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Water Resources Management

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Water Environment for the 21st Century : Water Resources Management

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Introduction

In the 21st Century, water resources managers must address fundamental economic, social, and environmental goals for the survival and advancement of the human race and the environment. Challenges include global change, population growth and migration, demands for rising standards of living, poverty, natural disasters, and environmental degradation. Tools available will include new technologies, management innovations such as privatization and devolution of management authority, and increased understanding of issues through the knowledge revolution. In the final analysis, success can only occur in a framework of effective government and political institutions.

The task faced by water resources managers, scientists, and engineers will be to respond to the challenges by applying appropriate tools to benefit society and sustain the environment. This laudable goal masks deep complexities and conflicts, and to deal with them successfully, water resources managers will require higher level skills than in the past.

Given these challenges, my goal in this paper is to describe the problems facing water resources managers, and to lay out the skills and preparation they will need if they are to succeed in the 21st Century.

The Work of Water Resources Managers

Some years ago, it was thought that water resources management was primarily an engineering task-building dams, laying pipelines, installing pumps, and operating systems. The building and operation of these infrastructure systems was to take a comprehensive approach and be coordinated by government. In the United States, the era lasted into the 1950s and 60s, but has now ended.

In some other countries, development pressures continue apace because of growing populations and unmet basic needs. However, unless environmental needs are fully considered along with economic advancement, the prospects for sustainable societies are not bright anywhere.

The shift in practice in the United States was described by Gilbert White (1994) in looking back on 60 years of practice. He wrote that when he began work in 1934 the mood was the same as in the 19th Century American West where there was "the conviction that the earth was awaiting further development for human good, and that the challenge was in providing prudent stewardship". By 1994, however, he saw that the mood had changed and that the quest is now for a "lasting, healthy, balanced place for existence. It was to be a home for all in sustenance and in spirit."

In my view, the defining characteristic of water management is the interdependence inherent in the ecological and social systems that water supports. The environmentalist John Muir summed up interdependency with his saying: "When we try to pick out anything by itself, we find it hitched to everything else in the universe" (Chesapeake Bay Program, 1994).

This interdependence causes both complexity and conflict for water managers. The playing field was aptly described by the California's Water Education Foundation (1993): "Water has become one of the hottest political and scientific issues in California." The complexity and conflict were summed up in a quote attributed to John F. Kennedy: "Anyone who solves the problem of water deserves not one Nobel Prize but two - one for science and the other for peace."

In contrast to the view of some, water management is not purely a "command and control" activity, nor is it something that can be entirely "privatized". It requires a comprehensive framework with elements of both systems. However, at the dawn of the 21st Century, we see that no such comprehensive and coordinated paradigm for water management is in place in the United States or in other countries.

The stakes are high. The water industry accounts for a large share gross domestic product, and has more control over the natural environment than other industries. If nations are to solve the problems of their water industries, they will need effective water industry managers who straddle the technical, administrative, and political worlds.

Major Issues in the Water Arena

Global water issues have received much attention. In its policy paper on water resources management, the World Bank (1993), described a vicious cycle in developing countries of poor water services, leading to consumer unwillingness to pay, inadequate operating funds, and a further deterioration of services. These problems, which affect health, welfare, and safety around the world, also exacerbate environmental problems at a time when due to rapid population growth and urbanization water is becoming increasingly scarce. In developing countries solutions have been elusive due to misallocation and waste of water, institutional weakness, market failure, distorted policies, fragmented public investments, and excessive reliance on government agencies.

As examples of specific problems, Frederiksen (1992) described how cities greater than one million in India do not have 24-hour water service, how groundwater that is over-drafted in Beijing will force population relocations or large scale water transfers, and how poorly understood are Mid East shortages, including their linkages to regional conflicts.

In the Water Center at Colorado State University we have studied the major water issues that require the university's attention. Our classification system

highlights a few clear categories of issues:

Providing water for new and expanding demands. Growing populations, rising incomes, urbanization, and renewed environmental values cause rapidly-increasing demands for water, often in areas already at-capacity or with limited supplies. As an input to economic development, water is critical to almost all industries. Urban growth requires large quantities of water to provide for people, businesses, and amenities. As living standards increase, people demand water-based recreation.

Maintaining habitat for fish and wildlife. The need to sustain environmental resources is focused on the species that live there, and pressures to develop and use water and land will threaten water as a resource for these species unless balanced management methods and decisions are provided. On the one hand, providing secure habitat can be thought of as a use of water, as in instream flows in the West, and on the other hand, it can be viewed as an investment in the world's own future.

Maintaining productive agriculture. As the world's population increases after the millenium, pressures on food resources will continue to increase. Water makes possible and sustains productive agriculture, both in irrigated regions and even in rainfed regions where drought, pollution, or poor drainage can ruin crops. Technologies, management methods, and social adjustments are needed to enable agriculture to prosper along with rising demands in other sectors.

Providing security against floods and droughts. In spite of advances in technologies, water management, and land use control, flood and drought as natural and man-made hazards continue to cause serious losses. Flooding causes greater property damage in the US than any other natural hazard, and drought causes wide-spread human suffering around the world. Solutions require social adjustments and both structural and non-structural management solutions.

Minimizing water quality degradation. According to Water Quality 2000, a US policy study group, the fundamental causes of water pollution lie in the way we live, farm, produce, consume, transport people and goods, and plan for the future. While the US has made a tremendous investment in water quality, some

$500 billion since 1972, many water quality goals remain unmet, and water quality is an even more serious threat to health and the environment in other nations. Rather than narrow approaches, we need integrated policies such as watershed-based approaches, preventing pollution, developing individual and collective responsibility for water, and new technologies.

Developing appropriate institutions for a complex and interdependent environment. Of all water concerns, our institutions are the most interdependent and determine ultimately the success or failure of our management efforts. Institutions include laws and standards, organizations, regulatory procedures, ways of doing business, and other issues that affect how people live and work together. Engineers and scientists must work on institutional improvements, as well as social scientists. Ultimately, the goal is to impart improved citizenship for water management.

The Water Industry

Water managers have much in common and work in an industry which has four parts: the service providers, the regulators, the planners, and the support organizations. Figure 1 shows the linkages between different parts of the water industry.

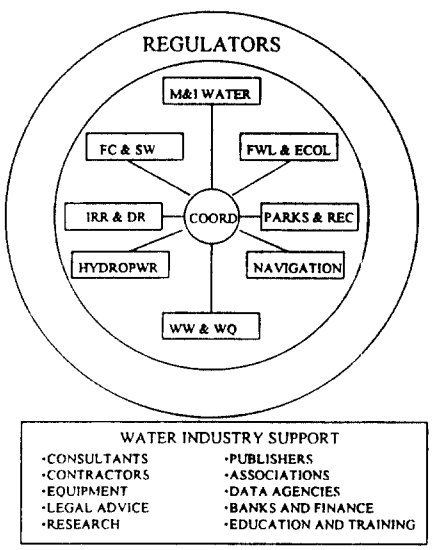

Fig. 1 The Water Industry

To describe the water needs of humans and nature, we refer to "purposes" of water resources management: water supply, wastewater and water quality management, storm and flood water control, hydropower, transportation, recreation, and water for the environment, fish and wildlife. The purposes serve four categories of water users: people, industries, farms, and the general environment. Thus, we speak of

water supply for people (domestic water supply); for cities (urban water supply); for farms (irrigation); for industries (industrial water supply); for cities and industries (municipal and industrial or M&I water); or we can speak of water for the environment (water for natural systems).

We can also speak of wastewater management for the same categories, as urban wastewater, industrial wastewater, and drainage for farms.

Storm and flood water control is a different type of activity that involves handling excessive water. As a "protective" service it doesn't provide water, but it removes or stores the excess water.

For the most part, the service providers are local government agencies or special districts that furnish water supply, wastewater and water quality management, storm and flood water control, hydropower, transportation and water for the environment, fish/wildlife and recreation. Although for the most part the players work in government, there is increasing interest in privatization and private provision of services may be increasing.

Regulators may be responsible for regulating rates, water quality, health issues or service levels. The planners and coordinators have responsibility for planning and coordination functions other than in the course of providing services or regulating. Support organizations provide a diverse array of services and goods and include those providing support such as research, technical services, supplies, information and data and others.

Planning and coordination organizations provide needed coordination in the water industry. They are few in number, but their roles are very important.

Support organizations are numerous and diverse. They provide the goods and services not provided by the service organizations, items such as research, data, technical assistance and training, public information through the press, financial assistance, equipment, professional services, legal support, construction services, and yes, environmental opposition.

Environmental organizations are influential in the water industry because of

their dedication, focus and zeal. They, along with the press, provide a balance to actions of service providers and regulators, and in some ways represent a "fourth branch of government" operating in the water industry.

Planning and Management Scenarios

One of the realities of water resources management is that problems can't be fully understood from their parts; they must be examined holistically. The mechanism used to portray water management cases is the scenario, following the assumption that these can be studied to see the main issues and options facing water managers, and the skills needed to solve the problems.

A scenario is a concept for a hypothetical or projected chain of events. It is a framework to show how a water resources system will influence and be influenced by the external environment and the players in the management game. Scenarios for water resources management might include the following:

Planning and coordination. Water management might be undertaken by single entities with control of planning, but this is becoming less common. More often, water management is a multi-jurisdictional activity, requiring careful attention to political integration. Scenarios include river basin planning and coordination, drought water management, regional integration of investment, water use, environment, and water and sanitation in developing countries.

Organization. As in any management enterprise, organizational issues arise constantly. Scenarios might include the organization of agencies in the water industry or collaborative efforts to solve major problems or build major facilities.

Water operations management. Operations management focuses on reservoirs, one of the most important water problems encountered. Other operating decisions involve selecting system pressures to maintain, allocating water to users, moving water from place to place, generating power, and selecting modes of treatment.

Regulation. Regulatory programs have evolved in the United States (exploded might be a better word) to control water development and operations. Water and environmental laws are the basis for regulation, and they affect water quality management and nonpoint source control, and estuary management. Water supply regulation involves health, environment and water conservation and efficiency. Water quantity regulation involves water allocation, control, transfers, and compacts. Environmental issues involve watersheds, wetlands, and riparian zones. Groundwater regulation and floodplain regulation are special problems.

Capital investments in facilities. Capital facilities may be classified as conveyance systems (channels, canals, pipes, bridges); dams; reservoirs; treatment plants for water supply and wastewater management; pumping stations; hydroelectric plants; spillways, valves and gates; wells; river training systems (diversion structures, boat chutes, levees and locks; and appurtenances. These require infrastructure planning and management.

Policy development scenarios. Unique policy problems require special attention, such as developing laws and policies to solve political issues dealing with resource use.

A Model for Water Resources Management

Although a simple model for water resources management does not exist, we can present a comprehensive framework for the management activities that are required and the issues, policies, scenarios, processes, principles, tasks, tools, roles, and players of an integrated water industry.

The term "comprehensive framework" was used by the World Bank (1993) to describe a policy framework meant to apply in developing countries: "An analytic framework for water resources that views water as a single resource with many uses and linkages with the ecological and socioeconomic system".

First, let me define the term water resources management: (Grigg, 1996)

Water resources management is the application of structural and nonstructural measures to control natural and man-made water resources systems for beneficial human and environmental purposes.

This definition includes traditional engineering (structural measures), planning and management (nonstructural measures), social aspects (human purposes), and natural sciences (environmental purposes).

Having defined water resources management, we now need to examine conceptual frameworks for organizing the elements of the field.

Integrated water management is a popular conceptual framework, but it is hard to explain because it contains so many concepts. Mitchell (1990) gave clues to the concept: "··· problems that cut across elements of the hydrological cycle, that transcend the boundaries among water, land and environment, and that interrelate water with broader policy questions associated with regional economic development and environmental management." My definition is:

Integrated water resources management balances the views and goals of affected political groups, academic disciplines, geographical regions, and purposes of water management; and protects the water supplies for natural and ecological systems.

Comprehensive water management is an older term, and generally means the same thing as integration (Wagner, 1995), but there is an important difference, integration implies linkage whereas comprehensive implies broad coverage. Comprehensive implies that an umbrella exists to cover all views and goals, but they are not necessarily integrated.

Total Water Management is an alternative term provided by the American Water Works Association (1994). According to a task force of AWWA, it is "the exercise of stewardship of water resources for the greatest good of society and the environment. A basic principle of Total Water Management is that the supply is renewable, but limited, and should be managed on a sustainable use basis. Taking into consideration local and regional variations, Total Water Management:

- Encourages planning and management on a natural water systems basis through a dynamic process that adapts to changing conditions;
- Balances competing uses of water through efficient allocation that addresses social values, cost effectiveness, and environmental benefits and costs;
- Requires the participation of all units of government and stakeholders in decision-making through a process of coordination and conflict resolution;
- Promotes water conservation, reuse, source protection, and supply development to enhance water quality and quantity; and
- Fosters public health, safety, and community good will."

It is my opinion that the call for balance in the term "integrated management" and the call to include all views in the term "comprehensive" is implicit in Total Water Management.

Holistic water management is a term suggested by (Kirpich, 1993) as an approach for the irrigation sector that emphasizes interagency coordination, performance standards for water users and staff, use of indigenous knowledge, local participation for corollary activities; top-down and bottom-up coordination and the linkage between water and agriculture policy.

Integrated resource planning, developed in the electric utility industry, has been translated into a procedure for the water industry. It generally involves: "defining the overall goals and objectives and establishing milestones; identifying all of the stakeholders and their concerns and involving them throughout the process; determining the problems, critical planning issues, and potential conflicts to be addressed during the process; identifying and managing risks and uncertainties; implementing the IRP; and evaluating the effectiveness of the process and making appropriate adjustments" (American Water Works Research Foundation, 1995).

Other organizing frameworks can be adopted as well. For example, the environmental impact statement process, the recovery planning process under the Endangered Species Act, and EPA's management planning process under the National Estuary Program all offer management processes.

EPA's management planning process was introduced under the National Estuary

Program (USEPA, 1988), with an approach based on "collaborative, problem-solving approaches to balance conflicting uses while restoring or maintaining the estuary's environmental quality". It is summarized briefly by EPA: "the program is woven together by two themes: progressive phases for identifying and solving problems and collaborative decision making."

Generalized concepts I found in other fields which apply are: systems thinking, civic environmentalism, and collaborative leadership. These offer useful frameworks and ideas for principles and processes, but don't give specific guidance for water managers. The business tool "systems thinking" (Senge, 1990) can be a valid framework, but its elements haven't been widely applied to water resources other than in systems analysis applied to operations. John's (1994) "civic environmentalism" is a search for alternatives to political confrontation and a new role for the federal government as a participant in decisions made at the state or local level on problems such as nonpoint problems, pollution prevention, and protecting ecosystems. Chrislip and Larson's (1994) "collaborative leadership" provides insight into complex issues, engaging frustrating and angry citizens, and generating civic will to break gridlocks. How well a community pulls together to solve its problems is a measure of its "social capital" or "civic infrastructure". As Chrislip and Larson state: "collaboration··· goes beyond communication, cooperation, and coordination··· to create a shared vision and joint strategies to address concerns that go beyond the purview of any particular party."

Finally, the field of total quality management, and related concepts such as management principles and practices offer promise. At first glance, total quality management wouldn't seem to apply to large scale problems, but parts of it might through the linkage with management practices. It might be worth exploring, for example, whether the ISO 9000 process could be a venue to implement best management practices for water. ISO, the International Organization for Standardization, is a "worldwide federation of national standards bodies representing 90 countries" with the purpose to facilitate the international exchange of goods and services and to develop intellectual, scientific, technological, and economic cooperation. "The ISO 9000 concept is that certain generic characteristics of management practice could be usefully standardized, mutually benefiting producers and users alike" (Voehl, 1994).

This is quite a mixture of concepts, but the question is how they apply to water resources management? My answer is that the organizing frameworks offer philosophical approaches and decision processes for water managers to work within, but it is up to water managers to apply correct principles to solve specific problems. Now, I would like to suggest some of the principles.

Management Practices in a Comprehensive Framework

Total quality management has identified "benchmark" management practices, and provided lists of attributes of quality organizations. The management practices are attempts to transfer the concept of "standards" to the fields of management.
From the literature, "lessons learned" and principles for good water management can be gleaned. Examples include Wagner (1995), the "lessons learned" publication of the Water and Sanitation for Health Project (US Agency for International Development, 1990), the keynote speech at the VIII World Congress on Water Resources in Cairo in 1994 of Ismail Serageldin (1995) of the World Bank, recommendations about water quality by Professor Dan Okun (1977), the management practices project of the American Public Works Association (1991), and suggestions by drought water managers (Grigg and Vlachos, 1993).

Although the suggestions come from widely differing sources and problem areas, the suggested principles can be classified in groups: comprehensive approaches; watershed focus; coordination mechanisms and stakeholder involvement; voluntary, cooperative, regional action; public involvement; conflicts and disputes; local responsibility and accountability; organizational management and role-setting; conservation approaches and environmental ethics; training, education and capacity building; market focus, pricing, incentives; risk management; decision support; finance; and regulation.

In addition, you find many platitudes and general concepts, as well as management practices that will apply in any situation, such as effective supervision. Suffice it to say that water managers must be good administrative

managers as well as effective leaders in the interdependent field of water.

The attributes can be placed into groups that require a coordinated framework, deal with inclusion, set up control requirements, outline process principles, and contain requirements for the framework.

Coordinated framework principle. This requirement sets out the concept of a coordinated framework for problem solving, an organizational structure to coordinate the efforts, a name for the program, something for the players to identify with. This attribute is necessary for management to be "comprehensive" and requires that the planning and management be broad in concept, include the stakeholders, purposes of water management, geographical regions, and related planning sectors.

Watershed focus. In an ideal situation, water managers would adopt a watershed focus for problem-solving.

Sustainable development. This is an over-arching goal of any process and is necessary to conform with environmental needs.

Process-based. This principle is that the framework has within it a decision and implementation process that can be identified and is repeatable, not arbitrary. Ideally, emphasis would be on voluntary and cooperative actions rather than a "command-and-control" approach.

Integrated. This is the linkage principle which requires that not only are the planning and management comprehensive, their parts are linked together to optimize the whole and to avoid optimizing just the pieces. Some integrating force is needed, going beyond just getting the players together.

Collaborative. This is the voluntary, collaborative requirement that includes incentives for the players to cooperate and coordinate with each other within a regulated water industry structure.

Action-oriented. This principle ensures that the planning and management exercise will, in fact, lead to results.

Adaptive. This principle ensures that the planning and management process is dynamic, leading to periodic reevaluation of goals, needs and actions, and not to a static plan.

Effective management practices. This principle requires that effective management practices in the sense of total quality control are identified and implemented. Management practices such as the enterprise principle, use of market mechanisms, effective maintenance, budget practices, and others would fit here.

Science-based. This requirement is that the impairment to be addressed is identified and defined by scientific means.

Risk-based. This principle incorporates uncertainty and risk into decision-making and ensures that decisions are taken with a proper perspective on risk, cost, and measures to reduce uncertainty.

National policy framework. The national policy framework principle requires the federal government to identify and set goals and standards to guide local officials.

Local control. This principle asserts that authority and decision-making ought to be devolved to the lowest levels possible to ensure maximum incentive to identify problems that are real and implement cost effective solutions.

Capacity-building. Local authority requires that the capacity to decide, implement and management. Planning and management framework may require capacity-building in different forms to form effective water managers and public officials.

Example

What I have described for a management model will, no doubt, sound idealistic. In the real world, it is necessary to proceed without a perfect approach. For this

reason, we ought to view the management model as an ideal approach. To take that ideal approach one step further, let me describe a hypothetical scenario for water management.

Consider the watershed shown in Figure 2 with multiple players and purposes of water management. Actually, this drawing is over 45 years old, having appeared in (Presidents Water Policy Commission, 1950).

An ideal approach to water management in this area would be a collaborative one where the stakeholders are working together to solve common and shared problems. For example, releases from the reservoir are coordinated by some joint decision body that includes representatives of local, state, and national authorities, each representing his/her own interest.

When decisions are necessary for the construction of new facilities or changes in present use of water, the decisions are coordinated by a process such as the IRP.

Advanced approaches to water finance are used, and pricing is used as a tool to allocate water and avoid waste. All organizations have adopted the enterprise principle so that no wasteful subsidies are distorting the purposes of water management.

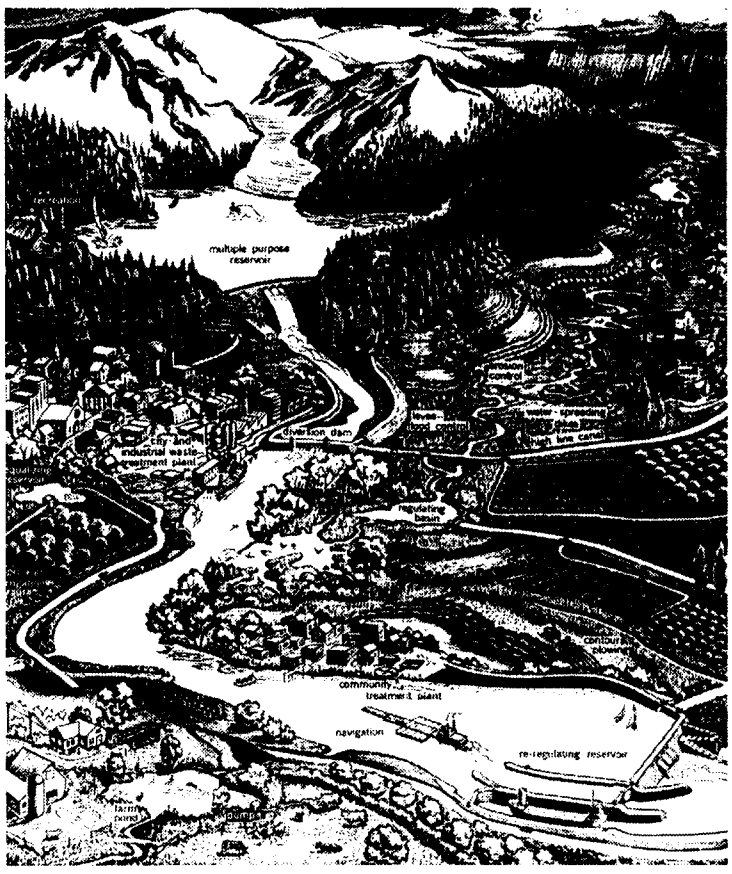

Fig. 2 Comprehensive Watershed

Social purposes are fully attended to, and might include water supply for low income, social equity, and full attention to environmental needs.

Modern technologies are used to assure effective water and wastewater treatment. Nonpoint source control is achieved by citizen actions to maintain a clean and responsible environment. Flood warning systems are in place where people or assets might be vulnerable. SCADA systems are widely used for automatic monitoring and control.

Regulatory authorities are not oppressive, but give full attention to health, environment, reliability, and cost of service.

Yes, this is an ideal situation, but the paradigm, applied to actual places, can illustrate what we are trying to achieve with water management.

Who Will Be Water Resources Managers?

Who will be the professionals who manage the water industry in the 21st Century? In the past they came from engineering and from the ranks of workers in the industry. In the future, some water resources managers will be civil engineers, but water management will no longer be their exclusive province; they will be joined by other professionals and officials who have learned the lessons about technology, ecology, law, and management sciences applied to water resources.

In the US, a nation of 265 million people, I estimate that there about 100,000 practicing water managers. In addition, another 100,000 to 300,000 are preparing for work in water management. They work in, regulate, or support state, local and federal government organizations, and consist of managers of the water, wastewater, and stormwater utilities; regulators, planners, and support personnel in the federal and state governments; and consultants, policy analysts, attorneys, and scientists who work in support of the industry. Also included are the elected and appointed officials who, once they begin to work in the water industry, discover their own needs to learn more about the

planning and decisionmaking process.

How Will Water Managers Be Educated?

What skills will these water managers need? To begin, their scope of work will be expanded to include both providing water and protecting the environment. Their educational background should be broad. The American Society of Civil Engineers stated (1994) that future engineers must be strong in their technical and scientific knowledge base, and supplemented by exposure to: a global vision and approach to problem-solving; a basic management knowledge base (business, resource, cost, and time management); and a solid foundation in personal and interpersonal attributes, ethics, and social science/humanities. These skills apply, of course, to managers in general, not just engineers. They have been described in a Water Center publication (Grigg, 1996b).

Some categories of education that seem critical are:

Hydroecology. The engineering and natural sciences that underlie water management actions are hydrology, hydraulics, water quality, and ecology. A basic understanding of them will help the water manager to assess options and impacts of decisions.

Infrastructure of water management: structures and systems. A water resources system is, by definition, a combination of water control facilities and/or environmental elements. Management strategies must consider how the system's components work together. This requires system-wide decisionmaking and control from an integrated viewpoint.

Planning and decisionmaking. The planning and decisionmaking process deals with the questions: given a goal for water management, what is the best way to accomplish it; and can approval and support be gained? Finding the best plan is technical in the sense that financial, institutional, economic, legal, engineering aspects are "technical". Gaining approval requires dealing with the public, politicians, and regulatory processes. The best way to view the steps is as a

technical process functioning inside of a political environment.

Organizational theories. Along with planning and decisionmaking techniques, the water manager needs insight into organizational issues, both as they affect internal aspects of organizations and for inter-organizational dynamics.

Systems analysis and decision support systems. To accomplish technical planning, it is essential to use quantitative techniques for analysis of water resources systems. The set of techniques used fit into the framework of "decision support systems" (DSS), a term which generally means the data bases, models, and communication systems necessary to provide the manager with good advice for decisionmaking.

Water and environmental law. Water managers need to know a lot about water and environmental law. With conflicts over values and rights on the increase, the venue for solving them is the legal system.

Financial management. Finance is one of the key steps in implementing any water project or action, and one of the most important subjects in the field of water resources planning and management. Financial tasks are planning, programming, budgeting, accounting, cost control and revenue management.

Principles for water resources management. After considering the tasks and scenarios of water resources management, a group of principles for effective management emerge. Some of these, such as the enterprise principle for managing a water utility, were learned only after mistakes were made.

Case studies to integrate principles. Actual case studies can illustrate major, cross-cutting topics such as water quality and river basin management, and provide interesting material for the study of the principles of water management.

A strong theme that is implicit in these skills is the creation of citizenship skills, the ability to work for the public good on teams and build trusting relations with others.

Conclusions

In the 21st Century, water resources managers must take actions to help sustain and advance the human race and environment. They will face complexities and conflicts, and require higher level skills than in the past. The paper outlined skills and preparation they will need to succeed in the 21st Century.

There has been a sea change in the requirements on water managers. Some years ago, they were primarily engineers - building dams, laying pipelines, installing pumps, and operating systems. In the United States, the era lasted into the 1950s and 60s, but has now ended. In some other countries, development continues faster than in the US, but environmental needs must still be met. What is needed in all countries at the dawn of the 21st Century, is a workable paradigm for water management.

Although they come in many forms, water issues can be placed in a few categories: providing water for new and expanding demands; maintaining habitat for fish and wildlife; maintaining productive agriculture; providing security against floods and droughts; minimizing water quality degradation; and developing appropriate institutions for today' s environment.

Water managers have much in common as they work in an industry with four parts: service providers, regulators, planners, and support organizations. They face scenarios that include, in addition to capital investment, planning and coordination, organization of management processes, operating water systems, regulatory tasks, and policy development.

Although no simple model for water resources management will be adequate, we can present a framework for the management activities that are required and the issues, policies, scenarios, processes, principles, tasks, tools, roles, and players of an integrated water industry.

Concepts for organizing the framework include integrated water management, comprehensive water management, total water management, holistic water management, integrated resource planning, and a number of other modern

management concepts.

Whatever framework is chosen must be accompanied by "benchmark" water management practices and attributes of quality organizations. These include practices such as the watershed approach, water pricing, conservation, and others.

In the future, some water resources managers will be civil engineers, but they will be joined by professionals from other fields who apply technology, ecology, law, and management sciences to water systems. The educational background for these officials must be broad, and they must exercise excellent citizenship skills because their success in an interdependent industry requires the ability to work for the public good on teams and build trusting relations with others.

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