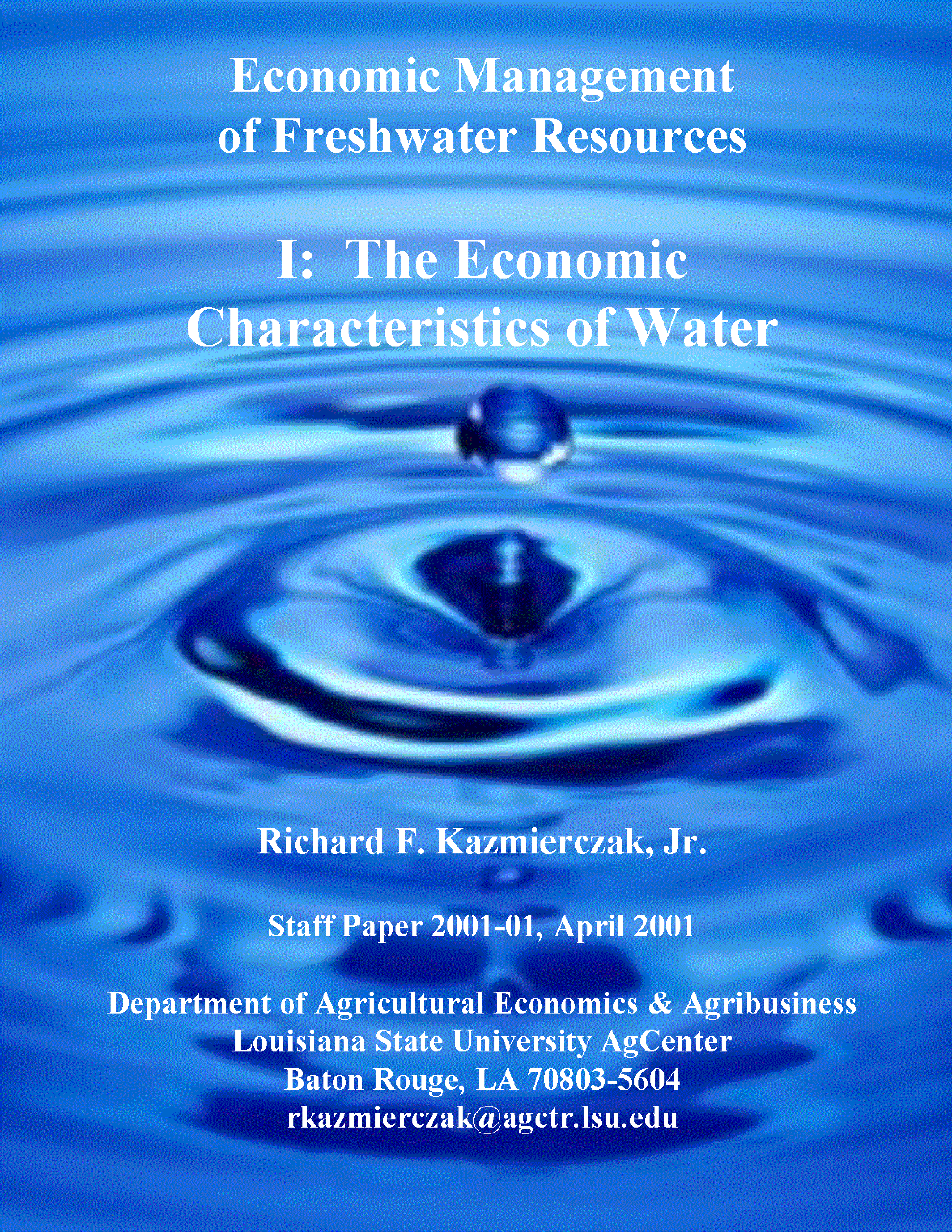

Economic Management of Freshwater Resources

I: The Economic Characteristics of Water

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Forward

This paper is the first in a planned series that seeks to synthesize and describe many of the economic questions that arise when attempting to develop groundwater and surface water management policy in Louisiana. In this series, current economic perspectives on water policy will be drawn from the technical and policy literature, with particular emphasis placed on the challenge of coordinating tradeoffs among different water users. While these reports will not attempt an exhaustive review of the broad water management literature, a comprehensive discussion of economic-based water management is a primary goal. In addition, the series will try to avoid focusing on a specific policy approach, but instead detail the issues and policy options that are often confronted when managing water resources. This information should help to frame water management issues within a broader resource-economics context and provide a basis for the development of enlightened management policy.

Given that this series is evolving over time, each report will be updated as new research and information sources are uncovered. Thus, these reports should be considered "living documents" and will be available on a continuing basis at the Department of Agricultural Economics & Agribusiness' website. They can be directly accessed through the following URL:

http://www.agecon.lsu.edu/WaterEconomics

As always, your comments and suggestions are welcome and will be considered in future revisions (please email them to the address on the title page).

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Economic Management of Freshwater Resources I:
The Economic Characteristics of Water

The potential for diminished freshwater resources, and the management of the resulting water scarcity, will be a challenge facing Louisiana policy makers in the coming decades (Louisiana Coastal Wetlands Conservation and Restoration Task Force and the Wetlands Conservation and Restoration Authority 1998; Louisiana Economic Development Council 1999; State of Louisiana Executive Order No. MJF 2000-44). The definition of water scarcity, however, remains open to debate in a state that has traditionally treated groundwater as an open-access resource and has managed surface waters through a simple riparian rights system (Klebba 1993). In common usage, scarcity generally refers to a situation where physical supplies of a resource are limited relative to the total physical demand for its use. This form of scarcity conjures images where freshwater is not available in sufficient quantity to meet basic human requirements without radical changes in lifestyles and standards of living. A distinction should be made, however, between basic water needs and the larger set of demands on water to provide above-subsistence levels of goods and services (Lundqvist and Gleick 1997). Given the abundant stocks of groundwater and flows of surface water in the state (Louisiana Department of Transportation and Development 1984), the vast majority of Louisiana residents are not faced with physical scarcity.

While it is unlikely that many Louisiana communities and industries will face critical physical water shortages in the foreseeable future, the groundwater and surface water supplies that they rely upon are experiencing degradation (Louisiana Department of Transportation and Development 1984). Stresses on freshwater supplies can come from growing population, expanding cities, chemical and thermal contamination from agricultural, industrial, and power plant operations, and mismanagement through over pumping of slowly recharging aquifers. For the most part, these types of stresses do not create physical scarcity, but economic scarcity. Economic scarcity in this context can be defined as a situation where supplies of freshwater are limited relative to the demand for its use *at a price that users of the resource have become accustomed to paying*. In states like Louisiana, where institutional arrangements aimed at regulating private appropriation of common water resources currently do not exist, the direct and indirect subsidization of water supplies has transformed the user's concept of water demand into one where the resource is expected to be available at status quo (often zero) costs (Arrojo 1999).

Considered from the perspective of economic scarcity, a large number of Louisiana communities and industries may face water shortages because of the limited opportunities and rising costs of developing new supplies. Addressing this problem may require basic changes in how water is managed and allocated. A state's ability to manage water resources, however, depends to a large extent on its overall capital endowments, and in particular on the infrastructure for redistributing water of a desired quality over space and time. It also depends on the existing social capital, where social capital can be loosely defined as the relationships among individuals and institutions.[1] Thus, while ultimately technical and political in nature, water policy has, at its core, a number of economic issues that will determine the ultimate success and stability of any management scheme. This paper focuses on the economic characteristics of freshwater resources because these characteristics affect the potential

[1] Empirical evidence suggests that communities poorly endowed with freshwater, but which develop formal or informal resource management rules, perform better at efficient allocation than communities which, despite their resource abundance, are unable to develop rules for allocating water resources among different users (Gleick 2000). Given that Louisiana enjoys a relative abundance of water resources, the state is not facing a classic resource crisis, but rather a potential policy crisis.

establishment of property rights, user decision making, and the role of government in resource management.

Water as an Economic Good

Water has been traditionally viewed in the eastern U.S. as an abundant, nontradable commodity with little economic value. As a result, water property rights[2] rarely were an issue, particularly if compared to the attention they received in the western U.S. Recent perceived threats of water scarcity, however, have focused public attention on the value of water and the costs involved in obtaining it. In Louisiana, drought has led some consumptive and instream flow water users to experience acute and intermittent surface water supply shortages. Problems with groundwater supply have primarily appeared as increased costs of access, diminishing aquifer storage capacity, saline intrusion, land subsidence, and (rarely) as physical shortages. Degrading water quality also plays a role in the perceived threat of water scarcity, as specific water demands are often tied to water of a given purity. Louisiana's lack of a comprehensive water use policy has been highlighted by these recent problems, but successful policy adjustments will be complex because water users face interrelated water quantity and quality problems. For long-run water management to be successful, a balance has to be achieved between the withdrawal uses of water (irrigation, drinking water, industrial, power generation), the instream uses of water (recreation, ecosystem maintenance), and the use of water to discharge effluents (Zabel,

[2] A property right is a set of relationships between the right holder, others who may interfere with or be affected by the right holder's choices, and the social mechanism to which the parties refer for definition and enforcement of their respective rights and duties (Bromley 1993; Libby 1994). The term property "right" in this report is defined in the Hohfeld (1913, 1917) jurisprudence sense to be the jural correlative of "duty." Under this concept, an individual can legitimately claim a "right" to a resource only if at least one other person has a corresponding "duty" not to interfere with its possession and use (Cole and Grossman 2000). Privileges, liberties, power, immunity, or mere historical precedence do not constitute a "right " under this legal definition. Using this very specific definition of a property right will place this report's economic discussion in a context familiar to the legal profession and past rulings of various courts. Property rights are in a perpetual state of flux as threats, opportunities, and social values change. There is no unique allocation of rights that merits serving as the baseline against which all future changes

Andrews and Rees 1998). While many of these uses may be rationalized by the development and adoption of new technology, in many cases water resource problems are primarily the result of inefficient policy and institutions (Adamowicz and Horbulyk 1996). It is the inefficiency of policy and institutional arrangements that attracts the attention of economists.

Meaningful changes in water policy, institutions, and valuations begin with an understanding of the nature of water. As a natural resource used in economic activity, water exhibits both renewable and nonrenewable characteristics depending on its source. Surface water is generally considered renewable, although supply can fluctuate by seasonal and geographic factors, and water quality issues can change the availability of water for specific purposes. Storage reservoirs are used to temper the impact of fluctuations in surface water supplies, but their capacity is limited relative to the total water demand generated by irrigation, industrial, and drinking water users.[3] In contrast, groundwater is often (but not exclusively) consider a nonrenewable, stock resource that is mined by water users over time (Provencher 1995). Although groundwater stocks are clearly rechargeable by both natural and artificial means, the potential benefit of recharge in use decisions tends to be small relative to aquifer capacity, established withdrawal rates, and allocations based on time-discounted economic criteria. In fact, most economic research has treated groundwater recharge as either invariant with respect to the current stock of groundwater or variable only as the aquifer approaches

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in entitlements should be measured and from which all losses should be compensated. Property conflicts are pervasive and impose costs at every level of society (Colby 1995).

[3] The physical characteristics of water make it extremely costly to store sufficient supplies to meet quantity and quality demanded. As a result, the potential scale of most water projects and the monopoly power that might arise has created concern that private sector control over water could result in the exploitation of consumers. In an effort to overcome this problem, the public sector historically has weakened private investment incentives and erected obstacles to the private development of large storage reservoirs and canal networks. Even without these disincentives, private interest in developing water projects might be limited given that existing reservoir and canal systems exhibit strong public good characteristics (non-rivalry and high cost of exclusion). Maintenance of these systems also has public good characteristics because it is difficult to exclude individual users from benefiting from improvements.

maximum capacity (Brown and Deacon 1972; Burt 1964; Burt and Cummings 1969; Cummings and Winkelman 1970; Feinerman and Knapp 1983; Gisser 1983; Gisser and Sanchez 1980; Moncur and Pollock 1988).[4]

One of the main benefits associated with groundwater use is the predictability of the resource. Because of this predictability, groundwater often explicitly or implicitly plays the role of a contingent water source to buffer seasonal surface water supplies (Provencher 1995). In this contingent role, however, little attention has been given to the impact of local or global drawdowns of the resource. While it is true that water resources, considered as natural capital,[5] need not be preserved at a constant stock level in order to assure future economic activity, it is generally accepted that future economic growth depends on keeping the total capital stock of society (manufactured, human, as well as natural) constant (Hartwick 1977; Page 1977; Solow 1986). The policy challenge is one of jointly managing renewable, but stochastic, surface water resources and nonrenewable, but relatively predictable groundwater resources for the purpose of assuring continued availability in the future. The success of policy depends on the ability to accurately value the water resources being used (National Research Council 1997). Developing the institutions for this valuation process, and determining the impact of changing valuations on allocation of water to various users, is the primary role the economics profession plays in the creation of water policy (Whittlesly and Huffaker 1995).

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[4] Studies that do treat recharge as an endogenous variable typically do not focus on its valuation effects (Reichard 1987; Tsur and Graham-Tomasi 1991). Given the greater potential for stock effects and the existence of backstop technologies (i.e., desalination), coastal groundwater aquifers have been modeled as renewable and replaceable resources (Krulce, Roumasset and Wilson 1997).

[5] Capital assets take three forms (Pearce and Atkinson 1995); (i) man-made, or manufactured, capital (also called reproducible capital) in the conventional sense of machines, buildings, etc., (ii) human capital, or the stock of knowledge and skills possessed by people, and (iii) natural capital, which can be narrowly construed as product-generating natural resources (energy and minerals) or more widely interpreted as including all renewable and quasi-renewable resources yielding a flow of services and/or goods. The concept of natural capital extends the traditional economic notion of capital as a manufactured means of production to include resources that have value because they, in part or wholly, generate and maintain environmental services (Prugh et al. 1999).

Valuing Water Resources

Economics can be defined as the study of human attempts to meet desired goals with scarce resources that have alternative uses (Kessler 1997). The term "scarce resources" encompasses all the items that go into the production of consumptive goods and services. As a multiuse resource, water satifies demands for drinking and sanitation, industrial processing, irrigation, power generation, recreation and environmental maintenance. Whether water as a resource is scarce or not may depend on temporal and geographical factors that limit the ability of supplies to fully satisfy all demands simultaneously at no additional cost. But, if water is a multiuse economic good, then past research studies clearly show that efficient water allocation among competing users will only occur if the price of water reflects the full economic costs of its supply (Smith, Franks and Kay 1997). The economic cost of supply includes the long run marginal costs of supply (preferably computed by using future capital replacement costs rather than actual historic costs) plus the opportunity costs of the water used (Meinzen-Dick and Rosegrant 1997). Conceptually, a policy that promotes price-based allocation of water can also account for water's basic role as a requirement of life by first allowing non-priced allocations to meet the basic needs of each member of society (Hayami and Ruttan 1985). Once beyond providing a subsistence amount of water to its members, an economically efficient society would strive for water prices equal to the full economic costs of supply. This price level will lead users to demand water only up to the point where the benefits they receive from the last unit used equals the price they pay for it.

One difficulty encountered when trying to value water resources as economic goods is the need to develop a clear definition of water as a commodity (Bergstrom et al. 1996). Figure 1 summarizes the technical data required to define water as an economic good. Although the technical specification primarily involves the work of hydrologists, geologists, engineers,

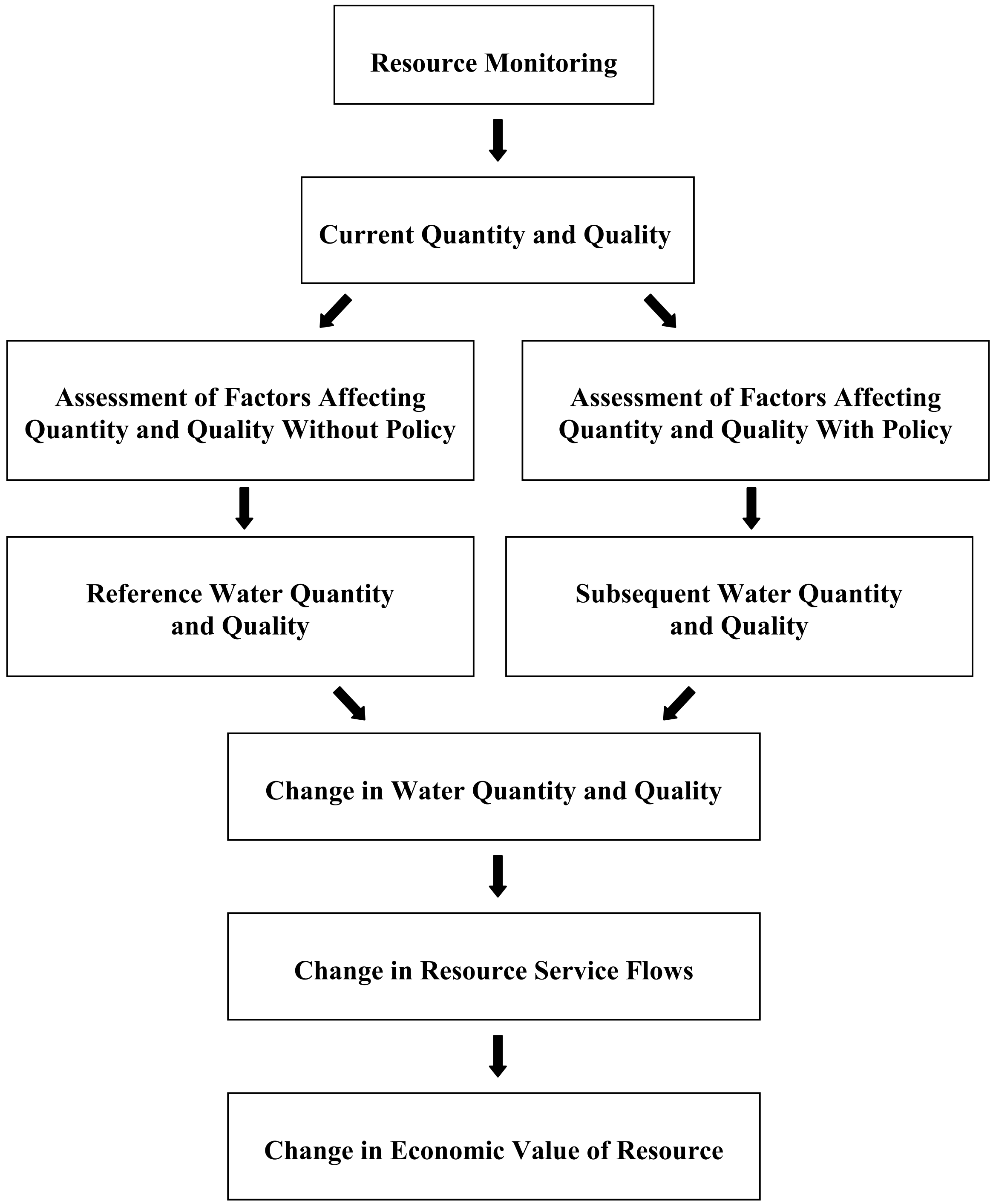

Figure 1. Summary of the Technical Data and Relationships Needed to Define Water as an Economic Good and to Development Economically Efficient Water Policy (adapted from Bergstrom et al. 1996).

ecologists, soil scientist, and other physical and biological scientists, economic valuation requires that a linkage be made between the technical data and potential changes in society's demand for water services. Economic valuation therefore requires that progress be made on two fronts; establishing the relationship between water policies and changes in the biophysical condition of water resources, and developing these relationships in a way that allows for the estimation of policy relevant economic values. Given that this process requires cooperation between economists and other scientist, the valuations that emerge may change over time as more technical information becomes available about the resource and its economic use (Bergstrom et al. 1996). As a result, policy that treats water as an economic good needs to have a flexible structure that allows for dynamic adjustments without having to constantly revisit the policy development process.

Public Good Characteristics of Water

Even when treated as an economic good, water resources have characteristics that might create inefficient supply conditions. In particular, natural mobility, extensive geographic distribution of resource pools, and to some extent supply variability makes it difficult and expensive to establish property rights based on water volume. The primary expense comes in the form of high transaction costs associated with determining water availability over time and the monitoring necessary when there is extensive user participation in resource withdrawals. While future changes in monitoring technology may reduce these transaction costs, they currently present a significant impediment to the establishment of water property rights. Where established, groundwater ownership traditionally has been tied to land ownership, while surface water rights have been based on flow shares (appropriative of rights) or location (riparian rights). In either case (rights not established or attached in some form to land ownership), water becomes an open access or common pool resource where there is a high cost of excluding users. If competitive users cannot be excluded, then individuals have no incentive to conserve water because they cannot hope to benefit financially from scarcity rents that will emerge in the future.

Given that common property resources are subject to degradation or overexploitation, individuals are motivated to increase utilization of the resource because they receive a direct benefit from doing so, but share only a part of the cost resulting from resource overuse. Unless there is coercion or some other special device to make individuals act in their common interest, rational self-interested individuals will not act to achieve their common or group interests (Olson 1965). The only viable solution to this problem in many cases is to privatize the common property or keep it under some form of government influence and control, thereby restricting free access to the resource (Hardin 1968).[6] For example, under potential Pareto-optimal economic solutions, groundwater depletion (when groundwater is considered a non-renewable resource) should result in increased adoption of water conserving technology over time. If, however, competition and open access to the groundwater aquifer are the norm, diffusion of water conserving technology will occur too slowly to be optimal, leading to resource depletion which occurs faster than economically desirable. This suggests the need for a time-varying policy instrument (water use tax or a subsidy based on water saved) to correct for this market failure (Shah, Zilberman and Chakravorty 1995).

[6] There is, however, a growing body of theoretical literature (Hardin 1982; Marwell and Ames 1979; Ostrom, Gardner and Walker 1994; Runge 1981, 1984; Sandler 1992; White and Runge 1994) and empirical examples (Bernard and Young 1997; Freeman 1989; Korten 1987; Korten and Klauss 1984; McCay and Acheson 1987; National Research Council 1986; Ostrom 1988, 1990; Siy 1982; Wade 1987) that explain and observe cooperation and defection in local common property situations on the basis of something other than the traditional economic free-rider problem. The dissonance occurs because in the standard public good game there is no provision for communication, no opportunity for persuasion or conercion, no possibility of reciprocity, and no social disclosure of individual choices (Rupasingha and Boadu 1998). In essence, the economic model of human behavior is one of very simple, egoistic rationality, and as such may not model actual human behavior very accurately when it comes to the management of local commons (Quiggin 1987).

Compounding the pure public good problems associated with water allocation is the frequent existence of externalities[7] and uncertainty. In principle, the valuation of water should include the costs of mitigating any negative externalities and the benefits of any positive externalities that might occur due to its use.[8] It is in the very nature of externalities, however, that the generator of the externality uses a resource for which he does not fully pay, or conveys a benefit through the use of the resource for which he is not fully compensated. While the consideration of externalities will have impacts on the management of new and existing water resources, actually incorporating (internalizing) externality costs and benefits is difficult without resorting to government intervention. In fact, attempts to internalize the costs of externalities have provided much of the justification for regulatory practices in the U.S.

Uncertainty associated with water resource services is another factor exacerbating the public goods problem in water management. Because data regarding the quantity and quality of groundwater are imperfect, the expected changes in groundwater service flows are a function of not just the number of alternative baseline and future groundwater conditions, but also the probability of each alternative occurring. In addition, there are often several competing policies for accomplishing a particular management goal, and each policy may have a different probability of success. Freeman (1993) demonstrated methods for adjusting measures of economic value to reflect this uncertainty, but their application in real-world policy development have been scarce.

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[7] Externalities in the current context can be defined as the costs (or benefits) related to the supply or use of water but that are experienced by someone other than the supplier/user and are not a part of the supplier/user's decision making process.

[8] Negative water externalities include phenomena such as increased pollution or salinity loads for downstream users, aquifer depletion, or the loss of aquatic habitats. An example of a positive externality would be the value of any aquifer recharge that occurs as a byproduct of irrigation using either surface or groundwater sources.

Of course, the problems of uncertainty extend beyond the typical water services focus on access and infrastructure problems. A major source of uncertainty in water management is the implementation of environmental flow requirements. While the concept of environmental water demand has not been well defined in many cases, required environmental flows will have an impact on the availability of water for both current and future consumptive uses (Beare, Bell and Fisher 1998). Concerns over this form of uncertainty becomes especially acute (and politically charged) when policy decisions involve some degree of irreversibility in investments or outcomes. When uncertainty and irreversibility are major issues, the often substantial costs associated with a safe minimum standard for resource protection may not dominate the policy decision criteria (Ready and Bishop 1991; Bishop 1993). In fact, policy makers may want to consider protecting water resources regardless of the cost to current users (at least for a short period of time) if the information deficiencies (and thus uncertainty) are large.

For example, suppose a particular aquifer is threatened with depletion in the long-run, but mitigating the depletion would impose high costs in the short-run. The uncertainty of future population growth and use demands, combined with the economic discounting process, can result in a very low priority being placed on the possible future benefits of protecting the aquifer. Consequently, a policy to protect the aquifer may not pass a standard cost benefit test (from Bergstrom et al. 1996). Thus, protection becomes a normative decision that must eventually be made at the some political or administrative level (Bergstrom et al. 1996).

Economics and State Water Management

The many public good characteristics of water, and the perspective of water access as a basic human right, has stimulated extensive government involvement in water resource management and the provision of public water services. This public sector management activity, however, has led to a series of problems, including the rent seeking and budget maximization incentives typically associated with government failure. Combined with government's susceptibility to interest groups, these failures have often led to the setting of management policy that provides water access to users at prices well below the short- and long-run marginal and average cost of supply. The end result is cheap water whose price does not take into account scarcity rents or capital costs and thus promote the overexploitation of the resource base.

Although the history of government management of water resources is checkered, there may be opportunities between the extremes of rent maximization and total rent dissipation for government institutions to manage and allocate common pool resources like groundwater with reasonable economic performance. The difficulty is in identifying these opportunities. Gordon (1954) described how monopolist ownership would internalize common pool resources externalities, thereby creating incentives for total rent maximization and efficient resource allocation. In the context of groundwater, Brown (1974) and Gisser (1983) argued that legal restrictions on user access to common pool resources could improve rent accrual. This argument led Eswaran and Lewis (1984) to demonstrate that the degree of rent accrual depends inversely on the number of users depleting the resource. Libecap and Wiggens (1984), however, found that cooperative, non-competitive (and thus resource overexploiting) behavior in oil extraction occurred only with fewer than five firms. Walker, Gardner, and Ostrom (1990) and Walker and Gardner (1992) reached a similar conclusion in laboratory experiments, where a high degree of rent dissipation and/or resource destruction could occur with access limited to as few as eight individuals. Of course, specific forms of property rights are widely recognized as reducing or removing the incentive to overexploit a common pool resource (Levhari, Michener, and Mirman 1981). Smith (1977) recommended that rights to a share of groundwater stock should replace open access capture, while Gisser (1983) noted that individual rights to annual water quantities, combined with a guaranteed time period of depletion, effectively defined a share right. Both authors reasoned that this form of property rights – stock quotas – would achieve most of the benefits associated with the efficient economic use of groundwater. Gardner, Moore and Walker (1997), however, showed that although entry restrictions and stock quotas distinctly improve performance, a substantial amount of rent remained unappropriated.

Part of the efficient-management challenge lies in recognizing that water valuation, especially under changing property rights structures, must include consideration of changing demand for water, the uncertainty in annual supply augmentation from conjunctive sources, and the imbedded institutional cost of modifying water rights.[9] Uncertainty about the level of the excess demand influences the level at which management should switch from governmental to market institutions. Increasing supply uncertainty drives a larger price wedge between marginal trade conditions and makes the use of government institutions for management more attractive. Because water demand evolves stochastically over time, the switch point cannot be defined in terms of time, but must be defined in terms of the expected cost of current and future excess demand (Howitt 1995). Looking at the government versus market management question from this viewpoint is important because the level of uncertainty about the resource is one parameter that can be altered by policies aimed at research and information dissemination. Under certain conditions, the public goods, externality, and uncertainty problems might even be best dealt with by considering alternatives to central control. A key to the success of these alternatives would be the reliance on private user-held information or information generated at relatively low cost. One alternative is control by local water districts. Compared with a single, centralized state regulator, these smaller units of control might prove more responsive to changing economic and hydrologic conditions, and more capable of obtaining the production and cost information

[9] Actually taking these factors into account in a water valuation process would require the development of a dynamic stochastic model with lump-sum institutional adjustment costs (Howitt 1995).

necessary to make the appropriate allocative decisions. The disadvantage of local control is that in so far as a small number of independent entities extract groundwater from a common aquifer, the potential still exists for inefficient use of the resource. In particular, each local district may only consider the marginal user costs that its pumping imposes on its members, ignoring the marginal user costs its pumping imposes on nonmembers. Even in this case, however, the broader perspective of a water district charged with maximizing the net present value of the water revenues of its members would generate a welfare improvement over the common property arrangement.

Summary

The design of effective water management policy requires understanding whether specific water resources are private or public goods. If private, allocation can reasonably be left to free market forces following the establishment of appropriate institutional structures. If public, extra-market management (usually in the form of government regulatory intervention) is likely to be needed to attain social objectives. The classification of specific water resources as private or public goods depends primarily on the characteristics of resources (stock size, geographic extent, recharge rates, flow variability), the form of property rights associated with the resource (and thus the number of current and potential users), and the existing management institutions.

Perhaps the biggest problem associated with Louisiana's current water policy (or lack thereof) is related to the fact that individual water users have no incentive to conserve water when specific water rights do not exist or when they are strictly related to land ownership. Under both open access and riparian rights, an individual either cannot exclude others from access to the resource stock or the cost of exclusion is high (as with litigation over individual claims). Under these conditions, an economically rational water user will not conserve water or invest in water conserving technology because they cannot capture future increases in the resource's scarcity rent. Water use rights must be separable from land ownership and granted for extended periods if users are to have structural incentives to invest in water conservation. The allocation of water rights, however, generally involves the redistribution of significant economic rents and needs to be developed through a transparent process that includes stakeholder participation. Historical use can provide a guide in the assignment of rights, but this approach will not work if past use significantly exceeded actual supplies or if there are overlapping claims to water resources. In these latter cases, assigned rights might incorporate uniform use reductions to balance typical annual supply and demand.

Governmental failure (in the political economy sense) in the public provision of water to private users has led to overexploitation of the resource base. Public water programs historically have been promoted for their potential to create economic development, address public goods issues, and provide access to water as a basic human right. In the process, however, agency rent-seeking and budget-maximizing behavior, as well as the influence of interest groups on agency decision making, has often led to the setting of water prices that are below both marginal and average supply cost. The result is short-run, low-cost access to water and long-run over use of water resources (primarily due to the exclusion of scarcity rents and capital costs from the rate-setting process).

In addition to the previous points, the conjunctive use of surface water and groundwater resources must be considered when developing water rights regimes and allocation mechanisms. The recognition of this need has manifested itself through increasing regionalization of water resource management, hindered primarily by the difficulty in obtaining appropriate hydrologic and economic data to develop the sophisticated models needed to assess the economic effects of various large-scale management schemes. Unless investment is made in developing the needed information, state-level management of water resources may be infeasible on a technical basis. As an alternative, local management of conjunctive water use may be feasible and economically efficient when the requisite infrastructure and human capital are available. Compared with centralized management, smaller units of control tend to be more capable of obtaining the information needed for decision making and more responsive to changing economic and hydrologic conditions. However, the potential still exists for inefficient water use if local management authorities overlap common groundwater or surface water resource for which rights are not fully assigned.

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