCARPs has meant that no comprehensive surface drainage system and no regional outfalls are in place for some basins (*Pakistan country case study*).

In *Egypt*, the spectacular collapse of cotton, the major cash crop, in 1909 was of such magnitude that the Ministry of Public Works took over drainage as a state affair. In 1949, the state unambiguously made drainage a state responsibility. When Egypt adopted socialistic principles and enlarged the roles of the public sector, it maintained its strong emphasis on centrally planned and executed agricultural development projects. The completion of the Aswan High Dam in 1965 was the landmark for intensified agricultural production. Since natural drainage could not cope with the excess water of the perennial irrigation regime, drainage was given high priority. Since its establishment in 1973, the Egyptian Public Authority for Drainage Projects (EPADP) has been implementing one of the world's largest drainage

development program. However, there is a substantial backlog of drainage improvements in the new lands, where EPADP did not have a strong role in the past (Egypt country case study; World Bank 2000).

Establishing User Organizations in Drainage

In *Egypt*, “collector-user associations” were established on a voluntary basis. These associations, organized in sections of 100 to 300 hectares of the gravity tile systems, were expected to concentrate on preventive maintenance. More than 2,000 collector-user associations were formed. No legal or institutional framework was developed to support their activities. They failed mainly because they had, and were allowed, too little to do. Since 1995, some fifty elected water boards have been established at secondary canal command level (500 ha to 750 ha) on a pilot basis. This level was more useful than the collector level. A point of discussion in Egypt now is whether water boards should operate at district level, which usually covers 10,000 ha to 15,000 ha. The reasoning is that the secondary canal level is too small and that district-level water boards could more effectively integrate irrigation, drainage, and other water functions and take up integrated water resources management at the local level.

Similarly in *Indonesia*, water user associations were developed at tertiary units in the government-developed lowland transmigration settlements. The heterogeneity of the settler groups and the large turnover among them in the early years made it difficult for the new organizations to flourish. In addition, water management in the government-sponsored tidal lowland systems turned out to be too complicated for these weak organizations.

In *Pakistan*, several drainage beneficiary groups were developed, usually to implement cost-sharing formulas in drainage development projects. These drainage beneficiary groups were established for construction and maintenance of tertiary open drains and tile drainage schemes. The experience has had mixed results. Under the On-Farm Water Management project in Punjab, a number of groups

actively cleared the route for new open drains. In Fordwah Eastern Sadiqia, they collected a down payment for the construction of a collector-with-subsurface drainage system. However, an effort to transfer responsibility for drainage tubewells under the Left Bank Outfall Drain in Sindh completely failed, because of the high costs of running the saline groundwater tubewells and the difficulty of identifying the beneficiaries of the deep tubewells. Under the National Drainage Program, the resources to support drainage beneficiary groups were never allocated, and the “local drainage improvement” component got stuck as a result. During all these efforts, group members were mostly farmers that were most affected by high water tables, even though drainage problems caused mainly by overirrigation or canal seepage elsewhere. The consensus now is that tertiary-level drainage beneficiary groups may be effective for supporting project financing and implementation but are less relevant for management. For this reason, and to achieve economies of scale, it has been recommended that drainage beneficiary groups should be part of farmer organizations with a broader mandate operating at the secondary canal command area level (covering 3,000 ha to 10,000 ha).

In *Bangladesh*, a policy has been put in place for establishing water management federations in larger systems (above 5,000 ha). These have to be built up from water management groups and water user associations, with membership open to all farmers, traders (small/big), craftsmen, boatmen, fisherfolk, and the landless and destitute within the subsystem or subproject. This is akin to what has happened in *Mexico*, where the administration created water user associations and drainage user associations (WUAs and DUAs) at secondary and main system level to deal with problems of deferred maintenance and inefficient water delivery service. Practically all the irrigation and drainage districts have been transferred to 440 WUAs, 11 societies (formed by WUAs to operate the main irrigation canals and drains), and 26 DUAs. These associations collect water fees, operate and maintain the systems, and keep water user records. They handle water concessions, infrastructure, machinery, and equipment and manage their own offices.

Appendix I Water Table Management and Controlled Drainage in the Country Case Studies

None of the drainage systems developed in Pakistan over the past decades have controlled drainage. Water tables are set at a fixed depth, determined by the depth of subsurface and surface drains—irrespective of farmers' preferences throughout the year. Vandalism has often been their response. Several drainage systems have reported that, during the rice-growing season, farmers routinely obstruct drainage pipes with jute bags, stones, and mud, afraid of losing the soil moisture that comes with subirrigation.

In response to similar problems, controlled drainage was piloted in two rice-growing areas in Egypt. The idea was to give landowners the means of selecting groundwater levels that suited their farming priorities, and thus introduce demand management in drainage. To this end, gates were installed on collectors so that farmers could close them in the rice season to raise water levels. But this experiment in controlled drainage was not a resounding success. In the absence of a strong local organization, a main problem was how to coordinate the different priorities of different farmers growing different crops. Recently established water boards to manage irrigation and drainage at secondary canal level have shown interest in controlled drainage. In fact, they chose to participate in selection and design of the system.³³

In the Netherlands, the number of regulating structures in drainage channels has been augmented to allow finer adjustment of ground water levels. The structures allow the retention and release of stormwater, which serves ecological and agricultural functions.

In Bangladesh, water table management is crucial to balance the different interests—fisherfolk preferring higher water tables and later releases like farmers on working higher lands, while farmers on low-lying areas prefer deeper drainage. To accommodate the different preferences, the main drainage canals have been fitted with gates (also see chapter 2 and appendixes). Regulators allow rainwater collected in the major and minor drainage channels to drain into the river system and controlled passage of river water through the system. Regulators are equipped with vertical lift gates, flap gates, or both at riverside and fallboards at both land and riverside. The lift gates and fallboards permit maintenance of the gates and water retention on the landside for fishing and agriculture. An additional and essential function of regulators is to maintain or raise water levels for irrigation, fisheries and domestic purposes.

³³ Al-Fadly Water Board, Kafr-El-Sheikh, Egypt, personal communication.

Appendix J Drainage Water Quality and Reuse in the Case Studies

In Egypt, the major problem with drainage water quality is not salinity but chemical and bacteriological pollution. Main surface drains passing through major urban and industrial areas turn into major carriers of untreated wastewater. Ideally, most reuse of water should take place before flows reach major centers of contamination, which would mean that investment in irrigation and drainage should be concentrated upstream of metropolitan areas or industrial estates. Another set of operational measures concerns mixing strategies. This is a matter of debate in Egypt where about 7 billion cubic meters of drainage water is reused for irrigation. The proposal is to shelve the present centralized mixing strategy, in which a few big mixing stations pump water from main drains back into main irrigation canals. The alternative is “intermediate reuse.” In this strategy, mixing drainage water with fresh irrigation supplies takes place at a lower level, where a drainage catchment coincides secondary canals. Intermediate reuse allows isolation of poor quality water and reuse of relatively good quality, low in salt and contaminants—but carefully integrated management of both freshwater and drainage water would still be necessary.

When the government of *Indonesia* embarked upon its large-scale transmigration and swamp development program in the 1970s and 1980s, a main objective was to increase rice production. Only minimal drainage was provided. However, flooding for rice cultivation often left stagnant water conditions, and acidity and toxicity accumulated due to acidification of acid sulphate soils. Rice yields under these circumstances were generally low. It was realized that this strategy

was not suitable in many areas. The “dead-ended” canal systems constructed in the early transmigration sites hamper water circulation and do not allow flushing of the canals. The new consensus is that controlled drainage (chapter 5) is the key to the reclamation and management of acid sulphate soils. Therefore, the drainage system must be designed to maintain a high water table while allowing the evacuation of acids and toxicants. Under the second stage swamp development program, the drainage systems were retrofitted. Drains were double-connected to rivers and main canals. Where soils are sufficiently consolidated, water control structures are put in place. Crop yields of paddy increased to 2.5 tons/ha and higher with increased soil ripening. A larger range of crops was grown, and access to the areas improved. Excess drainage has to be avoided, although this is not always easy, particularly during unusually long dry seasons.

Too little attention was paid to the quality of the drainage effluent in the Salinity Control and Reclamation project well fields in *Pakistan*. The deep vertical drainage wells pumped water from great depths, where water is usually more saline. While this was done to maximize well field operations, it also brought extra salt to the surface. In some wells in the saline groundwater zones, the salinity of drainage effluents exceeded marine concentrations. As many disposal facilities were insufficient, local landowners went to court to close down deep tubewell operations. In retrospect, the choice of deep vertical drainage over shallow drainage has been questioned and regretted.

Glossary of Terms

This glossary contains explanations of the concepts that are essential for the integrated approach to drainage developed in this report.

Biophysical Change

Biophysical change: alteration in the characteristics of a natural resources—including soil, water, air, flora, and fauna—resulting from a physical intervention.

First order change: change that results directly from an intervention.

Second and higher order changes: changes that result from first order changes through a causal chain of events or processes.

Effects and Impacts

Biophysical effect: change in the quality (or quantity) of goods and services provided by the biophysical environment, that is, a change affecting the functions of the biophysical environment.

Human (social) impacts: the impacts resulting from biophysical effects, as experienced (felt) by an individual, family or household, community or society, whether in corporeal (physical) or perceptual (psychological) terms.

On-site impacts: impacts resulting from a physical or social intervention that occur in the area where the intervention is conducted.

Off-site impacts: impacts caused by a physical or social intervention, but which occur away from the location where the intervention is conducted, due to biophysical or social effects that influence distant areas.

Functions: the goods and services provided and performed by natural resources systems. They include production functions, processing and regulation functions, carrying functions, and significance functions.

Governance: the balance of power and the balance of actions at different levels of authority. Governance is about who sits at the table, who sets the priorities, and who plays what role in making and implementing the rules of the game. Governance translates into authority; decides on laws, regulations, and institutions; creates financial mechanisms; and defines user rights.

Hydroecological Region: a group of landscapes with more or less similar natural resources and a coherent water management system.

Institutions: organized, established procedures, the “rules of the game” in society. They include: written laws, rules and procedures set by different types of government, and “informally” established procedures, norms, practices, and patterns of behavior. Institutions define and fashion the behavioral rules of individuals and groups.

Intervention

Physical intervention: planned human activity that physically intervenes in, and possibly alters the biophysical environment.

Social intervention: planned human activity that intervenes in, and possibly alters the social environment.

Landscape: a unit of land with homogeneous natural resources (soil, water, climate, vegetation) that performs a homogenous set of functions.

Management: the activity of providing day-to-day drainage services. It involves evacuating and/or retaining water (e.g., by operating pumping stations), maintaining, repairing, and improving the infrastructure, measuring and monitoring water levels, collecting and spending drainage service fees, and drafting operation and maintenance plans and budgets.

Organizations: recognized and accepted role structures (often, confusingly, referred to as “institutions”). They are groups of individuals with defined roles and bound by some common purpose

and some rules and procedures to achieve set objectives.

Participatory planning: a series of approaches that emphasize stakeholder involvement in decisionmaking for natural resources development and management. Some of the main characteristics of participatory planning are decentralization, inclusiveness, situation-specificity, and dialogue-based negotiation.

Policy: a set of ambitions or objectives *and* a set of directives or guidelines for action *and* dedicated organizations *and* resources to realize these ambitions or objectives. Policies often, but not necessarily, have a base in law. Good policy has built-in learning mechanisms and is able to incorporate change. We normally think of policies that are (formally or informally) “owned” by groups of people, rather than individuals. These groups may be institutionalized and have formal powers or they may be informally bound by a common understanding of their group’s policy.

Stakeholders: direct beneficiaries of functions such as farmers (soil productivity) or fishermen (productivity of aquatic resources), but also include distant beneficiaries (e.g., urban inhabitants dependent on water supply from elsewhere), or indirect beneficiaries such as nature conservation nongovernmental organizations. The stake that stakeholders have may or may not be recognized by other stakeholders. We use “stakeholders” and

“interest groups” interchangeably.

Systems

Socioecological system: the summary term for the ensemble of material and social phenomena and relations that humans live in and are part of.

Resources (sub)system: the ensemble of biophysical objects, relations, and processes that provides functions (goods and services) for human beings. Resources systems are multifunctional.

Societal (sub)system: the ensemble of people, social relations, and social processes that attributes values to the functions provided by resources systems.

Land and water control (sub)system: the sociotechnical configuration by means of which human beings manage land and water resources from day to day. It consists of institutional arrangements, technology and infrastructure, and knowledge and human resources capacity.

Values: the societal preferences, perceptions, and interests with regard to functions provided by natural resources systems. They include social, economic, and (temporal and spatial) ecological values.

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