WATER POLICY AND WATER MARKETS

Selected Papers and Proceedings
from the World Bank's
Ninth Annual Irrigation and Drainage Seminar

Editors

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Contents

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Contents (cont'd.)

Foreword

The World Bank's Ninth Annual Irrigation and Drainage Seminar focused on two important and timely issues: water policy and water markets. The former was chosen in part because the World Bank had begun the process of preparing its own water resources policy in 1991, a process that culminated in the approval and publication of this policy in 1993. One of the key principles of the comprehensive water resources management that has been endorsed at UN conferences (and in other fora) is that water must be treated as both an economic and social good, and in the context of managing it countries should explore the possibilities of efficient allocation of water through the use of pricing. Water pricing through markets has of course existed for some time, but use of markets has not been widespread. The growing scarcity of water, as well as the renewed attention on water resources management, has heightened interest in water markets.

The Irrigation and Drainage Seminars are among the World Bank's most important training efforts for water resources professionals. The seminars include not only World Bank staff but representatives of multilateral agencies, nongovernment organizations, international professional associations, and representatives of developed and developing countries. The seminars are a means not only of enhancing professional skills but of exchanging ideas and building the contacts and professional spirit that help to forward many ideas and programs. About 110 people attended the December 8-10, 1992 seminar in Annapolis, Maryland.

This volume presents selected papers and proceedings (in the form of remarks by speakers) from the seminar. It covers the traditional field of irrigation and drainage with an emphasis on World Bank performance and the perceptions of water resources professionals about the problems in this field. Water policy is addressed in the keynote speech by World Bank Vice President Caio Koch-Weser (offering a regional perspective on water issues) and in papers on the Bank's water resources policy and on planning in China. The final section of this volume is devoted to water markets, in the form of papers and remarks on general concepts or specific examples of markets or market-like systems for allocating water in Chile, the western United States, Spain, Mexico, and Chile. The suitability of markets for Central Asia and for the Indo-Gangetic basin are also examined. Unfortunately, not all of the papers and presentations could be included. Mr. Ismail Serageldin, the World Bank's Vice President, Environmentally Sustainable Development, gave an excellent (but unrecorded) address on the the importance of water from cultural and societal perspectives. Mssrs. Mark Rosegrant of IFPRI and Hans Binswanger of the World Bank presented a joint paper on water markets that is to be published elsewhere.

The Agriculture and Natural Resources Department, which sponsored the Seminar, has consistently pursued strategies and research to improve agricultural performance. Such performance cannot be sustained without strong, clear policies and programs in water resources management, of which irrigation and drainage is a vital component.

[redacted]

MICHEL PETIT

Director
Agriculture and Natural Resources Department

Glossary

billion	1,000 million
GDP	gross domestic product
GWh	gigawatt-hour(s)
ha	hectare(s)
km	kilometer(s)
km^2	square kilometer(s)
Kwh	kilowatt hour(s)
l	liter(s)
m	meter(s)
m^3	cubic meter(s)
mm	milimeter(s)
MW	megawatt(s)
M&I	municipal and industrial
O&M	operations and maintenance
sec	second(s)

Please Note: Unless stated otherwise, all dollar ($) amounts are current U.S. dollars.

Section I

Water Policy

THE STRATEGIC ROLE OF WATER IN REGIONAL COOPERATION AND PEACE IN THE MIDDLE EAST AND NORTH AFRICA

*Address by Caio Koch-Weser**

It is often said that future wars will be fought over water, not oil. Nowhere is this more true than in the Middle East and North Africa, where water constitutes a strategic element in cooperation among countries and in peace.

While most of the seminar discussions have focused on country, institutional, technical, and economic aspects of water, this speech will focus on strategic regional aspects of water in the Middle East and North Africa. Water issues will therefore be discussed within the broader context of the agenda needed for domestic economic reform and cooperation among countries of the region, and of the ongoing multilateral Middle East peace talks in which the Bank plays a role.

I shall discuss five central development challenges the Middle East and North Africa region faces, one of which is water. This will be followed by a description of the vision for economic reform, as well as for regional and international cooperation. Finally, I shall elaborate on the World Bank's role, particularly our participation in the Middle East peace talks. In each case, the discussion will focus on the issue of water.

Development Challenges in the Middle East and North Africa

First, there is general stagnation and even economic deterioration in the region. The economic crisis that started in the early 1980s continues today. Annual economic growth declined sharply in the 1980s to an average of one-half of one percent a year. Over the same period, population growth averaged 3.1 percent a year, well above increases in output.

In this respect, the region, in spite of its good resource endowment, failed to keep up with developments elsewhere in the world. A telling example is that in 1960, South Korea and Egypt had approximately the same income per capita. Today, Korea's is almost ten times as high as Egypt's.

The second challenge—rapid population growth—has complicated economic management and constrained overall progress. Many countries in the region have population growth rates that are among the highest in the world. Even under optimistic scenarios, none of the countries

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in the region is likely to reach a stationary population level until well into the next century. The implications for the environment and water are severe.

Unemployment, the third of the five challenges, is a direct consequence of inadequate growth in economic activity relative to population. It is now a serious problem throughout the region. Most countries have unemployment rates well over 15 percent. In Jordan and Yemen, a quarter of the total labor force is unemployed.

The fourth common development challenge is water and the environment. Water is of paramount importance in the countries of the region. The Middle East and North Africa is the region with the lowest per capita availability of water in the world. In 1960, water availability amounted to 3,480 m^3 per capita, which declined to 1,450 m^3 per capita in 1990, and will be further reduced to 680 m^3 per capita by 2015 due to the rapid population growth. Several countries, including Malta, Libya, Jordan, Yemen, and Saudi Arabia will have less than 100 m^3 per capita. That is less than 300 liters per capita per day for all water uses, while industrialized countries' use is between 300 liters and 500 liters per capita per day in the urban sector alone. There are also the problems of frequent and prolonged droughts and increasingly serious water quality problems in ground and surface waters.

With few exceptions, the region is rapidly moving to a water crisis. There are very few untapped sources of fresh water, and countries are increasingly mining underground aquifers. The fact that most rivers as well as some important underground aquifers cross national boundaries has been a source of increasing tension in the region. Rational management of the region's water resources will increasingly require national and transnational agreements. The region is also experiencing difficult environmental conditions due to urban migration and to the concentration of the region's population, industry, and agriculture along seacoasts and in river valleys. In rural areas, long-term sustainability has been undercut by the loss of arable lands to urban expansion, by soil erosion from deforestation of watersheds, and by deterioration of rangelands from overgrazing. The need to use natural resources more sparingly in the future is an added burden to any effort to accelerate economic growth.

Last but not least, the fifth challenge is the issue of economic management and governance. The oil boom of the 1970s and early 1980s masked fundamental developmental problems that ensured an economic decline as soon as the boom subsided. Government control of production, a regulatory environment that stifled private initiative, an influential and often less-than-fully responsive public sector bureaucracy, and systems of governance that lack transparency, accountability, and predictability, all contributed to the disappointing economic performance. Throughout the region, large but inefficient parastatal enterprises dominate the economy. One-half of Egypt's GDP, for example, is still produced by the public sector. In Algeria, the share of parastatals in industrial production is over 80 percent.

These problems make the current situation untenable economically, socially, and environmentally. They are also a major cause of political instability, since the problems seem overwhelming.

The question at hand is whether the interplay between stagnating living standards, political instability, and the quality of economic management perpetuate the vicious cycle in which the region has found itself in the recent past. Another question is whether there is any cause for optimism that this cycle could be reversed and the success of some other regions of the world such as East Asia and, more recently, Latin America, can be reproduced in this region. I believe it can. Throughout the region, there is growing awareness that the concepts of nationalism, socialism, and oil wealth have failed, and that only bold reforms and cooperation can avert a disaster. The end of both the Cold War era and the Gulf War have helped to shift the focus to those issues.

Agenda for Regional Cooperation

Given the context described, the issue is defining what needs to be done in order to make economic and social progress happen. What is the vision to be put forward? The answer must be a strategy that accords a primary role for the private sector in economic activities, with the public sector playing a lesser but more efficient and supportive role. The latter sector would concentrate mainly on the provision of infrastructure and social services. Essential to this strategy is a heavy emphasis on human resources development, and on water and the environment.

To implement this strategy successfully, action is required at three levels. First and foremost, bold domestic reforms are needed to generate increased savings, to redeploy current expenditures to higher priorities, and to increase the efficiency of existing resource use. Second, there is scope for significant additional gains in economic efficiency and welfare by supplementing these reforms with a new element: market-oriented regional cooperation. And finally, the success of such actions will require international support to smooth transitional costs and supplement domestic resources.

Against this backdrop, domestic reforms require action in macro-economic stabilization, liberalization, public sector management, and human resources development. Action is also needed to manage the region's fragile natural resource base, the aim being to avoid or reverse, wherever possible, the environmental degradation that has accompanied past growth.

The Middle East and North Africa Region at the World Bank now recognizes that development strategies can only be sustainable when countries integrate environmental issues and actions into their plans and policies. This is all the more important for this area considering the widespread shortage of water, the fragility of the natural resource base, and the severe pressures on the environment caused by a combination of rapid population growth and urbanization.

Sustainable development strategies call for addressing major policy and regulatory constraints, strengthening relevant institutions, and supporting investments that are both economically sound and environmentally acceptable. There are encouraging signs that the countries of the region have become more aware of water problems and environmental issues. For example, in the past two years, the World Bank has worked with Morocco, Tunisia, and Egypt to develop national environmental management strategies and action plans. Similarly, a number of other countries in the region, including Morocco, Jordan, and Israel, are now developing national water management programs.

The second element of the agenda—increased regional cooperation—is a critical complement to domestic reforms. Economic cooperation among countries tends to reduce tensions, thereby simultaneously enabling countries to redirect resources to development, promoting a more favorable economic environment, and increasing the prospects for peace. Cooperation in trade enlarges the market and allows gains from economies of scale and from the adoption of technologies. Similarly, labor mobility improves the allocation of resources between countries with abundant labor and those with abundant capital. Capital flows—bilateral loans and foreign direct investment—in the reverse direction can serve the same purpose. Finally, some infrastructural water, and environmental projects can only be implemented in a regional context; such projects hold the promise of contributing to both economic prosperity and a lasting peace. Water, in particular, offers an important prospect for regional cooperation.

There are major advantages to regional cooperation in water management in the Middle East and North Africa. Major structures, such as the Unity Dam on the Jordan River, now held hostage to the lack of an agreement, could be built, allowing for a much better utilization of the Jordan River water. Moreover, the joint rational exploitation of aquifers that extend across borders in North Africa and the Arabian Peninsula would be facilitated through regional cooperation. Major water transfer schemes could also be considered.

There has been no lack of proposals. Some have been quite spectacular and include the Ozal Peace pipeline, the diversions of the Euphrates water into Jordan, Israel, and the Occupied Territories, as well as the water transfers from the Mediterranean Sea or the Gulf of Aqaba to the Dead Sea to generate hydropower and desalinate water. Of course, these proposals require careful evaluation from economic and environmental standpoints and many will be hard to justify.

In terms of regional cooperative arrangements, one can also visualize the joint construction and operation of dams, desalination plants, and joint international water distribution networks, similar to energy distribution networks. The effect would be a much more flexible management of water. For traditional water development projects, large, lump investments are needed. The new "unconventional" investments, such as large transfer schemes and desalination plants, are even more expensive. While traditional water development projects may cost several cents per cubic meter, the cost of water from unconventional projects will probably range from $1.50 to $3.00 per cubic meter. Thus, there is a great incentive to build the conventional projects, such as the Unity Dam, first. Development of international joint ventures for the much more expensive unconventional projects, if they prove to be economic, would be a second step.

As discussed, there are clear advantages for strategic regional cooperation on water to complement action at national levels. In the past, however, cooperation has been prevented by conflicts, especially in the Middle East. Israel and Jordan, Israel and the Palestinians, Egypt and Ethiopia, and Iraq, Syria, and Turkey have long been feuding over water, and many of those feuds have escalated into political conflicts.

A seemingly attractive way to reduce a number of these conflicts is by resolving disputes over water. Unfortunately, past attempts have proved unsuccessful. One example is the Johnson Plan. In the 1950s, this United States-sponsored effort proposed a sharing formula for the joint utilization of the Jordan River while United Nations agencies tried to mediate between Egypt and Ethiopia, and numerous meetings were held between Turkey, Iraq, and Syria. To this day these "hydropolitical" conflicts remain unresolved.

It is my belief, however, that there is now a new window of opportunity to turn joint interests into powerful instruments for achieving peace and, in turn, lasting development. The end of both the Cold War the Gulf conflict have led to a very different situation from the 1950s and the days of the Johnson Plan. Today, we are witnessing bilateral and multilateral peace talks initiated by the United States and sponsored by other countries. There is a major change in the political situation: Israelis and Arabs talk to each other directly. The political will (and undoubtedly the need) to come to an agreement has never been as great.

Not surprisingly, one of the major topics of the peace negotiations is water. Special delegates from the countries concerned are dealing with water issues. While there has been no breakthrough, the discussions have addressed specific problems, and some of the delegates have expressed some cautious optimism about possible solutions.

International Support for Reform and Cooperation

The third element of the strategy is international support in general for domestic reform and regional cooperation in the Middle East and North Africa. Several principles for international support must be clarified since the program of domestic reforms and regional cooperation outlined here entails costs.

Increasing the levels of domestic investment, spending more on human resources, and cooperating on regional projects all require that consumption be cut to release resources for capital accumulation. A major principle in support of reform and cooperation is "burden sharing" between the regional and international communities, based on shared interest in the stability of the region. Another principle should be the maximization of the private sector role. The last two principles for international support are related: international support should depend on the successful implementation of the reform programs and it should be provided in a way that contributes significantly to regional peace and reduces domestic tensions. Both principles can be pursued by using external support to fund regional programs and projects in the strategic area of water. In this, the World Bank could be a major player.

The World Bank's Role

The World Bank can and should play a role in ensuring that regional cooperation on water contributes to lasting development and the peace process.

At the national level, the Bank's long experience in the area is one argument in favor of a continuing role. The Bank has also had a traditional role in sector work. From 1960 to 1992, the World Bank lent almost $4 billion for 100 water projects. That is equivalent to 16 percent of all lending. Moreover, water and the environment are among the central objectives in all Country Assistance Strategies for the Middle East and North Africa region.

Regional projects and a regional agenda would constitute a new role for the Bank, however. I believe this is the key to our future contribution in the region, in conjunction with, and separate from, the Middle East peace process.

Several initiatives have been well received in the region. They include the creation of the Council of Middle East Advisers as well as the development of an economic research institute network. The regional environmental projects in the Gulf of Aqaba, the Jordan River Basin Study, and our participation in the Middle East peace talks are still more initiatives that have been met with positive reactions from players in the region.

The multilateral Middle East peace talks are a particularly interesting prospect where the World Bank's help was sought to conduct several studies. Water is one issue to which the Bank can contribute greatly. What can it contribute?

First of all, it is necessary to carefully identify the feasible technical solutions. Politically motivated, uneconomic projects should be avoided. Identifying solutions would require developing technical programs that can be implemented within the context of regional cooperation, and developing ideas on how such programs can be phased in. This will allow politicians to make rational choices and select options depending on their political and technical feasibility.

The advantages of regional initiatives in the area of water must be identified, just as the implications of the absence of regional cooperation need to be underscored. This is where the knowledge, expertise, and imagination of the World Bank's irrigation and drainage engineers are absolutely key. We need to expand the capacity of our water units within the Bank's Middle East and North Africa and its Europe and Central Asia regions.

The Jordan River Basin Study is a good example of the World Bank capabilities I am referring to. We have taken the initiative to assist in identifying technical options and commissioned studies in riparian countries of the Jordan Basin to review the situation, to identify such options for water development, from the perspective of the individual countries concerned. Local consultants are working separately on politically feasible programs in the countries concerned, using the same terms of reference. Just as importantly, they will identify solutions for the whole river basin.

Subsequently, we will organize country workshops to review all the results of the studies, and we hope to organize an international workshop with all the participating countries to identify technical options that appear to be attractive or acceptable to all. This approach—the identification of technical solutions in a very broad framework—will hopefully contribute to the peace process.

Another requirement is the availability of financing. Most investments in various projects ranging from the Unity Dam to desalination plants to water transfer schemes are large. And such investments will be needed. But compared with military spending, they are not that big. A desalination plant, for example, costs approximately $250 million. An airborne warning and control systems (AWACS) plane would cost twice that amount. Since domestic savings will not be sufficient to finance these investments, external financing is required.

The combination of feasible ideas and options for regional cooperation with assurances of financing would be a powerful tool in the peace process. It would build on the wave of goodwill and reinforce positive developments. Additional resources, such as trust funds, can also be considered.

Thus, the Bank has a unique role to play. There is our traditional role, providing technical expertise and financing at international levels. But there is much more we can contribute to forge a consensus on the need for joint action and regional cooperation. We have many advantages as an objective and independent third party, and I believe we could contribute to lasting, peaceful development in the region by actively promoting regional cooperative projects, acting as an independent broker using our lending program as a powerful incentive, and providing leadership in donor cooperation and acting as catalysts for the mobilization of both private and official funding.

The agenda I have outlined for World Bank involvement in the water sector, while not without risks, seems to be a promising avenue to promote such regional cooperation and to contribute to peace, in an important region of the world. That is why your expertise and this seminar are so important! Thank you.

THE WORLD BANK'S WATER RESOURCES POLICY

Editors' Note: The World Bank's water resources policy was being finalized at the time of the Ninth Irrigation and Drainage Conference in December 1992; it was the subject of a presentation and keynote address by Michel Petit and K. William Easter. The policy was approved by the Bank's Board of Directors and published 1993 as the World Bank Policy Paper "Water Resources Management." The policy paper was prepared by K. William Easter, Gershon Feder, Guy Le Moigne, and Alfred M. Duda. The following is a condensed version of the paper's executive summary.*

Water resources have been one of the most important areas of World Bank lending during the past three decades. [By the end of 1991, the Bank had lent over $34 billion for water projects, over half of which was for irrigation.] Through its support for sector work and investments in irrigation, water supply, sanitation, flood control, and hydropower, the Bank has contributed to the development of many countries and helped provide essential services to many communities. Yet, as pointed out in reports of the Bank's Operations Evaluations Department, the water resources investments supported by the Bank have often encountered implementation, operational, and social problems. Underlying these problems is a vicious cycle of poor-quality and unreliable services that result in consumers' unwillingness to pay, which, in turn, generates inadequate operating funds and a further deterioration in services. Moreover, the Bank and governments have not taken sufficient account of environmental concerns in the management of water resources.

The difficulties encountered by Bank-supported projects reflect a larger set of problems faced in water resource management. Water is an increasingly scarce resource requiring careful economic and environmental management. The situation is exacerbated by rapid population growth and urbanization in developing countries. As the demand for water for human and industrial use has escalated, so has the competition for water used for irrigated agriculture. At the same time, the engineering and environmental costs are much higher for new water supplies than for sources already tapped. New challenges call for a new approach. Governments have often misallocated and wasted water, as well as permitted damage to the environment, as a result of institutional weaknesses, market failures, distorted policies, and misguided investments. Three problems in particular need to be addressed:

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- Fragmented public investment programming and sector management that have failed to take account of the interdependencies among agencies, jurisdictions, and sectors.

- Excessive reliance on overextended government agencies that have neglected the need for economic pricing, financial accountability, and user participation and have not provided services effectively to the poor

- Public investments and regulations that have neglected water quality, health, and environmental concerns.

To manage water resources more effectively, a balanced set of policies and institutional reforms should be sought that will both harness the efficiency of market forces and strengthen the *capacity* of governments to carry out their essential roles.

A Framework for Improving Water Resource Management

The proposed new approach to managing water resources builds on the lessons of experience. At its core is the adoption of a comprehensive policy framework and the treatment of water as an economic good, combined with decentralized management and delivery structures, greater reliance on pricing, and fuller participation by stakeholders. The proposed approach is consistent with the Dublin Statement (1992) from the International Conference on Water and the Environment as well as with Agenda 21 from the 1992 United Nations Conference on Environment and Development.

Need for a comprehensive framework. The [comprehensive] framework would facilitate consideration of relationships between the ecosystem and socioeconomic activities in river basins. The analysis should take account of social, environmental, and economic objectives, evaluate the status of water resources within each basin, and assess the level and composition of projected demand. Special attention should be given to the views of all stakeholders.

The results of the analysis at a river basin level would become part of the national strategy for water resource management. The analytical framework would provide the underpinnings for formulating public policies on regulations, incentives, public investment plans, and environmental protection and on the interlinkages among them. It would establish the parameters, ground rules, and price signals for decentralized implementation by government agencies and the private sector. Decentralizing the delivery of water services and adopting pricing that induces efficient use of water are key elements of sound water resource management. ...for decentralized management to be effective [however], a supportive legal framework and an adequate regulatory capacity are required, as well as a system of water charges to endow water entities with operational and financial autonomy for efficient and sustainable delivery of services.

Country focus of the policy. The comprehensive analytical framework will need to be tailored to the situations and constrains facing individual countries. Many of the countries with limited renewable water resources are in the Middle East, North Africa, Central Asia, and Sub-Saharan Africa, where the populations are growing fastest. Elsewhere, water scarcity may be less of a problem at the national level but is nevertheless severe in many areas. For some countries, pollution is the largest problem affecting water resources, In much of Africa, implementation capacity is a critical issue exacerbated by the frequency of prolonged droughts. In some countries, water resource management is not yet a significant problem. These differences among regions and countries will shape the design of strategies and programs for a given country.

Water policy objectives. Differences among countries notwithstanding, water resource management that follows the principles of comprehensive analysis, opportunity cost pricing, decentralization, stakeholder participation, and environmental protection will yield more coherent policies and investments across sectors, promote conservation, and improve the efficiency of water allocation.

The World Bank Policy

The Bank's overarching objective is to reduce poverty by supporting the efforts of countries to promote equitable, efficient, and sustainable development. This entails support for the provision of potable water and sanitation facilities, flood control, and water for productive activities in an economically viable, environmentally sustainable, and socially equitable manner. The Bank will give priority to countries where water is scarce or where the problems of water allocation, service efficiency, or environmental degradation are serious. In these countries, through its economic and sector work, lending, and participation in international initiatives, the Bank will promote policy reforms, institutional adaptation and capacity building, environmental protection and restoration, and, when requested, cooperation in the management of international watercourses. Because of the crucial interdependencies between water and other sectors, the Bank will incorporate water resource policy and management issues in its country policy dialogues and in the formulation of country assistance strategies where water issues are considered to be significant.

A comprehensive analytical framework. The Bank will encourage, and, when requested, selectively help countries develop a systematic analytical framework for managing water resources that is suitable for a country's needs, resources, and capacities. The framework will be designed so that options for public water management can be evaluated and compared in the context of a national water strategy that incorporates the interdependencies between water and land use. It will enable coherent, consistent policies and regulations to be adopted across sectors. To facilitate the introduction of such a framework, the Bank is ready to support capacity building through training, demonstrating participatory techniques, and helping in water resource assessments. The Bank will also promote the creation, enhancement, and use of hydrologic, hydrogeologic, socioeconomic, water quality, and environmental data bases for both groundwater and surface water, as well as help governments effectively use this information in decisionmaking.

Institutional and regulatory systems. The Bank will assist governments in establishing a strong legal and regulatory framework for dealing with the pricing, monopoly organizations, environmental protection, and other aspects of water management. Similarly, the Bank will support the adaptation of institutional structures at the national and regional levels to coordinate the formulation and implementation of policies for improved water management, public investment programs, and drought planning.

Incentives. The Bank will highlight the importance of pricing and financial accountability by using estimated opportunity costs as a guide in setting water charges. In practice, immediate adoption of opportunity cost pricing may be politically difficult. Thus, given the low level of current cost recovery and the importance of finances in the sustainability of operations, pricing to ensure financial autonomy will be a good starting point.

Water-conserving technology. As water scarcity and waste disposal problems become more acute, adopting and improving water conservation practices, wastewater reuse systems, and overall approaches to reduce pollution will become increasingly important.

Poverty alleviation. Inadequate water services have a particularly adverse impact on the poor, facilitating the spread of disease, especially in crowded low-income areas. Thus, special efforts will be directed to meeting the water needs of the poor. Moreover, the health benefits of better hygiene and clean water should be emphasized so that the advantages of having an improved water supply can be fully realized.

Decentralization. Because of their limited financial and administrative resources, governments need to be selective in the responsibilities they assume for water resources. The principle is that nothing should be done at a higher level of government that can be done satisfactorily at a lower level. Thus, where local or private capabilities exist and where an appropriate regulatory system can be established, the Bank will support central government efforts to decentralize responsibilities to local governments and to transfer service delivery functions to the private sector, to financially autonomous public corporations, and to community organizations such as water user associations. In countries where provincial or municipal capabilities are inadequate to manage a complex system of water resources, the Bank will support training and capacity building to improve local management so that decentralization can eventually be achieved.

Participation. Participation is a process in which stakeholders influence policy formulation, alternative designs, investment choices, and management decisions affecting their communities and establish the necessary sense of ownership. As communities increase their participation in managing water resources, areas such as project selection, service delivery, and cost recovery will likely improve. Therefore, the Bank will encourage the participation of beneficiaries and affected parties in planning, designing, implementing, and managing the projects its supports. Special attention will be given to the participation of women because they are essentially the managers of domestic water. The Bank will encourage governments to follow the principles of stakeholder participation more broadly in their investment programs and other activities related to water resources.

Environmental protection. Preservation of the environment and the resource base are essential for sustainable development. The protection, enhancement, and restoration of water quality and the abatement of water pollution will therefore be a focus of Bank-supported operations, particularly since providing safe drinking water is so critical to maintaining and improving human health. Accordingly, the Bank will increase its support of government efforts to improve and expand sanitation and the collection and treatment of wastewater. Similarly, the Bank will promote the use of efficiency pricing and "the-polluter-pays" principle through he imposition of pollution charges to encourage water conservation and reduce pollution. The Bank will assist governments in developing strategies and cost-effective mechanisms for the ecologically sustainable management, protection, and restoration of recharge areas and water-dependent ecosystems such as wetlands, riverine floodplain areas, estuaries, and coastal zones. Given the increasing importance of groundwater, especially in arid and semiarid areas, the Bank will pay attention to the linkages between ground and surface water in managing river basins and will support the establishment of government programs and polices, including land use policies, that restore and protect the quality of groundwater and preserve groundwater recharge areas.

Upgrading skills. In tandem with the promotion of a comprehensive framework and with institutional and policy reforms, country policy analysts, planners, managers, and technicians will need to upgrade their skills. Accordingly, where water resource management issues are significant, the Bank will support the training needed to deal with a variety of subjects. The Economic Development Institute of the World Bank will be an important element in this training effort, through a special initiative to support the implementation of new policy.

Designing country programs. The design of relevant reforms and the time frame for implementation will need to be developed and evaluated case by case. Nonetheless, introducing the recommended reforms will typically entail difficult political choices, and commitments by governments will therefore be essential. Given the present status of water resources management and institutions in many countries, implementing the necessary changes will take time. The Bank will take a number of steps to work with governments and other entities to assist in the design of programs for water resources management, and will work through its own country assistance strategies to deal with the issues outlined here.

International watercourses. Existing guidelines describe Bank policy on the financing of projects dealing with international waterways. The Bank, together with other international organizations, will help countries improve the management of shared international water resources. Through technical, financial, and legal assistance, the Bank, if requested, will help governments establish or strengthen institutions, such as river basin organizations, to address transnational water management activities. Furthermore, the Bank will support studies and consultations to review available organizational arrangements and to help countries develop alternative solutions. The focus will be on international watercourses in which the Bank's assistance is likely to have a substantial effect.

Implementation. To help implement its water resource management policy, the Bank will undertake a range of activities, including the preparation of guidelines and best-practices papers, staff and country training programs, capacity building, and the development of coordination mechanisms to improve the management of water resources. More specifically, in collaboration with the United Nations Development Program, a guide on capacity building is being prepared for countries interested in formulating strategies for managing water resources. Guides are also being prepared on establishing water resource information systems, on best practices for setting up coordinating mechanisms, on generalized economic models for river basin analysis, and on best management practices for water user associations. Regional units are preparing regional water strategies which incorporate the recommendations of this water policy within the specific circumstances of their areas. The skill mix of available and required Bank staff in the area of water resource management has been analyzed, and training programs, workshops, and seminars are being prepared to upgrade existing staff skills. Pilot projects will be used to implement some of the newer aspects of the water policy such as decentralization and opportunity cost pricing. Finally, the implementation of the new water policy will be reviewed in two years.

APPLICATION OF A BASIN-LEVEL MODEL TO THE YELLOW RIVER

Daniel J. Gunaratnam, Gary P. Kutcher, and Stephen J. McGurk[*]

One in nine Chinese live within the Yellow River basin, and most of these depend, directly or indirectly, on the river for their livelihood. The World Bank has helped to finance eight irrigation development projects in the basin to date, and has recently appraised a major multipurpose dam, Xiaolangdi. Dozens more projects have been proposed.

In order to evaluate potential investments (specifically, investments in reservoirs and irrigation) with respect to development goals and the physical and economic constraints under which investments would operate, a team of World Bank staff and consultants, working with Chinese authorities, developed a basin-level model (BLM) for the Yellow River. The model seeks to enforce consistency between the available resources and proposed projects to augment or utilize those resources. The BLM takes advantage of the latest computer technology to combine simulation and optimization techniques in a flexible yet powerful planning tool.

This paper discusses application of the BLM to the Yellow River basin to illustrate how such a model is, and can be, used for basin-level planning. First, the paper mentions features of models similar to the BLM developed for the Yellow River. A description of the hydrology and water resources of the basin precedes a discussion of the BLM and its results for the basin including a few of the major issues identified by the model. Since this is not a technical paper, the BLM is described only in terms of its major assumptions and features.

Infrastructure projects in river basins are becoming more complex and more costly. River basin managers and project planners will require more powerful tools to make rational decisions, tools that must be forged with economics as well as other disciplines. The basin-level model for the Yellow River presents a consistent overview of the water resource use and availability; it is also a basis for development of a generalized economic model for river basin planning that can be widely disseminated.

River Basin Planning Models

Recognizing that river basin development planning involves the simultaneous analysis of a multitude of highly interdependent factors, the World Bank first constructed an economic modeling study of the Indus basin in the late 1970s. That early model was an extension of

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agricultural modeling methods developed for Mexico, northeastern Brazil, Turkey, and elsewhere. The Indus basin model was used to identify areas of water shortages and surpluses for reallocations under a water apportionment agreement. More recently, an economic model of the Nile basin was completed and used to analyze alternative investment and policy measures to forestall probable future water shortages.

These models and their successors (including the model for the Yellow River basin) have only become possible due to rapid development of mathematical programming solvers and of high-speed, low-cost personal computers. Another key element has been the General Algebraic Modeling System (GAMS), which was originally produced at the World Bank to assist large-scale mathematical modeling and has since become a widespread commercial product.

The optimization models have each demonstrated a unique value in their ability to present a concise, consistent "big picture" of the water resource availability and use within a basin. Neither spreadsheet analyses nor simulation models can match their capabilities. For example, a monthly simulation model cannot enforce annual allocation constraints by region or sector except through time-consuming, trial-and-error techniques. The "solution" to a spreadsheet is pre-supposed by the user in the specification of the relationships. Neither form of model can provide an economic optimum to a basin's activities, and neither can provide economic evaluations of water.

Optimization models can provide feasibility tests of a wide range of interventions proposed for a river basin, ranging from diverting the Yellow River for municipal supply (the model assesses some of the costs of doing so) to new land development in Egypt given future water supplies and growing demands from other users. The models can place economic opportunity costs on such activities, as well as providing rough estimates of economic returns to projects and policies designed to alleviate water shortages or to use water more efficiently.

Although each model was constructed at a different time, for a different basin, and for different purposes, they possess some common elements.

- Each model enforces consistency both with respect to water supply and demand at the level of the river and at the level of the irrigated area. Such consistency is often lost or ignored altogether in less rigorous methods.

- Each produces shadow prices, or marginal economic values of water, at various points in the system. These values are difficult, if not impossible, to estimate by indirect or partial analytic methods.

- Each is flexible, with a wide range of potential uses.

- Each is a linear or non-linear optimization model.

- As mentioned previously, each is written and solved by the GAMS system.

While these models have tremendous advantages, their construction and use to date has required a relatively high level of skill in (among other fields) mathematical programmi economics, water resources engineering, and data base management. GAMS has dramatically improved the productivity of the mathematically inclined researcher, but the language and methods of the model are beyond the immediate comprehension of non-technical decisionmakers who need rapid results in a comprehensible format. To this end, it would be useful to develop interface software that would hide the standard mathematical detail (as well as the GAMS software) behind a user-friendly shell. In addition to helping make investment and policy decisions, a user-friendly form of the model would identify such specific and basic needs as the types of data necessary for analysis. Identification of information needs is one element of the water sector assessments that precede development of comprehensive water management strategies.

A brief discussion of the hydrology and economic uses of water in the Yellow River basin will help to describe the basin-level model for that area.

The Yellow River Basin

The Yellow River basin is the cradle of Chinese civilization; irrigation has been practiced these for thousands of years, generating agricultural surpluses that permitted the development of ancient societies that were the envy of the world. With a distance of 5,464 km, the River is China's second longest. Its source is in the foothills of Bayankala Mountains on the Qinghai-Tibet plateau. It passes through nine autonomous regions and provinces (Qinghai, Sichuan, Gansu, Ningxia, Nei Mongol, Shaanxi, Shanxi, Henan, and Shandong) before emptying into the Bohai Sea, supporting on its way an agricultural population of over 100 million people.

The basin is divided into three distinct sections: the upper, middle, and lower reaches. The upper reach, with a drainage area of 384,000 km^2, lies between the source and the gauging station Hekouzhen in Inner Mongolia (the start of the Yellow River's great turn to the south). It is characterized by mountain gorges and wide, lake-filled high valleys near the source, followed by high mountains, deep valleys and narrow gorges that empty into the great alluvial Ningxia and Inner Mongolia plains. The vertical drop in this region is 3,231 m, making the reach ideal for hydropower generation. On average, 56 percent of the basin's runoff is to the upper reach. The two largest reservoirs in the basin, Longyanxia and Liujiaxia, are located in its upper environs, and two more large reservoirs are planned. Minimal precipitation, between 300 mm and 600 mm per year, falls on most of this reach. The extreme upper reach has limited water demand, but the lower stretch of the upper reach, from Lanzhou north to the Mongolian steppes, has large and growing irrigation demands. These demands are difficult and costly to meet: the distribution systems are poor and losses are high, and in places water must be pumped up several hundred meters.

The middle reach, with a drainage area of 344,000 km^2 between Hekouzhen and Huayuankou, lies between 400 m and 1,000 m above sea level and encompasses the loess plateau as well as two of the Yellow River's major tributary basins, the Fen River basin in Shanxi and the Wei River basin in Shaanxi, both of which rely on the Yellow for much of their irrigation supply. Water supplies to this reach are invariably short; groundwater extraction is often excessive, and water diverted from the River must often be pumped tens of meters or more.

The middle reach also contains large concentrations of population, industrial complexes, and mining. These are all significant water consumers with increasing demands for this resource.

The lower reach begins near Huayuankou and stretches to the Bohai Sea. Most of the area is alluvial plain created by the meandering of the Yellow River. The lower reach contains most of the irrigated land in the basin, and on the whole, is the most productive. Its temperate climate permits year-round cropping, and even paddy production is significant in its southernmost areas. Rainfall is sporadic, but often sufficient to grow some crops without irrigation. Irrigation is widespread, however, involving complex systems to make maximum use of groundwater and of Yellow River water when available (and when silt concentration is acceptable). Both are used conjunctively and are often stored in field ditches along with re-usable drainage water. The lower reach is disadvantageously situated on three accounts. In periods of shortage, it is last in line to receive water. It is most prone to the consequences of flooding. Finally, the lower reach receives most of the silt deposited in the river from upstream regions.

The unique feature of the Yellow River is its unparalleled sediment content. The River has the highest concentration of sediment in the world—nine times higher than the sediment content of the Ganges, its closest competitor. Sudden brief but intense storms cause concentrated inflows into the River system that carry with them the easily erodible soil. Most of the sediment in the lower reach of the river originates from the world's largest loess plateau, located in the middle reach. From 1919 to 1960, the average annual sediment load passing Huayuankou was 1.60 billion tons, for an average annual runoff of 47.5 billion m^3. Twenty percent of this sediment, primarily consisting of coarse sediments with a particle size larger than 0.05 mm, was deposited on the river bed downstream of Huayuankou. Most of the deposition of sediments occurs over the lower reach of the river, resulting in a naturally aggrading system. At places the river is suspended ten meters above ground as result of stabilization of the river course through centuries of dike construction; the main embankments stretch 798 km from Huayuankou to the Bohai Sea.

Floods are inextricably linked to sediment. Uncontrolled dike breaches have killed millions and devastated large areas of productive land. The floods typically originate in the middle reach or upperen of the lower reach during intense summer storms. Floods bring large amounts of sediment, the deposition of which makes flood control more difficult and more costly. Peak historical discharges have been estimated at over 33,000 m^3/sec, while the existing structures can accommodate only 22,000 m^3/sec. Flood control on the lower reaches can only be maintained at present (relatively low) protection standards of a recurrence level of one flood in 60 years through increasingly costly and massive work programs. In addition, there are at present about 2.3 million people living between the dikes in 2,000 villages. These people are subjected to frequent flooding.

The greatest potential damage from a flood would occur in the event of overtopping or breaching the main dikes. These dikes now protect about 120,000 km^2, with a population greater than 100 million. Fatality rates could be as high as 3 percent of the population with a major flood.

Economic Uses of the Yellow River

The most important economic use of Yellow River water, by far, is for irrigation. From a very low base in 1949, nearly 44 percent of the cropped area was irrigated by 1987. The expansion of irrigation was not without problems. Many of the early programs were carefully conceived and well managed, and function effectively to this day. Some of the poorly planned and overly ambitious programs during the late 1950s, however, had disastrous consequences. Without adequate drainage, waterlogging and salinity rendered large areas unproductive. In other areas, groundwater mining led to rapidly falling water tables. During the early 1960s, a drought combined with these failures led to China's greatest agricultural catastrophe. Reportedly, millions died of starvation, particularly in the lower reach. Since then, the lessons have been taken to heart. Most projects are carefully managed from an ecological, as well as hydrologic, point of view. Not all, however, are managed to maximize economic output from limited water supplies.

Today, there are over 110 major irrigation projects in the basin, covering over 85 million mu (39 percent of the total cultivated area).[1] The importance of irrigation to the basin's economy cannot be questioned. The basin is roughly self-sufficient in grains and many other commodities, although per capita grain production is still less than the national average. Irrigated grain production in China accounts for over 68 percent of total grain production, most of this from Yellow River sources. In most areas, irrigated grain yields are nearly double those of rainfed grain. Most irrigated grain yields are nearly triple those of the poorly endowed loess plateau.

The differences in productivity between irrigated and rainfed areas are not because of the different average volumes of water available, but because of the timing of the water that is applied. Most of the rain falls in the late summer months, while water requirements peak in the spring, early summer, and late fall. The patterns lead to very high returns to water applied at critical times, and hence translate into high returns to irrigation.

Several Bank-assisted irrigation projects in the basin have economic returns to irrigation that are estimated to be in excess of 20 percent. Data from these projects were used to estimate the incremental value of water used in the irrigation of grain crops. Two levels of irrigation were considered: partial, and full. When rainfed areas receive partial irrigation for grain crops, the returns in terms of net economic value range from 17 fen/m^3 to 78 fen/m^3, averaging 46 fen/m^3.[2] When partially irrigated areas receive full irrigation, the incremental returns are typically even higher, averaging 65 fen/m^3. Estimates of the marginal value of water were also obtained as shadow prices from the BLM. At the field, additional water available during the critical spring months produces a marginal value of 125 fen/m^3 in the lower reach and 111 fen/m^3 basin-wide. Accounting for distribution and field losses, the value is still 50 fen/m^3 measured at the river. This implies that any scheme diverting Yellow River water to other uses during the critical irrigation season needs to have an economic return greater than 50 fen/m^3, and that any scheme augmenting Yellow River water (such as the proposed south-northwest

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1 One mu is approximately equal to .07 hectares.

2 A fen is a unit of Chinese currency. One hundred fen constitute one yuan.

transfer) during these periods could have a return of 50 fen/m^3 (\$0.091/m^3) or more, depending on the location. It also implies high returns to improvement of existing schemes, in terms of both saving water and timely delivery of water to users.

In 1990, irrigation's value added due to water accounted for an estimated 13.1 billion yuan (77 percent of the value of crop production), hydropower for 2.5 billion yuan (15 percent) and M&I water supply 1.2 billion yuan (8 percent), measured in economic prices in agriculture and willingness to pay charges for power and M&I. The three reservoirs (Longyanxia, Liujiaxia, and Sanmenxia) and several run-of-river plants produced nearly 18,000 GWH per year, valued at 2.45 billion yuan—15 percent of all benefits. About 70 percent of the energy that is generated supplies peak load to the energy-short north and central China networks. The opportunity cost of the thermal alternative is about 36.6 fen/Kwh based on long-run marginal costs.

M&I users (including those supplied by extra-basin transfers) accounted for about 10 percent of all Yellow River water consumption in 1990, a percentage that will likely increase sharply in the future. Based on willingness to pay (between 32 fen/m^3 and 42 fen/m^3), these uses accounted for about 8 percent of all economic benefits from Yellow River water.

Existing water supply tariffs range from 20 fen/m^3 to 32 fen/m^3. Virtually all of this is accounted for by treatment and conveyance costs. The implicit opportunity costs to M&I uses is only 5 fen/m^3—only one-fifth of the average return to water in irrigation, and only one-tenth of its marginal value to irrigators measured at the river during the critical months. There may well be social benefits from water supply that justify such low opportunity costs charged them, but it is difficult to see why, implicitly, farmers must subsidize industrial users, whose output per cubic meter is about 50 times the cost of their water input.

A BLM simulation indicates that by 2010 irrigation's added value of production will increase by 250 percent but its share will drop to 66 percent, while the share of hydropower output will increase to 25 percent and the M&I share will remain at 9 percent. This is due to the increasing shortages of water and the non-consuming nature of water use in hydropower generation.

Farmers do not pay anything near the opportunity value of their water. Water charges range from about .5 fen/m^3 in parts of the upper reach to 4.5 fen/m^3 in Shanxi in the middle reach averaging about 2.5 fen/m^3 (\$.005/m^3)[3]. These charges are but a fraction (17 percent) of the average return to irrigation and even less to the marginal returns. In most parts of the basin, it is doubtful that water charges cover the full costs of system O&M. There is substantial room to increase water charges to farmers given the sharp differences that irrigation makes to productivity. In 1988 the Ministries of Water Resources and Finance issued guidelines that stated that water institutions should become financially autonomous. The guidelines required that water fees be raised over a period of five to ten years to recover all costs (essentially marginal cost pricing). Since then water fees in several provinces have been increased dramatically to cover at least 65 percent of the supply costs. These price increases still fall far short of the

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3. These values are very rough estimates given the complex nature of water pricing involving one or more of the following components: volumetric charges, fixed charges, area-based taxes, and contributed labor for system maintenance.

opportunity cost of water during critical periods (16 percent of opportunity cost) and as an average (34 percent of opportunity cost) throughout the year.

An inter-country comparison of water prices and opportunity costs at critical periods shows similar differences between prices and costs in some Californian (Central Valley Project) and Victorian (Australia) irrigation systems, where the water fees only cover between 12 and 30 percent of the marginal costs and form only a small percentage (2 percent) of the opportunity costs. The only projects where water fees approach opportunity costs are those with a very strong urban bias such as the Metropolitan Water District and state water projects in California; fees cover between 75 and 96 percent of costs in these areas.

There are strong indications that higher water charges promote more efficient use: the areas charging highest fees also happen to be the most efficient water users. For example, until 1987 the water fees were highest (4.5 fen/m^3) in Shanxi and the on-farm efficiencies were also the highest (88 percent), while much lower fees were collected in neighboring Inner Mongolia (1.79 fen/m^3) where field efficiencies were only 50 percent. High water fees also deter the high use of water. In 1991 Shandong Province instituted high water fees of 7 fen/m^3 and water use was 350 m^3/mu while in Inner Mongolia and Ningxia water fees are about 1.7 fen/m^3 and water use is between 1,100m^3/mu and 1,200 m^3/mu. In most water-short countries the price elasticity of demand for water ranges from -0.4 to -1.0. Based on pricing data obtained during a World Bank mission, the price elasticity in the basin is estimated to be closer to -1.0[4]. Hence there should be a dramatic reduction of water use if water fees are raised.

Given the high scarcity value of water in the basin, sediment flushing requirements described previously are a major economic constraint. These requirements are the second largest water use after irrigation, averaging some 38% of mean annual flows at an estimated opportunity cost of as much as 1.1 billion yuan ($200 million) annually. Even saving small portions of that opportunity cost would be significant.

Organizational Responsibilities

The Ministry of Water Resources (MWR)is responsible for overali basin-level planning, but must coordinate all investments with the State Planning Council. MWR's local arm, the Yellow River Conservancy Commission (YRCC), plays the leading role in carrying out regional studies, identifying and designing projects, and promoting sound water use policies. It also undertakes a coordinating role among the nine provinces that the basin encompasses. These provinces also plan, invest, and make policy, sometimes in unison, and sometimes at odds with one another and the YRCC. The Ministry of Energy (MOE) has jurisdiction over all hydropower installations including some key reservoirs.

The YRCC's last attempt at a comprehensive basin-wide plan was in the early 1980s, based largely on data from 1980 or before. The latest of several options was published in 1988 (YRCC 1988). The study has been updated in piecemeal fashion since then, in part using data pertaining to 1987. Although comprehensive and factual, the methodology employed is now

[4] This elasticity has been computed using some of the data on pricing obtained during the mission.

obsolete, the data used are often inconsistent and incomplete, and the results may be overly optimistic both in terms of future water supplies and in what can be accomplished through structural changes (an early version called for no less than 29 major reservoirs). Furthermore, the YRCC study reflects the hydrologic and engineering bent of that institution, and is virtually devoid of economic rationale.

The Basin-Level Model

The BLM constructed for this study is a non-linear optimization model of approximately 1,000 equations. It maximizes the value added from Yellow River water subject to a variety of physical, hydrologic, agronomic, and, if desired, policy constraints. The value-added recognized by the model originates from irrigated agriculture in each of ten regions, hydropower output from six existing reservoirs and run-of-river plants, and from diversions to M&I users. The BLM also provides for, but does not attempt to count, benefits from flood control, ice-jam prevention, and navigation through embedded restrictions on reservoir operations and channel flows. The physical and hydrologic constraints ensure that water demands cannot exceed water supplies, and that the limitations of water storage and delivery capacities are respected. The agronomic relationships relate irrigated crop output to available water supplies, subject to the stock of irrigable land and other resources.

The available data do not permit derivation of a full water balance for any recent year, and some of the numbers YRCC previously used to project water balances to 1990 are inconsistent with data reported for 1987. A major concern raised by this study is that the database for planning must be improved, both in terms of technical and hydrologic data, and in terms of related agricultural, economic and social data. Future plans for water development and use must rest on accurate estimates of future water supplies.

The constrained optimization approach is taken for the BLM because it is assumed that the relevant Chinese authorities wish to obtain maximum economic benefit from the operation of the system as well as from investments in the system, subject to a variety of hydrologic, physical, and agronomic constraints. The core of the BLM is a network of nodes and connecting arcs common to simulation models. Water enters the system at selected nodes as exogenously given runoff, and is directed through the system according to predefined paths. Certain nodes represent offtake possibilities for irrigation or M&I demands or both. Some nodes represent run-of-river hydropower plants. Reservoirs are unique nodes in that inflows may be stored for later release; each reservoir also has an associated hydropower plant, and most have offtake possibilities. Other nodes are included because reports on water balances are desired for comparison with similar data available elsewhere. Each node is constrained to be in balance on a monthly basis; that is, the sum of inflows from upstream nodes plus runoff plus return flows from previous diversions plus releases from storage (if a reservoir) must equal flows to the next downstream node plus diversions to agriculture and M&I plus retained storage (if a reservoir) plus losses.

Irrigated agriculture is represented in each of ten regions for the four major irrigated crops: wheat, corn, cotton, and rice. Based on available irrigated area, a fixed cropping pattern, and given monthly crop water requirements net of effective rainfall, a "desired" diversion pattern is determined. According to the availability of water in the system and its opportunity value elsewhere, three outcomes are possible: (a) full yield is obtained and the entire irrigated area is cropped, (b) the entire area is cropped, but yields are reduced because of water shortages, and (c) yields are reduced and part of the irrigated area is operated as rainfed. Thus the model endogenously determines both irrigated area of each crop and its resultant yield given water supply. Requirements for M&I use are specified as demands and include certain extra-basin transfers; furthermore they are given first priority among demands. Hydropower energy output is computed endogenously for each reservoir and major run-of-river plant, and exogenously for other run-of-river plants in each month. For reservoirs, energy output is a function of the net head and the discharges through the powerhouses. Net head is endogenously determined by non-linear functions relating reservoir storage and elevation, and discharges and tailwater elevation. Discharge through the powerhouses are determined as releases from the reservoir up to the limit of powerhouse capacity. Net head is assumed to be given for run-of-river plants, thus energy output from them is computed directly given the flows in the relevant river reaches.

Flood protection, sediment control, and environmental protection measures are included in the model as either restrictions on reservoir operating procedures, or as river reach flow constraints. For each reservoir, upper and lower operating limits constrain the storage permitted in each month. Flood protection measures imply that the downstream reservoirs must be near dead storage at the onset of the flood season, and must remain low until the flood season has passed. In the ice-jam prone reaches, river flows must be restricted (through reservoir control) in the coldest months to limit flooding. Minimum flows in each month are attempted in the last reach to minimize ecological damage to the estuary.

The objective function is the value added from Yellow River water. The value added is measured in economic prices for irrigated agriculture plus the economic value of the energy produced, based on willingness-to-pay. Because the priority ranking of Yellow River water demands ensures that M&I requirements are met first, an economic evaluation of M&I water is not relevant to the optimal solution, but is included in the estimates of benefits.

A solution to the model provides the following information:

- Monthly flows in all river reaches
- Monthly reservoir storage and elevation
- Monthly diversions to agriculture and M&I
- Irrigated area by crop in each region
- Irrigated area used as rainfed lend by crop in each region
- Water shortage for each crop in each region
- Resultant yield and production for each crop in each region
- Energy output of each reservoir and power plant
- Energy "spilled" by each reservoir
- Value added from irrigated agriculture
- Economic value of energy output
- Shadow prices of water at each node and in each month
- Economic "costs" of each constraint on flows or reservoir operating rules.

Critical Issues in Planning

A number of critical issues have emerged from analysis. Some of these have been known or suspected for a number of years and have been confirmed by the BLM.

Emerging Water Shortages. At present, aggregate water supply and demand in the basin are roughly in balance in all but the driest years. Shortages do occur in most years, but these are seasonal and localized and due to either insufficient reservoir storage or insufficient diversion capacity from the main stem. The YRCC expects consumption of Yellow River water to grow at a 2.7 percent annual rate during the 1990s. By their calculations, shortages will be 1.65 billion m^3 in a P50 (median) runoff scenario in 2000. However, that analysis ignored much of the lower reach's demands, supplying only about 2 billion m^3 out of a projected demand of over 10 billion m^3. The YRCC may also have excluded some of the planned extra-basin transfers, that could total 4 billion m^3 by 2000 or soon thereafter. When these assumptions were corrected, we find that the shortage will likely be 5.75 billion m^3 (12 percent) in a P50 scenario, and 8 billion m^3 (17 percent) in a P75 scenario.

Beyond 2000, the shortages are likely to intensify further. M&I demands, including extra-basin transfers, are projected to be more than 10 billion m^3. Planned irrigated area expansion is targeted to reach 87 million mu, from about 59 million mu at present. Even under the most optimistic scenarios tested, with significant improvements in water distribution efficiencies and up to 14 billion m^3 of additional storage facilities, serious shortages remain in all but the years of highest runoff.

Equity Considerations. With a population far in excess of the carrying capacity of the land, the remote, heavily eroded loess plateau and the cold, high, and arid upper reaches of the Yellow River have long been among China's principal poverty-stricken regions. They are also the least efficient water users. Delivery and field losses are extremely high, and many areas must be served by energy-intensive pumping schemes. With increasing frequency, Yellow River water will be in short supply, and the water used in the regions will have an ever higher opportunity cost downstream. Sooner rather than later, Yellow River planners will have to squarely face equity versus efficiency issues.

Energy. Hydropower plants, both run-of-river and storage reservoir, have an installed capacity of 3,660 MW and an average annual energy capability of 17,750 GWh. However, this is only 7.6 percent of the demand from the three major grids supplied, a demand that is growing by 7 to 10 percent per year. Hydropower costs far less than the alternatives of coal and gas; thus another 14,260 MW of capacity are scheduled to be installed in Yellow River facilities by 2010.

Although hydropower does not constitute a consumptive use of Yellow River water, it does generate severe conflicts in systems management. Run-of-river plants require a relatively uniform base flow, hence regulation through storage in larger upstream facilities is required for their optimal use because the intra-year patterns of runoff and irrigation demands are far from uniform. Furthermore, maximum energy output from storage reservoirs requires *full* reservoirs and constant releases. This is in direct conflict with (a) irrigation releases, which require reservoirs to be emptied during the dry spring months; (b) flood control, which requires that specific amounts of storage be available during the flood season; (c) with sediment control, which necessitates flushing the river with heavily silt-laden storms; (d) ice-run control, which requires the releases of large flows prior to freezing to expand the cross-sectional area of the channel and reduced flows after icing and prior to thawing to prevent ice jams from forming; and (e) navigation and water supply, which require constant releases.

Flood Control Needs. Because of intense development in the main detention basins—Beijindi and Dongpinghu—the use of these basins for flood diversion could result in unacceptable economic losses. There are at present no flood storage facilities in the middle reach, and the reconstructed Sanmenxia has very limited flood storage capacity (about 1.5 billion m^3). Reasonable protection of the lower reach areas must await the construction of the Xiaolangdi Dam. Likewise, protection of the lower middle reach must await the construction of the Qikou or Longmen dams or both.

The use of reservoirs for flood control engenders losses in irrigation supplies as well as hydropower output. Water supply to irrigation is most critical in the spring and filling up of the reservoir must occur in summer months when water is abundant-precisely the time when reservoirs must be kept low in order to receive incoming floods. Floods of an entirely different origin than intense summer rains are caused by ice jams both near the estuary (where the river turns north) and in the great northern river bend near Hekouzhen on the middle reaches. To minimize damage, flows must be carefully regulated from November to March. Too little flow will induce a hard freeze while too much may result in ice jams. This factor reduces water available for irrigation during early spring for all areas in the middle and lower reaches. A proposed reservoir at Daliushu, approximately midway between Liujaxia and Hekouzhen, will improve ice run control on this river section, permit full use of the upstream six-plant Longyangxia-Daxia hydropower system currently constrained by ice-run control, and re-regulate upstream power system discharges for downstream irrigation, run-of-river, and water supply needs. The proposed reservoirs at Longmen and Qikou, between Hekouzhen and Sanmenxia, will alleviate middle reach irrigation and M&I shortages; they will also contain middle reach floods and control sediment.

Interregional Conflicts. Yellow River water needs by season and by reach often lead to conflicts. Ice-run control on the Great Bend of the Yellow River in Inner Mongolia not only constrains upstream power generation in Liujiaxia Reservoir during the thawing season (perhaps by as much as 200 MW of continuous power), but also irrigation and water supply in southern Gansu and Ningxia, and irrigation and navigation needs below Hekouzhen. Sediment control requires tradeoffs between middle reach sediment delivery and downstream power generation, reservoir regulation, ice-run and flood control, water supply, irrigation, navigation and estuary control. Within the middle reaches, there are significant problems in balancing power generation, sediment regulation, water supply, flood and ice-run control, navigation and irrigation. On the lower reaches, flood and sediment control operations also create conflicts with other uses. Finally, regional priorities, for example, costly high-lift irrigation or coal washing supply on the upper and middle reaches may not agree with aggregate basin-wide water supply priorities.

In the short term, contradictions between upstream power generation and irrigation supply, and downstream water supply and navigation and ice-run control on the Inner Mongolia Plain will continue. Responses to conflicts between sediment control and downstream needs include soil and water conservation programs in the loess plateau, improvements to lift irrigation schemes on both banks of the main stem between Yumenkou and Tongguan, improvements to river training works on the Longmen to Tongguan river section, and investments in navigation works on the Fugu-Yumenkou river section. In the medium- to long-term, only with construction of re-regulating facilities at Daliushu can flood and ice-run control, drought management, and water supply be ensured in the middle reaches; only with the completion of the Qikou Reservoir can sediment delivery to the middle reach be reduced, allowing relatively sediment-free water to be supplied to M&I use in the Taiyuan region of Shanxi Provinces; and only the completion of the Xiaolangdi Dam will permit significant improvements in lower reach flood and sediment control without sacrifice of other downstream demands.

The Planning Pròblem. Competing and often conflicting demands pose complex planning and management problems. Without massive additional investments in the Yellow River system, future demands from agriculture and M&I simply cannot be met with reasonable reliability. If sediment and flood control are to be the dominant efforts, as local planners believe they should, economic losses in agriculture, urban water supply, and industrial energy output will loom ever larger. It is extremely difficult to minimize these losses while managing the conflicts induced by competition for scarce Yellow River resources. The BLM offers a tool to assist in making these different decisions

Major Conclusions

The model results confirmed the YRCC's major concerns and priorities for planning and management of the Yellow River basin. These are:

- Control of flooding, particularly on the lower reach, is the highest priority.
- Control of sediment, the deposits of which have aggraded the lower reach and exacerbated the flood control problem, is the second largest user of water requiring some 38 percent of the annual average flows for flushing.
- The promotion of "rational" utilization of the basin's water resources, which implies maximizing the economic benefits from irrigation, but with due consideration to equity concerns for the poorer farmers in the upper and middle reaches, is essential to avoid waste, inefficient use, and misallocation of scarce water resources.
- Harnessing as much as economically feasible, the enormous energy-producing potential of the river.

Furthermore, the study noted that the objectives for development and management often incur severe conflicts; most objectives can only be achieved at the expense of others. There is no panacea for the basin's problems. Whatever solutions are pursued must be addressed carefully and within a framework that enforces consistency and permits simultaneous evaluation of a variety of effects. The agencies responsible for Yellow River development and management do not have such a framework, and many of the data upon which they base their decisions are essentially supply driven and outdated, incomplete, and inconsistent. If nothing else, this study offers a preliminary version of such a framework, and has pointed out the critical areas in which data need to be improved.

Although Chinese planners have long discussed the looming water shortages in the basin, their numerous projections were often at odds with one another, and with their own data. The use of the BLM forced transparency on the assumptions and data employed for such projections, and provided some sobering results. Although water demand and supply are approximately in balance at present (apart from local and seasonal shortages), this balance will deteriorate rapidly.

Section II

Irrigation and Drainage

A REVIEW OF WORLD BANK IRRIGATION EXPERIENCE

*W.I. Jones**

The Operations Evaluation Department (OED) of the World Bank is conducting a desk study[1] of the Bank's irrigation experience. The study reviews evidence from evaluations (project completion reports, OED audits, and OED impact evaluations) of 208 projects involving significant amounts of irrigation (including drainage) approved by the Bank and the International Development Agency (IDA) between 1961 and 1985. These projects are just over one-third of the nearly 600 projects involving some irrigation that were approved by the Bank in those years. The 208 projects selected are a non-representative sample temporally and in some other respects as well. There is less data available on the rest of the projects, in most cases because they are in the early stages of implementation. In an attempt to present a balanced view, the OED study supplements its analysis of evaluation data with data available on all Bank and IDA irrigation lending.

Moreover, to explore questions raised by irrigation evaluation but not answered (and there are many), the study draws on experience from outside the Bank. For example, there is a consensus that if irrigators are involved in projects, O&M will be good. Involvement implies some kind of irrigation organization. OED evaluations reveal that much, but offer few hints about what correlates with successful irrigation organizations. Some outside analyses of empirical studies do just that, however. A second example of the use of outside studies relates to canal irrigation systems. World Bank evaluations and supervision experience conclude that the canal irrigation systems in northwest India designed and operated according to *warabandi*[2] principles are superior to systems elsewhere in India in terms of efficiency and equity. Identically designed systems in the Pakistani Punjab do not seem to manifest the same superior efficiency and equity. World Bank evaluations and supervision experience give no clue as to the reason this should be so; two empirically based outside studies do, however. Such outside studies can thus help in understanding the Bank's experience.

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1 Please note that the ideas presented in this paper are the author's own based on preliminary conclusions of the study. The ideas do not represent the official views of the World Bank. The full study will be published in 1994.

2 *Warabandi* is a system of rotating water turns among farmers with deliveries fixed and proportional to land farmed. Canal design must be precise, but operation is simple.

Outline of the OED Study

The study is divided into three major parts. The first clarifies what the Bank's irrigation policy has been; it analyzes the patterns and practices of lending for irrigation. The second part explores what factors are associated with success and failure, based on the data from 208 projects. The third section, also looking for factors associated with success and failure, explores two prominent themes that emerge from irrigation audits and impact evaluations. It is based on both the audits and outside sources.

Bank Irrigation Policy

The Bank has defined its irrigation policy by making loans, not by writing policy papers. What does analysis of 42 years-worth of loans tell us about the Bank's intentions?

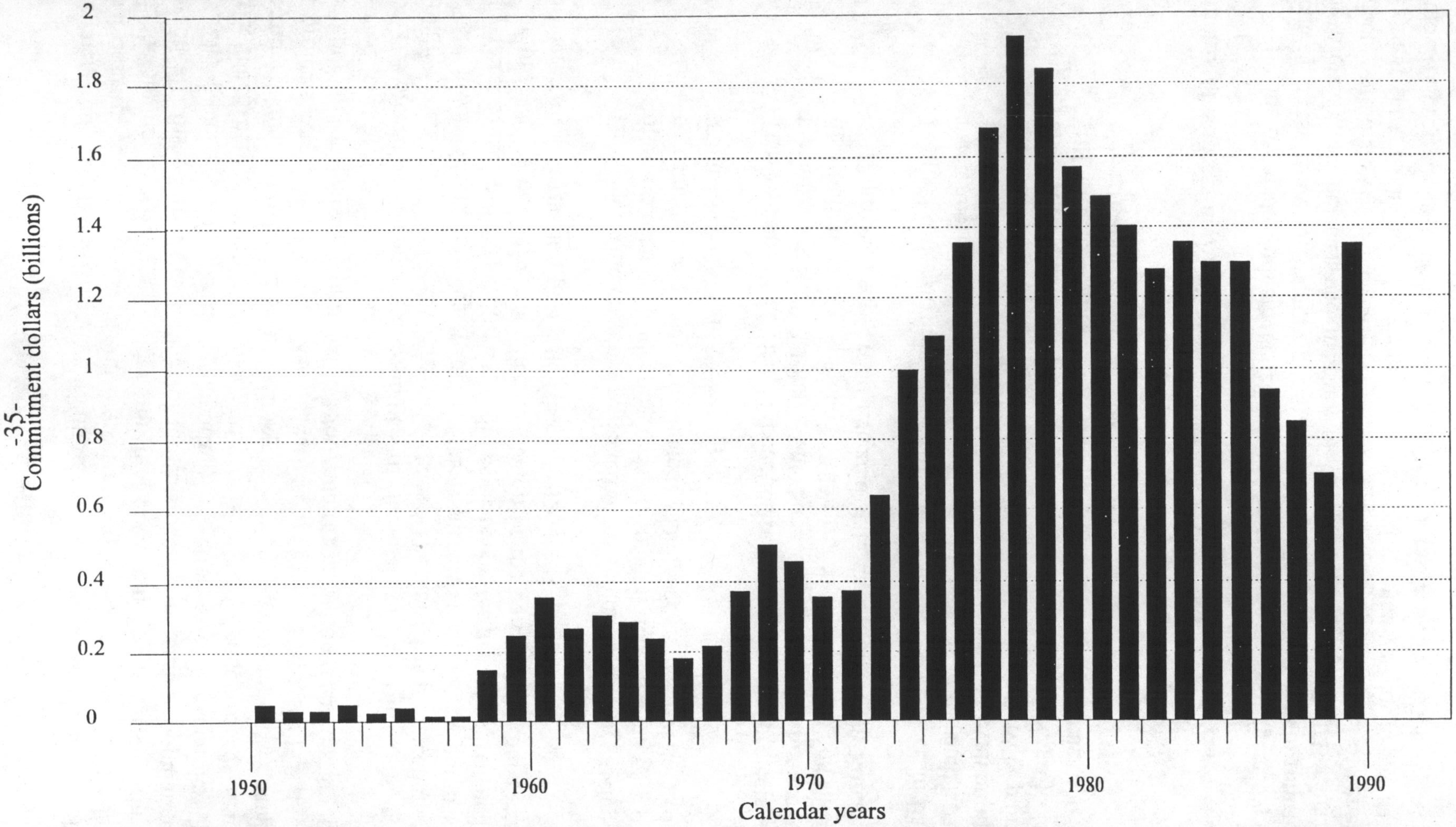
The World Bank's irrigation loans and the projects they support are getting bigger and more comprehensive, tending to go from, in the beginning, specific, geographically defined schemes to sub-sector, policy-based lending. The general perception is that irrigation, like lending to agriculture as a whole, is not quite the priority for the World Bank that it was a few years ago. This perception is not quite accurate.

When the lending is adjusted for U.S. dollar inflation, and corrected for annual "bumps" by using a three-year moving average, there is a pattern (please see figure 1). After a token start in the 1950s, lending for irrigation established a base in the next two decades, growing significantly in the late 1970s and early 1980s. It is too early to tell whether the resurgence in 1991, heavily influenced by very large commitments to four countries, is a new trend. Ignoring 1991, real irrigation has come down to only 40 percent of what it was in the late 1970s. Fitting a trend line to the 1978–90 three-year moving average and projecting into the future, Bank lending for irrigation disappears altogether by 1995! This shows how figures can mislead. No doubt Bank lending for irrigation is not about to disappear. The constant-dollar figures do show, however, that irrigation is part of a pattern that is different from that portrayed by current-dollar figures.

In real terms, irrigation projects were smaller in the 1970s and in most of the 1980s than they were in the 1960s; they only exceeded their earlier size in the late 1980s and 1990s. That is because the "integrated rural development" revolution of 1973–74 affected irrigation lending. Before that time, projects supported by irrigation lending were unambiguously irrigation projects; from 1974 until the end of the 1980s, "irrigation lending" became more ambiguous. Only about half of the projects covered by the term "irrigation lending" had an irrigation component that was over 50 percent of the total loan. Many projects (including those that were, in fact, mostly irrigation) were called rural or area development projects, agricultural sector loans, agricultural credit projects, rural electrification projects, and the like. Many of the loans were small or were in small countries, or both. Many were in Africa, where the average amount of irrigation lending per project on our master list was about one-fourth of the amount in Asia between 1974 and 1989.

Even projects that were patently for irrigation were affected by the integrated rural development style; they contained a broader range of elements to be funded such as on-farm

Figure 1. World Bank Irrigation Lending
(three-year moving average, constant 1991 U.S. dollars)



Source: The share of total loan or credit amounts allocated to irrigation and drainage was inferred from Agriculture and Natural Resources Department cost breakdowns. The commitment deflator series for pre-1970 amounts was supplied by the International Economic Analysis and Prospects Division. The PAC deflator series of October 1991 was used otherwise.

development, agricultural extension, agricultural marketing, roadbuilding and levelling, field channel construction, and organization of water users' associations. By the later 1980s and 1990s, the amount of irrigation "hidden" in rural development and agricultural credit projects had practically disappeared (these types of projects became much less popular, too).

The typical lending package supporting irrigation now is much less geographically specific, much bigger, much more likely to proclaim itself "policy-based" than "integrated," much more likely to cover the sector state-wide. While the names have changed, these new super-projects recall some of the Bank's earliest irrigation loans such as the Indus waters settlement plan for Pakistan (approved in 1960) and the irrigation rehabilitation loan for Mexico (approved in 1961).

The preceding statements are samples of the kinds of generalizations that can be made by looking at nearly 600 projects over four decades. The study has produced more conclusions, especially involving geographical patterns, the relative importance of pump schemes versus gravity-fed schemes, project size (in terms of people benefitted and areas irrigated), and so forth. This summary does not permit detailed revelation of the conclusions, but three findings may seem interesting to irrigation professionals:

- Drainage, which is often neglected in implementation and which professionals are often accused of neglecting, was an integral and obvious part of design for 86 percent of the projects evaluated. Drainage is *not* overlooked during project preparation and appraisal.

- The average farm size of beneficiaries of evaluated projects is 216 ha. The median farm size 2.1 ha. The huge difference is explained by the bimodal distribution, with one mode of 196 projects around 2 ha and the other composed of 12 projects supporting irrigated state farms, mostly in Romania.

- Pumped water or groundwater irrigation has a bigger place in Bank lending than meets the eye, especially if one goes by what is designated "irrigation" by the Bank's management information system. The OED evaluation concludes that about 21 percent of irrigation projects are almost exclusively pump projects, with another 6 percent a combination of pump and gravity feed projects. These figures still probably miss some Bank financing of pump irrigation hidden in rural electrification and rural credit projects.

Elements of Success and Failure

Evaluators make judgements about project outcome, two of them overall assessments: whether the results are satisfactory or not, and what the economic rate of return is (which, when done properly, is the least-bad measure of overall project worth). Because most irrigation projects unfold slowly, often not realizing their full-development level of benefits until decades after their start, evaluators' judgements are unusually tentative, not to say suspect. Sixty-five of the 208 projects have been evaluated only by a project completion report (PCR), typically done eight years after approval) of a project by the Bank's board of directors. Of the 208 projects, 123 have been audited (typically ten years after approval) but have not been subject to impact evaluation; 20 have been the objects of impact evaluation (typically 15 years after approval). Anyone who has participated in this process knows how imperfect it is, yet the overall assessments are the best evaluations anyone has.

Before proceeding to the factors that correlate with satisfactory assessments by evaluators, we should look at the ratings for irrigation projects as a group. As a group, irrigation projects have overall ratings that are just slightly higher than those for all agricultural projects. Like the ratings for agricultural projects, those for irrigation have been falling. Overall, two-thirds of irrigation projects are considered to have satisfactory outcomes. The latest re-estimate of economic return averages 15 percent, not as high as the 21 percent estimated at the project appraisal stage, but still a return that investors should be proud of. Still there is plenty of variation around the averages and plenty of opportunity for improvement.

What factors tend to correlate with satisfactory assessments?

Macroeconomic Distortions. The 1991 *World Development Report* showed that a good deal of the variance in performance of all projects can be explained by different levels of distortion in the macroeconomic environment. Good policy fosters good projects. Interest rate, exchange rate, and foreign trade distortions do not. These three distortions are the only ones for which the authors of the *World Development Report* could get quantified estimates and which showed significant correlations. There are a lot of other distortions, of course, that cannot be quantified or correlated that affect project results, such as civil war, corruption, and shortages of construction materials.

Regarding these distortions, irrigation is similar to the rest of the Bank's portfolio, except that moderate foreign trade distortions *help* economic performance! Apparently, when the Bank's borrowers protect rice farmers, for example, from the painful effects of falling rice prices, not only do irrigators reap a financial windfall, but they farm better and get better economic results.

Commodity Prices. Unexpected commodity prices explain much of the gap between expectations and results. For projects approved in the 1960s and 1970s, disappointing technical results were covered by rising commodity prices. For the past two decades, reality has been even more disappointing than expectations. For 40 percent of evaluated irrigation projects, benefit calculations were based only on rice; for 61 percent of the projects, benefit calculations were based principally on rice. Most of the rest of the projects depend heavily on wheat, cotton, and sugar, all of which are in a deep and protracted price slump that helps consumers but hurts producers. This is associated with a large decline in overall project ratings.

Clearly the biggest factors affecting irrigation project results are ones over which the projects have no control. Of course, irrigation professionals are interested in factors over which we do have some control. Beyond the external factors, are the results just "random noise?" There is quite a bit of randomness, but a number of significant correlations remain. I will discuss two of them.

Economies of Scale. There are economies of scale with irrigation projects. Size has costs as well as benefits. The cost of the complex task that water users have in organizing their participation in a project (or the higher cost of *not* participating) is one such cost. The "small is beautiful" partisans have pointed out these and many others. Data from OED's early review of 20 irrigation impact evaluations suggested, however, that on average the incremental benefits of large irrigation projects outweigh their additional costs. The data from the larger sample of 208 projects confirms that project size and evaluation economic return vary directly. The coefficient of correlation is about .3, remarkably high for a complex social phenomenon like irrigation. There is a very high confidence level in this figure because of the large number of observations.

Could there be some other factor that correlates with irrigation project size and makes it look as though big is beautiful and small is not? The study looked for such factors. The most obvious factor is that irrigation projects in Sub-Saharan Africa, like other projects, do worse than projects elsewhere. Those Sub-Saharan African irrigation projects tend to be smaller. If that factor is controlled for, the positive relationship between project size and economic returns weakened only slightly. The correlation coefficient fell from .32 for all gravity projects to .31 for all but Sub-Saharan African projects. For pump projects, the equivalent figures are .34 and .31. And for the 23 evaluated irrigation projects in Sub-Saharan Africa, the size/returns correlation is very high indeed—.61 for gravity projects and .68 for pump projects—though, of course, the number of projects is small so that the confidence level is not high. Each situation has to be examined on its own, but there is an undeniable link between size and results. Big tends to be beautiful.

Rainfall and Results. This factor is actually notable because of the absence of a correlation. We all believe that irrigation works better where water is really scarce. Most of the Bank's irrigation lending, however, is *not* going to make deserts bloom. Well over half of irrigation lending is going to humid areas already cropped and watered with rainfall and residual soil moisture, including growing more rice in areas where there is enough natural water to grow one good crop and sometimes two. (Please remember that for this review, irrigation embraces drainage.) Some of the Bank's most successful investments have consisted of making a second annual rice crop possible in a humid area. Nevertheless, there seems to be something about the poverty of the alternative to irrigation in arid areas that inspires all hands to work together, to get the systems working, and to keep them working. There can be no question that a lot of equity problems between users as well as instances of poor O&M occur in humid and sub-humid areas where rainfed farming is an alternative to irrigation and where the unpredictability of rain makes the system operation extremely difficult.

Statistical analysis of evaluated irrigation projects fails to confirm that projects somehow work better in arid places. Gravity schemes do about equally well whether they are in wet or dry zones. Pump schemes do better in wet areas than in dry (although the results are not very strong). Maybe this is because aquifer strength in dry areas was often overestimated at appraisal. Maybe the unexpected neutrality of gravity scheme results to rainfall stems from the concentration of upgrades and rehabilitations (with their lower unit costs) in wet areas. We just don't know.

The lack of an inverse correlation between rainfall and results was just as surprising as the strength of the direct correlation between size and results.

The above factors are statistical correlations. They are not rules; most irrigation professionals can think of exceptions. Despite exceedingly difficult macroeconomic conditions, the Kinda Multipurpose project in Myanmar and the Dau Tieng project in Vietnam are, overall, successful, the former even though the irrigation part will probably not work well for lack of water. Both projects show what diligent implementation and, in the case of Dau Tieng, willingness to tinker until something works, can overcome. Imagine how much more successful these projects might have been in more felicitous economic environments. The oasis subprojects in Tunisia financed by the Southern Irrigation project and the Nebhana part of the Medjerda-Nebhanadam irrigation project are very small and successful. The Muda I project in Malaysia is in a humid and subhumid area but a model for economic returns, equity of benefit distribution, successful institution building, and ecological sustainability.

To get beyond mere statistical correlations, the review turns to OED's own impact evaluation studies, to its more perspicacious audits, and to non-Bank research.

Themes in Irrigation Projects

The third part of the OED review selects a number of themes that emerge from OED evaluations and from non-Bank work by, for instance, the International Irrigation Management Institute (IIMI). Four of the most important themes that emerge follow.

Land Acquisition Delays Implementation. Implementation of surface irrigation projects is usually stretched out over a far longer period than the project appraisal anticipates. The Bank's management information system documents this. Evaluations of the 208 projects with a significant irrigation component attribute these lags to a shortage of borrowers' funding (46 percent of the projects have this problem), procurement problems (38 percent), problems with design preparation and changes (36 percent), shortages of construction materials (29 percent), the convenient, all embracing "institutional problems" (27 percent), problems with contractors (26 percent), land acquisition problems (22 percent), and more. Land acquisition is way back in seventh place. When the sample is narrowed to surface-irrigation projects, however, land acquisition moves from seventh to fourth place. It is only in reading audits of these projects that the land acquisition problems emerge as a salient feature. The picture varies markedly from country to country. Land acquisition is not mentioned as a problem in Romania, but is a major source of delay in the Banks' biggest irrigation borrower, India, and in a host of others. It is comforting to find that, despite the first statistical impression, the audit record confirms what people who have tried to implement a surface irrigation project in most countries have know all along—no matter how early you start it, land acquisition seems to end up on the critical path.

Over-reticulated Systems in Humid Areas. Is the design of surface irrigation systems too crude, too sophisticated, or about right?

The mindset with which irrigation problems are approached often determines the design solution chosen. Time and data almost never really permit the comparison of alternative solutions. Economic analysis is rarely used for design solutions. Professionals in the irrigation field seem often to retain the mindset established in their earliest field experience, be it the Canal du Provence or the Jordan River system. Some of these environments are much drier and water-scarce than others, which seems related to whether they spawned either intensive, high-tech or extensive, low-tech design solutions.

Obviously, there is no universal design solution. Yet a number of the most insightful recent OED audits find that irrigation design was overly sophisticated. The most striking examples are audits of certain projects in Indonesia, the Philippines, Malaysia, Thailand, India, and Yemen. All but one of the projects in this group were in very wet areas. The intensifications were different. On short, steep rivers, surface systems without storage were not able to expand dry-season cropping; their gates were not used because the canals ran full when there was water and not at all when there wasn't. In the Malaysian project, adding tertiary distributaries and drains to part of an earlier project did not increase output vis-a-vis the control area.

The design of some of these problem projects is the work of the best minds in the business. All but the Yemeni project are in areas well-endowed by nature for agriculture; generally there were already working irrigation systems that the projects were meant to intensify. The previously existing systems, and the new ones, have been and are preponderantly for growing rice. The innovations that have been introduced all involve increased reticulation and control—reticulation to bring the branches of the system closer to individual plots and control to permit the amounts and timing of water deliveries to or drainage from individual plots to be varied.

None of the OED evaluations find problems with overly sophisticated design in arid areas, except in the Yemen project mentioned above. Impact evaluations show that sophisticated systems with a high unit cost per hectare pay their way in arid areas, but so do relatively low-tech systems. Whether they use cutting-edge or conventional distribution channels, cross-regulators and gates, where the alternative to irrigation is grim enough, the irrigators and the bureaucracy seem to make the system work. In these arid areas, audits, impact evaluations, and PCRs don't mention wide gaps between how the system is supposed to function and how it does. They don't mention those at the head of the irrigation water taking everything and those at the end getting nothing. They don't mention destruction of the systems by irrigators.

One should not infer too much from these observations. They should, above all, not be a license to stop seeking technical solutions to the irrigation needs of the humid tropics, which have received well over half of total World Bank and IDA irrigation investment. The observations should, however, inspire some reflection.

Finding the Appropriate Degree of Discretion in System Operation. The high-tech versus low-tech debate in the Bank and outside is related to another debate that can be characterized in a number of ways. One characterization is the appropriate degree of discretion in system operation. If neighbors want to grow crops with different water requirements, say rice and tobacco, and if the irrigation system is to help them, then deliveries will have to be fine-tuned to meet their diverse demands, no mean feat in a big system. The discretion in water distribution that such a regime implies invites appropriation of various kinds: some irrigators take water they are not formally entitled to and some irrigation agency staff take informal payments for helping to accommodate these irrigators. (Economists will point out that this happens because the water is worth more than irrigators are paying.) Soon system deliveries hardly resemble design deliveries and often become quite chaotic. The evaluation record contains many examples of such misuse and sometimes degeneration of on-demand, water-to-crops surface systems.

One solution is to minimize discretion in operation. This implies a rigid system. It requires farmers to adjust crops to the water delivered, not system operators to adjust water deliveries to the crops farmers want to grow. *Warabandi* in the Punjab and adjacent areas is such a system. The rigidity, though, limits what the farmer can do, although an agile farmer might just be able to grow tobacco while his or her neighbor grows rice.

The broad view of the 208 projects in our sample is not going to resolve debates over the appropriate degree of discretion in system operation, that is, over crops-to-water versus water-to-crops, or over the appropriate degree and level of "structuring." About all that can be said is that, so far at least, low-discretion, crops-to-water systems like ungated *warabandi* are found only in semi-arid areas. There are some possible explanations, but these are hypotheses, not evaluation findings.

The fascination with *warabandi*-type systems, of course, stems from evidence that, where they are used, they work quite well. Our perceptions on this point are shaped not just by evaluation findings but also by the important work of Sampath, Seckler and Raheja (1988) who measured and timed canal deliveries in northern India and found that the system was delivering what it was supposed to when it was supposed to. The Bank's push to spread *warabandi* to southern and western India is an old one. And it has not yet worked, except very recently in the drier parts of Gujarat. Again, we don't really understand why. What has recently come to light from outside the Bank is that the same design and operational system in the same ecosystem across the border in Pakistan has all the problems of creative redesign of the system by head-enders, chaotic deliveries quite unlike those in the design, and no water reaching the tail, just like *shejpali* and other non-*warabandi* surface systems in southern and western India. This is the unmistakable conclusion of work done since 1987 by Bhutta and Van der Velde of IIMI (1992) on the Lower Chenab Canal. It is forcing us to re-think where low-discretion, crops-to-water, "structured" systems can, and could, work well, and why.

Water Charges, O&M, and User's Groups. Why group these three together? Of the nine areas of "institutional performance" our study looked at, performance was more often unsatisfactory than satisfactory in five of the areas. Two of these were monitoring and evaluation (M&E) and adequacy of final design. Everyone knows that M&E units rarely work satisfactorily, and not just in irrigation. Final design could always be better. The three other areas were water charges, O&M, and user's groups.

The Bank has devoted a lot of energy to irrigation cost recovery. There has been little effect. OED reviewed the situation in 1986 and said so (World Bank 1986). The Bank still feels that those who benefit from public irrigation systems should pay for what they get, and it apparently believes this for irrigation more strongly than it does in the case of roads, schools, and health services. The operational directive on this subject, however, has been softened to emphasize cost recovery to cover O&M (with some contribution to investment costs), which goal is far from being realized in almost all instances.

Why should costs cover O&M? It is an arbitrary standard. O&M cost has no particular relationship to the users's benefits. O&M is often performed by a monopolist—a branch of the irrigation department—with the efficiency and cost effectiveness characteristic of monopolists. It is fair to impose that particular cost on irrigators, and for what purpose?

Many people have come to believe that the purpose of cost recovery through water users' charges is to improve O&M. Common sense tells us that the satisfactory overall outcome of irrigation projects should be related to satisfactory O&M, and vice versa. The evaluation record does not show such a relationship. Only 57 percent of irrigation evaluations even commented on O&M. Of these, 45 percent found it satisfactory. Some 51 percent of irrigation evaluations commented on cost recovery. Of these, 32 percent found it satisfactory. The overall outcome of projects with satisfactory cost recovery was somewhat worse than for those with unsatisfactory cost recovery.

There is a relationship between the "grade" on cost recovery and on O&M. Three-fourths of the time, they are either both satisfactory or both unsatisfactory. As OED's 1986 study concluded, however "It cannot be assumed that this is a causal relationship..." (World Bank 1986.) The weakness of the relationship presumably stems from the usual practice of paying water charges directly to the central treasury. Whether the charges are paid or not has nothing to do with the money spent on O&M, or with the quality and timeliness of the work. There is no feedback. Why should there be a correlation?

If urging irrigators to pay water charges covering at least O&M costs (and some contribution to investment costs) doesn't improve O&M (and doesn't lead to increased collections either), what is to be done about poor O&M, which is clearly one of the most pervasive problems with public systems? Covenants by which the borrower promises to fund adequate O&M don't seem to help. There may be disagreement on what is "adequate" in physical terms and what is "adequate" will vary even more financially, depending on the efficiency of the O&M.

There is evidence (principally from outside the World Bank) that O&M is improved if whoever does it is financially autonomous. This was the major conclusion of Leslie Small's study for the Asian Development Bank (Small 1986). These conclusions stand to reason. If an irrigation department's O&M wing depends financially on water charge collections, and if it doesn't keep the system working, irrigators will tend to stop paying. Irrigators and O&M engineers become acutely aware of the link between payment and results and payment. With financial autonomy, however, irrigators are paying for O&M. Irrigators may hire the irrigation department O&M wing, or they may hire somebody else, or they may "pay" themselves by doing the work themselves. This solution that achieves cost recovery up to the amount of O&M expense at least, generates O&M up to the quality demanded by the irrigators, and even involves the now-popular privatization.

All of these solutions require group action by irrigators—something almost everyone supports, but which is difficult to achieve. Only 30 percent of Bank irrigation evaluations even mention water users's groups. Ruth Meinzen-Dick and Michael Cernea (1991) have at least found that Bank appraisal reports are paying increasing attention to irrigators' groups. A lot of that attention, however, is just ex ante; it is what project officers put in staff appraisal reports because that is what bosses like to hear. Ex post, evaluations judged that groups were operating satisfactorily in less than half (45 percent) of projects where they were mentioned. And there is no evidence of an improving trend.

Under what conditions do irrigator's groups form and what tasks can they usually tackle successfully? The evaluation record has little to say, but Shui Yan Tang, Elinor Ostrom (Tang 1992, Ostrom 1992), and others at the University of Indiana have been collecting and reviewing empirical studies of such groups and have some conclusions that may be summarized as follows:

- Organizations that endure operate with clearly defined boundaries as regards the area they serve, who can belong, and their functions.
- Member contributions are proportional to benefits.
- There is no taxation or altering water-allocation rules without representation.
- Auditors of physical conditions and irrigator behavior are accountable to irrigator members.
- Rule violators suffer punishments that fit their crimes.
- Users and their officials have low-cost, local ways to resolve disputes.
- Government recognition is not necessary but governments must, at least, not challenge the irrigators' groups.
- Organizations are formed of "nested" groups of very small and larger organizations, each with its appropriate responsibilities.

Tentative Nature of Conclusions

The above are not all the points to be covered in OED's irrigation review by any means. They have a tentative quality, and must be treated accordingly. Many of the things we would like to know about what makes irrigation work well or not so well just cannot be known from the evaluation record. It is as if we had looked for jewels scattered on the ground at night. We have picked up and presented only a few that happened to be under the street light. It would be dishonest to pretend to have done more. A study of this breadth has at least the virtue of revealing enough unsolved problems to assure full employment for irrigation engineers, economists, agronomists, and sociologists for a long, long time.

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HOW IRRIGATION COULD BE IMPROVED: RESULTS OF A SURVEY OF PROFESSIONALS

Bill Battaile and William A. Price[*]

The results of irrigation projects are usually concrete. Unlike the results of some of the World Bank's agricultural extension projects, education projects, or "structural adjustment" loans, the results of irrigation lending can be readily seen and measured. Similarly, problems with irrigation projects are often relatively easy to identify. In order to pool knowledge and perceptions concerning the major problems in irrigation projects, the Bank's Asia Technical Department conducted a survey of professionals from many disciplines who are working in the field of irrigation in developing countries. The results suggest some common perceptions and some interesting differences in perceptions of the problems with irrigation.

Initial Survey

In March 1992, the irrigation group of the Bank's Asia Technical Agriculture Division (ASTAG), which has since been dissolved during a reorganization, held a series of sessions to list all of the problems in irrigation. After eliminating duplication, 129 problems were sorted into 16 major problem areas. These 16 categories and the problems they cover are listed in table 1. The ASTAG group then asked each person to allocate a fixed number of points among the sixteen categories to show the relative importance of the problem areas in irrigation. All but one of the seven ASTAG respondents were engineers.

In non-engineering circles one often hears, unofficially of course, that engineers have a professionally biased view of irrigation's problems. Such remarks have been heard in the World Bank's Operations Evaluation Department (OED), which monitors irrigation loans, and which is staffed mostly by economists. Engineers, on the other hand, have voiced the opinion that OED pays excessive attention to cost recovery and economic policy issues and not enough time to design and construction quality. To test perceptions of irrigation problems, OED's irrigation evaluators were assigned the same task as the staff from ASTAG: allocating the fixed number of points among the 16 major problem areas according to their importance for irrigation in developing countries. Five OED staff responded.[1]

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1 One OED respondent did not quantify a ranking, but gave qualitative responses in support of the overall OED "economist" view.

As shown by figures 1 and 2, there is a remarkable amount of agreement between the ASTAG "engineers" and the OED "economists". A reference line of 6.25 points shows the average level of importance if all 16 categories of problems are ranked equally. Both groups show similar results for over 60 percent (10 out of 16) of the categories. For instance, both groups isolate irrigation system design (category 3) as a very important problem area for irrigation projects. This category has the largest aggregate score for the two groups. Both groups also agree that planning and resource assessment (category 2) and the effectiveness of World Bank project preparation and appraisal (category 15) are prominent problem areas. The two groups agree about problems in the very early stages of the project cycle. In the later project implementation stage, system water operations (category 8) is also identified as an important area. This reflects concern over the availability of water, equity over the service area, and the timeliness, quality, and reliability of water delivery to the user.

There is also a strong agreement between ASTAG and OED staff as to what are *not* major irrigation problems. Various agricultural factors (represented by categories 5, 10, and 11) are not major problem areas. The processing, marketing, and transport category (category 12) is also not ranked high in the problems posed for irrigation. The consistencies between what are and what are not ranked as problems suggest areas for future attention.

The "engineers" and the "economists" did differ in several areas. ASTAG staff perceive the biggest problem overall as project implementation (category 7), which is given a less-than-average ranking by OED staff. This category includes a focus on procurement or bidding (or both), management, supervision, technical assistance, and consultant performance. Other categories significantly more important to ASTAG staff are basic data availability (category 1) and system maintenance (category 9). On the other hand, OED staff stress outside project factors (category 6) and other project elements (category 13) more heavily than ASTAG staff. These results are striking. They suggest that there is some professional bias within the irrigation fraternity, but that it is not overwhelming, and that the areas of agreement are more numerous than the areas of disagreement.

Can we be sure these differences are primarily because of professional background? It is possible the differences reflect a contrast between experience with irrigation projects in Asia versus a more global experience. Also, ASTAG staff worked on project preparation, appraisal, and implementation, while OED staff evaluate irrigation projects after Bank supervision has ceased. Is this, rather than professional training, the main reason for different rankings? Finally, the results are based on small samples. How rigorous are they?

Irrigation and Drainage Seminar Survey

The same questionnaire was circulated at the Ninth Irrigation and Drainage Seminar held in December 1992. The self-classified participants in the study included 38 engineers, 10 agriculturalists, 18 economists, and 3 "others" (whom we will call sociologists). The economists in the sample were not project evaluators and are assumed to have experience at the same project stages as the other seminar participants. The results by professional group are presented in the figures 3–6 following.

Compared with the ASTAG and OED results, the responses are more evenly distributed among the categories. The seminar participants had a short time in which to make their judgements—this might tend to make the emphasis more uniform. Seminar participants as a whole emphasize World Bank preparation and appraisal far less. The larger sample size allowed agronomists to stand out as accentuating agricultural support design (category 5) and agricultural technical support (category 10) while giving agricultural production factors (category 11) below-average emphasis (as did other groups). Overall, the seminar respondents stress system maintenance and drainage system design more than the ASTAG and OED respondents.

Survey Lessons

The relative problem areas emphasized by the seminar engineers are consistent with the results of the ASTAG engineers. Both groups of engineers chose the same top six categories. They also agree on the below-average importance of eight of the ten remaining categories. The seminar group of economists, however, did not match the OED group as well. The seminar group of economists revealed more similarities with the ASTAG engineers than with the OED economists. This suggests that the *stage* at which professionals deal with irrigation projects influences perception of the problems. OED economists (who evaluate irrigation projects after implementation) discount the importance of project implementation and basic data availability; they choose other project elements as problem areas. OED economists are also the only group surveyed that rated system maintenance as a below
-average problem. Most areas of difference between economists and engineers noted above are not supported by the evidence of the larger seminar sample. Outside project factors (category 13), however, are more important to economists across the board. Economists believe factors such as macroeconomic disturbances are significant problems while engineers and agronomists (and to some degree sociologists) do not.

This exercise has important lessons for the next generation of irrigation and drainage projects. At the very early stages of the the project cycle, there is agreement among disciplines as to what the problems are. Heavy attention should be paid to design—particularly irrigation system design—planning, and appraisal. Indeed, an ongoing OED review of irrigation has found a very high level of unsatisfactory planning or design in irrigation projects. Project implementation and maintenance are areas that deserve particular attention later in the life of a project. On the other hand, agricultural production issues, including technical support, are not key problem areas. If irrigation systems can deliver water when, where, and in the amounts they are supposed to, farmers will know how to use that water. There is a clear consensus regarding these points. Given the complex nature of irrigation projects, to reach such collective understanding is significant. Differences between the responses, however, suggest continuing debate on the allocation of irrigation project resources.

Table 1. Perceived Irrigation Problems Grouped by Major Category

Number and Category	*Issues/Problems*
1. BASIC DATA AVAILABILITY	Water Resources Data
	Land Resouces Data
	Rainfall Data
	Soils Classification Data
	Temperature and Evaporation Data
2. PLANNING AND RESOURCE ASSESSMENT	Land Capability
	Water Availability
	Climactic Factors
	Crop Potentials
	Agriculture Planning
	Engineering Planning
	Feasibility Analysis
	Economic & Cost Data
	Topographic Mapping
	Assessment of Environmental Fatal Flaws
3. IRRIGATION SYSTEM DESIGN	Layout & Alignment
	Cropping Pattern
	Detailed Water Requirements
	Mode of Operation
	Sizing of Canals
	Hydraulic & Structure Design
	Construction Materials
	Constructability
	Design Standards
	Technical Design Capability
	System Layout
	Cost Effectiveness
	Plans and Specifications
	Tendering
	O&M Equipment Needs
4. DRAINAGE SYSTEM DESIGN	Basic Drainage Criteria
	Drain Layout
	Type & Sizing
	Disposal Requirements
	Plans & Specifications
	Tendering
5. AGRICULTURAL SUPPORT & DESIGN	Cropping
	Ag.Research
	Ag.Extension
	Fertilizer
	Pesticide
	Agricultural Processing
	OperationaL Equipment
	Credit
	Marketing
	Monitoring & Evaluation
6. OTHER PROJECT ELEMENTS	Environmental Design
	Institutions
	Financial Arrangements
	Audit Capability
	Monitoring & Evaluation
	Training
	Technical Assistance
	Government Clearances
	Land Acquisition
	Catchment Area Treatment

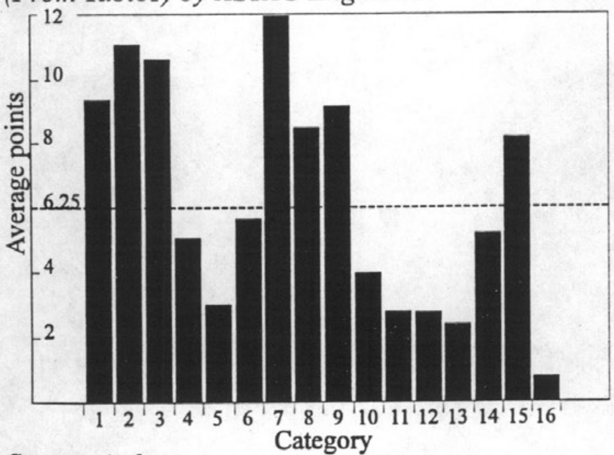
Table 1 (cont'd.). Perceived Irrigation Problems Grouped by Major Category

Number and Category	*Issues/Problems*	*Number and Category*	*Issues/Problems*
7. PROJECT IMPLEMENTATION	Procurement & Bidding Project Management Construction Quality Timeliness of Construction Timeliness of Programs Cost Control (Overruns) Personnel Management Project Supervision Training Technical Assistance Consultant Performance	**11. AGRICULTURAL PRODUCTION FACTORS**	Crop Varieties Cropping Patterns Pest Control Fertilizers Farm Equipment/ Labor Cultural Practices Climactic Conditions over Evaluation Period Environmental Impacts
8. SYSTEM WATER OPERATIONS	Bulk Supply Availability Equity Over Service Area Timely to User Quality as Promised Reliability to Farmer System Performance	**12. PROCESSING, MARKETING, TRANSPORT**	Support for Agroindustries Environmental Limitations Farmgate Prices Farm Cooperatives (Marketing or Pricing) Marketing Effectiveness Markets Available Road Net Adequacy
9. SYSTEM MAINTENANCE	System Facilities Maintenance Shops & Offices Organization Staffing Level Training Equipment Adequacy Funding Level Management/Timeliness Effectiveness	**13. OUTSIDE PROJECT FACTORS**	International Commodities Prices Country Monetary Policies Political Corruption Natural Disaster (Flood or Drought) Inflation
10. AGRICULTURAL TECHNICAL SUPPORT (AFTER OPERATIONS)	Ag.Extension Access to Info. Water User Associations Ag. Research	**14. COST RECOVERY TAXATION, REGULATIONS, AND BENEFITS**	Farmer Repayment Capacity Water Charges Other Charge Mechanisms Product Taxes Land Taxes Other Constraints Profit Levels Net Income Change

Table 1 (cont'd.). Perceived Irrigation Problems Grouped by Major Category

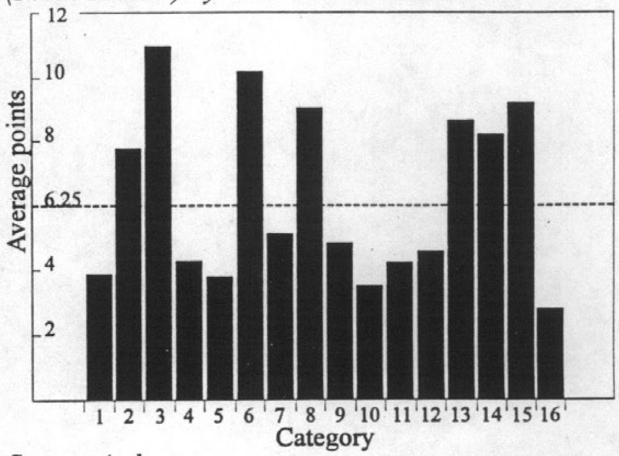
Number and Category	*Issues/Problems*
15. EFFECTIVENESS OF WORLD BANK PREPARATION & APPRAISAL	Technical Initiatives Influence of Project Formulation Internal Rate of Return Adequate SAR/ Preparation Technical Initiatives Adequate Supervision Components Complete Supplemental Project/ Follow-on Project Needed
16. OTHER FACTORS	War Civil Disorder Political Disruption

Figure 1. Rating of Irrigation Problem Categories (From Table1) by ASTAG Engineers



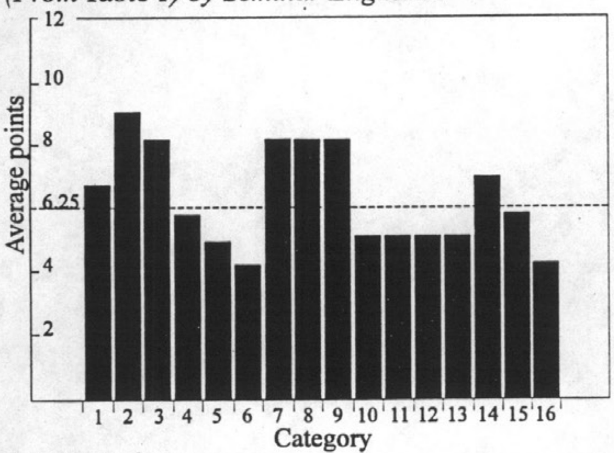
Source: Authors

Figure 2. Rating of Irrigation Problem Categories (From Table 1) by OED Economists



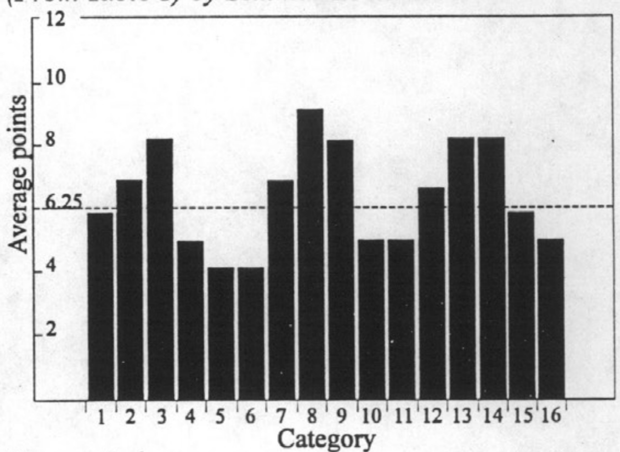
Source: Authors

Figure 3. Rating of Irrigation Problem Categories (From Table 1) by Seminar Engineers



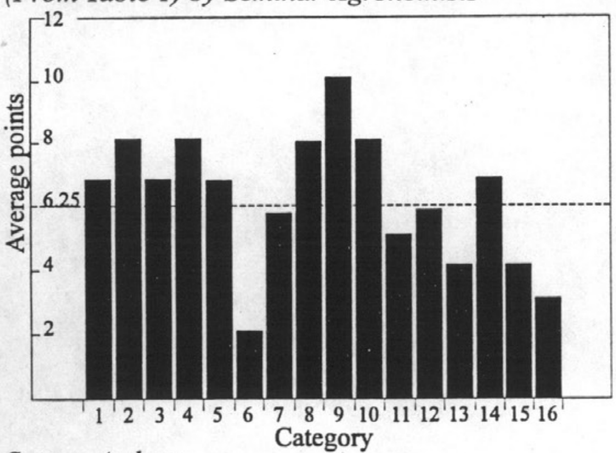
Source: Authors

Figure 4. Rating of Irrigation Problem Categories (From Table 1) by Seminar Economists



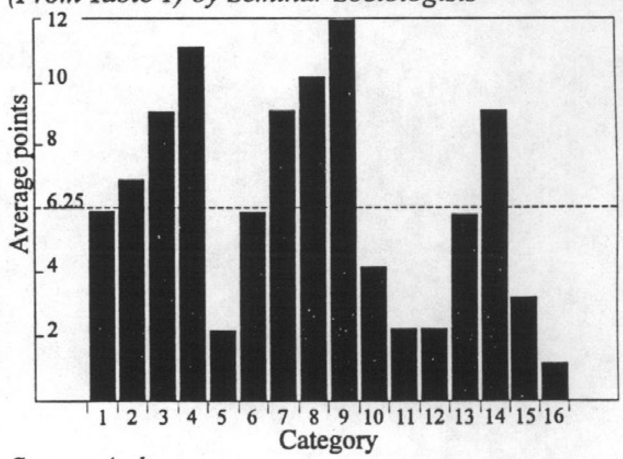
Source: Authors

Figure 5. Rating of Irrigation Problem Categories (From Table 1) by Seminar Agronomists



Source: Authors

Figure 6. Rating of Irrigation Problem Categories (From Table 1) by Seminar Sociologists



Source: Authors

Section III

Water Markets

OBSERVATIONS ON WATER MARKETS FOR IRRIGATION SYSTEMS

Richard Reidinger[*]

Although originally asked to address the subject of water markets in East Asian rice cultivation, I would instead like to describe three water markets I have observed. I am not familiar with water markets in East Asia; moreover, I doubt such markets would be very effective in the continuous flow irrigation systems that are the norm for rice cultivation in the region. In these systems, rice cultivation relies on a continuous supply of water. Selling the water would necessitate interrupting the continuous flow and would probably be unacceptable to users. In addition, most irrigation systems in East Asian rice cultivation lack the necessary water control or canal capacity (or both) to respond to changing water delivery demands during the growing season that would result from water market operation. And where irrigation service is paddy-to-paddy, the institutional marketing arrangements would be very complicated; the marketing of water by one farmer would affect many others on the same outlet.

None of the three water markets I would like to describe involve rice cultivation. The descriptions will not be rigorous, but should give some idea of the conditions under which water markets can function and of their limitations. The three cases are from Spain, the western United States, and northern India.

Before starting, I would like to clarify what I mean by water marketing. First, these are "micro" water markets, that is, water markets between similar users (farmers) in the same irrigation system. Indeed, a more accurate term might be "water rental" because the basic use right is neither sold permanently nor divorced from the owner of the land. The markets are *not* "macro" or intersectoral water markets, or those involving interbasin transfers. Far be it from me to argue the free-market economic justification for monopsonistic water buyers who are also monopolistic water sellers to users who substitute irrigation of lawns for crops. I do not want the job of justifying that in our client countries! Second, the water markets described are limited, special purpose markets in which the objective is very simple: to transfer the limited water available to the system at any given time to higher-value uses. Finally, in two of the cases, the process may be more accurately referred to as trading rather than marketing. The buyer does not pay the seller for the water transferred.

The purpose of this paper is to stimulate discussion. The market-oriented model (and its shortcomings when applied to water) is not new in economics, and there is no need to rehash that body of literature. The three cases below are intended to show that "micro" water marketing or trading does function in irrigation systems, and it seems to add to their overall economic efficiency. However, it works under very specific conditions—the institutional requirements in particular are intricate and rigorous. Finally, in addition to the three cases, I

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will present some thoughts on how water marketing could be enhanced and formally used in northern Indian irrigation systems to help improve their performance with minimal change in the existing physical or institutional framework.

Spain: The Huerta of Alicante

Alicante lies on the Mediterranean coast of Spain, just south of Valencia. The *huerta* (irrigation service area) of Alicante has been in continuous operation for hundreds of years.[1] The *huerta* comprises 3,700 ha of fertile land and receives water from four different sources: a reservoir, two interbasin transfer canals, and local groundwater. Sixty-three percent of the farmers own 1 ha or less. The irrigation system is owned, operated, and maintained by a water user association (WUA), the Community of Irrigators. The predominant characteristics of the water supply are:

- It is scarce and irregular; total water available is only some 23 percent of what the area could use.

- It is partly divorced from the land. The *huerta* and its members own or control only part of the water rights they use (the so-called New Water from the Tibi Reservoir that they constructed in the late 1500s and that accounts for about 30 percent of the total water used). They purchase the remainder.

- It is paid for and delivered by volume (actually flow time in minutes at a constant flow rate of 150 l/sec).

Thus, there is a strong demand for very limited water, only part of the water used is directly owned and controlled by the WUA members, and water charges are volumetric. The allocation procedure is a public water market or auction that is held every Sunday morning in the village of San Juan in the middle of the *huerta*. Market prices for water from each source reflect its relative scarcity and value at any given time. What is actually purchased at the market are tickets for the right to take a fixed flow for a certain amount of time during that particular cycle of canal flows. The tickets thus correspond to traded water rights. The tickets are owned by both irrigators and non-irrigators, and some are owned by the WUA itself, which uses the proceeds from ticket sales to cover operating costs. Since only enough tickets are sold to correspond to water time that is actually available, an absolute balance between supply and

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1 Scott-Moncrieff (1863) and Hall (1886). The authors' technical and institutional descriptions of the irrigation systems are on the whole still valid. They are of particular interest because in both cases the studies represented an effort to learn from other country experiences, and because the authors' observations had long-term effects in other countries, the first in India and the second in California. One can see the genesis of both the *warabandi* system in northern India and the *shejpali* system in western India in Sir Colin Scott-Moncrieff's descriptions of irrigation in Spain. For a more contemporary analysis and description, see Maas and Anderson 1978, which compares operating rules and economic performance for three irrigation districts in the United States and three traditional irrigation systems in Spain, including Alicante.

demand is maintained. Simulation model analysis indicates that the Alicante type of water market or trading allocation produces the highest net financial returns, compared with the fixed-limited and fixed-unlimited rotation systems of Murcia-Orihula and Valencia (Anderson and Maas 1971).

The flexible market system allocates available water supplies to the highest-value uses during the season, whereas the other two rigidly apply fixed water allocations to prescribed users regardless of the value in use.

United States: California Irrigation Districts

Years ago I visited a large number of irrigation districts in California and contacted many more. One of the questions I was interested in was how the districts resolve the inevitable mismatch of water supply and demand for their individual water users, and whether this resulted in water trading among their members. The example of water trading that I most clearly remember was the Southern San Joaquin Municipal Utility District, which also served a large irrigation area. Although water trading in California irrigation districts was not universal, it was widespread, especially where water was relatively scarce. Further research showed that water trading was also common in other western states.[2]

Farmers served by the District had to contract or commit to buy a certain amount of water before the beginning of the crop season, the total amount of which was limited by their water rights (actually, by this time they were the District's water rights). Once contracted, they had to pay for the water regardless of whether or not they actually needed it or took it. (Their water charge was a combination of a fixed annual assessment plus a volumetric fee.) For an individual farmer, a mismatch in water supply and demand could and did frequently occur when conditions changed during the season, after the farmer had contracted for the water. At the same time, all the farmers wanted to order enough water to be sure their needs were met, but not too much because they would have to pay for the excess whether they used it or not. The same problem was magnified for the District. Based on the demands of its members, the District contracted to buy a total volume of water at the beginning of the season, and had to pay for that amount regardless of whether the irrigators actually took the water. Keep in mind that the farmers own the District and as a group pay its annual operating costs through their water fees; they would hardly want to pay for water that was not needed.

This was the dilemma of the manager or water master of the District. This person's job was to make sure the District ran efficiently and wasted no water. However, some farmers always had a little extra water, while others were a little short. Furthermore, in years when water was short, a little more of it was much more valuable to some farmers than to others. For

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2 Accounts of water trading and water markets in the western United States go back decades, although they have rarely received much general attention; see Hutchins 1936, Anderson 1961, and Gardner and Fullerton 1961. However, for California itself, little appears to have been documented specifically on water markets in irrigation districts, although the practice was well established and widespread in California irrigation districts. Bain, Caves, and Margolis 1966 has a general analysis of efficiency and institutions in the development of present-day irrigation in California; see also Goodall, Sullivan, and De Young 1978, and Hartman and Seastone 1970.

each farmer, the incremental amounts of water needed were not large compared with the total, but all knew that a little water at the right time would often produce a large yield increment.

The question was how to meet these conflicting demands; the answer was simple. The water master maintained a log and bulletin board of potential water sellers, buyers, and amounts; that is, of water supply and demand. The water master simply matched buyers with sellers over the phone. Water buyers were billed by the District for the incremental water they received, and water sellers had their payment obligation reduced by a like amount. In this case, there was no actual water market like Alicante, but the effect on water allocation was the same. Water was traded from lower-value uses (or waste) to higher-value uses during the season. Farmers the world over never have enough irrigation water; there is never "excess" in their eyes. They certainly know the value of it, however, especially when they have to pay for it by volume whether they use it or not, as in this case. Because the District was required to make deliveries to individual farmers according to their specific water orders (on a "limited demand" basis) under normal operations, the physical system had sufficient water control capability to deliver these incremental amounts to the buyers as required.

The main difference from Alicante was the yardstick or "market" price of the water. The water price in the District is actually the fixed volumetric rate that the farmers normally pay, which was probably relatively low compared with the actual value in alternative uses. In Alicante, the price at a given water auction reflected the actual value of the water to the buyer. The Alicante water market may therefore result in a more economically efficient allocation.

Northern India: Punjab/Haryana

In the late 1960s, I worked for several years with farmers served by the Bhakara Canal system in what is now Haryana (Punjab until 1966). Covering hundreds of thousands of hectares, the Bhakara system is well known as one of the best-performing irrigation systems in India, despite the very low design duty for water that itself is sufficient to irrigate only about one-third of the command area each season. To us in the World Bank, the most well-known aspect of this system is probably the *warabandi* system of rotating water turns among farmers. Under the *warabandi*, each farmer on a given watercourse should receive his water on fixed day of the week during a specific time period. Theoretically, he should receive his water every week according to the *warabandi* schedule. In practice, however, the farmers could not depend on receiving their water each week and frequently went three or four weeks between irrigations. This had little effect on the traditional crop varieties, but damage to the modern high-yielding varieties was frequently severe. The operating engineers, on the other hand, were generally following their operating rules as closely as they could; although they could do nothing to help the problem, they also did not seem to be its cause.

What was the cause of such uncertainty in one of the most modern and highly revered irrigation systems in India? A number of factors were involved, but the most important appeared to be the mismatch between the seven-day *warabandi* rotation and the eight-day rotational and priority program for the supply canals. The details are too complex to cover here

(Reidinger 1974, 1980).[3] The uncertainty that resulted, however, was clearly very costly to the farmers. It lowered their yields, reduced response to fertilizer, forced them to grow low-profit but drought-resistant crops, and wasted much water. Their main response was to install their own tubewells. With the new high-yielding varieties, a little water at the right time was highly beneficial, and often they could recover the cost of the tubewell in a year or two.

Another response to the uncertainty was for the farmers to trade *warabandi* turns among themselves. Such trading was illegal without the consent of the operating engineers (which in any event was never given). The trading was only among farmers on the same watercourse, and generally only between neighbors; that was the only way that the trading could be considered safe by the farmers, for they had no legal recourse if the recipient in one rotation did not return the favor during the next rotation. The trading was almost entirely short-term, turn-for-turn trading during the growing season. However, there was some direct selling of water turns by farmers who were unable to cultivate their land. In general, although water trading was common and widespread, the amount of water actually traded was small relative to total deliveries, and the amount traded was only significant during times of water shortage. Similar water trading has been documented in the irrigation systems of the Pakistan Punjab, which have similar conditions. Water trading in the Punjab follows the same operating rules, including the *warabandi* system. In 1982, I appraised the Haryana II Project in the same area and found that water trading among farmers was alive and well, even in areas where there were tubewells.

The Bhakara water trading was in effect a limited water market, for the same purpose as in Alicante and California. It helped farmers balance their water needs (demand) and supplies. There are several reasons why it could function.

- The Bhakara irrigation system, like Alicante's, was designed to deliver constant, measured flow rates; the *warabandi* specified the period of time for each farmer. Although deliveries were not controllable, they were at least volumetric

- The *warabandi* itself established a de facto water right, or more correctly an access right to the water flow. The water right was enforced under the law by both farmers and engineers, and this is what was traded, albeit illegally. The principles of the *warabandi* are well known and accepted among the farmers of northern India as standard operating procedure.

- As in both Alicante and California, there was a strong water users' organization present. The Bhakara watercourses were originally constructed though local "shareholder committees" that formed close relationships and a sense of ownership among the users from the beginning. Although these committees had no legal standing, they were still closely involved in supervising the operation of the *warabandi* and watercourse maintenance.

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[3] More recent findings by Indian researchers in northern India indicate similar uncertainty for *warabandi* water deliveries. A recent study in Pakistan indicates that similar problems with the myth and reality of the *warabandi* extend to the northwest frontier; see Bandaragoda and Garces-Restrepo (1992).

Using Water Markets in Northern Indian Irrigation Systems

Farmers in northern India have by and large adapted to the uncertainties of their canal water supply through tubewells, water trading, crop patterns and varieties, and other farming practices. Some of these options are costly, however, and they may not be feasible for all farmers and areas. As an alternative, it may be possible to reduce or eliminate much of the uncertainty through institutional means, with relatively little change in the hardware of the system. This would involve:

- Some relatively minor changes in the operating rules of the canal system (the changes are required to make the rotational periods of the supply canals and the *warabandi* match)
- Establishment of formal (legal) WUAs at the watercourse level that would facilitate and oversee water trading as well as distribution
- Legal acknowledgment that the *warabandi* in fact provides a legal water use right that can be traded by the owner
- Enhancement of water trading or markets at the watercourse level, perhaps including improvement of the watercourse to provide better water control (small structures and lining).

The details of this proposal are outlined in Reidinger 1974. It should be emphasized that these options would not obviate the need for tubewells; northern Indian systems by design are very water-short, and additional water has a high value. However, more certain canal water deliveries, with increased flexibility from water trading, should increase the use efficiency for both canal and tubewell water, and the investment cost would be low. With the appropriate social engineering, these changes should be applicable for much of northern India as well as Pakistan.

The cases reviewed above suggest several important (albeit general and preliminary) conclusions about the potential for intra-seasonal water markets and water trading in irrigation systems. Water marketing or trading systems function under diverse conditions ranging from relatively modern systems in the western United States to an ancient system in Spain to modern-day but traditional irrigation systems in India. It appears that the practice grows out of the need of farmers to maximize the irrigation benefits in systems when water supplies are short and the opportunity cost of water is high. The water market process can be the primary method of water allocation, fully integrated into the institutional operating framework as in Alicante; it can be a secondary method of internal reallocation used informally but explicitly to meet operating requirements and improve technical and economic efficiency as in the western United States; or it can be a completely informal (indeed illegal) method developed spontaneously among water users to provide at least some flexibility in a rigid water allocation system as with the *warabandi* system in northern India. Three key conditions appear necessary for such water markets to function effectively: water rights must be clearly specified and legally enforceable; water supplies have to be reasonably reliable and delivered on a measured basis; and water user organizations, whether formal or informal, must be functional and effective.

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CHILE'S MARKET-ORIENTED WATER POLICY: INSTITUTIONAL ASPECTS AND ACHIEVEMENTS

*Renato Gazmuri Schleyer**

One of the most dramatic changes in the last twenty years has been the continuing development of an international consensus favoring free-market economic policies and repudiating the government's role as an owner of resources. In the early 1970s, Chile, with a history of democracy and capitalism, had become an economy that was more radically socialist, highly centralized, and regulated than the economy of any other country in the so-called free world. Aside from regulating the economy and fixing the most important prices, the state owned practically all the productive system of both goods and services, leaving no room for private initiative. Immediately after the change of government in 1973, the most orthodox market-oriented social and economic policies were applied. The policies were based on private property, market allocation of goods, private businesses supplying goods and services, open trade, and a small, strong, state sector. Both the radical application of socialist policies (which meant expropriation of water rights) and the shift to new social and economic concepts occurred in a very short time, and both were key factors in determining Chilean water policy from 1974 until the present.

The goals of water policy in Chile are familiar to natural resource economists, especially water specialists, throughout the world. The tools, however, are different from those chosen elsewhere. Among the goals are increasing the availability of the resource (mostly through increases in efficiency—physical and economic), exploiting new sources only when absolutely necessary, and minimizing any ecological damage from new infrastructure or from different uses of water. The policy goals also of course include improving water quality and avoiding third-party effects. If third parties are adversely effected, one objective is to guarantee compensation.

Chile has developed legal and institutional means to reach these goals, beginning with the basic definition of water rights. This paper provides an outline of these rights and of the legal and institutional basis of enforcing them, including the role of government authorities and the state's role in the development of infrastructure. In its final section, this paper focuses on the impressive achievements of Chile's market-oriented water policy in the 18 years it has existed.

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Legal and Institutional Framework

In general, Chilean water law entitles secure water rights that are both tradable and transferable. The prevalent form of these rights are proportional rights (shares) over a variable flow or quantity; deeds stipulate an owner has the right to a number of shares at a certain location. These rights are expressed in volume by unit of time (liters per second or cubic meters per year or month) and are aliquot (proportional) if supply is insufficient. Water is allocated by the market within and between sectors, and the law provides effective protection from detrimental third-party effects. Water users are organized in strong and compulsory users' organizations, with faculties to solve most conflicts between members. The law provides judiciary recourse for conflicts not solved by users' organizations or government water authorities. Before turning to an outline of basic water rights, it would be useful to identify some of the main government and other institutions involved in water management.

The General Directorate of Water (Dirección General de Aguas, or DGA), under the Ministry of Public Works, is responsible for water development planning. The Directorate supervises the National Hydrometric Service and is responsible for vigilance over natural inland waterways. It also publishes data and funds and manages studies of water resources. It is also in charge of entitling original rights (either originating from prescription or requests for rights to available water), keeping the National Official Water Record (Catastro Público de Aguas), approving all major hydraulic works, authorizing private irrigation infrastructure, and looking over hydrologic (not economic) third-party effects.

The National Irrigation Commission (Comisión Nacional de Riego, or CNR) is in charge of national irrigation planning and of evaluating and ranking state-financed projects for irrigation infrastructure. In conjunction with the Directorate of Irrigation (below), CNR supervises the bidding for the construction of infrastructure.

Directorate of Irrigation (Dirección de Riego, or DR) is primarily in charge of the preparation and supervision of state-financed irrigation projects once they have been approved by the CNR. The construction itself is let for bid to private construction companies.

The Ministry of Commerce (Ministerio de Economía) fixes public monopolies' rate charges, taking into account the underlying costs. Water rates are applied to urban water and sewage companies regardless of their ownership.

Users' Associations are a very important factor in the enforcement of water rights and in self-regulation of water users, including collecting fees for the construction, maintenance, and administration of infrastructure.

Water Rights

In Chilean law[1], water is considered a public good but individuals can obtain private rights over water by receiving a grant from the state, by prescription, or by purchasing water

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1 Aside from the Constitution, the legislation most relevant to water is the Civil Code, the Water Code (Law 1.122-1981), the National Irrigation Commission Law (Law 1.172 of 1975 reformulated in 1981) and the law regulating state-financed irrigation or multipurpose infrastructure (Law 1.123-1981).

rights. The Constitution of Chile (passed in 1980 and modified in 1988) provides that "The rights of private individuals, or enterprises, over water, recognized or established by law, grant their holders the property over them."[2]

The Water Code, introduced in 1981, integrates previously piecemeal legislation. There are three sections: the first covers definitions and concepts concerning ownership, development, and exploitation of water; the second elaborates administrative and judicial procedures and regulations; the third establishes the functions and procedures of the DGA and establishes rules for the construction of certain water works.

The Water Code establishes the basic characteristics of water rights. The right to utilize water is an actual or real right that confers ownership to its holder. The owner is entitled to use water, obtain benefits from it, and dispose of it, and water rights can be alienated from land and mortgaged. According to the Water Code, rights of use are consumptive or non-consumptive. Their exercise can be permanent or contingent, continuous or discontinuous, or rights may alternate among several persons. *Consumptive rights* entitle the holder to completely consume the water in any activity without any obligation to replenish it. *Non-consumptive rights* allow the holder to use water but compel the owner to restore the water at a stipulated quality or in a manner (or both) set forth in the deed or private contract evidencing ownership. Water extraction or restitution must always be accomplished in a way that does not adversely affect the rights of third parties over the same water in terms of its quantity, quality, and use opportunity. Non-consumptive rights do not imply any limitation to the consumptive rights that may exist over the same water.

Permanent water rights allow the owner to use unexhausted sources of supply every year without restriction. As stated previously, rights of use are expressed in volumes per unit of time. In the case of permanent rights, water can be used in corresponding volumetric shares, except when the source of supply is insufficient to satisfy them fully. In this case the available volume will be distributed proportionally. This applies both to surface and underground waters. *Contingent rights* empower the holder to use water only after the main waterway has a surplus volume, that is, after the needs all users with permanent rights have been met. Lake or dammed water is not subject to contingent rights. *Continuous rights* allow water to be used uninterruptedly 24 hours a day, every day in the year; *discontinuous rights* only allow water to be used during certain periods. *Alternate rights* are those where use is distributed among two or more persons in successive turns.

The trade, transfer, or loss of the right to utilize water is performed according to the provisions of the Civil Code, unless otherwise regulated by the Water Code. Obtaining and documenting water rights that were previously owned by the state is a feature of the Water Code. The rights to utilize water are originally granted by act of authority. The authority and associated rights can be obtained on the basis of prescription or simply for water that is available or surplus. The other means of acquiring rights is by outright purchase. Thus, there are three ways of obtaining rights: (a) by application on the basis of prescription; (b) by application or bidding for new or surplus water; and (c) by outright purchase in the market. The ownership

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[2] Constitución Política de la República de Chile, Chapter III, Article 24, final paragraph: "*Los derechos de los particulares sobre las aguas, reconocidos o constituidos en conformidad a la ley, otorgarán a sus titulares la propiedad sobre ellos.*"

of these rights is established by inscription of the right in the respective water registry of the property registration authority (Registro de Propiedad de Aguas del Conservador de Bienes Raíces). Grants of water use or deeds of purchase specify the type of right and the number of shares.

Of the methods of obtaining water rights mentioned above, prescription has been the most important given the state's expropriation of water rights in 1966. After 1966, a high proportion of state-owned water was assigned through precarious concessions, mostly to the same use, but not to the previous owner. The next step was that private owned water was progressively expropriated. By the early 1970s the state owned all the electrical companies, almost all the urban water services, and over 90 percent of the irrigated land. After 1973, privatization began and the agrarian reform was consolidated by distributing the state-owned farms (expropriated between 1966 and 1973) to 60,000 peasants and a few thousand former owners. In 1975, when Chile shifted from a highly regulated system where water rights were state-owned to a private, market-oriented one, the government, through administrative orders and transitory laws, froze the actual use of water at 1975 levels. Because of this sequence of events, most new water users had fairly good bases to obtain water rights that were established in 1979 (by Law 2.603 of the Ministry of Agriculture) through prescription.[3]

After prescription, the second most common way of obtaining water rights has been market transactions. Only a very small proportion of water rights has originated from grants over available water, either for unowned surplus water or for water from new infrastructure development. There is little available water left in areas that need irrigation, and that water that is available comes mostly from very deep rivers or streams or from deep aquifers. Chile has built virtually no new water infrastructure since 1975, limiting that source of new water rights.

Perhaps the most frequent transaction in the water markets is rental of water between neighboring farmers with different water requirements. Renting water offers greater flexibility for irrigation and increases efficiency. Payment can be in money or in use compensation.

Water rights transactions between different uses consist mostly of purchases of rights from farmers by the urban water and sewage companies. A typical case would be where one of the three companies serving Santiago buys water rights on the Maipo river from several farmers in order to provide water to a new housing development or new industry. The farmers would mostly sell a small portion of their rights, which they can dispose of because they are using irrigation water more efficiently. The farmers obtain an important amount of new capital in exchange for their water rights. A farmer who increases irrigation efficiency by 30 percent on a 40 ha grape plantation can dispose of water rights shares equivalent to 24 l/sec, for $7,000-$10,000.

Typical transactions within the same use would be sales and purchases of water rights between two urban water companies serving different sectors of the same city, or serving neighboring cities, or transactions among farmers.

In addition to specific rights and their establishment and transfer, the law addresses rights to specific kinds of water. Tail water running naturally into neighboring premises may be used

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[3] Between 1973 and 1979, water was regulated mostly by the Ministries of Agriculture, Finance, and Commerce, which had all the power granted by the 1966 agrarian reform law (Law 16.640), the 1969 Water Code, and the 1975 Law 1.172 that created the CNR.

by the recipients without the need to establish a right of use. The production of this water is contingent upon the flow of the main waterway and its distribution or use; there is no obligation to supply tail water and the supply is, of course, not permanent. Rights, liens, or easements on spillage and tail water can only be established in favor of third parties by way of a title deed.

Chile's Water Code has a chapter dedicated to underground water. Once the existence of underground water has been confirmed, the interested party may apply for the respective right of use. In general, the right to use underground water is covered by the same legal regulations applicable to the use of surface water; the Water Code, however, has some ad-hoc regulations for this type of water. First, the resolution granting the right of use to underground water will establish an area of protection in which the installation of similar works (for example, pumps) will be banned. Additionally, if the exploitation of underground water by certain users causes detriment to others who are legally entitled to the water, the DGR, at the request of one or more of the affected parties, may establish temporary and proportional reduction of the rights of use. By publishing a resolution in the official journal (*Diario Oficial*) this agency may also establish proscribed areas, barring any new exploitation therein in order to protect the aquifer. Where there is a serious risk of depletion of a specific aquifer, the DGA may also establish restricted areas in hydrogeologic sectors for common use. This will be done at the request of any user of the respective sector on the basis of the historical exploitation, if the user produces enough evidence that demonstrates the need for restricting access to the aquifer. This restriction will be imposed proportionately.

Where there is water that is available but not claimed by prescription, the DGA establishes rights by public bidding; public bidding may also be applied when two or more people request the same available water. Also, surplus water provided by new infrastructure (rights beyond the allocation of at least 50 percent of "new water" to those who are committed to financing the infrastructure) must be let for bid.

Mortgages on water rights must be executed by public deed and registered at the Water Mortgage and Lien Registry (Registro de Hipotecas y Gravámenes de Aguas) of the respective property registration authority (Conservador de Bienes Raíces). Rights are always encumbered with liens in order to guarantee the payment of fees owed for the use or acquisition of irrigation works, or the administration, distribution, maintenance, and water distribution expenses of the users' association. These liens have priority over any others. Acquirers of any title to rights will be jointly liable, together with their predecessors, for any rates outstanding at the time of acquisition. Users' organizations may deprive holders of the use of water in the event of nonpayment of the aforementioned fees and rates as well as if members extract water in excess of their allotment.

Easements

Water-related easements are governed by the provisions of the Civil Code, unless otherwise amended by the Water Code. Chilean law establishes the following types of easements: natural runoff, aqueduct, overflow and residual water, cattle watering, towpath, research, and voluntary easements. Two of the most relevant for farmers are aqueduct and cattle watering easements.

Aqueduct easement authorizes water to be conveyed through someone else's property at the expense of the interested party. This includes the right to build the necessary channels and waterworks as well as outlets to allow the water to empty into natural courses. The owner of the property through which these channels, waterworks, or outlets run will be entitled to receive by way of compensation the value of all land that is occupied and any improvements that are affected by the construction of the aqueduct. Occupied land will include a space on either side of an aqueduct not less than 50 percent of the width of the channel, with a minimum width of one meter along the entire length of its course (the minimum width can be increased if so agreed by the parties or if so directed by a judge). The property owner may modify the location of the aqueduct.

The property owner will also be entitled to receive compensation for any damage caused by the building of the aqueduct or by the seepage, spillage, and overflow that can be attributed to construction defects or bad management. Should any disagreement arise regarding the amount of compensation due, a judge will decide on the basis of expert reports. Building may start once the sum provisionally established as security for the final compensation has been paid.

Any town, village, hamlet, or property lacking the necessary water for its animals will be entitled to impose a cattle-watering easement. This easement consists of the right to take cattle along customary paths and tracks to drink on private property at established locations and on established days for a certain number of hours. Nonetheless, the owner of the property may sell the rights of use.

Regulations

One of the most discussed issues in water policy is priority in the use of the resource. There is no priority in Chilean law. When no other means are available to satisfy the domestic water needs of a locality, rights of use may be expropriated for reasons of public welfare, and prior payment of compensation must be made. The expropriated party must be left with enough water for domestic use. To assure rights of third parties, any transfer of the rights of use (not the trade itself) of natural watercourses requires authorization from the DGA. This authorization will only insure the absence of damage in those third-party effects covered by the Water Code, which are effects on water rights or on hydraulic infrastructure. The respective application will be announced in the *Diario Oficial*. Those with hydraulic infrastructure that would be affected by a transfer of water rights to natural watercourses may file relevant motions before the respective user organization and the DGA. In order to obtain authorization to transfer natural watercourse rights, the interested party will assume responsibility and cost of constructing any works that may be necessary to avoid affecting the water rights or the infrastructure belonging to third parties.

The merits of constructing any new water-related infrastructure will be determined in the first instance by the DGA and, upon appeal, by the judiciary. Any disagreement arising about compensation due because of detrimental effects of building water infrastructure will be settled by a judge. Operation and maintenance of new waterworks will continue to be incumbent upon the entities that operated and maintained the original system (users' organizations). If the necessary modifications involve an increase in operation and maintenance costs, the interested party will pay the resulting higher cost.

Ownership of rights of use may lapse in circumstances established by ordinary law and in the manner prescribed thereby. These are fundamentally expropriation, loss of sources of origin, sale, or barter, acquisitive prescription by third parties, and enforcement of mortgages or liens.

Intervention of Authorities

If the directors or managers of any users' organization commit serious offenses regarding the distribution of water or if they misuse their authority, any of the affected parties may request the intercession of the DGA. If the reported errors, offenses, or misuses should continue, the DGA may request the courts to order that the DGA control the distribution of water for periods not exceeding 90 days. All of the authority of the directors or managers would be exercised by persons appointed by the DGA. This has not happened yet.

The DGA is also empowered to undertake vigilance over water in natural channels for public use and will prevent the building, modification, or destruction of waterworks along natural channels unless prior authorization has been obtained.

The president of the Republic, at the request or upon the report of the DGA, may declare drought zones during extraordinary dry periods for maximum and non-deferrable six-month periods. The DGA will determine, by resolution, the drought periods that are to be considered extraordinary.

Once a drought zone has been declared, if no agreement is reached between the users regarding the distribution of water, the DGA is empowered to distribute for public use water available in natural waterways and in channels that impound water from them. With the aim of minimizing the general drought-induced damage, the DGA may suspend the authority of the users' organizations. Any holder of rights who might receive a lesser portion of water than is their due (in accordance with existing availability) will be entitled to state compensation for the lost portion.

Water accumulated in private dams is not subject to any drought zone declaration. In natural currents or artificial channels where no users' organizations have been established, the DGA may, at the request of one of the parties, take charge of water distribution in declared drought zones.

Infrastructure

All major infrastructure construction (dams of more than 50,000 m^3 or aqueducts carrying more than 2 m^3 per second) need authorization of the DGA in order to prevent harmful third-party effects or environmental damage.

Obtaining state funding for irrigation water from multipurpose infrastructure construction requires a clear positive economic evaluation and the active participation of potential users in the respective project.[4] In order to be eligible for the government's financial assistance, the total cost of the projected infrastructure, or the portion of it that is allocated to irrigation (in the case of multipurpose infrastructure) cannot exceed the incremental value of the total irrigated area, considering market values for comparable irrigated and non-irrigated land in the same official *región*[5]. Aside from this requirement and the associated evaluation, 33 percent of potential beneficiaries must approve the proposed project in writing. If the project is an improvement to an existing system, beneficiaries must contract for at least 33 percent of the additional water availability. In order to actually program the construction of works, this acceptance and the financial commitment of 50 percent of the beneficiaries are required. The infrastructure constructed under this process must be transferred to the users, represented by their organizations. On the basis of public interest, the president of the Republic may order (by decree) the study of state-funded water infrastructure projects and construction of respective works, even if they do not meet the prerequisites. The market value of the infrastructure will be paid by the users, and any excess will be financed by the state.

Notwithstanding the provisions of the law regarding the compulsory transfer of state-built or state-funded water infrastructure to the users, the president of the Republic, for reasons of public welfare, may direct the state to preserve waterworks within its patrimony, and to take over their administration or exploitation. The beneficiaries of such works are compelled to pay annual dues for the use thereof and for exploitation expenses. This has happened with state-owned infrastructure constructed before the rules of market value were in effect and the actual construction cost was higher than its economic value. For example, the cost of the Digua Dam in the VII Region, financed by the state, and the Inter-American Development Bank (IADB) went far over the economic value. Construction was abandoned in 1970 and recommenced in 1974; the IADB made resumption of construction a requirement of considering any new loans to Chile. The final cost was three times the estimated cost. The economic return to irrigation in that specific area of the VII Region is very low; many farmers can't even pay the rates for use and exploitation. Today only 40 percent of the Digua Dam's capacity is actually utilized. This dramatic case, similar to most state irrigation infrastructure projects in Chile (and all over the world) strongly influenced the adoption of the evaluation system and the state responsibility for irrigation infrastructure costs previously described.

Users' Organizations

Any entity holding rights to water must join a users' organization or organizations. There are several types of water users' associations established by the Water Code. These organizations are fundamental to management of Chile's water. The general function of these associations is to distribute the water according to rights and to collect the fees for administration, distribution, maintenance, and amortization of constructed or acquired of infrastruc-

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4 Law 1.172-1975, modified by Law 1.123-1981, specifically regulates state-financed irrigation or multipurpose infrastructure.

5 Chile is divided into 13 *regiones*.

ture. They are empowered to withhold water from those who neglect paying user fees or who extract excess water. They are also responsible for solving conflicts among members according to the law.

Users' associations are responsible for drawing water from main or secondary waterways, as well as for building, exploiting, administering, preserving, and improving water infrastructure necessary for their members. This applies to state-constructed dams (which are transferred to water users' associations as representatives of users on small aqueducts). The Water Code stipulates that if two or more persons hold the right to use water from the same source (for example, river, dam, channel, or underground water) this creates a de facto association between them, which they may regulate by establishing a water community (*communidad de aguas)*, a channel user's association *(asociación de canalistas*), or any other legal association they may agree on.

The formalities of organization are simpler for *communidades de aguas* than for *asociaciónes de canilistas*. The former are usually in charge of secondary infrastructure used by neighboring farmers; the latter are in charge of large infrastructure, from principal channels to dams. Frequently a farmer belongs to both types of organizations. For example, a *communidad de aguas* might govern a secondary channel coming from a principal channel governed by an *asociación de canalistas*. In the case of natural sources of water, such as rivers, users must organize as a control committee (*junta de vigilancia*). Both types of organizations mentioned previously may be members of a *junta de vigilancia*, which may also include individuals, public entities, urban public utility companies, hydroelectric enterprises, or any other user that has rights over water coming from a natural source.

Urban Public Utility Companies

Urban water and sewage city services that were once state-owned have been transformed into urban water and sewage companies. Shares are owned in different proportions by the public, municipalities, the regional governments, and the national government. Shares are traded in the stock markets. The government has embarked on a program of selling its shares to the public on a bid system; full privatization is expected before December 1993.

These companies have concessions to supply water and sewage services to a specific city or specific sectors of larger cities. The companies own the water rights to which the former municipal service entities were entitled, and many have bought additional rights in the private market. They are obliged to supply services to new users. The water company may fulfill these obligations through the the market purchase of raw water rights by the new user, with subsequent transfer of the rights to the company. In practice, however, this rarely happens; the company usualy buys rights directly from farmers or other water companies. Utility companies apply for state grants over surplus water only in Chile's south, which enjoys a high level of well-distributed rainfall.

Since utility concessions are a natural monopoly, the maximum fees for urban water and sewage services are fixed by the Ministry of Commerce, taking into account the market price of raw water, amortization of infrastructure, preservation, maintenance, management, distribution, collection, and a certain percentage for investments in infrastructure improvement.

Each utility fixes its rate, which must be below the maximum set by the government. The government subsidizes rates paid for urban water by low-income sectors of the population. This subsidy amounts to a certain monthly free quantity of water in predetermined sectors of the cities. The subsidy is paid directly to the water company.

Recent Developments

Eighteen years after the construction of the last irrigation infrastructure in Chile, some new projects are underway. The long period without construction is because of the restrictive project evaluation system in effect and the obligatory purchase of new irrigation infrastructure by potential users. This policy made it more profitable in most cases to increase the efficiency of existing water use rather than to invest in new infrastructure.

The CNR has approved three projects: Tonco Viejo Canal in the VII Región, Laja Diguillín Canal in the VIII Región and Convento Viejo Dam in the V Región. The first two are only canal construction, and are quite economical; the Convento Viejo dam has a higher cost per irrigated acre than established standards, but it will irrigate a priority area.

The most important of these three projects is the Laja Diguillín Canal. This is an aqueduct between two rivers. The new rights to use water have already been allocated among owners of 240,000 acres the extra water will irrigate (160,000 acres of which had previously insufficient irrigation; the remainder is newly irrigated land). Most of the improved or newly irrigated land will be devoted to export crops such as asparagus, raspberries, blueberries, pears, and apples, and to sugarbeet for domestic consumption. The project will be finished by 1996 and the cost of the shares necessary to irrigate an acre will be about $200, payable in 25 years starting in 1993. Using Law 1.123, the government will subsidize small farmers on a sliding scale down to about $18 an acre for those who have 20 acres or less.[6]

Almost all formerly state-owned electrical generation and distribution companies have been sold, including the Empresa Nacional de Electricidad (ENDESA), the largest of these companies and owner of most of the hydroelectric generators in the country (about 66 percent of Chile's electricity comes from hydroelectric power (Chile 1992)). The Empresa Eléctrica del Norte (EDELNOR) is being let for bids; another remaining company, Colbún-Machicura, has a negative economic value.

The electricity companies that own hydroelectirc infrastructure are entitled to non-consumptive rights to utilize water. Despite the lack of legal restrictions on holding both consumptive and non-consumptive rights to the same water (use of non-consumptive rights—the kind used by hydroelectric dams—does not imply any limitation on use of consumptive rights), there has been conflict between the Colbún-Machicura electrical complex and the farmers who hold consumptive rights over the same water. The Supreme Court has ruled in favor of the farmers, in accordance with the Water Code.

Another conflict, more artificial than real, arose when power companies were accused of buying consumptive water rights in large quantities for their future development programs.

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6 This was written into a letter between potential users of Laja Diguillín canal and the DGR signed in January 1993.

The companies had actually purchased less water than they were accused of buying, and the water they did buy was in an area that did not lack the resource.

There has been intense controversy over the construction of the hydroelectric dam on the upper reach of the Bio-Bio river. This dam will flood an extensive area covered by native forest containing several species that are close to extinct. In addition, some of the last members of a native tribe, the Pehuenches, live in the area. Also, some of the most impressive rapids for kayaking in the world are located in the area to be flooded. After receiving assurances that there will be enough water to ensure a continuous flow of the river, even during the dry season, and that pollution would be sufficiently controlled, the president of the Republic approved the project. There is substantial doubt as to whether alternatives were adequately considered or whether this was a correct decision. A new environmental protection law is at this writing still being considered in the Parliament. Until stronger environmental legislation is passed[7], this kind of construction will continue to depend on the discretion of the government administration.

Achievements

The market allocation of water has not only proved to be efficient in assigning water to its best economic use, but in the process has correctly priced water with the subsequent benefits, mostly in efficiency and redistribution of income.

The water policies applied in Chile, mostly because of adequate pricing and uncoupled transferability of water and land, have fostered efficient agricultural use of water, allowing the country to increase its productivity—generating more production with the same, or even (because of transfers to urban uses) less water. The policies have also increased the agricultural frontier, in its traditional definition. More land can be irrigated with the same amount of water as a consequence of correct pricing.

From the mid-1960s until 1973, Chile's agricultural GNP grew at around 2 percent per year, less than the population growth of the country (Valdés 1973, Varas 1975). In this period, the agricultural trade balance was almost always negative; by 1973 the agricultural trade deficit had reached $544 million (imports were $607 million and exports just $63 million)(Mujica 1991). In addition, rural life at this time was very poor; incomes were low and social services deficient.

Substantial agricultural development occurred after the 1973 shift to market-oriented social and economic policies. The agricultural GNP grew at an annual average of 5.1 percent between 1974 and 1990. Area under wine-producing grape cultivation has more than doubled from 25,000 ha in 1973 to 60,000 in 1992, and the area under fruit cultivation nearly quadrupled from 54,000 ha in 1973 to 205,000 ha in 1992 (ODEPA 1993). Chile is now the largest fruit exporter in the world, having the advantage of location in the southern hemisphere to grow and market during the northern hemisphere's winter. In 1991, there was an agricultural trade surplus of some $2 billion (exports of $2.5 billion and imports of $0.5 billion), despite a decline

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7 Current environmental laws include Laws 3.133 of 1916, 3.557 of 1981, 382 of 1988, and 18.902 of 1990.

in the annual agricultural GNP growth rate to about 2 percent (ODEPA 1992, Banco Central). Part of the decline in the growth rate is due to a drop in international prices and to restrictions on fruit imports imposed by most European countries and the United States.

The rural population is about 15 percent of Chile's total population, and agriculture accounts for some 24 percent of the country's jobs. Half of the new jobs created by the agricultural reconversion from traditional to export-oriented crops are occupied by women (mostly in labor-intensive fruit harvesting and processing)(Valdés 1988). In large measure, Chile's low (4.4 percent) unemployment rate is because of the agricultural sector's full employment.

As mentioned previously, the dramatic increase in agricultural production and employment has been accomplished without the need for new hydraulic infrastructure. The increase has been achieved mostly by shifting land from cultivation of grain, corn, oilseeds, and cattle-raising to the more water-intensive fruit production. The freedom to buy and sell or "rent" water has given farmers greater flexibility to shift crops according to market demand.

Efficiency in urban water and sewage services has been greatly increased with no impact on prices (except in a few cities that were previously highly subsidized). Unlike previously, when state-owned public water services had a national price for all cities, the tariffs of each water and sewage company now depend on its costs. The price of raw water and the cost of transportation are responsible for most of the difference in water and sewage tariffs, especially in the northern desert region.

One of the greatest achievements of Chile's water policy is allowing cities to buy water without having to buy land or expropriate water. As a matter of fact, growing cities now buy rights from many farmers, in some cases buying a small portion of each farmer's total rights. There have been no negative effects in the agricultural zones surrounding water-demanding urban areas. This is probably because of the very efficient watering technology used for the new crops grown in those areas.

The coverage of potable water has risen to 99 percent in urban areas and 94 percent in rural areas from 63 percent and 27 percent respectively in 1970 (Wisecarver 1992). Rural areas include towns of less than 5,000 people. Having a real right over the use of water and an active market has fostered the construction and operation of treatment plants that sell water for agricultural or urban use, like those being constructed in Santiago and Arica. The certainty of water rights and the legal and managerial attributes of users' organizations have greatly diminished the conflicts arriving in the courts. In the past, all conflicts that are today resolved by users' organizations were sent to criminal courts. The resolution of such conflicts could take several years, often benefitting the offender.

Perhaps the most important achievements of Chilean water policy are social benefits through redistribution of wealth and eradication of poverty. In the past, the construction of mostly unprofitable hydraulic infrastructure, the distorted water prices, and deficits caused by inefficiencies in state-owned water services were all financed through taxes. This meant transferring resources from the poorest sectors of the population (that had no water) to the wealthiest (that had water). The new policy liberated tax resources through private financing of infrastructure and correct pricing. Such tax resources can be used by the state to redistribute wealth, to use tax resources to help those in need and to eradicate poverty. The state can also subsidize the poorest water users through direct, transparent, focused, and efficient mechanisms.

Chile had a unique opportunity to dramatically shift its water policies that not all other countries have. The fact that all water rights were expropriated in 1966 and transferred to the state made it possible to clearly define the characteristics of the new water rights in 1975. The definition of sure, tradable, transferable, water rights not attached to land was essential for constructing the new water policy in Chile and accounts for most of its achievements.

It is often said of those who work in water policy all over the world that there is "a bear on our back and a wolf in front of us." The bear is the enormous resources that have been used inefficiently in the past trying to supply water for irrigation and urban use. The wolf in front of us is the dramatic scarcity of water with which we will have to cope in the near future. Perhaps Chilean experience in water policy can contribute to efficient use of water. Some of the tools that can help are clear water rights, market allocation, correct pricing, and direct and focused subsidies. These fundamental approaches should be taken seriously before considering construction of mega-projects with severe environmental consequences. Such projects do not guarantee the long-term efficient use of water.

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THE USE OF WATER PRICING TO ENHANCE WATER USE EFFICIENCY IN IRRIGATION: CASE STUDIES FROM MEXICO AND THE UNITED STATES

*Ronald G. Cummings and Vahram Nercessiantz**

Persisting increases in the scarcity of water resources are a major concern in both the United States and Mexico. Growing water scarcity in the United States is manifested in a number of ways, probably most clearly in the range and nature of increasing social conflicts concerning the manner in which water is allocated.

Interstate conflicts concerning water have sharpened over the last two decades necessitating, in some cases, the entry of the judiciary in the role of a water manager. Some view such conflicts as having the effect of reshaping the doctrine of prior appropriation (first in use, first in right) that has been the cornerstone of water rights law in the western United States since the 1800s (see Johnson and DuMars 1989). Further, conflicts between groups of water users, for example in rural and urban areas, as well as conflicts between users and nonusers (environmental groups) have become increasingly common in the western United States.

The demography and geography of Mexico are such that water scarcity has long been an issue of critical importance. More than half of Mexico's land lies in areas that receive less than 20 inches of rainfall each year, and more than 50 percent of the mean annual flow of all major Mexican rivers are in drainage areas that constitute 10 percent of Mexico's total land area (Cummings 1972). The relative scarcity of water in Mexico is being exacerbated by persistent and rapid growth in population and the concomitant need for food, along with dramatic increases in urban populations.

Opportunities for enhancing water supplies through new reclamation projects are limited in both the United States and Mexico. Substantial opportunities exist in both countries for easing the pressures of water scarcity by the elimination of waste and the enhancement of water use efficiency, however. Given that irrigation will typically account for some 85 percent or more of a region's total water use, enhancing the efficiency of water use in irrigation is particularly important.

Reflecting these concerns and opportunities, this paper examines generally the pricing of water resources as a means for enhancing the efficiency of water use in irrigation. It is well known that economically efficient patterns of resource are obtained where (at the margin) the

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value earned by the resource in any given use equals its scarcity value. In theory, these conditions are typically viewed as resulting via one of two resource allocation institutions.[1]

The first is a decentralized institution wherein the resource is obtained by all users within a competitive market; competitive forces result in a market price that reflects the resource's relative scarcity—the market price is a scarcity value—and the value of the resource's marginal product is equated in all uses. The second is a centralized institution wherein the resource is controlled by some kind of a central manager who knows a priori the scarcity value of the resource. The manager, assumed to be motivated by the desire to maximize the sum of profits for all users, then either directly allocates water so as to equate value-marginal-product and the scarcity value of water or makes the resource available to users at a price that equals this scarcity value. In theory, the ultimate allocation of resources will be the same under these two institutions.

If this theory is so well understood, then an obvious question arises. Given growing water scarcity in the United States and Mexico, as well as in many other countries in the world, why is it that water pricing is *not* commonly used as a mechanism for providing water users with incentives to use water efficiently? What sorts of institutional or policy changes (or both) might result in water pricing becoming an effective *and practical* means by which water resources are allocated?

Understanding the current institutions that control the allocation and use of water resources in irrigation is the starting point. The social mandates that these institutions serve have implications for institution's flexibility in adopting new policies designed to enhance water use efficiency. For this purpose the institutions selected as case studies are the major agencies in the United States and Mexico charged with the development of irrigation: the Bureau of Reclamation (BuRec) in the United States, and the Comision Nacional del Agua (CNA) in Mexico. The dramatic differences in the evolution of social mandates of these two agencies will broaden the policy relevance of this paper to many other countries that are attempting to deal with the problems of growing water scarcity. Following an explanation of the basic institutional framework, the paper examines the role that water prices currently play in determining patterns of water use. Within this context, water prices are simply the costs of water that farmers in irrigation districts that are under the auspices of the BuRec and the CNA must pay. This paper is concerned with two related questions: what are water costs and do they in any sense approximate the relevant scarcity value of water? Is the institutional context within which each agency must operate one that would likely permit the agencies to raise water costs to levels that would approximate a scarcity value for water, or to levels that would provide farmers with meaningful incentives for improved water efficiency?

The legal and regulatory settings within which both the BuRec and the CNA now operate impose limits on their ability to directly use any form of scarcity pricing as a means for improving water use efficiency. There may be several general policy changes, however, that would eliminate or reduce these limitations.

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[1] "Institutions" is used here in the broadest sense of the word as "an entity; an organization or an individual, or a rule, a law, regulation, or established custom. An institutional arrangement is defined as an interrelated set of entities and rules that serve to organize societies' activities so as to achieve social goals." (Fox 1976)

Overview of the BuRec and CNA

The BuRec is a western regional institution as opposed to a national institution. All lands under the auspices of the BuRec are located in western states. Its mission has been limited primarily to the development and management of surface waters used in irrigation; it has not played a major role in the development and management of pump irrigation. Irrigated land in BuRec projects totaled almost 4 million hectares (ha) in 1987 (United States 1987). Irrigation in BuRec lands accounts for about 21 percent of all irrigated farming in the United States, and about 1 percent of total land in farms in the United States (United States 1990). The average farm size in BuRec districts is 31 ha, compared with a national average for irrigated farms of 64 ha.

The CNA is a national institution with irrigation districts in most Mexican states. Its responsibilities extend to the development and management of all water resources, both surface and subsurface. Indeed, some irrigation districts, such as the Costa de Hermosillo in the State of Sonora, obtain all of their water from groundwater supplies. There are approximately 3.5 million ha of land in irrigation districts. Land in CNA irrigation districts accounts for some 20 percent of all agricultural lands in Mexico (Mexico n.d.(a)). The size of irrigated farms in irrigation district ranges from 12.2 ha in the northwest to 2.1 ha in Mexico's central *Vale de Mexico,* and they average 5.9 ha (about 20 percent of the size of BuRec farms).

The BuRec and Development of the American West

Beginning with the Desert Land Act passed by the United States Congress in 1877, irrigation development in the United States can be viewed as one of the national priorities related to the country's manifest destiny to populate and settle the western states (see Dickerman and others 1970). The Reclamation Act of 1902 made clear the nation's reclamation objectives: the development of arid western lands. The Reclamation Service was established within the Department of the Interior in 1902 for the purpose of administering United States reclamation policy in this regard—thus the earlier description of the BuRec as a western institution. The Reclamation Service was expanded into the Bureau of Reclamation in the early 1920s.

The original 1902 Reclamation Act provided only for irrigation uses of project water. This limitation was quickly removed, however. In 1906 Congress authorized the delivery of project water to towns and cities in the vicinity of irrigation projects, as well as the leasing of surplus hydroelectric power. In 1920 Congress authorized the Secretary of the Interior to expand water services to uses other than irrigation. Restrictions on the use of federal project water have been still further liberalized over the last decade. There appears to be growing numbers of circumstances wherein the BuRec can facilitate transfers of water (via either sale or lease of water rights) to uses and to users well beyond the confines of irrigation districts (see Wahl 1986).

At the outset of irrigation development in the west of the United States, the expectation of the Congress was that irrigation would be totally self-financed. A Reclamation Fund was established through the sale of public lands, and these funds were made available to farmers as interest-free reimbursable loans for the development of needed irrigation facilities or for their contribution to the major reclamation projects or both. (Major reclamation projects included the construction of dams and water storage facilities). The repayment period for such loans was initially set at ten years; it was extended to 20 years in 1914, to 40 years in 1926, and to 40 years with an initial ten-year grace period in 1939.

Although the "beneficiaries should pay" premise underlying early reclamation policy in the United States was defined rigidly in principle, it could not be enforced in practice. Irrigation farmers were persistently in arrears for loan repayments, necessitating annual legislation by the Congress to forgive or otherwise defer annual payments due from them (Burness and others 1980). The apparent inability of farmers to pay their share of reclamation costs resulted in the creation by Congress of a special commission in 1937 that was given the mandate to investigate reclamation projects and recommend the best payment plan for each.

The commission's report set the stage for the Reclamation Project Act of 1939, which resulted in a complete restructuring of the rules of the game for water reclamation in the United States and which remains the legislative cornerstone of contemporary reclamation policy in the United States. Reclamation projects were to be viewed as multiple-purpose in scope and were to serve beneficiaries that included private and public entities. Private beneficiaries include irrigators, users of electric power, and municipal and industrial water users. The public, as beneficiaries, derives benefits from those aspects of the project that effect such things as recreation, fish and wildlife preservation, and environmental protection or enhancement. Project costs attributable to public aspects of the project are nonreimbursable. Thus, for post-1939 BuRec projects, capital and O&M costs are allocated among public and private beneficiaries. Public costs are absorbed by the federal government. Repayment contracts are established with private beneficiaries of the project. Nonagricultural beneficiaries repay the full amount of their allocated costs with interest. Irrigation farmers repay a proportion of their allocated costs that is based on their ability to pay (typically some 33 percent of estimated increases in net income), and interest costs are forgiven.

Several observations related to rights to water and water costs in BuRec projects are relevant.

- BuRec does not control water rights per se. It owns, controls, and manages the storage and distribution facilities, but water rights are controlled by state laws relevant for the area in which the project is located. The BuRec's release of water to farmers for irrigation is then determined by federal and state laws (typically, interstate compacts) and the amount of available water in storage for which contracts have been made.

- BuRec has no legislative mandate that would allow it to levy charges on water users for anything other than repayment contracts for capital costs and O&M costs. Its legal responsibilities are limited to the operation and maintenance of the project's facilities—it can neither change water allocations established by contracts and state laws nor impose water prices or costs in excess of amounts required for the repayment of capital and O&M costs. These contacted water costs are essentially fixed costs—they do not vary in any real way with the volume of water use.

By the mid-1970s, at least two developments resulted in substantial changes in BuRec mandates and policies, changes that may be described as a shift from a focus on construction to a focus on management. First, opportunities for the continued construction of new large-scale water projects had dissipated. There were no ideal locations left for large facilities, and the best locations for smaller reservoirs had also been taken. Second, by the mid-1970s, there was a change in attitudes in the Congress and the United States itself. The development of the west had been accomplished, and national priorities were on the pressing problems such as the need for fiscal austerity and the need to focus on the environment. The era had ended in which the government provided virtually all of the up-front money for reclamation projects, and in which project costs could be charged to public beneficiaries and substantial subsidies were made available to irrigators. In the post-1980 era, cost sharing is the relevant principle. Host states of proposed projects must now provide substantive shares (typically on the order of 50 percent) of up-front money, and the feasibility of proposed projects must now be based upon demonstrations of project benefits that largely exclude public benefits.

The CNA: Tool for Implementing Land Reform

From shortly after the Mexican Revolution until the early 1980s, water reclamation in Mexico was under the auspices of the Ministry of Water Resources, called the Secretaria de Recourses Hidraulicos (SRH). The SRH, like its BuRec counterpart in the United States, was largely a construction-oriented agency. Ambitious water reclamation projects were developed during the period extending from the 1930s through the 1970s. With the creation of the National Water Plan Commission (Plan Nacional del Agua, PNA) as an adjunct to the SRH in the years 1972–73, the SRH initiated a shift in focus from construction to management and planning. In the early 1980s the SRH was combined with the Ministry of Agriculture (forming the new ministry called the Ministry of Agriculture and Water Resources (Secretaria de Agricultura y Recoursos Hidraulicos, SARH) in an effort to more efficiently coordinate water management and development activities of the SRH with those affecting the ultimate clients of the agency: irrigation farmers. Given serious declines in the productivity of Mexico's irrigation sector between the late 1970s and the late 1980s, in 1989 the responsibility for managing the country's water resources was effectively split off from the SARH with the formation of the National Water Commission, the Comission Nacional del Agua (CNA).

The position of land reform as a centerpiece of the Mexican Revolution has had two implications of primary interest. First, the development of irrigated lands was to be a tool in the implementation of land reform. In virtually all water reclamation projects constructed by the CNA, large parts of the newly developed irrigation lands were used for the formation of farm cooperatives (*ejidos*), populated with previously landless farmers (see Venezian and Gamble 1969). Indeed, the national character of the CNA, in contrast to the BuRec's regional character, may largely be explained by this linking of irrigation development to a national program for land reform. Second, it can be argued that concern by the framers of Mexico's constitution for the importance of available water supplies in efforts to redistribute land lead to their nationalization of all water resources; that is, water resources are, by the constitution, the property of the state. The elimination of private property rights in water is consistent with a concern that this vital resource would not be monopolized by the wealthy *latifundistas*, thereby thwarting the goals of land reform.

With property rights to water vested with the federal government, the CNA, as a federal entity, can technically be viewed as owning both water facilities and water rights. Unlike the BuRec, the CNA's authority to own both water facilities and rights is not limited by states' control of water rights. Similar to the restrictions facing the BuRec, however, the CNA's ability to price water at amounts that exceed costs is questionable. The CNA has a legislative mandate to collect all (or in some cases, a proportion of) O&M costs. Limits on the recuperation of capital costs are also set out by law. Strictly speaking, it seems that Mexican law is mute on the issue of whether or not the CNA could impose charges for water that exceed legislative limits on cost recuperation. As in the case of the BuRec, water costs in CNA projects are fixed in nature.

Historically, the *ejidos*, including those in Mexico's irrigation districts, had available to them special facilities for the acquisition of credit, agricultural extension and educational services, and marketing facilities. The government's paternalistic interest in the development of the *ejido* system is of interest for our discussions given the long history of subsidies afforded by the system. Subsidies for water costs ultimately extended to all farmers in irrigation districts. Thus, with few exceptions, CNA farmers have never been required to repay capital costs associated with water reclamation projects; moreover, for long periods of time O&M costs were heavily subsidized by the government.

There is an obvious contrast between goals sought by federal water reclamation projects under the auspices of Mexico's CNA and those of the BuRec in the United States. CNA projects have been essentially single purpose in nature, serving basically to promote agricultural production from irrigation within a context that emphasized the goals of land reform. On the other hand, since the 1930s BuRec projects were intended to be multiple-purpose in nature, serving not only the needs of irrigated agriculture but those of urban centers and society at large.

Aside from possible implications related to cost allocation, this difference can have important implications for discussions of alternative decentralized market mechanisms as they might be used to affect water prices and therefore incentives for efficient water use. With its evolved tradition of concern with multiple-purpose uses of water, mechanisms by which competing demands for water are transmitted through water prices may be easily accommodated within existing procedures used by the BuRec in its efforts to deal with the water needs of its diverse clients. Such may not be the case with an agency like the CNA whose client-agency ties have been limited to agriculture.

Mexico's CNA faces changes in public mandates and priorities that reflect changing conditions paralleling those in the United States. As in the United States, the best locations for new, large-scale water reclamation developments have been taken and there are few if any opportunities for new developments of any substantial scale. The demands for fiscal austerity and growing environmental concerns have resulted in both dramatic declines in monies available for the subsidization of water reclamation activities and in more stringent requirements for improved water management practices. It may indeed be the end of an era of federal interest in the financing of expanded irrigation in Mexico as well as in the United States.

In response to pressures for the elimination of subsidies to farmers in CNA districts, the CNA is in the process of implementing an institutional change that is of central importance for the theme of this paper. User associations are being formed within each irrigation district. The associations will have responsibilities that parallel those in irrigation units: water users will have the responsibility for contributions to the CNA's O&M costs for reservoirs and major distribution canals, as determined by the associations and collected from individual water users. It seems to be the case that the charters that establish the associations provide them with a great deal of latitude in terms of permissible activities approved by association members.

Water Costs: Incentives for Efficient Water Use?

To what extent do the water costs paid by irrigators in BuRec and CNA projects provide incentives for efficient water use? This portion of the paper will consider capital and O&M costs separately and examine the proximity of water costs paid by irrigators to the scarcity value of water.

Capital Costs. As noted above, the bulk of United States water reclamation projects are viewed as multiple-purpose projects. Thus, strictly for the purposes of cost allocation, project costs are spread among private and public beneficiaries of the project. For the purpose of determining repayment of allocated costs, farmers pay based on their ability to pay. The power industry, municipalities, and industry will typically pay the full amount of their allocated costs, and all costs allocated to the public as a beneficiary are absorbed by the federal government. For 49 BuRec projects, the percent of total construction costs that was allocated to irrigation ranged between 18 and 100 percent, and averaged 70 percent (Burness and others 1980). The percent of costs allocated to farmers that were in fact to be paid by farmers ranged from 9 percent to 100 percent, and averaged 31 percent (Burness and others 1980). Notwithstanding that BuRec farmers pay less than the full amount of capital costs allocated to them, their current outstanding payment obligations total some $5 billion, involving an average annual payment of $43/ha in 1990 dollars, or about two percent of average gross farm income (United States 1987). With average water use of 6.8 acre-feet per hectare on BuRec farms, implying capital cost payments of $6.32/acre-foot (United States 1988).

As mentioned above, reclamation projects in Mexico are typically single-purpose in character. Potential public beneficiaries of CNA projects, such as recreation, wildlife enhancement, and the environment. are not considered for the purpose of cost allocation. Nor is it the case that municipal or industrial users are allocated any substantial portion of costs. Thus, the costs of CNA projects would generally be allocated solely to the irrigation sector. Allocations notwithstanding, there is little if any history of capital cost recuperation from farmers in CNA projects. CNA farmers do not have an existing capital cost obligation as do farmers in BuRec projects.

As an aside, there has been little in the way of new authorizations for large reclamation projects in either the United States or Mexico. Over the last two decades, however, one finds in both countries ongoing investment programs for the rehabilitation of existing projects. The ability-to-pay principle does not seem to guide cost-sharing arrangements for such programs in the United States. While there are no hard and fast rules for determining cost-sharing for rehabilitation projects in BuRec districts, it appears that on average farmers contribute some 50 percent of these costs. In terms of rehabilitation programs in Mexico, the CNA is seemingly breaking with past capital cost-recovery policies. It is making efforts to institute a limited form of cost recuperation for these costs, particularly in the northern and northwestern regions. There presently exists no agency-wide criteria for the recuperation of capital costs for rehabilitation programs, however. Ad hoc negotiations are conducted in each region. In those districts where capital cost recuperation has been successfully negotiated, the arrangements will typically involve a contribution of 20 to 30 percent of costs by water users, and 20 to 30 percent by the state government, with the balance absorbed by the CNA.

O&M Costs. It is generally the case that annual O&M expenditures in BuRec projects are at levels required to fully maintain irrigation facilities, and setting aside issues concerning the allocation of O&M costs among beneficiaries of BuRec projects, farmers pay the full amount of O&M costs that are allocated to them. With the BuRec on average delivering some 24.8 acre-feet per hectare with irrigation of 3.66 million ha, water use on BuRec farms averages 6.8 acre-feet per hectare with O&M costs of approximately $13 per acre-foot (in 1990 dollars) (United States 1988).

For the last decade or so, annual O&M expenditures in CNA districts have been substantively less than levels required to adequately maintain all irrigation facilities. The difference between full O&M expenditures, those required to adequately maintain irrigation facilities, and actual expenditures is referred to as deferred maintenance. The result of continuous deferred maintenance in the CNA's irrigation districts has been an irrigation system that is in extraordinarily poor shape. The CNA's multi-million dollar rehabilitation and modernization program to which reference was made above is an effort to catch up on past deferred maintenance.

Until very recently, CNA farmers paid a small (15 to 25 percent) portion of these less-than-adequate O&M expenditures. Over the last year or two, the CNA has made notable progress in increasing the level of O&M expenditures in many irrigation districts, as well as increasing the proportion of O&M costs that are paid by water users. For 1990/91, CNA's planned O&M expenditures were $89 million, which is 66 percent of estimated full O&M expenditures (Mexico 1991). Water users are expected to pay 52 percent of the planned expenditures.

Using the 1990 pattern of water use in CNA districts as being representative of an average year, on average the CNA delivers some 23 million acre-feet of water to farmers for the irrigation of 2.81 million ha (Mexico n.d.(b)). Water use averages 8.2 acre-feet per hectare, and, during 1990–91 farmers will pay O&M costs of $2 per acre-foot.

Costs as Incentives for Efficiency. The proximity of water costs paid by irrigators to the scarcity value of water and the possibility of raising water costs to improve efficiency are the two main concerns in this area.

While the scarcity value of water is determined by myriad factors and can vary widely under different conditions, the following observations may be useful in setting out the possible range for water's scarcity value in BuRec and CNA irrigation districts. A recent study by the CNA provides estimates for the average value of water as measured by net farm income in irrigation districts located in northwest Mexico. These values range from $30 to $60 per acre-foot (assuming water use of 8 acre-feet per hectare). To some extent, this range is consistent with estimates for the marginal value of water in northern irrigations districts found in earlier works: $30 to $45 per acre-foot in the Comarca Lagunera District (Cummings 1972) and $40 to $65 per acre-foot in districts along Mexico's northwest coast (Cummings 1974)(values have been inflated to 1990 dollars). Values for water used in irrigation in the United States also seem to lie in the range of $30–$60 per acre-foot (see Cummings 1977, Saliba 1986, Saliba 1987). Furthermore, $50 as an average scarcity value of water is consistent with average market values for water rights traded among farmers observed in western states (this is $500, which would be the capitalized value of water profits of $50 per year, using a 10 percent discount rate. See Saliba and others 1987.) Thus, recognizing that ranges for water scarcity values may be quite broad, we take $50 per acre-foot as a reasonable range for such values. Using this figure, BuRec farmers pay about 39 percent of the scarcity value of water (an average of $6.32 per acre-foot in capital costs and $13 per acre-foot in O&M costs, for a total of $19.32). CNA farmers have no capital cost obligations and presently pay some $2 per acre-foot in O&M costs. Their water costs are about 4 percent of the scarcity value of water.

With water costs one-third or less of scarcity values for water, and absent any good reason for believing that such costs (which are fixed) may affect water use efficiency in irrigation, an obvious questions is: what are the options available to BuRec and CNA for using prices to improve the efficiency or water use? At least two general alternatives in this regard might be considered. First, they might simply increase water costs charged to farmers by amounts that would approach the scarcity value of water. This is clearly unfeasible for the BuRec, which manages water facilities, not water per se, and has no control over water costs beyond those related to actual annual O&M expenditures. For similar reasons, it appears that this alternative would be equally unfeasible for the CNA, but this is not totally clear. In either case, a movement in this direction would require legislative changes. Second, even if this were possible, a farmer's resistance to higher costs is a predictable reaction. These considerations might then lead on to a second alternative that involves rents or some proportion of rents accruing directly to farmers: individual or group marketing of water rights.

Achieving Water Use Efficiency With Market Institutions

Institutions that fit within a decentralized paradigm for efficient resource allocations include markets, or market-like arrangements. In market institutions, willing buyers and sellers of water rights exchange those rights. A market price is established that reflects the relative scarcity of water. The extent to which this price accurately measures the scarcity value of water and results in an efficient allocation of water will typically depend upon the extent to which the characteristics of the market-like institutions approximate those of the competitive paradigm (see Brajer and others 1989). In broader terms, our concern is with mechanisms for transferring usufructuary or property rights to water from one user or group of users to others. Such transfers presumably involve reallocations of water to higher-value—that is, more efficient—uses. The relevance of this concern in the United States (given that there are no private property rights to water in Mexico, there are no *formal* precedents for water transfers in that country, particularly within any kind of market context) has been manifested by the increase in public interest in reallocative mechanisms that has occurred over the last two decades or so. Such interests reflect an evolving decision environment that is receptive to increased reliance on water transfers as a means for resolving water scarcity problems. This is to say that judicial rulings that place growing emphasis on water use efficiency in considerations of interstate water disputes, the increasing political strength of urban areas, growing water scarcity, and the decline in federal subsidies for water projects have all had the effect of creating a political environment in the United States that is conducive to considerations of water transfers.

In the simplest and most general terms, a private water market is an institution, formal or informal, that facilitates the exchange of water rights among willing buyers and sellers. The major strengths claimed for water markets are, first, that under ideal conditions it can be shown that unfettered markets for water will result in an allocation of water rights that is economically efficient, that is, resulting in water being placed in its highest-value uses. Second, it is argued by some that water markets can eliminate water shortages as well as limit distributional conflicts (Anderson 1983).

The private sale of water rights is reasonably common in many western states, in many instances involving the sale of water rights by private individuals or farmers to municipalities (see Brown and others 1982, Wahl and Osterhoudt 1985). In transactions involving one farmer's sale of perpetual water rights to another farmer, prices average about $500 per acre-foot. Farmer sales of water to municipalities bring much higher prices. A broad sample of water rights prices in western states, primarily involving the sale of agricultural water rights to municipalities, is given in table 1.

Probably the best example of a functioning water market in the west is within the Northern Colorado Water Conservancy District (NCWCD). Each year, the NCWCD divides the amount of project water available to it among the owners of its 310,000 shares. These shares can be

Table 1. Representative Prices for Sales of Perpetual Water Rights: 1984–87
(1986 dollars per acre-foot)

Year	*Arizona*	*Colorado*	*Nevada*	*New Mexico*	*Utah*
1984	560	1,460	1,570	1,460	430
1985	920	1,080	1,450	1,250	350
1986	1,430	--	--	1,210	--
1987	1,000	--	--	1,110	--

-- Not available.
Source: Saliba 1987.

bought, sold, or leased within the district. The price at which these water shares have been transferred has varied considerably over time, averaging (per acre-foot in 1980 dollars), $99 in 1961; $504 in 1970, $2,895 in 1980, $1,600 in 1983, and $900 in 1985 (Howe and others 1986). Rapid growth in the area's economy during the 1970s gave rise to rapid increases in the price of water rights in the NCWCD; the slowdown in urban development after 1980 is reflected in the water prices.

There are two important caveats in these considerations of private water markets. First, one must understand that the private market transactions for water rights to which reference is made above do not generally take place within a market setting analogous to the paradigm of pure or perfect competition. They may involve one or a few transfers of water rights within a competitive environment, or any mixture of market conditions between these extremes. One finds few (probably no more than one or two) examples in the United States of highly organized, competitive water markets; there are none in Mexico (Weatherford and Shupe 1986). The assumed conditions underlying the competitive model that are most often lacking in private water markets are: many sellers and buyers, perfect mobility (as it relates to small transactions costs), well-defined property rights, and, to a lesser extent, perfect information. Second, to an extent that is determined by state laws, water rights transactions must be approved by the state. This will typically involve an application for a transfer submitted to the office of the state engineer who examines the proposed transfer for any adverse effects on third parties. In some states, the transfer is publicized and any interested party can challenge the transfer at hearings conducted by the state engineer. Thus, the ideal conditions to which reference was made above are seldom found in U.S. water markets, and such markets should be viewed as involving market-*like* exchanges of water rights. However imperfect these markets, one might reasonably expect efficiency gains from these market-like transfers.

Asserted weaknesses of the private market for water rights focus primarily on equity considerations. As one example in this regard, in most western states, municipalities are exempt from the payment of property taxes imposed by counties. It is then argued that the market acquisition of rural water rights by municipalities can have the effect of deteriorating the tax base of rural county governments. As an example, a common practice (particularly in Colorado and Arizona) is for a municipality to purchase of farmland that has water rights associated with it. This means for acquiring water rights removes lands on the county government's tax rolls, with the potential result of eroding its ability to maintain social infrastructure. Second, a great deal of opposition to the idea of allowing water rights to be transferred via markets came from the wide range of potential externalities associated with the transfer of water rights, particularly in cases where the transfer results in a change in the location of use. Typical external effects relevant in these regards include effects on fish and wildlife habitat, the protection of aquatic life, recreation, navigation, water quality, and access to public waters (Wilkinson 1986). While some argue that such externalities might be taken into consideration in water markets via the careful construction of water rights and market institutions (Anderson 1983), equity considerations lead many to question the efficacy of water markets notwithstanding efficiency benefits that might come from their use. Brown and Ingram (1986) argue that unfettered water markets will threaten both environmental quality and the rights of non-urban constituencies by ignoring the non-econonomic values of water; Mumme and Ingram (1985) see water markets as nothing less than a program for the "redistribution of control over western water...toward those parties most able to purchase scarce water rights." A number of scholars are particularly concerned with water markets as a source of social conflicts.

Indeed, there is growing evidence that water law in western states is becoming increasingly influenced by considerations related to equity, or, more generally, to the idea that water has a communal value. The idea here is that water is so essential to western society that any transfer of water rights must be subject to close scrutiny by representatives of the general public for assessments of the potential impacts of the transfer on traditional cultural patterns of communities (Mumm and Ingram 1985). A number of western states have institutionalized public interest provisions regarding water rights transfers in their water codes, or, in the case of California, in their state constitutions. In short, the contemporary debate in the United States concerning greater reliance on water markets as a means for resolving growing water scarcity is centered on tradeoffs between efficiency and equity.

Transfers of Water in BuRec Projects

U.S. federal law provides that in federal projects the right to use water shall appurtain to the land that is being irrigated. This provision was at one time interpreted as disallowing transfers of water beyond the boundaries of an irrigation district. In more recent legislation, the Congress has authorized the delivery of project water to urban areas in the vicinity of irrigation projects, and in 1920 authorized the Secretary of the Interior to contract for water "for purposes other than irrigation." (Wahl 1986)

Over the last twenty years or so, the more limited interpretation of the appurtenance requirement has been relaxed considerably, and a large number of water transfers within irrigation districts as well as between irrigation districts and municipal or industrial users have been allowed by the BuRec (with the concurrence of appropriate state bodies, and after determination that external effects are minimal) (Wahl 1986). The extent to which such transactions have been market-like, in the sense of farmers surrendering water rights in response to prices determined within something of a market context, varies from case to case. The following paragraphs describe some water rights transfers involving the BuRec. Some are, and some are not, market-like.

One example of BuRec-sponsored water transfers that are not market-like occured in the BuRec's Casper-Alcova irrigation district located in northern Wyoming. The city of Casper, Wyoming, was facing severe water shortages due to rapid urban growth. Under an agreement that was effectively brokered by the BuRec, the city is financing the rehabilitation and lining of parts of the Casper-Alcova districts 59-mile major distribution canal and its 190-mile lateral systems. The effect of this capital investment will be to reduce canal seepage, thereby yielding the city 7,000 acre-feet of water per year without reducing the quantity of water available for irrigation.

A second example, much grander in scale, is the cooperative transfer planned by the BuRec and the California Department of Water Resources involving the imperial Irrigation District (IID), which diverts some three million acre-feet of water each year through the BuRec's All-American Canal, and the Metropolitan Water District of Southern California (MWD). The IID has 1,627 miles of main canals and laterals used to irrigate some 450,000 acres of land. The MWD is concerned with finding a source of municipal water supplies to replace water allocated to but previously unused by the state of Arizona that the state will begin to use. A study by the California Department of Water Resources demonstrated that as much as 437,000 acre-feet of water could be saved in the IID by investments for canal lining, spill-interceptor canals, tailwater recover systems, system automation, more regulatory reservoirs, and a more flexible system of deliveries. (see Wahl and Osterhoudt 1985). Water so conserved would cost between $8 and $115 per acre-foot. Ownership of water "saved" by this program is challenged by Mexico. Noting that seepage from the canal recharges aquifers that extend into Mexico, the government of that country clams that the United States cannot line the canal without consulting them under a 1973 International Border and Water Commission Minute Agreement (see Hayes 1991).

Among water transfers involving BuRec projects that approximate market transactions, a particularly interesting example is the BuRec's role as a water bank during the 1976–77 drought in California. The fourth-driest year in California in over 100 years was 1976, and 1977 was the driest year on record. In April 1977, the U.S. Congress enacted Public Law 96-18, which authorized the operation of Federal water banks during California's drought. The BuRec, as an agent of the Secretary of the Interior, was authorized to assist willing buyers and sellers of water rights to transfer water in federal (BuRec) projects and other sources. Priorities among purchasers were established: preservation of orchards and other perennial crops, irrigation of support crops for dairy and beef-cattle herds and other breeding stock, and irrigation of other crops. The law also made funds available for interest-free loans to irrigation purchasers of water with a repayment period not to exceed five years. A Congressionally imposed caveat for such transactions was that no undue benefit or profit should accrue to water sellers. Thus, the BuRec was directed to establish water prices that would recover all expenditures in acquiring the water, and that would reimburse sellers for any lost income from their transfer of water to other users. The price at which water was exchanged in the water bank was then the opportunity cost of water to irrigators. Lease prices for water arranged at the water bank ranged from $55 to $142 per acre-foot, and averaged $61 per acre-foot (Wahl and Osterhoudt 1985). Bearing in mind that this average price included conveyance and pumping costs required to get water to the purchaser, the proximity of this average least value ($61) to our earlier estimate for an average scarcity value of water ($50) is remarkable. The bank purchased some 46,438 acre-feet of water from the California State Water Project and the BuRec's Central Valley Project, and sold 42,544 acre-feet (the difference represented return-flow and conveyance losses). The operation of this water bank in California is credited with substantively easing the hardships suffered by California farmers and cities during the drought.

The BuRec has since played a banker's role in a number of other transfers. One example is the transfer of water between the Emery Water Conservancy District and the Utah Power and Light Company (UPLC) in central Utah (Wahl and Osterhoudt 1986). Following their assessment of environmental effects that could attend such a transfer, the BuRec facilitated a reduction in irrigated areas in the Conservancy District, which freed 6,000 acre-feet of water that was then transferred to the UPLC. Both private parties as well as the federal government benefitted from the transfer. Farmers were directly compensated for the transferred water (the amount of compensation was not reported). The UPLC was required to pay the farmer's remaining debts to the federal government for costs allocated to the Conservancy District for Capital cost recovery, but at municipal and industrial rates rather than at rates established for farmers. This resulted in a net increase in the total capital cost repayment obligation to be received by the federal government in the amount of $3.9 million.

A final example is the Arvin-Edison Water Storage District (AWSD) in California's San Joaquin Valley. The AWSD operates a water-exchange pool wherein each year offers and requests for water exchanges are submitted to the District. Buyers and sellers are bought together for the purpose of facilitating water exchanges. Some 7 to 8 percent of the district's water supplies are exchanged each year.

There has been increasing reliance on market-like sales and transfers of water in BuRec projects to the end of improving the efficiency of water use among all water users. Water prices provide irrigators with incentives to economize on water use in a number of ways: adopt more water-efficient cropping patterns, collaborate in investment programs for reducing distribution losses of water, and stop irrigating marginal lands. Equity issues—externalities and other public interest concern—are accommodated in such transactions by the BuRec's involvement as a third party in all transactions. The BuRec's concern with equity issues is mandated by federal environmental laws requiring preparation of an environmental impact statement for all permanent water transfer programs.

Requirements for Private Water Markets

The examples above do not represent a trend to greater reliance on private water markets in the United States. At least three sets of changes would be required for this to occur. First, congressional repeal of appurtenance requirements in federal reclamation laws would be required. Second, legal mechanisms for bringing private markets and the public interest doctrines into congruence would require development. Third, attention would be required for means by which the structure of water markets might be more closely aligned to the structure of a competitive market. Absent a change in the Mexican Constitution, it appears that there can be no market for perpetual water rights in that country inasmuch as individuals do not have property rights in water. Farmers in CNA districts do, however, appear to have something akin to usufructuary rights and possible market transactions involving the lease of these rights might be considered.

There is no question that allocating water within the context of a market would promote greater efficiency; questions do arise as to undesirable effects. There must be some middle ground, however, between living with an existing pattern of water use wherein water use may be grossly inefficient and the paradigm of perfect competition. Such a middle ground is seen in the evolving role of the BuRec as a broker in market-like water transfers in the western United States. Greater reliance on market-like allocations of water could substantively enhance overall water use efficiency. The CNA or water users' associations would seem to be ideally suited for the broker's role played by the BuRec in the United States.

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CONDITIONS FOR SUCCESSFUL WATER MARKETING

Larry D. Simpson[*]

Water marketing is a concept that has evolved over many generations into a useful tool in the allocation of water supplies in regions of the world that are short of water. It has developed in the western regions of the United States over the last century and more recently in South America, especially in Chile. Water marketing is viewed with suspicion by many and as a panacea by others. Free-market economists view it as a path to the efficient allocation of this scarce resource, while many engineers and sociologists view water marketing as a path toward monopolistic control of the resource and misallocation between "haves" and "have-nots." Water marketing can be either, but if properly handled it can be an effective tool to help the efficient allocation of scarce water resources. Like any tool, it can be abused. In this paper, some of experiences from working in a very successful, partially controlled market system are used to develop suggestions for how to successfully institute a market allocation system with moderate controls.

Prerequisites for Successful Water Marketing

In order for a water market to function effectively, there must be a number of antecedent conditions in place. Without these, the result will be chaos, monopolization of the water, and misallocation of this valuable resource. These conditions are discussed below.

Water rights. There must be a clear title to the water that will be traded. The title must be on record in such a manner that there is no possibility of dispute over the ownership of the right. The right can be actual ownership, a usufructuary right, or a contractual right of use. This right must be in perpetuity or be of sufficient length to be valuable to a buyer. If the right has time limitations, that period of right of use must be clearly defined and must be protected by the government. If a set of priorities of use are established, it must be clear that the water right cannot be taken from a lower-priority titleholder without fair and just compensation. If a system is instituted that provides for the annual rental of the water rights as well as the permanent transfer of title, this must be outlined so that the titleholder to the water rights understands clearly what his or her options are.

The water right must be defined in readily understood and measurable units so that all parties to a transaction know what is being transferred and what quantity of water the right entails. Any conditions that affect the market transfer, such as third-party considerations,

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environmental restrictions, geographic limitations, or limitation on the use of the rights after transfer, must be clearly defined.

If control over the transfer of water from one area to another or from agriculture to municipal use is desired by the government, a totally free-market will probably not be the answer. If a water right is limited in the type of use that can be made of the water, this should be clearly defined as a part of the right. If changes in the type of use are contemplated as a part of the free-market system, the process for accomplishing that change and any limitations that may apply should be clearly set out. It should be recognized at the outset that restrictions on the free transfer of water rights will limit the mobility of the rights and lessen their value on the open market.

Quantification. A mentioned previously, the water right must be defined in easily understood and measurable units. In order for a user to be assured that he or she is receiving his full entitlement under his or her water right, a system of water measurement must be established and administered. It can take the form of volumetric quantification such as acre-feet, cubic meters, or rate of flow for a set period. Regardless of the measuring devices used, the measurement system must be fair and it must be easily understood and verifiable by both buyer and seller. The most effective method of quantification of a water right is one that is defined in volumetric terms as opposed to a rate of flow. This is most effective if the water being transferred in the transaction is capable of being stored. When a rate of flow is the measurement of the right, as in the case of a direct diversion from a stream, then the pattern of use and timing of the right of diversion must be specified. If the buyer anticipates that he or she will change the diversion pattern from the historical pattern, as in the case of a change from agricultural use to year-round municipal use, then the impact on other users who may have the right to divert water on the stream at other times must be taken into consideration as a part of the transfer.

A water right that can be quantified in volumetric terms within a supply-based stored water supply system is easier and has less danger of third-party effects than a demand-based, rate-of-flow diversion right. Most successful water markets operate within a volumetrically quantified system that assures both the buyer and the seller of the amount of the commodity being traded and that allows a great deal of flexibility in both the pattern of use and the timing of delivery.

Institutional Requirements. A free-market in water rights must be administered so that rights as well as the title are secure and so that any transaction in those rights is sanctioned by the relevant government jurisdiction. This requires recordkeeping and administration that is fair and reliable. In most areas where a free-market system functions, a government agency administers water rights. The agency functions as a repository of the identity of the owners of the rights and also administers the measurement and delivery of water. Government agencies are also frequently responsible for surveillance, which involves assuring that the water is used in a beneficial way, in accordance with the water rights, and without waste. In some instances, agencies are also responsible for water quality.

A free-market system cannot function successfully unless an efficient administrative system is in place to insure that abuses of the system do not occur and that a proper chain of title is maintained over the water rights. Without an efficient administrative process, the transfer of water rights will undoubtedly result in disputes about ownership and rights of use.

Infrastructure Requirements. In any market the mobility of the commodity being traded greatly affects its marketability and the ease with which the market functions. Marketing of water is no exception. The best free-market allocation systems function where infrastructure is in place to allow the easy delivery of the commodity to the buyer. The mobility of water between users in an irrigation district, for example, depends on the capacity of the ditches or canals to carry the water. For this reason, a market both in permanent rights and in rental rights is easily established within a existing system and for the same category of use. Any improvements needed for the physical transfer of water from the place of use of the seller to the place of use of the buyer should be a part of the transaction cost to be paid by the parties involved.

Typically, the infrastructure necessary to accomplish intersystem or interbasin transfers must be built as a part of the cost of achieving the transfer. Similarly, any improvements should be part of the transaction costs. In order to assure the success of such market transfers, the buyer must be certain that he or she has the necessary permits and clearances as well as the financial means to build the infrastructure. Frequently, market transfers of water that depend upon future construction of facilities are conditioned on successful completion of the infrastructure. The cost of such construction must of course be considered in setting the price for the water transfer.

Third-Party Implications

Third-party effects of the transfer of water rights can take various forms. Typically, these third-party effects are not the concern of the buyer and seller of the rights and they will be ignored unless there is some forum for third parties to intervene in the transaction. The right to express damages (and to have the cost of those damages included in the costs of the market transfer) can be enforced by judicial review, government intervention, or voluntary resolution. Typically, all three methods are involved to some degree or another as long as a forum for intervention is made available.

In the State of Colorado, the forum is the water courts where each allegedly injured party has the right to present evidence of third-party damages. Other systems use administrative review by government agencies. In any case, for a market system to work, all real damages to third parties must be included as a cost of the transaction. Failure to take these effects into account will eventually result in the failure of the market system and will result in diseconomies within the market process. The true market value of the water rights must reflect all economic costs in order for the most efficient allocation to occur.

Some of the most difficult areas to evaluate are the effects of the removal or transfer of water on the environment and on the social and economic mileau. The latter is particularly true in areas short of water, where the economy depends on the water being transferred. Economic dislocation, environmental changes (both good and bad), return flow or secondary use dependency, and sociological dislocation and disruption must be valued by some common denominator so that their cost can be included by the marketplace as a cost of the transaction. Unless all of these considerations are included, the market system is an imperfect market and misallocation of the resource can occur.

In a real-world market system, most of the aforementioned effects are handled through regulatory or judicial means or, in the interest of expediency, are ignored. Even the most sophisticated market systems for water rights have yet to offer the complete resolution of all third-party effects. In the real world, those with the most political power or the most financial means generally succeed in obtaining the water necessary to meet their needs. This is true in developed countries and in developing countries. Those with the greatest need and the greatest strengths get the water. In the old days in the western United States, it was said that the best water right was to be upstream on the river with a shovel in one hand and a shotgun in the other.

Implementing a Market System

Even with the cautions above, a carefully regulated market system coupled with a well-devised water rights system that includes strong administration is still the most efficient way to allow water resources to seek their highest and best use. In order to implement such a system, the aforementioned water rights, quantification, and administration systems must be in place. In many instances, this will require traumatic changes in the way water rights are viewed. In many countries, the concept of private ownership of the use or right to the water has not existed historically. The laws must first be modified to create private ownership.

This same change in the laws must establish an initial allocation process that recognizes the historical use of the water supplies and, at the same time, redivides the use in an equitable manner that reflects the needs of the nation. Such reallocation should, in all fairness, compensate those effected by such reallocation. Once this initial allocation is in place and the rights of the owners of the water is clearly recorded and quantified, then a market for the rights can be established.

In addition to the initial allocation system, a process must be devised and outlined to allocate any surplus water to meet future needs. Decisionmakers should consider whether to institute policies such as payment of full cost of infrastructure to develop new (surplus) water by the prospective users or whether government subsidies are necessary to meet social or economic goals of the nation. There should be careful consideration given to the regulatory framework in which a water market may be used to reallocate the water from new development if it has been subsidized or assisted by the government. The questions of whether the government must be repaid for its original subsidies or whether the water market will be allowed to function without consideration of things like potential windfall profits to original water users (especially in the case of sale or transfer) must be dealt with in the initial policy process.

In a region where the concept of water markets is foreign to the historical allocation process, it would be best to first initiate a market within an existing water system (that is, one with complete infrastructure or with the same use) to educate the users before attempting to initiate trans-system or transbasin market transactions. The third-party implications of the latter two types of transfers makes the initiation of a market system that involves all types of transfers much more complex and controversial.

The acceptance and success of the implementation of a water market depends on the trust that the users have in the security and fairness of the system. This can only be developed by education and by demonstration. Since the initial success of the program will largely determine its long-range acceptability, it is very important to control the initial stages and keep them simple enough to ensure demonstrable success. Trust can best be developed by limiting the initial water marketing program to transactions within irrigation districts or systems that are within the same drainage basin so that the chance of third-party effects can be reduced.

Conclusions

Water marketing is an efficient tool for the allocation of water rights under very specific circumstances where the antecedent conditions outlined above can be put in place. The transition from an historical system that differs greatly from a defined water rights or water marketing system to a new system can be very traumatic and will probably be strongly resisted by those with vested interests in the available water resources. The long-range success of the implementation of a private property-based water rights system coupled with a market-driven allocation system will depend on the care taken in educating the water user constituency and in the development of a high degree of trust in the security and fairness of the administration of the program.

THE RELEVANCE OF WATER MARKET CONCEPTS IN CENTRAL ASIA

Remarks by Jeremy Berkoff[*]

For the forseeable future, market concepts for water allocation are probably of limited relevance in Central Asia. Proposing the introduction of tradeable property rights in water would tend to divert attention from what is truly important. A system of water charges, however, could be very important in promoting efficient water use, encouraging investment in water-saving technologies, and establishing financial accountability. Such a system has already been introduced in, for instance, Kazakhstan, and proposals have been made to introduce such a scheme in Uzbekistan. Recognizing that water-charge systems have an important role to play, I would like to address why water market concepts have limited relevance in the region.

The Economic Transition and Cultural Factors

Central Asian and other countries of the former Soviet Union are currently enduring a wrenching economic crisis. This can be described as the transition from a centrally planned to a market economy. Important characteristics of this transition include a move to incentive mechanisms in line with underlying economic realities. Price reform, trade liberalization, and privatization of the means of production are all rightly part of this transition. Application of the market logic, however, has led some to advocate "market" solutions for water.

I believe such talk could be misleading. First, and most obviously, there are strong cultural and social reasons working against the introduction of market principles. In Islamic tradition, water cannot be owned by individuals although it can of course be used. There is no tradition of property rights in water, either in Islamic tradition or under communist rule, and no experience of water markets. Raising such possibilities can be expected to encounter strong social and political objections and, at the very least, consideration must be given as to whether it is worthwhile taking on these objections given the many other reforms and policy changes that are required.

Water Market Prerequisites

Even without these cultural and political objections, however, the possibility of tradeable rights in water should in my view be approached with caution. Market failure in water is well

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documented in the literature and needs no repetition here. There are very few contexts or countries where markets in tradeable rights have been a principle mechanism for water allocation between users. Tradeable rights are particularly problematic in the large river basins of Asia. It is true that where individuals or small groups have unambiguous control over water supplies (such as from a tubewell or pump) or specific aspects (for example, a water turn), and can deal directly with their customers, local water markets can play an important role in redistributing supplies between users. Such markets will arise spontaneously whether or not they are encouraged. This is a very different proposition to the creation of markets in tradeable rights enforceable in law, however. For such markets to be successful, it seems to me that there are three major prerequisites.

First, there must be a strong management and regulatory system in place. It is useless for one user to agree to sell a tradeable permit to another user unless both can be assured that the transfer will actually take place. With a fixed and relatively immutable asset such as land this may be relatively straightforward. It is far less straightforward with a highly variable and uncertain asset such as water, where the transfer must inevitably be made through an intermediary such as a river basin authority or irrigation agency. No doubt there are examples where sales of a share in storage in a reservoir, or sale of a share in a flow, or a permanent transfer of a water right, can be effected. However, there are also many other cases where this will be far more difficult, especially in very large river systems, where there are numerous and small potential property owners, water is highly variable, supplies in a river system are poorly regulated, institutional arrangements are relatively weak, and regulations are difficult to enforce. Such factors no doubt help explain why market arrangements are so atypical, even in countries with a strong regulatory environment.

Second, environmental and third-party effects need to be fully accounted for under the regulatory or taxation system, or else distortions will occur in the external impacts of the market mechanisms.

Third, the general price system must be fairly stable and equitable; otherwise, all sorts of distortions and monopoly rents can be expected to be earned by newly established property owners. It is, for instance, one thing for a land owner to sell his water right on the market where the value of the water has already been fully reflected in the value of the land. It is quite another thing for water rights to be allocated to small landholders who have recently obtained access to land, and where newly acquired rights could result in windfall gains and create various social, third party, and resettlement issues.

In Central Asia, none of these prerequisites seem to exist. It is true that there is a tradition of strongly administered management of water through river basin agencies in support of centrally planned activities. It might be argued that this provides a basis for introducing property rights in water along with those in land. Indeed it was suggested earlier in this seminar that political crises of the type faced in Central Asia may be just the moment to also make radical changes in water law. However, Central Asia is very different from Chile, which had a comparatively short-lived Marxist regime and a history of capitalism and democracy. In central Asia there is no memory or tradition of regulation of private activities and land reform itself entails controversial and very difficult issues in all the countries of the region. It will take time to evolve a strong effective legal and regulatory system. Until this is in place, there is no clear way of dealing with third-party and environmental effects resulting, for example, from salinization, reuse, pollution, or issues related to the shrinking of the Aral Sea. Finally, the transition from a centrally planned to a market economy has created enormously volatile economic and pricing conditions where a market in water rights could be highly distorted. Priority must be given to the stabilization of property rights in land and other fixed assets and the evolution of relatively stable commodity markets before the much more difficult issues associated with introduction of tradeable rights in water are raised.

Importance of Basin Management

There is a serious danger that the political and related changes resulting from the breakup of the Soviet Union will weaken the present basin management arrangements. In my view, first priority must be given to preserving and strengthening effective management of basin water resources in the face of the political changes and international stress. Three important elements in such an approach will be: an effective and pragmatic system of incentives for encouraging efficient water use; investment by newly privatized landowners in water saving technologies; and a good system of financial accountability. In establishing these three elements, as I have already mentioned, a system of water charges will play a crucial role.

WATER MARKETS IN SOUTH ASIA

William A. Price[*]

The ways that water is allocated and managed throughout the world vary widely and depend on numerous factors such as culture, religion, the amount of water available, and the degree of competition for the resource. In every country in the world, access to water is taken as a matter of government concern. The government almost always becomes involved in managing water resources, since water is usually considered to be the collective property of the people of the country. The distribution of rainfall, streamflow runoff, or access to good aquifers are rarely sufficient to supply every need without control or conveyance of water outside its natural course.

In South Asia, the precipitation pattern is primarily monsoonal—over 80 percent of rainfall and resulting runoff occurs over a two- to four-month period. During the peak rainfall periods, it is common for streams and rivers to flow at or above flood stages, while during the dry season some of the smaller streams become ephemeral and larger rivers run at only 5 to 10 percent of the peak flow. The true economic value of water for irrigation, municipal supplies, or power probably varies at almost every moment. Consider also that during the monsoon the value might even be considered to be negative; farmers, households, or industries might be willing to pay some amount to have the water removed. In many developed countries, that is precisely the case when landowners pay for flood protection projects or for a flood insurance policy.

During the dry season, there is normally a competitive demand that requires controlling and moving the water from the stream for a multiplicity of uses, for example irrigation, municipal and industrial uses, hydropower, or maintaining a minimum streamflow for fish, wildlife, or water quality.

While there may be a specific economic value of water for any one type of use at a particular point in time, a market system that will allow a daily or hourly sale or purchase of water to reflect this value does not exist. In South Asia, there are many constraints that limit the existence or development of water markets. This paper examines the existence of water markets and explores the extent to which they might develop in the future.

"South Asia" in this paper is limited to Pakistan, India, Nepal, and Bangladesh. In those countries over 90 percent of the water diverted from the natural courses (streams and rivers) or taken from aquifers through pumped wells is used for irrigation of agricultural lands. In general, as countries become more developed, a higher percentage the population lives in cities, and per capita use of water increases. Yet it will be decades before irrigation is the minority use of water in this region. Water for expanding cities and for related industrial use must either

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be developed with additional control and conveyance facilities (usually dams, canals, and pipelines) or it must be transferred from agriculture to municipal and industrial use. In examining the potential transfer, one must keep in mind the fact that the urban supply needs to have a high reliability (95 to 98 percent) compared with the acceptable reliability for irrigation (60 to 75 percent).

Existing Markets

In South Asia, there are markets where water is traded, either with cash terms or by barter. This is most prevalent around the fringes of irrigation projects, where neighboring farmers make direct trades, monetary payment, or payment with commodities for the use of another farmer's water for short periods. Normally this occurs on a "spot market" basis to serve convenience, for example when one farmer becomes ill or temporarily incapacitated. These agreements for surface water exchanges or sales are rarely for more than one cropping season. Transactions in which a permanent right to surface water is sold for use in perpetuity are rare.

A more common type of water market in this region concerns groundwater and water pumped from wells. One farmer may take the risk of making a capital investment in drilling a well that is larger in capacity than needed to irrigate his or her own land and will sell excess supplies to neighbors. There is some physical limit to such water in regard to quantity and time; thus there may be a competitive market where the spare water is sold for the highest offer. In some instances, government regulation on well spacings will not allow future development and the first person to drill a well gains a small local monopoly.

A water market also depends on the ease of delivery. Obviously a neighbor living very close to the well and on flat terrain could easily build a small ditch or even install a short pipeline. A farmer who needed the water but lived more distantly over hilly areas could not afford to build a long pipeline (and perhaps also an extra pump). The owner of the well in these cases would almost certainly make the water available only at the border of his or her land—the ultimate user would have to transport it any further.

Conditions for a Water Market

For a market to exist and operate, there needs to be

- A willing buyer (demand)
- A willing seller with legal ownership and control over the water to be sold
- Some type of legal system that allows and records the sale or ownership
- A physical means for the seller to make delivery to a suitable point or for the buyer to take delivery and convey it to the point of use (often requiring easement or purchase of rights of way across the property of others

- An agreement on the price and an agreed way to measure the cost basis (volume, flow rate, time)

- A judicial system to settle disputes (commonly to settle claims of third-party damage or mismeasurement of the goods purchased).

In South Asian countries, the above factors are rarely found in a serviceable combination. A true water market would provide for both the short-term market, where a certain volume of water over a specific time would be delivered, or a long-term or perpetual water rights market where the buyer acquires the right to use the water now and in the future. For the long-term market to be sustained, a very complete water rights system must be in place that will define priority of use, joint reduction in flow by all users, or some type of volume adjustment during dry seasons.

Constraints for Creating Water Markets in South Asia

A complex, long-term, and accurate system to define and record water rights for individuals is probably the greatest constraint for developing fully functional water markets in the region. Such a system would have to expand upon existing water laws that of course already have many regional, local, and cultural influences. Some of the large irrigation systems in South Asia serve over 2 million farmers and if water were to be bought and sold, recorded, measured, and monitored, some very special physical structures, laws, regulations, and institutions would have to be in place. The spot market or seasonal sharing or trading on the fringe of irrigation systems will informally continue as in the past but there will be strong resistance to setting up market systems to handle purchase and transfer of water use rights from within the irrigation system to some more remote location outside the project area or for another type of use.

The mechanics of measuring and monitoring small units would be very costly, inaccurate, and unjust to existing irrigation users. However, large blocks or whole sub-units of an irrigation scheme might agree to sell their water (if defined by a right) to an outside entity. The mechanics of measuring and monitoring would matter a great deal in this case because the return flows from a larger area of irrigation are often a portion of the supply to downstream users. The water flow and quality must be analyzed and evaluated in order to prevent harm to third parties. These third parties also have water rights (de facto or real) and should have an opportunity to know whether or not the effects of a sale are adverse. If they are adverse, there should be either monetary or physical compensation (such as leaving adequate water in the system to make the hydrologic regime after transfer equivalent to that before transfer.

Another constraint on an active market is what can be termed "regional plumbing." In an urban setting, where water is piped to almost every user, water users can turn on the tap and get water on demand. If the user were to sell his or her right to someone else, the tap could be locked in the off position and a portion of the system would no longer be used (the pipes leading to the seller's tap.) The buyer would merely open his tap wider and take the transferred supply. In other words, the plumbing is in place. For taking water from one point to another within an irrigation system, however, there may not be adequate conveyance capacity or, in the case of purchase of water outside the projected use, there may be no canal or pipeline. Frequently, additional conveyance systems (canals or pipelines to serve new users) need to be built and maintained.

Seasonal markets or spot markets require that the "plumbing" be in place to switch from one delivery point to the next. This also means that the entire system must be maintained even though only a portion might be used at one time. In the case of long-term purchase of perpetual use water rights, a new system of conveyance must be built to deliver the water to the new points of use. It is not economically efficient to build large complex canals, hydraulic structures and other systems, only to abandon them a few years later to build other delivery systems to a municipal area. Well-planned comprehensive water resources management for river basins and regions would normally identify future needs, and make allocations (assignment of water rights) to present and future users including reserve allocations. Such planning and allocation of water rights and management systems would short-cut the need for water markets.

As noted earlier, one of the main constraints to water markets in South Asia is potential for third-party effects. This could upset economic balances of a region. For example, well-funded speculators could purchase water rights and basically shut down agricultural production. If the purchase price and resulting payment were large enough and the farmer could turn to another livelihood, the family might survive but the regional service industry would be crippled. Those who service equipment, or who sell seeds, fertilizers, supplies, would suffer. This is in addition to potential harm to downstream water users. In a sophisticated water market these factors do come into play and require institutions to make markets equitable. For example, the downstream users should have a right to adjudication and to make a claim on the return flow from an upstream user who is selling irrigation water. The buyer would have to either leave a portion of the flow in the stream or monitoring would be needed to ascertain if the calculated relationships hold true. There would need to be a public record of the sale and new legal water right. After that, the original water users in the region would have to arrange for measurement and monitoring of the residual flow to make sure the buyer does not take too much. If a buyer did take too much and this could be proved, original users would need access to a direct, inexpensive, low-level court system to right the error. This type of institutional service is decades away in South Asia.

With the minimum requirements for the transfer of a single water right, it soon becomes clear why water markets have not been found necessary among the millions of water users in South Asia. The primary water operations are not managed well enough in this region to maintain the proper share of water (or the de facto water right) of original farmers.

In time, markets in water may expand, but only in locations with extreme scarcity of resources and where municipal or industrial users can afford to pay large amounts per unit of water to an agricultural user—enough for a farmer to invest in another business or to become economically independent. The conditions in South Asia are a long way from this. Full transfer of water resources may not be in the best interest of the country, which introduces the political dimension. If a country or sub-areas (states or provinces) found that attempts at water marketing produced large groups of impoverished farmers, there would be a tendency for governments either to tax water sales in order to assist the poor or to ban such sales.

Advantages of Water Markets

Economic theory indicates that a commodity or resource should be used for the highest economic gain. Thus the opportunity cost of new water supply development should be close to the price offered in an open marketplace for water. The problem with this comparison is that the social impacts, third party impacts, and regional development multiplier effects are often not considered. For example, an incremental amount of water for agricultural production may not show a large direct economic benefit. Yet in a moderate or large project, the true regional benefits including the indirect benefits could be multiples of four or more of the direct benefit.

With the complexities surrounding previous developments for irrigation in South Asia, there are no real advantages to promoting water markets in the region. There is some potential within the municipal and industrial sectors and on the fringe of the agricultural irrigation areas, but the cultural, legal, and institutional elements necessary to support a fair market are not in place and would be extremely difficult to fully establish. The countries in South Asia are faced with assuring clean water supplies to hundreds of millions of people in the urban areas that will double in 30 years or less. Politicians will be very reluctant to allow reduction of irrigated agricultural land that is needed for national food security. As long as there are still some supplies that can be harnessed by reservoirs or other off-season storage, governments will opt for paying the cost of developing new supplies. The cost of foregone agricultural production, multiplier effects regionally, and the resulting social problem of large pockets of poor rural residents are possible results that are politically unacceptable to governments and present little incentive to promote open water markets.

WATER MARKETS: OPPORTUNITIES AND CONCERNS
Seminar Report

*K. William Easter**

Because of growing interest in the subject, one day of the Irrigation and Drainage Seminar was devoted to a discussion of water markets. The papers and subsequent discussions helped clarify many of the issues and different points of view concerning the potential role of such markets.

At one end of the spectrum were those who argued that because of market failures and the critical nature of water, governments must maintain complete control over water allocation. At the other end were those who felt that once the proper institutional setting existed, water markets could provide an efficient allocation of water both within and among sectors, with a significant economic gain for society. The most commonly held view favored the use of market-like forces where feasible, although in this view high transaction costs, externalities, and the potential for monopoly control in water markets would probably limit the use and efficiency of water markets. The main concern among those favoring market-like forces was whether or not these failings could be corrected and transaction costs lowered by appropriate government action. Although there was significant difference in opinion concerning the potential use of water markets, most participants agreed that there were certain pre-conditions for effective water markets. Three pre-conditions were highlighted as being critical.

First, the physical infrastructure and management capabilities must be such that the purchased water can be transported, at a reasonable cost, to the new owner. For neighboring farmers, this is usually not a significant constraint, but in irrigation systems with few control structures or with limited canal capacities, it may be very costly to alter existing deliveries to accommodate water sales. Capacity constraints are most likely to occur during periods of peak water demand. Inadequate or non responsive management can also stop water transfers from occurring. In Chile, water user groups are important in implementing water exchanges.

A second pre-condition is the establishment and allocation of tradable water or use rights that are separate from land rights and granted for a sufficient length of time. Without such rights, buyers would not have any certainty concerning what they were buying. These rights should be specified in terms of volumes or shares of a stream or canal flow. If they are in terms of a share of the flow, the buyer must accept the uncertainty regarding the future flows. No matter how the rights are defined, they need to be recorded and generally accepted by the water users if they are to be enforceable.

The third pre-condition involves mechanisms to resolve conflicts over water exchanges. Many conflicts can arise over third-party effects, particularly when return flows are changed.

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These types of conflicts can be minimized by limiting sales only to consumptive use. Conflicts may also arise if enough farmers sell their water to users outside of the region and the remaining farmers have a difficult time financing system O&M costs due to the decline in the number of farmers contributing.

Several other potentially necessary conditions for water markets were also discussed. One was the need to specify the water quality as part of the water right. When quality is not specified and there are no enforced water quality standards, then the owners of water rights have no legal means of preventing upstream users from polluting their water source. Another potentially necessary condition is the establishment of consistent water rights for both surface and groundwater, particularly when the two sources are interconnected. If this is not done, surface water rights will not be secure because anyone can install a well next to a canal or river, and, essentially, pump out much of the surface water. Finally, if these conditions are to be met, a certain amount of basic information is needed regarding the quantity and variability of the water supply over time. This is particularly true for rights specified in volumetric terms. Yet these information requirements are no greater than those needed for an effective administrative allocation of water or for an efficient system of (administratively set) water fees.

There was also general agreement that in most countries, the lack of some of these preconditions has limited most water sales to localized exchange for one crop season or less. These sales or trades are usually for a volume of water delivered at a certain time in the crop season to the buyer, or a certain length of irrigation time often provided by a tubewell. In systems where farmers have the right to irrigate from a canal during a set period of time, some farmers trade or sell part or all of their irrigation time. In such cases, the buyer has to accept the risk involved in the variable nature of the canal flows. Even the Water Bank in California involves only the seasonal sale of water and farmers do not risk losing their permanent water rights due to non-beneficial use of their water.

In Chile and in some states of the western United States, there have been sales of permanent water rights or water use rights. For Chile, the sales have been for use rights since the national government retains the official water right for the people of Chile. The water sales tend to occur in the drier regions and are among farmers as well as between farmers and buyers from the urban sector such as land developers and water companies. The real benefits from water markets will come in regions where water is scarce and there are opportunities to reallocate water among sectors. With water markets, there is a direct incentive to reallocate water to its highest value use since the seller retains the revenue from any sales. In addition, markets can respond quickly to changing conditions. This is quite different from administrative reallocation where government agencies make the decisions but do not compensate the losers. Consequently, losers will try to block such transfers. The end result is a long, drawn out process before any reallocation can be completed.

Even with the diverse views concerning the potential role of water markets in developing countries, most participants expressed a wish for more information concerning water markets and think the Bank should support research on this topic in developing countries. Hopefully, such research will help clarify the role of water markets in the Bank's efforts to decentralize the delivery of water services. It is already clear that there can be complementary relationships between water markets and water user associations. Associations can provide the management component necessary to implement water sales and can also make the necessary structural changes, usually at the expense of the buyer or the seller. In addition, they can be a source of information for those individuals or enterprises wanting to make trades and can reduce negotiating costs.