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Economics Research Supporting Water Resource Stewardship in the Pacific Northwest

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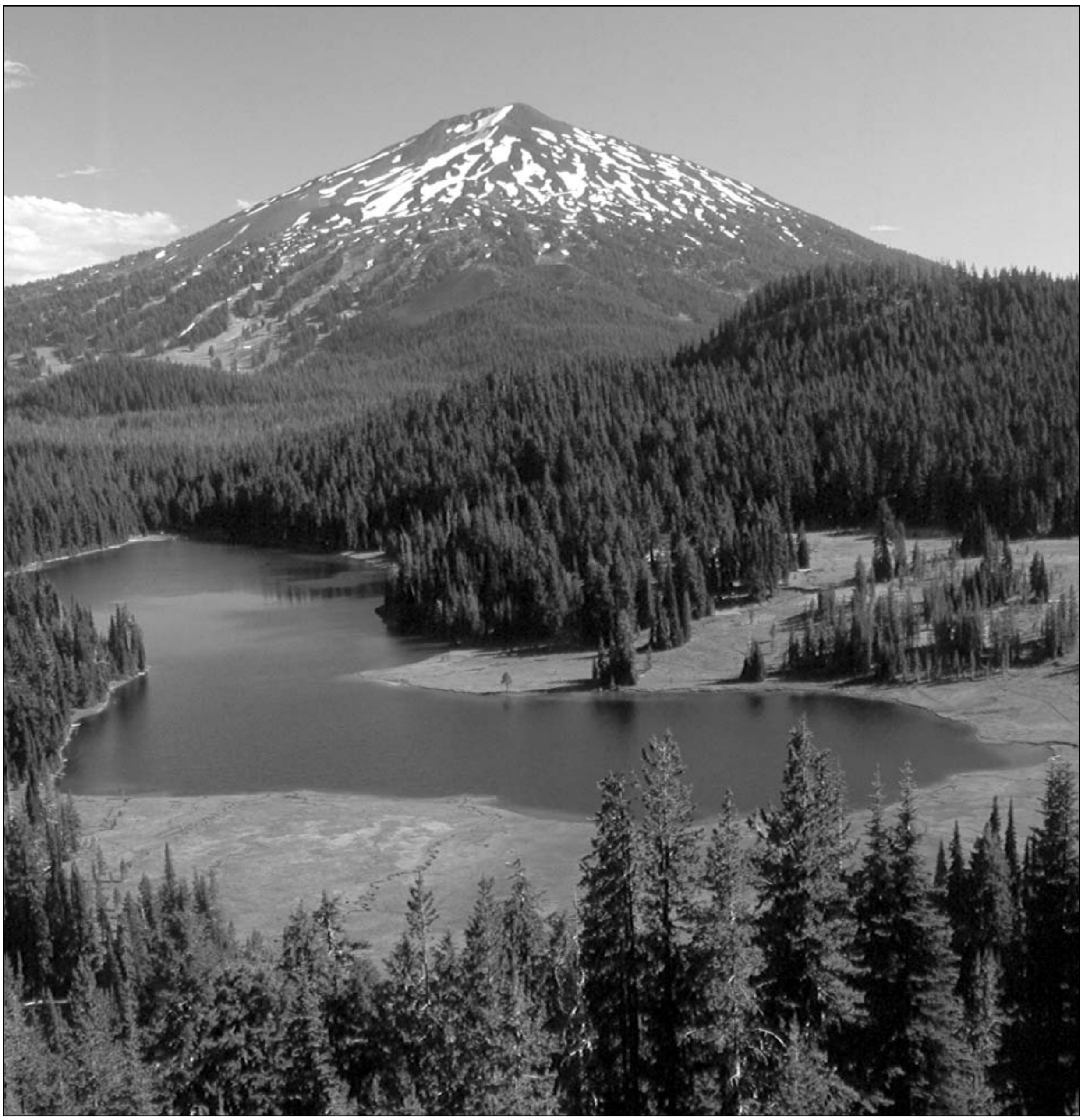

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Abstract

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The use of water increasingly involves complex tradeoffs among biophysical, economic, ecological, and societal values. Knowledge about the value of water to different users and methods with which to evaluate biophysical, economic, ecological, and social tradeoffs associated with allocating limited water resources among competing uses is vital to devising appropriate and effective water resource policies. A review and synthesis of water resource economics research can contribute to a foundation on which to plan and conduct interdisciplinary research evaluating tradeoffs regarding water. It also can assist in setting research priorities for developing analytical processes and tools with which to evaluate tradeoffs, as well as develop water resource management strategies that are ecologically sound, economically efficient, and socially acceptable. Intended primarily for noneconomists, this report reviews existing water resource economics literature concerning the economic value of water in different uses in the Pacific Northwest, the evaluation of tradeoffs among uses, and the use of economic incentives for water conservation and protection or enhancement of water quality. The synthesis of water economics literature culminates in the identification of priority research topics relevant to the Pacific Northwest. An annotated bibliography of a sampling of water resource economics research is provided in an appendix.

Keywords: Economic values and tradeoffs, water quality and quantity, riparian species.

Contents

Introduction

The use of water increasingly involves complex tradeoffs among biophysical, economic, ecological, and societal values. Demands for water in different uses are projected to increase at a moderate rate in the future (Brown 1999). Increased demand will be driven largely by steady population growth, tempered by accompanying increases in various conservation efforts. In the Pacific Northwest, water is subject to various competing uses that have different values and tradeoffs associated with them. These uses include navigation, power generation, industrial uses, irrigation, boating, fishing, swimming, drinking, household uses, lawn and landscape maintenance, and habitat for salmon and other fish and wildlife species. Knowledge about the value of water to different users and methods with which to evaluate the biophysical, economic, ecological, and social tradeoffs associated with allocating limited water resources among competing uses is vital to devising appropriate and effective water resource policies.

Water resource economics can help in this process. Principles of water resource economics are based on the laws of supply and demand for water. A significant amount of research pertaining to water resource economics provides analytical techniques for addressing distortions or impediments to the efficient workings of the marketplace for water. Water resource economists have developed methods for estimating the value of water in different uses and for evaluating economic tradeoffs among different uses. A review and synthesis of the water resource economics research can contribute to a foundation on which research institutions can plan and conduct interdisciplinary research evaluating biophysical, economic, ecological, and social tradeoffs regarding water. A review and synthesis also can assist in setting research priorities for developing analytical processes and tools with which to evaluate tradeoffs, as well as assist in developing water resource management strategies that are ecologically sound, economically efficient, and socially acceptable.

Intended primarily for noneconomists (with a glossary of selected economics terms provided in app. 1), this report reviews existing water resource economics literature as it relates to the economic value of water in different uses in the Pacific Northwest, the evaluation of tradeoffs among uses, and use of economic incentives for promoting water conservation and protection or enhancement of water quality. Specific objectives include providing (1) a conceptual overview of water uses, (2) a review of methods and research regarding the valuation of water in different uses, (3) a review of methods and research evaluating tradeoffs among water uses, (4) a conceptual overview of economic incentives to manage water resources, with examples, and (5) an overview of the changing socioeconomic context of water resource management at national and regional levels. The synthesis of water economics literature culminates in the identification of priority research topics relevant to the Pacific Northwest. An annotated bibliography of a sampling of water resource economics research is provided in appendix 2.

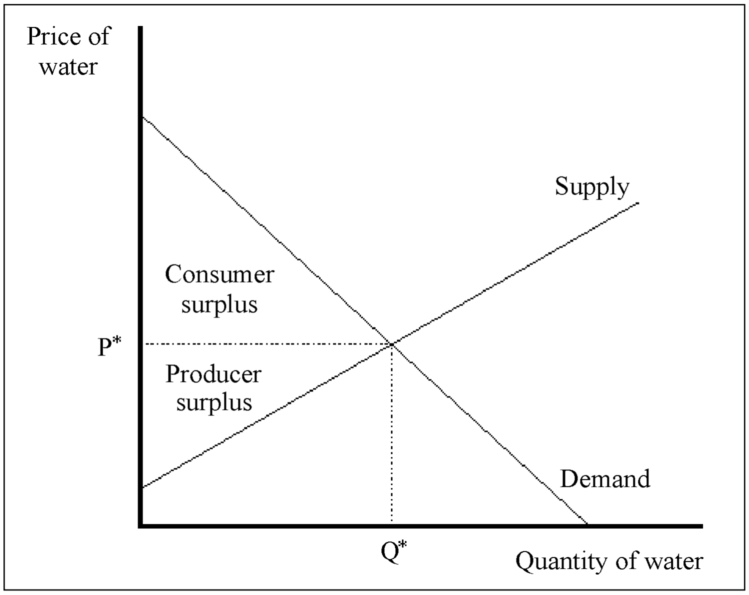

Figure 1—Supply and demand for water in a competitive market.

Conceptual Overview of Water Uses

The value of water differs greatly by time, location, quantity, quality, and use. Water is often grouped into four categories of use: residential (or municipal), commercial (or industrial), agricultural, and recreational. These categories also generally can be separated into consumptive uses and nonconsumptive uses. Agricultural and residential uses generally are consumptive uses because they remove ground or surface water that is consumed for irrigation or household uses. However, a small percentage of the water withdrawn for these uses will not be consumed because it will be returned to the water system as return flows from irrigation or wastewater from domestic use. The quality of these return flows can be impaired and not suitable for all types of uses.

Industrial uses can be either consumptive or nonconsumptive depending on the specific use. For example, hydroelectric power generation generally is a nonconsumptive use because water is removed from rivers temporarily to power generators, then returned. Other industrial uses, such as manufacturing, might consume a significant portion of withdrawn water in production processes. As with agricultural and municipal uses, even if the use is considered consumptive, a portion may be returned to the water system and considered nonconsumptive, but quality may be impaired. Recreational uses, such as boating and swimming, are typically nonconsumptive (or instream) uses, because water is not consumed by these uses. Other less tangible though valued uses of water include its role in providing wildlife habitat, ecosystem services, flood control, and pollution assimilation.

The quantity of water used (or consumed) and its value depend on the factors of supply and demand. The supply of water represents how much water a seller (or supplier) is willing to supply at various prices at a given point in time (fig. 1). In a competitive market, the supply of water a seller would be willing to provide in the market would be determined by the marginal costs borne by the seller to produce water. The marginal cost of water is the cost associated with producing one additional unit of water. For example, the supply of water in a particular geographic area might be determined by the marginal costs associated with pumping and transporting ground or surface water to specific locations where water is desired. The supply curve for water generally will be upward sloping, because the marginal cost of producing water generally increases as the quantity supplied increases. For example, if additional water were desired in the short term, bigger and more costly pumps might be needed or deeper wells might have to be dug, both of which would likely increase the cost of supplying additional water. The steepness and curvature of the supply curve is dependent on the mobility and marginal costs of resources and infrastructure needed to supply water at a given point in time. With respect to prospective supplies, water scarcity has been called the top global issue of concern in the 21st century in developed and developing countries alike (see, for example, Kundzewicz 1997, Rosegrant and Meinzen-Dick 1996), and costs of providing water are likely to receive more attention in the future.

The demand for water is represented by the price people are willing to pay for each unit of water. People's willingness to pay for each additional unit of water is a function of the marginal utility they derive from the additional unit. Marginal utility is the additional utility held by a user for an additional unit of water at a given point in time. The marginal utility of water tends to diminish as more water is consumed, because users tend to become satiated. For example, to a single household the marginal utility of the first glass of residential water per day might be quite high, whereas the marginal utility of the 100th glass may be much lower. If given the choice, a household would not pay the same amount for the 100th glass of water as the first glass. For this reason, the demand curve for water is downward sloping because the marginal utility to users of additional units of water decreases, and the amount people are willing to pay for each additional unit of water also decreases (fig. 1).

Conceptually, the optimal price (or market value) of water is determined by the intersection of the supply and demand curves at price P^* and quantity Q^* (fig. 1). At this price and quantity, both producer and consumer benefits are maximized. Consumer surplus is a monetary measure of consumer well-being. It is measured as the area under the demand curve and above the market-determined price, and represents the amount above the current price that consumers are willing to pay for water at a given quantity supplied. Consumer surplus is the difference between consumers' total willingness to pay for water and the amount they actually paid. Thus, there is a gap between total utility and total market value, which the consumer gets because the consumer receives more than they pay or a "consumer surplus."

The concept of consumer surplus reflects that market price is determined by marginal rather than total utility, and represents the benefit consumers gain from being able to buy at lower prices than what the total is worth to them. Although use of consumer surplus as a measure of the economic efficiency benefits to the consumer seems relatively straightforward, actual expenditures are readily observable in the marketplace, and consumer surplus can be inferred only after the product's demand curve is statistically estimated (Swanson and Loomis 1996). For goods and services that are consumed in small units (a can of soda, for example), it is only the last unit purchased that is worth exactly just what the consumer paid. Because the last unit has value to the consumer exactly equal to what he or she paid, there is usually no consumer surplus on the last unit bought. The basic idea of consumer surplus is to attach a monetary value to the change in welfare resulting either from a change in consumption or from a change in prices and the budget. Changes in the supply of marketed outputs can sometimes generate no or little change in consumer surplus because the change in marketed outputs is usually small relative to the market, so that there is no change in the price of the output to consumer.

Similarly, producer surplus is a monetary measure of producer well-being associated with changes in production or prices. Producer surplus is measured as the area above the supply curve and below the market-determined price, and represents the amount below the current price that producers are willing to accept as payment for a given quantity of water. Producer surplus is the difference between producers' total willingness to accept for water and the amount actually paid to them, and can be viewed as one measure of "profit."

Economic theory states that under competitive market conditions, supply and demand will determine the optimal value of a good. In some cases of water, however, this is untrue for several reasons. First, water generally is not allocated among users under competitive market conditions. Often in a given region there may be only one supplier of water, such as a municipality or irrigation water district. Such suppliers may set a constant price for water based on the average costs associated with providing water to all users or some other criteria. The effect of a constant water price, from the perspective of the water consumer, is similar in effect to a horizontal supply curve for water. From the perspective of the consumer, the water supplier is willing to supply any amount of water at a specified price no matter how much water is demanded by the consumer. Because such consumers do not experience higher water prices associated with their increasing quantity demanded, they lack a strong incentive to use less water or to not increase their water usage. Constant water prices, set below a socially optimal level, generally result in too much water being consumed.

Another factor disrupting the optimal allocation of water is that water is often treated as a public good. A public good is a pure public good if, once produced, no one can be excluded from benefiting from its availability (Nicholson 1989, p. 729). In some cases, public goods also are nonrival in consumption—additional consumers are able to use or consume the good at zero marginal cost. In the United States, there are two distinct water rights that affect the allocation of water. Riparian water rights are predominant in the Eastern United States where water is plentiful. Riparian water rights accrue to landowners whose lands are adjacent to water bodies such as rivers and lakes. Generally, landowners adjacent to such water are allowed to consume or distribute as much water as they like, as long as they do not impair the quantity or quality of water for other downstream users. Prior appropriation water rights are predominant in the Western United States where water is scarce. Prior appropriation water rights accrue to the first person in time (senior rights holders), meaning the individual who first files a claim for use. Each user down the line in time (junior rights holders) has less right to water than users earlier in time. In times of increased scarcity, such as during a drought, the first user in time or senior water rights holders have the right to use as much water as they are legally allowed, and whatever is left goes to the next user in time, and so on down the line. It is possible for there to be no water left for the user last in line. In the absence of water-pricing policies or more clearly defined rights with respect to water use, users generally are free to consume as much water as they like subject to riparian or prior appropriation rules. As a result, the costs to users of obtaining water often do not accurately reflect the true scarcity of water to society, leading to overuse of water generally.

A final factor that disrupts the optimal allocation of water is the presence of externalities. Externalities are side effects of an action that influence the well-being of nonconsenting parties (Gwartney and Stroup 1980). Externalities can be positive, such as the pleasant smell outside a bakery, or negative, such as the unpleasant smell surrounding a sewerage treatment plant. Externalities generally are not reflected in the market prices of goods, so the external costs associated with producing goods are not borne by consumers or producers.

For example, an important use of water in the Pacific Northwest is irrigation. With water often a limiting factor in agricultural production in many parts of the West, irrigated acreage in 17 Western States increased from 17.2 million acres in 1939 to 30.8 million acres in 1959 and reached a peak of 43.6 million acres in 1978 (Van Kooten 1993). Irrigation now constitutes more than 80 percent of all freshwater withdrawals in the Western States (Solley and others 1998). Most of the increase in irrigated acreage was due to federally subsidized water projects, which have distorted the true cost of water for irrigation. Wahl (1989) describes the nature of the subsidies, within their historical context, which was mainly to help settle the arid West. In general, irrigation water was subsidized through repayment schemes that do not include interest charges on the costs of construction of dams, irrigation canals, and other facilities. Wahl (1989) also describes how these subsidies had a detrimental impact on the efficient use of water.

Irrigation prices in the West are gradually increasing to reflect costs closer to the true costs associated with the subsidized water projects. However, prices for irrigation water generally still only reflect the marginal costs associated with pumping and transporting water to agricultural fields, and generally do not represent potential external costs associated with, for example, negative impacts to salmon resulting

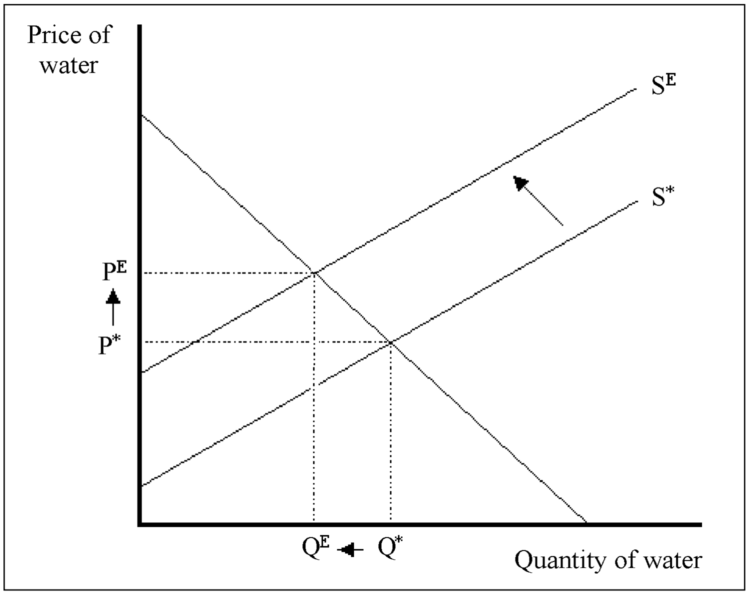

Figure 2—Supply of water when producers acknowledge external costs associated with producing water.

from too little water left instream, or negative impacts that agricultural drainage water and runoff might have on water quality. If the marginal costs of producing agricultural irrigation water resulted in the supply curve S^* (fig. 2), the optimal price and quantity demanded of irrigation water would appear to be P^* and Q^*. Suppose, however, that supplying irrigation water imposes external costs in the form of reduced streamflow, loss of salmon habitat, and decreased water quality owing to agricultural drainage water and runoff. If water producers were made to acknowledge the true marginal costs of producing irrigation water, their supply curve would be S^E (fig. 2), resulting in a higher irrigation water price P^E and a lower quantity demanded Q^E. Under these supply and demand conditions, when external costs are not internalized, irrigators pay less for water and consume more water than they would if the price of water did reflect external costs associated with salmon. Failure to internalize costs associated with negative externalities generally results in overuse of water.

An important goal of water resource economists is to remedy the misallocation of water through the use of economic incentives, such as pricing mechanisms and taxes, to correct imperfections in water markets. For example, tiered water pricing is used to increase the marginal price of water as the quantity of water demanded by a consumer increases, making each additional unit of water consumed cost more. Tiered pricing generally is implemented by a sole supplier of water in place of a constant price to simulate, from the perspective of the water consumers, an upward sloping supply curve for water to motivate conservation. The rate at which prices are made to increase depends typically on the steepness of the demand curve for water and the desired equilibrium quantity of use. The price elasticity of demand gives an indication of the percentage of change in the amount of quantity demanded in response to a given percentage of decrease in price. The steeper (typically more inelastic) the demand curve, the more the price must increase to have the same impact on quantity demanded.

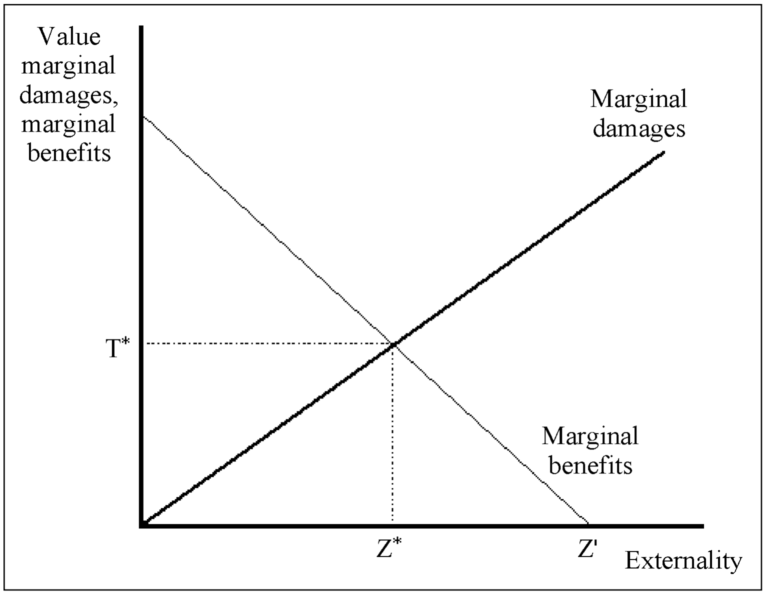

Figure 3—Determining the optional tax to mitigate an externality.

Another way economic incentives can be used to reduce the quantity of water to mitigate negative externalities associated with water overuse is to impose taxes on the quantity of water withdrawn for various uses. Returning to the example depicted in figure 2, a tax could be imposed on water producers, effectively increasing their marginal costs associated with supplying water, resulting in the supply curve S^E. The new tax-induced supply curve S^E would result in a higher equilibrium price of water at P^E and a lower quantity demanded at Q^E.

Conceptually, one way to determine an appropriate tax to mitigate negative externalities is to evaluate the marginal benefits to individuals of causing an externality relative to the marginal damages associated with the externality. Generally, individuals pursue actions that result in negative externalities, water pollution for example, because it is in some way beneficial privately or individually for them to do so. It is reasonable to expect individuals to generate increasing levels of an externality until the marginal benefit of generating the externality equals zero at Z', for example, in figure 3. Increasing levels of the negative externalities, however, also might be associated with increasing marginal damages borne by society, such as, for example, increasing degradation of riparian habitat and the resulting impacts to aquatic species caused by irrigation water withdrawal. Suppose society was willing to accept some level of habitat degradation to achieve a balance between the needs of irrigators and protecting riparian habitat. One solution would be to allow irrigators to withdraw water only until the marginal benefit they gain from additional withdrawals equals the marginal damages to riparian habitat associated with those additional withdrawals Z^*. Such an outcome would be possible by charging irrigators a tax T^* per unit of withdrawal, which would result in the socially efficient level of riparian habitat degradation. Actually implementing taxes in this way necessitates that policymakers have good information about the marginal benefits and damages of externalities, which may not always be available.

An economic remedy addressing specifically the public goods nature of water is to introduce a water market that enables holders of water rights to buy and sell their rights to use a specific quantity of water at market-determined prices. Because water markets enable users to sell their rights to unused water, water markets provide an incentive to users to conserve. Water users would consume water only to the point where the marginal net benefit of an additional unit of water equaled the price at which they would be able to sell that unit (if unused) in the market. For water markets to work properly, rights to water must be clearly defined, must be enforceable, and must be fully transferable from one user to another.

The institutional setting for water supply and use is an important consideration in relation to the types of water policies that could be implemented in different settings. Markets are valuable institutions for allocating resources, but historically there have been some important facets of water supply and institutional settings that have prevented water markets in the first place, and some of these still remain. For example, historically, prior appropriation laws generally were effective for protecting water users in the specific situations they faced during settlement in the Western United States. Relatively large-scale water development projects that facilitated water resource use and economic development in many regions of the West generally were costly and beyond the reach of private users. Without government intervention to finance such projects, many would not have occurred.

Another institutional consideration is land ownership and its impact on land as the source of water for downstream uses. Although nationally most watersheds comprise of a mixture of public and private land ownerships, public lands play a significantly larger role as sources of water in the Western United States. National forests, in particular, under the management of the USDA Forest Service, are the Nation’s largest single source of fresh water (Everest and others, in press). In the Western United States, national forests produce about one-third of the region’s annual runoff, and the ratio is even higher in the Pacific Northwest. The significant role played by public-owned lands as sources of water in the Western United States greatly affects the potential mix of programs and policies that could be implemented to deal with water allocation problems when and where they exist. In some cases, regions composed of significant proportions of public land ownership may be able to address some water resource allocation issues through changes in land management and policy without the need for more market-based economic remedies.

Determining the Value of Water

Ideally, water would be allocated among all users and uses over time and space so that the marginal benefit of an additional unit of water for any one use would be equal to the marginal benefit of an additional unit of water for any other use. To do this, it is necessary to know the value of water in different uses over time and space, and the costs imposed by externalities associated with those uses. Some values can be observed from market transactions, whereas others must be estimated based on various survey and analytical techniques. The values of water in different uses then can be used to evaluate tradeoffs associated with various policy alternatives intended to improve water management or mitigate negative externalities associated with different water uses.

When estimating and comparing water values, it is important to distinguish between the value of a water right and the value of a water use. A water right is legal access to a specific water source or quantity of water, and can be defined in a variety of ways (an allowable pumping or diversion rate per year, for example). A water right also could be defined in terms of priority of access to a water source relative to other users. The value of a water right generally is larger than the value of a particular water use because the value of a water right can reflect values associated with several alternative uses. Also, water right value analyses tend to report values that are capitalized over the life of the water right, whereas analyses of specific water use values tend to be estimated as value in a specific year of use.

Valuing Water Rights

Colby (1989) describes four methods commonly used to value water rights: sales comparison, income capitalization, land value differentials, and least-cost alternatives. The sales comparison method is similar to the approach real estate appraisers use to value real estate and involves examining similar and recent sales of water rights. Location and other characteristics, such as water quantity and quality, are compared among individual sales to estimate a range within which the water right value could fall. The value of water rights also can be inferred from actual transactions of water in short-term water markets. However, such market transactions tend to inadequately account for values of maintenance of instream flows and water quality (Saliba 1987), a trait that can characterize all the methods discussed.

The income capitalization method calculates the present value of future annual net benefits that a water right will generate in various uses. As such, this method generally is only useful if annual net returns can be attributed solely to specific uses for which the contribution of water can be clearly distinguished from other inputs. Water often is one of many inputs that generate net returns to a water right holder, however, so its value cannot easily be separated from those of other inputs (Colby 1989). More recently, inferential methods such as hedonic pricing and contingent valuation have been used to separate the value of water from other factors that contribute to net benefits.

Examining land value differentials between land parcels with and without water rights is another way to estimate the economic value of water rights (Faux and Perry 1999) and is most often used to value water for irrigation. Lastly, the least-cost method estimates the cost of creating a water supply similar to the one being valued (Colby 1989). This method often is used as a last resort when other methods are not feasible. This is because it does not necessarily represent a willingness to pay for water rights, but rather the potential costs of replacement. It is valid only if there is evidence that water users in the area actually would be willing to pay the costs associated with obtaining new water supplies. In some cases, however, it might be prohibitively expensive to obtain new water supplies, so users may choose to do without or find more innovative ways to conserve or develop alternative water supplies.

Valuing Water in Various Uses

The value placed on water is often determined by the manner in which it is used (Marcouiller 1999). Water can have a variety of economic and ecological uses. Water use can be valued in terms of marketed outputs, such as agricultural products, industrial products, and power generation, or as unpriced benefits such as instream uses including recreation, transportation, aesthetics, and wildlife habitat and other ecological functions. In rare instances where clearly defined water markets exist, economists can observe water values from actual market transactions. More commonly, markets for water do not exist. For these situations, economists have developed various nonmarket valuation methods to value unpriced benefits that water provides, including travel cost and contingent valuation methods, conjoint analysis and choice experiments, hedonic pricing, avoidance cost or cleanup cost analysis, and value added analysis, among others (Colby 1989, Gibbons 1986). Gibbons (1986) in particular provides an extensive reference to the valuation of water in a broad set of alternative uses. Detailed description of water valuation methods for specific uses also can be found in Adelsman and Bloomgren (1987), Colby (1989), Gibbons (1986), Knaff (1991), and Young and Gray (1972) among other sources. The appropriate method for valuing water in a given situation often depends on the specific use.

For example, travel cost and contingent valuation methods often are used to value water in recreational uses (Bergstrom and others 1990, Cordell and Bergstrom 1993, Creel and Loomis 1992, Johnson and others 1990, Shelby and others 1990). The travel cost method is an indirect valuation method based on the observed behavior of water users. It can be used to value water in a recreational setting by estimating the demand for access to a given recreational site (for example, Caulkins and others 1986, Layman and others 1996, Sorg and Loomis 1984). The theoretical basis of the travel cost method is that the distance visitors travel and the expenditures incurred en route represent visitors' willingness to pay to recreate at the site and can be used to construct a demand function for the recreational experience (Bockstael 1995, Young 1996).

The travel cost method is based on a set of assumptions that involve the cost per mile of a trip, opportunity cost of travel time, whether the trip is a single or multipurpose trip, the availability of substitute sites, and the amount of time spent at the site. Travel cost models commonly group visitors to a particular site by their zone of origin. The number of visitors from each origin is multiplied by an estimate of the travel costs associated with that origin. Travel costs are broken into two components: the cost of operating a vehicle and the cost of time spent traveling. The cost of operating a vehicle for one visitor's trip is the cost per mile times the number of miles, divided by the number of people per vehicle. The cost of time spent traveling is the opportunity cost of taking the trip rather than doing some other activity. This is generally estimated as a proportion of the traveler's wage rate. Visitation, cost, and income information generally is gathered from in-person, onsite interviews or from mail surveys. Many researchers now use an estimated vehicle operation cost per mile reported by the U.S. Department of Transportation. Many studies also calculate opportunity costs of travel time for a particular region as one-third of the per capita income for that region (see, for example, Sorg and others 1985).

The contingent valuation method is a survey-based technique that attempts to simulate a market for nonmarket goods, such as recreational services or water quality, by using hypothetical situations to elicit peoples' perceived willingness to pay for a good (see, for example, Bishop and Heberlein 1986, Mitchell and Carson 1989). By asking water consumers their willingness to pay for water or a service that water provides, contingent valuation attempts to measure the consumer surplus associated with the good or service at hand. Contingent valuation is a direct method of determining water values; rather than obtaining willingness-to-pay information indirectly through observed behavior, people are directly asked about their willingness to pay for access to a site or an activity. The contingent valuation method has been used to value many aspects of water such as water levels (Eiswerth and others 2000), instream flows (Brown and others 1991, Duffield and others 1994), and riverside wetlands (Kosz 1994). For the purposes of this general discussion, we also include conjoint analysis and choice experiments along with contingent valuation. Conjoint analysis and choice experiments also are survey-based methods in which survey respondents are asked to state their preference for an outcome or good described by its particular attributes. In the case of water valuation, attributes might pertain to water quantity and quality as well as cost, enabling dollar amounts to be placed on different levels of attributes by using empirical analysis.

Contingent valuation studies can be conducted either in person, by mail, or by telephone. Many researchers choose mail surveys because it is less time consuming and fewer people are needed to administer the survey. However, mail surveys pose a greater chance of nonresponse bias, although it is often possible to do followup telephone interviews of nonrespondents to determine if nonresponse should be interpreted as zero bids or as protest of the survey altogether (Mitchell and Carson 1989). The key to a successful contingent valuation study is creating an unbiased questionnaire. Ensuring this often requires conducting adequate focus groups and pretesting of potential survey instruments. A thorough pretest of the questionnaire can minimize problems such as embedded effects, starting-point bias, and misinterpretation of the questions being asked. A well-designed hypothetical scenario is straightforward enough that a variety of respondents will understand the situation and interpret it in the same manner.

An important element of contingent valuation surveys is the method used to obtain willingness-to-pay values. Some researchers use an iterative bidding process whereby a respondent is asked their willingness to pay $x for a good. If the respondent says "yes," they are asked their willingness to pay iteratively higher amounts until the respondent says "no." A commonly used alternative to the open-ended question format is the closed-ended question format in which respondents are asked if they would be willing to pay a specified amount for the good being valued. Payment amounts are varied across survey respondents, but each respondent has only one yes or no response. This method often is combined with an iterative process, whereby the initial question is followed by a single higher dollar value if the respondent answers "yes" to the first. The close-ended format has evolved in recent years into the referendum format, in which the question is posed to simulate an actual referendum on which respondents have the opportunity to vote. Often, the referendum format is implemented by varying different levels of the goods or attributes being valued across respondents, in addition to varying specified dollar amounts. Advocates of the referendum format argue that by mimicking the voting process, the method presents the otherwise difficult task of valuing natural resources and environmental goods in a survey process that is both more realistic and acceptable to survey respondents.

An advantage of the contingent valuation method over the travel cost method is that it can be used to determine the value of something that may not yet exist, such as increased water available at a site, or estimate the value of various changes at a site (Cameron and others 1996, Cordell and Bergstrom 1993, Creel and Loomis 1992, Fadali and Shaw 1998, Ward and others 1996). The travel cost method generally can only be used to measure the value of what does (or did) exist, because values are based on costs incurred while traveling to a site in its current, rather than hypothetical, condition. Contingent valuation also is the only method that can be used to determine nonuse values for water associated with water-related existence, bequest, and option values (Brookshire and Smith 1987, Kosz 1994, Walsh and others 1990). Many aspects of survey design and administration, however, can bias contingent valuation estimates, particularly in relation to nonuse values. In 1993, a blue-ribbon panel of economists was assembled that addressed survey design methods and provided guidelines to minimize bias of valuation estimates from such surveys (NOAA 1993). Many contingent valuation studies now follow these guidelines in survey development and administration.

Both the travel cost and contingent valuation methods can be appropriate for valuing recreation activities. The most appropriate method often is determined by the specific study context. For example, since derivation of a demand curve using the travel cost method requires sufficient variability in travel costs, it is not an appropriate method if most respondents travel equal distances (Forster 1989). Because contingent valuation is based on posing hypothetical situations, it is the most appropriate method when trying to value a hypothetical change to a site that may affect recreational opportunities, such as a change in water quantity or quality.

Hedonic pricing is an empirical technique based on the assumption that an individual's utility for a good is based on the attributes that characterize the good. Hedonic pricing most commonly is used to examine the attributes of land that contribute to its value. In the case of water, the marginal value of a water-related land attribute, such as water quality, would be measured by using an empirical model that describes land prices as a function of variables describing land attributes, such as location and access, and variables describing water quality. Land price and other data might be obtained from property tax assessors or from reported actual market transactions. This information could be used to estimate a regression equation that describes land values as a function of the land attributes, including water quality. Estimated model coefficients can then be interpreted as marginal prices for each attribute. Hedonic pricing has been used to estimate use values for water, such as for irrigation (Faux and Perry 1999), and nonuse values, such as the value of water quality along lakeshores (Steinnes 1992).

A limitation to hedonic pricing is that it potentially captures willingness to pay for perceived rather than actual differences in attributes (Freeman 1995) and may over- or under-estimate the true benefits derived from actual differences in attributes. For example, Malone and Barrows (1990) attempted to use this method to value ground-water quality in Portage County, Wisconsin. They determined that costs associated with nitrate pollution in the study area did not appear to be reflected in land prices. Rather, they concluded that costs of nitrate pollution likely are absorbed by land-owners in other ways, such as the length of time that land may exist on the market before eventual sale, or through averting expenditures by landowners, such as the cost of purchasing filters or the cost of obtaining a new source of quality water by drilling new wells.

Several other methods are used to estimate the value of water, and these tend to differ by water use. For example, irrigation water values often are estimated by using analysis of the value that irrigation water adds to agricultural crops based on comparison of crop production functions for dry and irrigated land (Colorado Arts and Mechanics College 1950, Gibbons 1986, Kulshreshtha and Brown 1990, Kulshreshtha and Gillies 1994, Thomas and others 1962). As a result, value-added analysis is closely tied to the specific crops produced and the productivity of land on which crops are grown. For this reason, water value estimated based on value-added analysis can differ greatly from one situation to the next. For example, value-added analysis likely will result in relatively high water value estimates in situations where irrigation water is used to grow high-value vegetable crops, compared to situations where irrigation water is used to grow lower value forage and grain crops. Water value estimates also tend to be higher in regions where soil quality is very high and above-average crop production is obtained, compared to regions where soil quality is low.

The value of water for industrial uses also is often estimated by using a value-added approach based on input-output models that estimate the value-added impact of water on an industry's output (Gibbons 1986). The value of water or water quality to industrial users also often is determined by estimating the costs associated with obtaining alternative sources of water. For example, a particular level of water quality in a particular source might be valued by estimating the costs associated with obtaining an alternative water source of equal quality or by estimating the costs associated with avoiding or preventing further degradation of water quality in the source (Gibbons 1986). These types of averted cost methods, however, can fail to provide an accurate measure of the true value of water for different uses, because they are not directly linked to users' willingness to pay for water (Courant and Porter 1981).

Municipalities generally determine residential water prices based on the average cost of supplying water, including the costs of utility infrastructure, operation, and management, plus profit (Gibbons 1986). Consumers' surplus for residential water must be determined by subtracting these costs of bringing water to the faucet from consumers' overall willingness to pay. Demand functions can be estimated to produce such consumer surplus estimates representing the value of water in various municipal uses (Gibbons 1986). In the absence of estimated demand functions, comparing price elasticities of demand—how responsive a percentage of change in quantity of use is to a percentage of change for price—for different uses can be used to determine relative values of each use.

Evaluating Tradeoffs and Allocation Scenarios

Evaluating tradeoffs among various water users can contribute to determining the best allocation of water among different uses. From an economic perspective, the optimal allocation of water is that which equates marginal values of water across all users or uses. Some uses, such as diversions for irrigation and instream uses for recreation or maintenance of salmon habitat, are competitive with one another in the sense that one use generally can only be increased at the expense of the other. Other uses, such as hydropower dam releases and white-water rafting or kayaking, can be complementary, because both can be increased or decreased together. Identifying potential complementarities among different uses often can minimize the need to make difficult tradeoffs between different uses. When complementarities do not exist, comparisons of the value of water in different competing uses can help to identify socially and economically beneficial allocations of water among competing off-stream and instream uses (Colby 1989).

Determining the most economically or socially advantageous way to allocate water among users in time and space depends on an accurate representation of the value of water to different users and the impact that each water user has on other water users. Meaningful comparisons among different users require that the quantity of water used both instream and off-stream is clearly defined, and that its timing, location, and quality are comparable across uses (Young and Gray 1972). Once economic values have been determined for different uses, tradeoffs can be evaluated to examine socioeconomic implications of different water allocation scenarios. In situations where particular water uses also have implications for the maintenance of ecological processes, information is needed about the relation between water uses and ecological processes and society's preferences or tradeoffs for water uses relative to the maintenance or enhancement of ecological processes.

Allocating water among competing uses does not always have to result in specific users being made worse off to benefit others. Policy options do not necessarily always come in the form of win-lose situations (Schaible 2000). Sometimes multiple users can all be made better off simply by changing such factors as the timing or duration of water withdrawals in ways that avoid the necessity for more difficult tradeoffs among competing users. Several examples of tradeoff analyses involving water exist in published literature, and we will discuss some of these next.

Tradeoffs Among Agriculture, Water Quality, and Other Uses

Agriculture often is at the center of policy debates about water allocations, because the agriculture sector generally uses the most water. Agriculture also is viewed as a major source of nonpoint source water pollution and so can be an important factor affecting the quality of water for other uses including aquatic habitat. Several studies have examined tradeoffs associated with the value of agricultural production and the public benefits derived from other factors, including water conservation (Schaible 2000), water quality improvements (Contant and others 1993, Randhir and Lee 1997), and habitat enhancement for specific species (Aillery and others 1999, 2001). Other studies have examined tradeoffs between benefits derived from irrigation and benefits derived from instream water uses such as recreational fishing (Hansen and Hallam 1990) and hydropower (Oven-Thompson and others 1982). These studies generally identify specific factors that are associated with individual water policies and how management of those factors will impact farm operations and revenue. Each situation requires a unique modeling approach depending on the policy context and purpose, as well as soil conditions, agricultural practices, and crop production objectives currently in use.

For example, Contant and others (1993) constructed a set of models simulating nitrogen and pesticide loading in groundwater and surface water runoff, and the sediment loading in surface water, to examine several policy alternatives intended to improve water quality in Iowa, including pesticide regulations, taxes, technical assistance, cost-sharing, and research and education. Aillery and others (2001) constructed a dynamic model of agricultural production, soil loss, and water retention in the Florida Everglades to examine alternative water-retention policies designed to restore the Everglades ecosystem, and evaluate their impacts on agricultural water use, production, and net returns. Aillery and others (1999) examined alternative recovery efforts for Columbia salmon, focusing on costs incurred by the agricultural sector resulting from different combinations of recovery strategies, including reservoir draw-downs, dam release timing, and flow augmentation.

Economic and environmental risks associated with different environmental policies also can be incorporated into tradeoff evaluations (Qui and others 1988, Randhir and Lee 1997). Generally, examples of such studies use empirical models to evaluate the maximum farm profit obtainable while holding adverse environmental risks below some specified target. For example, Qui and others (1988) examined the farm profit implications of alternative policies designed to reduce adverse impacts of nonpoint source nitrogen and sediment loading in water resulting from potential storm events. Randhir and Lee (1997) evaluated alternative policies related to restrictions of nitrogen and pesticide use in agriculture. Randhir and Lee caution that although policies targeting a specific pollutant may reduce that particular pollutant, they also can result in simultaneous increases in the use of other harmful substances not targeted by such policies. In this way, policies designed to reduce environmental risks associated with one pollutant can actually increase environmental risks associated with unforeseen increases in other pollutants. For this reason, analysis of tradeoffs is most effective if conducted at a scope appropriate to the issue under study.

When evaluating tradeoffs, it is important not only to look at total costs or benefits to a region but also to look at how costs are distributed within a region (Aillery and others 1999, Contant and others 1993). For example, Contant and others (1993) compared the costs of implementing water quality policies with the effectiveness of each policy within various regions and identified regions where particular policies were more effective than others. They suggest that targeting policies to particular areas may be an effective way to improve overall water quality and minimize impacts to farm profitability. Some regions may have a particular comparative advantage over others in meeting certain water policy goals. Identifying comparative advantages when they exist can be an important factor in improving overall efficiency and success of water policies and management strategies.

Many studies focus on the marginal costs of alternative policies or management scenarios, because the costs of implementing policies are relatively easy to quantify. Some studies do include quantitative estimates of the benefits of alternative policies or management scenarios; however, estimating benefits, particularly benefits to society, can be more complex owing to the nonmarket aspect of societal benefits. Consequently, many studies that compare values across different water uses do not attempt to evaluate tradeoffs as much as they focus on identifying costs associated with implementing policy options.

Tradeoffs Among Recreation Uses

Although many studies involving water recreation focus on evaluating tradeoffs between a particular water recreational use and some nonrecreational water use, often two or more different water recreational uses can be in conflict with one another. Johnson (1975) is one of the few studies that examines tradeoffs between two different water recreation uses—upstream, reservoir-based recreation, and downstream, reservoir release-based instream recreation. Benefit functions representing both types of recreation are combined in an objective function and optimized by using a nonlinear programming model. Johnson's conclusion is based on a basic tenet in resource economics theory, that the optimal allocation between upstream and downstream recreation occurs where the marginal benefits associated with water allocated to the reservoir are just equal to the marginal benefits associated with water allocated to the stream. This is the allocation that maximizes social benefits (Johnson 1975).

Conjoint Analysis and Contingent Choice Models

Conjoint analysis and contingent choice models provide a direct method for evaluating tradeoffs among different uses by using surveys of select individuals or the public. These methods combine economic theory of the utility individuals gain from goods or services with economic theory of the value derived from goods and services as characterized by their specific attributes or characteristics. Conjoint analysis and contingent choice surveys are similar in design to surveys using dichotomous choice contingent valuation. Survey respondents are asked to choose among two or more bundles of environmental goods or services described in terms of different levels of their various attributes. Empirical modeling of respondents' choices generally results in a set of estimated coefficients that represent the influence that each attribute has on the choices of (or utility to) respondents. Typically, one of the attributes included in the attribute set is money, enabling relative marginal values of all attributes to be compared along a common monetary scale. Consumer surplus estimates associated with changes in specific attribute levels can be derived for each attribute and compared to consumer surplus estimates for other attributes or from other studies.

An advantage of conjoint analysis and contingent choice models is that they can be used to examine tradeoffs among hypothetical policy scenarios characterized by different levels of environmental attributes for which values are otherwise difficult to measure. In the case of water, relevant attributes might include water quality, riparian habitat quality, instream flow, allowable recreational uses, and the quality of specific recreational uses. If implemented appropriately, such studies also can be appealing from a political perspective, because they enable a subsample of the public or other relevant target sample to choose (or vote) among predetermined sets of policy outcomes.

Conjoint analysis and contingent choice models have been used to evaluate public preferences for alternative forest landscapes (Hanley and others 1998b), examine perceived environmental tradeoffs associated with water supply alternatives (Blamey and others 1999), and evaluate public preferences for watershed management policy alternatives and outcomes (Farber and Griner 2000, Johnston and others 1999). Blomquist and others (2000) used a budget survey technique to determine the benefits of water quality programs in Kentucky. Individuals were asked to allocate surplus government funds across existing water quality programs. Individuals were assumed to allocate the budget such that marginal benefits were equal across programs. The approach enabled the social benefits associated with each program to be derived from individuals' marginal willingness to trade among water quality programs. Although the approach used by Blomquist and others (2000) does not provide measures of willingness to pay for programs, it does provide information about the relative values of programs.

Other Social Choice Models

D'Angelo and others (1998) provide a description of other types of social choice procedures that have been applied to water-resource management issues in northern Arizona. The methods include plurality voting, the Borda count, the Hare system, and pairwise voting. These procedures can be used to enumerate preferences among policy or management alternatives when multiple decisionmakers or decisionmaking groups disagree on the criteria used to make decisions. Because no quantification of the criteria is needed, these methods also are useful if decisionmaking criteria cannot be easily quantified, or data with which to describe and model economic behavior and decisionmaking are absent or difficult to obtain, or if values are uncertain. Plurality voting selects the alternative that has the largest number of first-place rankings. With Borda count, all choices are given a ranking, the rankings are added, and the choice with the highest rank is selected.

The Hare system is based on the successive deletion of less desirable alternatives. If any alternative is ranked the best for at least half of the criteria, then it is selected as the social choice. If two alternatives can be found, both are selected. Otherwise, the alternative that has the best ranking for the fewest criteria is deleted from the preference list. This process is repeated until either an alternative is the best for at least half of the criteria, or all the remaining alternatives are the best for the same number of criteria. In pairwise voting, pairs of alternatives are compared and voted on. The selected alternative then is compared to the next available alternative and so on until only one alternative remains, which is the social choice.

Policies and Programs for Managing Water Resources

Accurate price signals that reflect the true value of natural resources and their use can be essential to sound management. When markets fail to provide correct price signals, economic incentives can be used to adjust the effective prices of natural resources to attain environmental goals and targets in a cost-effective manner (Baumol and Oates 1988, Tietenberg 2000). Over the past two decades, there have been several examples of economic incentive programs implemented in the United States and abroad for the purpose of managing water resources. Economic incentives have been used to reallocate scarce water resources to improve fish and wildlife habitat, improve water quality, and increase municipal water supplies.

The goal of any incentive program is to modify existing market conditions to reflect the true scarcity or value of a good or to reflect the damages caused by excessive use of a good. In the case of water, economic incentives might include price adjustments, such as taxes and subsidies, and quantity controls that establish clear property rights to water by using marketable permits or transferable quotas that can be traded in water markets. Both approaches can be used as management tools to encourage both conservation and water quality improvements (Crase and others 2000, Lovell and others 2000, Weinberg and others 1993, Yoscowitz 1999). Well-designed economic incentive programs targeted toward specific individuals or firms often can preclude more expensive prescribed command and control actions mandated by water management agencies.

Taxes and Subsidies

Taxes and subsidies are used to adjust the price of a good to either encourage or discourage its use to obtain a desired level of use. A well-designed tax essentially raises the price of a good by an amount equal to the external costs associated with use of the good not accounted for in the marketplace. For example, in the case of nonpoint sources of pollution, such as agricultural runoff from irrigation, where individuals or firms responsible for the resulting water pollution cannot be identified, water managers might impose a tax on water use that reflects the marginal damage associated with negative externalities such as water pollution or diminishment of fish habitat. Because such a tax essentially would increase the price of water, users would be encouraged to conserve water, and there would be less pollution from agricultural runoff. Subsidies work in the opposite way, by reducing the price of a good to encourage its use. For example, policymakers might subsidize investments in water-saving technologies, such as more efficient appliances, to encourage their use. Subsidies might take the form of direct transfers of money, tax rebates, or low-interest loans and effectively decrease the cost of water-saving technologies to individuals.

In many cases, taxes and subsidies can result in the same target outcome in terms of obtaining optimal resource use; however, the distributional and equity impacts on welfare—who gains, who loses, and by how much—will differ. Some economists also recommend caution as to the use of subsidies, especially for achieving pollution control goals. Although subsidies can be effective at reducing emissions of individual firms, they have the potential to make an industry more profitable, enticing the entrance of additional firms to the industry, thus increasing total industry-wide emissions (Baumol and Oates 1988).

Tietenberg (1990) and Ekins (1999) provide several examples of the use of taxes and subsidies in water resource management, most of which are from Europe. For example, emission charges for effluent are being used to control water pollution in France, Italy, Germany, and the Netherlands. The design of such programs can be altered to achieve equity goals as well as use or discharge goals. By equity goals, Tietenberg is referring to equating marginal costs and marginal benefits among firms as opposed to efficiency goals that just aim to reduce pollution at the least cost, no matter how much each individual's costs may differ. In Germany, for example, dischargers are required to pay a fee on every unit of emissions. If dischargers meet or exceed effluent standards, they pay only half the normal discharge fee.

The fee forces dischargers to recognize that their polluting actions carry a cost and provides an incentive to reduce emissions. The fee reduction offered to dischargers meeting or exceeding effluent standards provides an added incentive to improve. Many countries use the revenue generated from such fees to fund improvements in water quality, subsidize installation of pollution-reduction equipment, and compensate victims harmed by pollution.

It is also possible to implement taxes and subsidies in combination to simultaneously provide disincentives for one action and incentives for another. In a non-water-related example of this "carrot and stick" approach, the Swedish government charged citizens a tax for cars purchased without catalytic converters and issued subsidies for cars purchased with catalytic converters, to increase the rate of purchase of cars with catalytic converters in Sweden (Tietenberg 1990).

Water Markets, Marketable Use Permits, and Transferable Quotas

The lack of clearly defined property rights in natural resource use often is one source of externalities (Baumol and Oates 1988). In the case of water, externalities often are associated with declines in water quality or excessive use of water that can limit water available to other potential users or can adversely impact riparian species if too little water is left for the maintenance of instream habitat. The absence of clearly defined property rights for water via ownership or rental agreement has meant that historical priority and allotments, rather than prices, have determined water use (Dales 1968, Weinberg and others 1993). As a result, water typically has not been allocated to those uses of highest value nor has it been used conservatively. For example, water in a river may be perceived or treated as a common good because no single person owns the river. In such cases, individual water users may have little incentive to expend time and money on management practices or technologies that will minimize degradation of water quality or conserve water, because only downstream users will reap these benefits. If individual users were able to gain from investments in conservation or improving water quality, they would be more willing to make those investments.

One way to encourage more efficient use of water is to establish clearly defined, enforceable property rights that can be freely traded among water users in competitive open markets. This would create more competitive market conditions. Marketable permits and individual transferable quotas have been used to protect air and water quality, and fish stocks since the mid-1970s (Tietenberg 1990). Water markets can be used to improve water quality (Howitt 1994, Lovell and others 2000, Weinberg and others 1993) and to maximize the economic value of scarce water through conservation and trading (Crase and others 2000, Yoskowitz 1999). Water markets enable the price of water to be determined in the marketplace and results in an allocation of water to its highest and best use. Assigning property rights for common property and open access goods such as water (or air and some fisheries) can reduce negative externalities associated with the overuse or misuse of community goods.

Assigning property rights to water that was previously treated as a common property resource, or enabling free trading of existing property rights, enables individuals who own those rights to gain from water quality improvements or conservation, thus providing incentives for innovation (McLean 1997). Firms are given the freedom to find the least costly manner in which to comply with their permit or quota. Such systems can reduce the societal costs of obtaining water quality or conservation goals and can be more efficient than prescribing one management strategy for all users. Water markets also can result in lower administrative costs and do not have the direct income-reducing consequences of taxes and regulations. For water markets to be successful, however, water rights initially must be assigned to water users and must be freely transferable or tradable among users, and transaction costs associated with trading must be minimal.

Related economic tools include marketable use permits and individual transferable quotas that have been used to protect air and water quality and fish stocks since the 1970s (Tietenberg 1990). These programs assign “property rights” to what was previously a common property good with the intent of providing owners of the right the potential to gain from either conservation of the good or reductions in externalities associated with use of the good. Marketable use permits and transferable quotas provide incentives for innovation that reduce the costs associated with achieving emission standards or meeting conservation goals (McLean 1997).

A significant obstacle to the establishment of water markets has been the nature of water rights established during the settlement of the Western United States (Van Kooten 1993). Western water law generally required that water rights holders use their water toward certain well-defined “beneficial uses,” which tended to include out-of-stream uses, such as irrigation, but not include instream uses, such as maintaining habitat for fish. Some observers suggest that such early definitions of beneficial uses of water under the Prior Appropriation doctrine, in combination with subsidized water projects designed to induce development in Western States, have contributed to wasteful water practices, environmental degradation, overcapitalization of marginal agricultural lands, and have exacerbated water shortages (Graff and Yardas 1998). Owing to the “use it or lose it” nature of water rights, many users overconsume the resource simply to maintain their legal rights to its use (Graff and Yardas 1998). Western water law developed and evolved in response to specific factors faced by Western settlers. In recent years, Western water law has been slowly changing and adapting to provide incentives for wiser use of water in arid regions. Many Western States have redefined beneficial uses of water to include instream uses.

For example, until recently, Oregon law stipulated that a water rights holder had to use their water at least once out of every 5 years or it would be considered forfeited or subject to cancellation (Oregon Water Resources Department 1997). In the past, leaving the water in the stream would result in the holder losing the water right. However, Oregon has recently changed its water law to include instream flow uses of water as a “beneficial use.” This allows irrigators to sell or lease their water rights for use in augmenting instream flows. This is beneficial for improvements in water quality, fish and wildlife habitat, and instream recreation uses of water. Such changes have enabled markets for water rights to emerge whereby water rights can be purchased or sold specifically for maintaining instream flows. Both long-term and short-term water rights markets have emerged. This change in policy has encouraged greater conservation of agricultural water for instream uses and allowed opportunities for water markets to emerge. These water markets have in turn allowed for the reallocation of scarce water resources via voluntary, compensated transfers in the marketplace rather than by regulatory or judicial intervention (Graff and Yardas 1998). Gillian and Brown (1997) provide a more complete discussion of instream flows and water law and management.

One of the major purchasers of water rights for instream uses has been the U.S. government. Congress has budgeted money to purchase water in several states for the purpose of increasing instream flows for fish and wildlife habitat, recreation, and water quality, and a few states are taking advantage of this money. For example, in 1990 Congress authorized $11.7 million for the procurement of agricultural water rights for wetland restoration in the Lahotan Valley of Nevada, which is home to the Stillwater National Wildlife Refuge, Stillwater Wildlife Management Area, Carson Lake, and Fallon Tribal Wetlands. These wetlands are important stopovers on the Pacific Flyway (Lovell and others 2000). As of September 1997, 40 water rights had been purchased that totaled 18,960 acre-feet. The current price offered for these rights is approximately $500 per acre-foot or $1,750 per acre. Most of these water rights are purchased from agriculture, which in most Western States account for 80 percent of the water consumed (Graff and Yardas 1998).

More recently, in 1996 the U.S. Department of the Interior and three counties in Nevada allocated $24 million to purchase water rights primarily from agriculture (Lovell and others 2000). These water rights are being used to increase instream flows in the Truckee River, which will improve water quality by increasing the assimilative capacity of the river. The goal is to acquire 24,000 acre-feet from agricultural water rights holders, for an average of $1,000 per acre-foot. Purchasing water rights from agricultural landowners is expected to have the added advantage of reducing nonpoint source pollution from these lands. Compared to a simple reduction in water supply to agriculture, an environmental water market can mitigate the economic losses borne by rural communities as a result of water reallocations because farmers will receive compensation for using less water. The results of a survey of water-rights sellers indicate that the lowest value water rights are being transferred to the public sector, a result consistent with economic efficiency (Lovell and others 2000, p. 26).

Prior to the significant water shortages during 2001, farmers in the Klamath Lakes region of south-central Oregon and northern California were interested in entering into a similar agreement to help reduce the demand for scarce water in the Klamath Project (Quinn 2000). The Klamath Project is an irrigation system developed by the federal Bureau of Reclamation in 1906. The project drained marshes for agriculture and constructed canals and delivery systems from three lakes and two rivers in the area to deliver water to 240,000 acres of dried lakebeds. Recently, it was determined that more water was needed in the Upper Klamath Lake to protect endangered Lost River and shortnose suckers and in the Klamath River to protect threatened coho salmon. Prior to 2001, farmers in the Klamath Basin had offered to sell 30,300 acres that include water rights to the federal government for $5,000 per acre (Quinn 2000).

In another example, Congress allocated $500,000 to the Little Applegate Streamflow and Fish Habitat Improvement Project to transfer senior water rights, some dating back to 1854, from the Little Applegate River in Oregon to the Applegate Lake. This enables water to be left in the Little Applegate River for instream use to improve streamflow and aquatic habitat. Landowners along the Little Applegate River annually divert about 14.5 cubic feet per second to irrigate about 580 acres. During summer irrigation seasons, virtually all flow is diverted. The Applegate River Watershed Council has coordinated the project with farmers on the Little Applegate River and other interested parties, including the USDA Forest Service, USDI Bureau of Land Management, and the Oregon Water Trust. The river provides habitat for a variety of fish species including steelhead, Chinook salmon, coho salmon, cutthroat and rainbow trout, and Pacific lamprey. Restoring streamflow to this river is expected to greatly improve aquatic habitat, especially in summer when the absence of precipitation combined with withdrawals for irrigation reduce streamflow dramatically.

The Oregon Water Trust itself also is involved in various projects offering incentives to water rights holders to convert consumptive water rights to instream water rights. The trust acquires water rights by purchase, lease, and donation. The trust also provides cost-share assistance to water rights holders to fund irrigation efficiency projects. In some cases, landowners willing to give up certain water rights are compensated for livestock feed that they can no longer produce. In taking advantage of such incentives, water rights holders are able to gain income from the sale of water rights for marginally productive areas or can be eligible for tax breaks associated with permanent donations of water rights to the Trust.

Metropolitan water districts also procure water rights. For example, in 1998 the Metropolitan Water District of Southern California negotiated with the Imperial Irrigation District for the purchase of a long-term right to divert 100,000 acre-feet of water annually in exchange for $100 million in water conservation projects in the Imperial Valley. As metropolitan water demands grow, such transactions are likely to become more common in the future.

Markets for short-term water rights also are becoming common in the West. In California, the Central Valley Improvement Act allows farmers to sell up to 20 percent of their contract water without approval of their local water district. Thus, for the first time, the property right to the first 20 percent of contract water has been vested directly to individual users. This change substantially increases the potential supply of marketable water (Howitt 1994) and provides an added incentive for irrigators to conserve water for possible sale.

An active spot market for water also exists along the Rio Grande River in Texas, which has many of the characteristics of a perfectly competitive market (Yoskowitz 1999). Prices for water are negotiated between buyers and sellers depending on demand and supply conditions. Between 1993 and 1998, an average of 251 transactions took place each year among the more than 800 individuals holding water rights. Water rights transactions are facilitated free of charge by a “water master” who brings together potential buyers and sellers, resulting in relatively low transaction costs. A key component to the success of the spot market for water along the Rio Grande is that water rights are well defined, enforceable, and transferable (Yoskowitz 1999).

Pollution Markets

The idea of using property rights for pollution control is attributed to Dales (1968). Dales suggested that the least costly means of pollution control would be to set a desired level of pollution (below the current conditions) and issue pollution rights to individual dischargers. Each individual discharging pollution must hold a right to do so. Dischargers who possess unneeded rights, owing to technical innovation (e.g., installation of new, cleaner technologies) or changes in management, can sell those rights to other dischargers who require additional rights. In this way the market establishes a price for pollution that individuals respond to by finding the least costly way to reduce discharges. Because pollution rights have a value, polluters have an incentive to find the least costly way to reduce pollution.

In Dales' (1968) vision, anyone would be able to buy pollution rights even if individuals had no pollution to discharge. This facet of the pollution rights system would enable environmental groups to purchase rights to pollute, thus reducing the total amount of pollution that could occur. However, many environmentalists have opposed the idea of creating markets for pollution, because they see the programs as authorizing or endorsing the right to pollute. Others, such as the Environmental Defense Fund, have argued that implementation of pollution markets are an improvement over traditional command-and-control regulations that essentially give away the right to pollute for free (McLean 1997).

Pollution markets have been most commonly implemented to manage air quality. For example, Clean Air Act amendments in 1990 created the sulfur dioxide allowance program to reduce sulfur dioxide emissions. Sulfur dioxide emissions by primarily coal-fired electrical plants have been implicated in the acidification of lakes and rivers in North America and in Europe. The program represents the first statutorily mandated, national, market-based approach to environmental management (McLean 1997). The program was implemented in 1995 by the Environmental Protection Agency.

The program was set up so that a maximum of 8.95 million tons of sulfur dioxide could be emitted annually in total. Each polluter was allocated a specified amount of sulfur dioxide they could emit. New potential polluters were not allocated any emission allowances and must purchase allowances from existing allowance holders. Firms able to reduce their emissions are given credit for those reductions and can sell or bank emission rights for another year. Firms not in compliance are penalized $2,000 per ton exceeded. Few trades occurred during the first years of the program, but the market-based program provided incentives for technical innovation. For example, some firms began blending coals of varying sulfur content or switched entirely to low-sulfur coal, whose price had fallen substantially over the previous 5 years. Such innovation was thought to be impractical just a few years ago (Burstraw 1996). Initial cost estimates of full compliance by 2010 were $5 billion per year if no trading of pollution permits were permitted, and $4 billion per year with unrestricted trading. However, technological innovation has enabled firms to adapt to tighter emission standards, and helped reduce compliance costs to about $2 billion per year (McLean 1997).

Combining Several Economic Incentives

Often a combination of economic incentives can be used. For example, the Broadview Water District in the San Joaquin Valley of California used a combination of three economic incentives to motivate improvements in irrigation practices among farmers to reduce agricultural drainage water (Wichlens 1991, Wichelns and others 1996). The first incentive involved issuing water allotments (or rights) to farmers based on their acreage within the district. These rights could be traded among users so that farmers not using all of their water allotment are able to sell unused allotments to others, thus creating an incentive to conserve. Farmers needing more water than their initial allotment are able to buy water from other farmers in the district, other water districts in the region, and the California Drought Water Bank, a statewide water rights exchange.

The second incentive involved implementing a crop-specific tiered water-pricing program. The price of water was based on historical water deliveries that reflected the evapotranspiration, leaching requirements, and cultural treatments associated with different crops. The first tier allowed farmers to purchase water at the usual price. If farmers exceeded 90 percent of historical water applications for a particular crop, however, all water above that level would be charged roughly 2.5 times the usual price. The increased price charged for the last units of water consumed provided an incentive to conserve.

The third economic incentive involved implementing a subsidy for investing in improved irrigation technologies. Funds provided by the California State Water Resources Control Board and money collected from the tiered pricing program allowed the water district to offer low-interest loans to farmers willing to invest in water-saving irrigation systems. The subsidy enabled farmers who were not growing high-value crops to overcome the financial constraints associated with converting to more expensive water-saving irrigation systems.

Irrigation and drainage data collected in the Broadview Water District during implementation of the three economic incentive programs suggest that the district was successful in motivating farm-level improvements in water management and in reducing drain water volume (Wichelns and others 1996). By the fourth year of the program, many of the farmers were able to adapt their irrigation regimes to grow their crops without purchasing water at the higher tier.

Changing Socioeconomic Context of Water Management

The Western United States is characterized by relatively intense competition for limited water resources. Increasing human populations coupled with growing concerns for maintaining ecological processes contribute to increased demand and increased competition for limited water resources. In the Pacific Northwest, water affects and is affected by socioeconomic as well as biophysical and ecological processes. These processes function at local, regional, national, and global scales and are affected by local, regional, national, and global demographic trends, changes in land use and land cover, changing economic conditions, and changing human values. An appreciation of these trends is essential for resolving existing and future water-related issues and conflicts.

Macro Socioeconomic Trends

Demands on water likely will continue to grow in the future and will be driven in large part by global population growth. The world's population is projected to grow from 6 billion in 2000 to about 9 billion by 2050 (United Nations 1999). Growing human populations and their use and consumption of the Earth's natural resources are placing more pressure on the ecological systems of the planet. The United States population also continues to grow, particularly in the South and West, and is projected to increase by more than 120 million people by 2050 (USDC Bureau of the Census 1996). Socioeconomic trends already are affecting options for maintaining and restoring ecosystems, and will continue to affect the supply and demand of ecosystem-based goods and services.

For example, the U.S. population is aging. Early in the 20^{th} century, 1 in 25 Americans was over age 65. By 1990, 1 in 8 was over 65, and this ratio will decline further (USDC Bureau of the Census 1996). The aging of the population is a key factor leading to increased mobility of the population as a whole as older residents relocate during retirement. Such relocations are an important source of in-migration in many regions of the country and can result in significant regional land use and socioeconomic change. Americans' personal incomes also have grown substantially during the second half of the 20^{th} century, and personal incomes in the Pacific Northwest have increased even more relative to the national average. Projected increases in new retirees and discretionary income will increase demands for renewable resources and could lead to further conversion of forests and other parts of coastal ecosystems to residential, commercial, and industrial uses.

The United States has experienced significant economic growth in recent years, with the stock markets experiencing relatively large gains in the 1990s. Wealthier nations are more likely to have a greater ability to accommodate restoration and maintenance of ecosystems than those under serious economic stress. Some development patterns resulting from economic growth, however, may increase vulnerability of land-based systems in spite of greater wealth. Growing and increasingly wealthy populations could increase both development pressure and recreational use stresses on forests, wetlands, and riparian areas.

Many economic sectors of the United States also are in the midst of rapid changes and advancements in technology. New information technologies have affected industrial and residential use of water, as well as agricultural production, and the forest sector to a lesser degree. Socioeconomic conditions will influence how technology is disseminated, and this will affect how well the Pacific Northwest and the Nation can effect improvements in water resource stewardship. The rapidly changing technological environment is part of a broader changing environment that can provide opportunities as well as challenges to resource managers and policymakers.

The U.S. population increasingly is located near coastal areas, and this trend likely will intensify pressure on associated coastal ecosystems that are a crucial link in water cycles. Fifty-three percent of the U.S. population lives on the 17 percent of land located in the coastal zone, and the largest projected population increases over the next several decades are in coastal areas. The majority of the 20 fastest growing counties and cities in the United States are in coastal areas. Such trends need to be factored into research planning, given implications for fish habitat, other riparian areas, wetlands, and recreational opportunities. For example, more than half of the threatened and endangered species in the Southeast United States depend on wetlands, as do 75 percent of forest bird species. Half of the region's wetlands, however, have been converted to other uses. The relocation of assets to coastal areas could complicate the rehabilitation of ecosystems for threatened and endangered species, such as Pacific coast salmon, as well as increase vulnerability of coastal areas to extreme events that some suggest may be associated with climate change (U.S. Department of State 1997).

The potential for climate change and associated disturbance patterns are additional factors confounding socioeconomic changes. Although it is difficult to predict the magnitude and timing of these environmental changes, climate change has important socioeconomic implications arising from its causes, possible impacts, and any adaptation or mitigation strategies or policies (see, for example, Frederick and Gleick 1999; Hurd and others 1999a, 1999b). An integrated research program dealing with water resource stewardship should address human dimensions of global climate change, so that society would then be better able to project the influence of humans on these events and the likely impacts that these climatic events will have on humans and water systems.

In a global context, the United States is a relatively large consumer of natural resources and is the world's leading producer and exporter of wood and wood products. The multiple production possibilities from forests and grasslands involve compatibility issues, as the U.S. domestic forest-based contributions include waterflows, wildlife, recreation, and other ecosystem services, in the face of competing and complementary demands and uses.

Regional Socioeconomic and Land Use Trends

At a regional level, the Pacific Northwest has experienced gradual but steady socioeconomic change in recent years. For example, Oregon's population increased from 2.0 million in 1970, to 2.6 million in 1980, and to a projected 3.4 million in 2000 (McGinnis and others 1996). Washington's population increased from 3.4 million in 1970, to 4.1 million in 1980, and to a projected 5.6 million in 2000 (McGinnis and others 1997). Oregon's population is projected to be 4.0 million by 2015 and 4.3 million by 2025. Washington's population is projected to be 7.0 million by 2015 and 7.8 million by 2025 (USDC Bureau of the Census 1996). Increasing populations can result in increasing demands for water in all uses. Although much of this growth is projected to occur in the western regions of both states, at least some predominantly rural eastern counties will experience significant growth as well. For example, in Oregon, Deschutes County, located on the eastern slope of the Cascade Range, currently is one of the fastest growing counties in the state.

As population has grown, it has gradually become more urban. For example, between 1980 and 1990, the number of Oregonians living in metropolitan areas of the state increased 14 percent, while the number living in nonmetropolitan areas decreased by 3 percent (McGinnis and others 1996). In Washington, from 1980 to 1990, the number of people living in metropolitan areas increased 20 percent, while the number living in nonmetropolitan areas increased by 8 percent (McGinnis and others 1997). By 1990, metropolitan residents accounted for 69 percent of Oregon's population and 83 percent of Washington's population. Increasing numbers of urban residents relative to rural residents can lead to increased demands for municipal water supplies. Increasing urbanization also may be accompanied by increasing demands for outdoor recreation and the protection of forest amenities and wildlife.

Population growth will increase demands for water, and this increases the likelihood that water markets in the Northwest will be further developed in the future. Markets for water are generally not as well developed in the Northwest as in some other parts of the country, especially for areas near large cities in arid settings such as Denver. Markets for water may become more developed in the Northwest as demands and concerns grow involving both water quantity and quality. The different scales at which markets interact with biophysical and ecological processes is an important part of understanding those processes and should be considered in research planning and large-scale conservation efforts. Examination of impacts on consumers and producers should be integrated in the research program, drawing upon principles of welfare economics. The example of proposals to remove Snake River dams illustrates that urban and rural residents may be affected quite differently by water resource management alternatives. Identifying those who gain or lose should be factored into research planning, so that better information is available to resource managers and policymakers when alternatives are considered.

Population growth also will affect the future water resource policy environment in the Pacific Northwest by inducing land use change resulting from the conversion of forest and farmland to urban uses (Alig and Healy 1987; Kline and Alig 1999, 2001). Urban expansion and associated issues are receiving increased attention around the Nation. In the Pacific Northwest, about 250,000 acres of forest were converted to urban and developed uses between 1982 and 1992 (USDA NRCS 1996). Oregon and Washington's populations have increased faster than the national average over the last decade, and both states have experienced relatively strong economic growth in the 1990s. Most of the population increase was in the western part of the region, especially along the Interstate 5 corridor (Zheng and Alig 1999). In Oregon alone, 70 percent of the state's 3.4 million people live in the Willamette Valley, with the valley population expected to grow by 1.3 million new residents in the next 40 years (McGinnis and others 1996, 1997).

Projected population growth will motivate increasing interest in examining where land use changes are most likely to affect forests and the goods and services that forests provide throughout the region. Urbanization may cause the forest land base to become more fragmented, impacting ecosystem conditions and economic outputs (Alig and others 2000). Conversion of forest land to developed uses essentially is a permanent change leading to permanent fragmentation of the landscape, in contrast to forest cutting where regrowth and succession may replace temporary fragmentation. Ecological impacts from conversion to urban and developed uses could include altered waterflows from more impervious surface area. As a population becomes more urban and wealthier, the area of paved and residential areas will increase, with the latter having implications for water runoff that may include lawn fertilizers and other chemicals.

Trends in Public Attitudes and Preferences

Population growth is accompanied by potentially changing attitudes and demands toward forests and forest management. A growing number of social scientists believe the Nation is experiencing rapid and significant change in forest values (Bengston 1994) and attitudes concerning forest management (Davis and others 1991, Schindler and others 1993). Egan and Luloff (2000) observe that in many places of the United States, urbanites are migrating to rural areas seeking to improve their quality of life. These exurbanites are bringing with them different attitudes, needs, and values than those of long-term residents. Egan and Luloff call it the “exurbanization” of America’s forests. The process is manifested in changing attitudes regarding the use and management of forests, and a push for forestry policies and practices that reflect changing forest values (Egan and Luloff 2000). Changing attitudes can result in changing demands for water in various uses as well as alter the political environment in which forest and water management and policy are framed.

There is a need to evaluate what current regional socioeconomic and land use trends imply about potential future water demands in the Pacific Northwest. This includes assessing potential future demands for water in various uses and identifying potential conflicts between specific uses. For example, society has spent billions of dollars on salmon restoration in spite of substantial information gaps, including information about the public’s willingness to trade salmon protection for other water uses such as irrigation and power generation. Opportunities exist for improved integration of socioeconomic and ecological information to analyze the implications of alternative water resource management scenarios.

Research Needs

More than a century ago through the Organic Act of 1897, Congress directed that “No national forest shall be established, except to improve and protect the forest within the boundaries, or for the purpose of securing favorable conditions of waterflows, and to furnish a continuous supply of timber for the use and necessities of citizens of the United States (USDA Forest Service 1998).” Although in recent decades, focus has been on the Organic Act’s provision for timber production, less understood has been the act’s focus on watershed protection. In fact, the need to protect water supplies and control floods was the driving force behind the Organic Act and other early forest legislation. The emphasis on watershed protection is consistent with the fact that today the national forests contain several municipal watersheds, and 80 percent of the Nation’s freshwater sources originate on national forest land (USDA Forest Service 1998). A potential research interest in water resource issues, management, and policy within the USDA Forest Service is not without reason.

Information about the interactions among streamflow regimes, forest and agricultural conditions, industrial and residential conditions, aquatic and riparian ecological conditions, and waterflow modifications by humans tends to be fragmented. Basic data, such as water cycle data, are needed to facilitate the development of water management alternatives that are biophysically possible, economically efficient, and socially acceptable. Information characterizing relations between waterflows and ecological processes are needed to evaluate the implications of alternative management scenarios on habitat for terrestrial and aquatic species. Socioeconomic research needs to be incorporated early in the conceptual design and planning of watershed research programs, and should be augmented with participatory monitoring and evaluation methods throughout a program or project cycle (Brooks and Eckman 2000). New databases are needed to evaluate tradeoffs among the multiple allocations and uses of water, and to inform resource managers regarding the joint socioeconomic and ecological implications of alternative water resource management strategies. Tradeoffs among alternative uses need to be analyzed in the face of competing uses, including broader consideration of substitutes and complements in the use of water while recognizing the dynamics of the land base, demographics, and society.

Specific needed research includes:

- Examine and describe relations between the timing and location of water and specific water uses, such as irrigation, power generation, and recreation, and maintenance of ecological processes and habitat for nonhuman terrestrial and aquatic species.

- Examine human dimensions of sustainable development in watershed management, with consideration of trends of change, spatial scale of impacts (extent and intensity, for example), and temporal dimensions (duration and frequency, for example).

- Identify existing and potential conflicts associated with different water uses and maintenance of ecological processes involving federal forest management, and identify and evaluate potential policies and management strategies for alleviating or mitigating such conflicts.

- Identify and evaluate policies and management strategies that will most efficiently and effectively meet societal demands for water, including investment components.

Future water research and policy will face new challenges in attempting to balance management of social, economic, and ecological components. Socioeconomic trends suggest that improvements in decision support are warranted to help managers and policymakers identify options, implications, and policies for allocating water in an increasingly competitive environment. This includes improved analytical processes, tools, and possibly institutions to develop innovative methods for analyzing the benefits, costs, tradeoffs, and risks associated with water resource management alternatives. This effort must be built on a strong foundation of how biophysical, ecological, and socioeconomic systems work and their key interrelations.

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Metric Equivalents

When you know:	Multiply by:	To find:
Acres	0.405	Hectares
Acre-feet	0.123	Hectare-meters
Tons	.907	Megagrams (tonnes)

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Appendix 1: Glossary of Selected Economics Terms

Definitions are taken from Gwartney and Stroup (1980), unless otherwise noted.

Competition—A term that denotes rivalry or competitiveness between parties (for example, producers or input suppliers), each of which seeks to deliver a better deal to buyers when quality, price, and product information are all considered. Competing implies a lack of collusion among sellers.

Consumers' surplus—The difference between consumers' aggregate willingness to pay for a good and their aggregate actual payments for the good (Hirshleifer 1984).

Demand, the law of—A principle that states that there will be a negative relation between the price of a good and the amount of it buyers are willing to purchase.

Diminishing marginal utility, law of—A basic economic principle that states that as the consumption of a commodity increases, eventually the marginal utility derived from consuming more of the commodity (per unit of time) will decline. Marginal utility may decline even though total utility continues to increase, albeit at a reduced rate.

Efficiency, economic—Economizing behavior. When applied to a community, it implies that (a) an activity should be undertaken if the sum of the benefits to the individuals exceeds the sum of their cost and (b) no activity should be undertaken if the costs borne by the individuals exceed their benefits.

Equilibrium—A state of balance between conflicting forces, such as supply and demand.

Equity—A term describing the fairness of a given resource allocation or distribution of welfare across individuals in terms of who gains and who loses. Although general agreement is lacking on what an equitable allocation entails, four views include (1) Egalitarian—all members of society receive equal amounts of goods, (2) Rawlsian—the utility of the least-well-off person is maximized, (3) Utilitarian—the total utility of all members of society is maximized and (4) Market-oriented—the market outcome is the most equitable (Pindyck and Rubinfeld 1992).

Externality—The side effects of an action that influence the well-being of nonconsenting parties. The secondary parties may be either helped (external benefits) or harmed (external costs).

Marginal cost—The change in total cost associated with a unit change in output.

Marginal utility—The additional utility received by a person from the consumption of an additional unit of a good within a given time period.

Market—An abstract concept that encompasses the trading arrangements of buyers and sellers that underlie the forces of supply and demand.

Opportunity cost—The highest valued benefit that must be sacrificed (forgone) as the result of choosing an alternative.

Price elasticity of demand—The percentage change in the quantity of a product demanded divided by the percentage change in its price.

Producers' surplus—The difference between producers' aggregate actual receipts for a good and their aggregate willingness to accept for the good (Hirshleifer 1984).

Public goods—Jointly consumed goods. When consumed by one, they are also made available to others. National defense, poetry, and scientific theories are all public goods.

Quantity demanded—The amount of a good demanded by consumers at a given price.

Quantity supplied— The amount of a good supplied by producers at a given price.

Supply, the law of— A principle that states that there will be a positive relation between the price of a good and the amount of it offered for sale by sellers.

Utility—The benefit or satisfaction expected from a choice or course of action.

Welfare—In the broadest sense, the satisfaction levels of all consumers (Henderson and Quandt 1980).

Appendix 2: A Partial Annotated Bibliography of Water Resource Economics and Related Literature

This annotated bibliography includes citations and abstracts from a sampling of published environmental and natural resource economics literature. Although in most cases we have limited the bibliography to literature specifically addressing water, we also have included a few more general reviews of valuation methods of relevance to water resource issues. In most cases, we have provided the published abstracts for each entry. In cases where published abstracts were unavailable or overly brief, we have provided our own synopsis of the paper's content. Although we have categorized each paper into a general topical category to provide some order, many papers justifiably could be included in several categories.

Water Valuation Methods

Beare, S.D.; Bell, R.; Fisher, B.S. 1998. Determining the value of water: the role of risk, infrastructure constraints, and ownership. American Journal of Agricultural Economics. 80: 916-940.

The authors examine the optimal value of irrigation water under supply and demand uncertainty by developing an integrated economic and hydrological model of farm-level water demand with exogenous prices. The authors use the model to evaluate farm-level and regional values of irrigation water under several infrastructure constraints on water supply, such as dams with fixed capacity and channel flow requirements.

Colby, B.G. 1989. Estimating the value of water in alternative uses. Natural Resources Journal. 29: 511-527.

A good general source describing water valuation methods.

Abstract from journal: Many public and private decisions regarding water use allocation, and management require estimation of water's value in alternative uses. This paper discusses economic concepts essential in valuing water, outlines and compares market and non-market based approaches used to estimate water values, and reviews the application of these methodologies for valuing water in instream, irrigation, municipal and industrial uses in the Western United States.

Garrod, G.; Willis, K.G. 1999. Economic valuation of the environment. Northampton, MA: Edward Elgar Publishing Limited. 384 p.

This book covers several environmental valuation techniques for revealed preferences and expressed preferences, including chapters addressing market price and cost measures of valuation, travel-cost methods, hedonic price models, contingent valuation, and discrete choice. The authors also present several examples of how valuation methods have been applied to recreation, landscape attributes, biodiversity, water quality, and amenity values.

Gibbons, D.C. 1986. The economic value of water. Washington, DC: Resources for the Future. 101 p.

A good general source describing water valuation methods. This book addresses the value of water in various uses including municipal, irrigation, industry, waste assimilation, recreation, navigation, and hydropower. The author discusses estimation methods and summarizes a substantial body of published and unpublished literature on the value of and demand for water in various sectors. The author suggests that "The study offers strong evidence of the shortcomings of a tradition which assumes that offstream water uses are insensitive to price and warrant priority over all instream uses" (p. viii).

Knaff, E. 1991. The economic value of water. Working Paper No. 7. St. Paul, MN: Metropolitan Council. 20 p.

The author discusses interdependency among water uses and the importance of scarcity in determining the value of water.

Marcouiller, D.W. 1999. The economic value of water: an introduction. Madison, WI: University of Wisconsin, Cooperative Extension. 6 p.

The author describes and categorizes several use and nonuse values of water in layperson language. The author suggests that the best way to determine how people value water is to determine how people use water. Use values are separated into direct use and ecological function values. The ecological function values include flood control, carbon storage, water storage, waste assimilation and ecological diversity. Direct use values are categorized as either marketed outputs or unpriced benefits. Marketed outputs include crops, meat and fish, timber, renewable energy, and industrial uses. Unpriced benefits include recreation, landscape attributes, and aesthetics. The author categorizes nonuse values as future option values, existence values and bequest values. Benefits from future drugs, potential gene pools, and recreational options are examples of future option values. Existence values derive simply from the satisfaction one receives from knowing that a resource exists. Bequest value is the benefit one receives from passing on benefits to future generations.

Oates, W.E. 1992. The economics of the environment. Brookfield, VT: Edward Elgar Publishing Company. 605 p.

The book is a collection of articles written from 1968 to 1991 addressing a variety of environmental economics issues. Included in one section are several articles addressing the measurement of benefits and costs associated with various environmental amenities, outdoor recreation, pollution control, and water quality using a variety of valuation methods.

Empirical Examples of Water Valuation

General and Multiuse Values

Adelsman, H.R.; Bloomgren, P.A. 1987. The economic value of water. St. Paul, MN: Department of Natural Resources, Division of Waters. 22 p.

The authors determine the value of water in Minnesota. The authors suggest that the value of water changes as a function of "to whom" the value accrues and scarcity. The authors suggest that determining the value of water in Minnesota is complicated because water has so many uses and therefore many values depending on use. To simplify valuation, the authors group uses into economic production and recreation categories. Economic production values are determined by using input-output and linear programming models to evaluate the economic impacts of water supply constraints and production technologies. Recreation values are separated into market and nonmarket values and were estimated by using surveys addressing willingness to pay for recreational trips and annual expenditures of respondents on water recreation.

Brown, T.C.; Harding, B.L.; Payton, E. 1990. Marginal economic value of streamflow: a case study for the Colorado River basin. Water Resources Research. 26: 2845-2859.

Abstract from journal: The marginal economic value of streamflow leaving forested areas in the Colorado River Basin was estimated by determining the impact on water use of a small change in streamflow and then applying economic value estimates to the water use changes. The effect on water use of a change in streamflow was estimated with a network flow model that simulated salinity levels and the routing of flow to consumptive uses and hydroelectric dams throughout the Basin. The results show that, under current water management institutions, the marginal value of streamflow in the Colorado River Basin is largely determined by nonconsumptive water uses, principally energy production, rather than by consumptive agricultural or municipal uses. The analysis demonstrates the importance of a systems framework in estimating the marginal value of streamflow.

Griffin, R.C.; Tanyeri-Abur, A. 1989. Case studies on the value of water in Texas. DIR 89-1 SP-5. College Station, TX: Texas Agricultural Experiment Station, Texas A&M University. 40 p.

The authors review several studies examining water values, with a focus on those estimating marginal and average water prices by using water demand models.

Romm, J.M.; Ewing, A.; Yen, S.J.; Haberman, R. 1987. The economic value of water in national forest management. In: Proceedings of the California watershed management conference. Davis, CA: University of California, Wildland Resources Center: 89-102.

Abstract from proceedings: This paper identifies the economic values of water in the National Forest System of California and institutional factors that influence their effect on Forest Management. The estimated values of forest water range from 0 to $320 per acre-foot among broad areas of the National Forest System and are highest in the southern and central Sierras and in Southern California. Although relatively uniform water values have been used in Forest plans, growing interdependence among State and Federal resource interests and capacities is raising and diversifying these values. Water supply will consequently emerge as an explicit objective of National Forest Management and a dominant objective in some areas.

Rosenberger, R.S.; Loomis, J.B. 2000. Using meta-analysis for benefit transfer: in-sample convergent validity tests of an outdoor recreation database. Water Resources Research. 36: 1097-1107.

Abstract from journal: The application of metaregression analysis models for the purpose of benefit transfer is investigated using in-sample convergent validity tests on average value transfers. The database on which the metaregression analysis models are developed is composed of empirical outdoor recreation use value studies conducted from 1967 through 1998. Results of the convergent validity tests suggest that the national model is slightly more robust to changes in application than the Census Region models. The results suggest that the application of meta-analysis for benefit transfers is promising considering limitations imposed by inconsistent data reporting of original studies.

Thomas, J.W.; Huffman, R.E.; Grace, C.T. [and others]. 1962. The value of water in alternative uses: with special application to water use in the San Juan and Rio Grande basins of New Mexico. Albuquerque, NM: The University of New Mexico Press. 426 p.

The authors determine the economic effects of different patterns of water use in the state. Impacts on gross state product are estimated for agriculture, municipal and industrial, and recreational uses.

Young, R.A.; Gray, S.L. 1972. Economic value of water: concepts and empirical estimates. Fort Collins, CO: Department of Economics, Colorado State University. 347 p.

Abstract from report: Conceptually valid and empirically sound estimates of water values are essential for rational allocation of water among uses and users over time. The study was divided into two parts. In the first part, a number of issues are examined that must be taken into account in deriving conceptually valid estimates of the values of water. These issues include (1) defining the quantity of water used in both instream and withdrawal uses, (2) assuring comparability of use in terms of time, location and quality, (3) maintaining a distinction between long run and short run values where water is used for production of consumer goods. The second part of the study involves analysis of water values for various uses with attention to regional differences. This analysis employs the conceptual approach developed initially and considers numerous previous studies from an exhaustive literature review. The water uses considered are municipal, industrial, irrigation, waste assimilation, recreation, fish and wildlife, navigation and hydroelectric production.

Irrigation

Faux, J.; Perry, G.M. 1999. Estimating irrigation water value using hedonic price analysis: a case study in Malheur County, Oregon. Land Economics. 75: 440-452.

Abstract from journal: Hedonic price analysis is applied to agricultural land sales to reveal the implicit market price of water in irrigation. This provides price information, where otherwise absent, which can facilitate reallocation of water supplies to meet growing demands. The failure to include available information on soil quality, an important determinant of agricultural land value, results in erroneous conclusions. Joint testing of heteroskedasticity and functional form is demonstrated. The value of irrigation water in this location is estimated at $9 for an acre-foot on the least productive land irrigated, and up to $44 per acre-foot on the most productive land.

Kulshreshtha, S.N.; Brown, W.J. 1990. The economic value of water for irrigation: a historical perspective. Canadian Water Resources Journal. 15: 201-215.

Abstract from journal: The value of water in alternate uses is required in all situations where water allocation mechanisms have to be activated, or where conflicts in its use develop. Irrigation being a major water user in the Prairie Provinces, as well as in Saskatchewan, has come under some public scrutiny. In this study an historical value of water in irrigation has been estimated using the concept of producer surplus. The value of irrigation water was estimated both from private (farmer) as well as society's accounting stance. The results suggest that the long-run value of water in irrigation is positive only from the farmers' standpoint. Under present crop mix and cultural practices, society has not realized a positive value for irrigation water.

Kulshreshtha, S.N.; Gillies, J.A. 1994. The economic value of the South Saskatchewan River to the City of Saskatoon: (III) value of alternative minimum river waterflow. Canadian Water Resources Journal. 19: 39-55.

Abstract from journal: This is the last of a three-part report on economic valuation of the South Saskatchewan River for the city of Saskatoon. This paper examines the value of the river in terms of its marginal waterflow. River flow has an economic value particularly if changes in the flow result in changes in economic benefits (or costs). Several benefit components, such as instream recreation, power generation, waste transport, aesthetics, water supply, and the aquatic ecosystems are associated with instream flow. These benefits were examined in this study for the South Saskatchewan River from a City of Saskatoon accounting perspective. Three levels of minimum flows were examined: present flow (42.5 m^3/S), reduced flows (25 m^3/S) and increased flow (100 m^3/S). Three conclusions are warranted on the basis of this study: One, that benefits from increased flow are very small, less than one percent of the annual value of the river to the city. Two, benefits from increasing vs. decreasing the river flow are not symmetrical. In fact, those associated with increased flow were even lower than those associated with decreased flow. Three, value of river flow should be examined in an integrated manner, such as both benefits of using the water within the city boundaries are considered together with those elsewhere. These two values suggest a situation of trade-off exists. Thus, policy makers should make explicit recognition of these values.

Recreation

Bergstrom, J.C.; Stoll, J.R.; Titre, J.P.; Wright, V.L. 1990. Economic value of wetlands-based recreation. Ecological Economics. 2: 129-147.

Abstract from journal: The loss of wetlands is an issue of growing concern. Previous studies have focused primarily on quantifying the commercial, storm protection, and energy-output value of wetlands. Relatively little research has been devoted to quantifying the outdoor recreational value of wetlands. In this paper, the recreational value of wetlands is discussed conceptually within a total economic value framework. Total economic value contains many value components which are broadly divided into non-use, current use, and future use values. Each of these value categories can be further subdivided into expenditures and consumer's surplus.

An empirical study was conducted to measure expenditures and consumer's surplus associated with on-site, current recreational uses of a coastal wetlands area. Aggregate expenditures were estimated at approximately $118 million and aggregate consumer's surplus was estimated at approximately $27 million. These results suggest that the economic impacts and net economic benefits associated with wetlands-based recreation may be considerations for wetlands policy and management.

Brookshire, D.S.; Smith, V.K. 1987. Measuring recreation benefits: conceptual and empirical issues. Water Resources Research. 23: 931-935.

Abstract from journal: The focus of this special section is the conceptual and empirical issues associated with the development of water-based recreation benefit estimation methodologies. The papers address two themes in the ongoing development of modeling the demand for outdoor recreation: the issues of characterizing and estimating nonuse (existence) values and the problem of developing consistent methodologies for modeling the household's recreation decisions. This paper attempts to identify and highlight the issues and interrelationships of these themes and attempts to identify remaining research issues.

Brown, T.C.; Taylor, J.G.; Shelby, B. 1991. Assessing the direct effects of streamflow on recreation: a literature review. Water Resources Bulletin. 27: 979-988.

The authors review 25 studies that have estimated the relation between streamflow and recreation quality. Studies are organized by the method used, including expert judgment, systematic assessment of flows by a small sample, user surveys, and empirical models. A discussion of pros and cons of each method is provided.

Abstract from journal: A variety of methods have been used to learn about the relation between streamflow and recreation quality. Regardless of method, nearly all studies found a similar nonlinear relation of recreation to flow, with quality increasing with flow to a point, and then decreasing for further increases in flow. Points of minimum, optimum, and maximum flow differ across rivers and activities. Knowledge of the effects of streamflow on recreation, for the variety of relevant activities and skill levels, is an important ingredient in the determination of wise streamflow policies.

Cordell, H.K.; Bergstrom, J.C. 1993. Comparison of recreation use values among alternative reservoir water level management scenarios. Water Resources Research. 29: 247-258.

Abstract from journal: Throughout the United States, reservoirs are managed for multiple uses, including hydropower, streamflow regulation, flood control, and recreation. Water level drawdowns for hydropower, streamflow regulation, and flood control often reduce the suitability of reservoirs for water-based recreation. The gain in aggregate economic use value of outdoor recreation under three alternative water level management scenarios was measured for four reservoirs in western North Carolina as part of an interagency policy analysis. Use values were estimated using a contingent valuation survey and expert panel data. The basic question addressed by this study was whether the value recreational users place on higher water levels held longer into the summer and fall is significantly greater than the value of using these reservoirs as they were managed at the time of this study. Maintaining high water levels for longer periods during the summer and fall was found to result in considerable gains in estimated recreational benefits. While not a primary objective of this study, having these estimates provided us an opportunity to compare increased recreational benefits with the value the Tennessee Valley Authority estimated for the reduced production of electricity that would result if the lakes were managed to hold reservoir levels higher, longer into the year.

Cordell, H.K.; Bergstrom, J.C.; Ashley, G.A.; Karish, J. 1990. Economic effects of river recreation on local economies. Water Resources Bulletin. 26: 53-60.

Abstract from journal: Outdoor recreation is a major, growing use of water resources in the United States. The economic effects of expenditures by visitors to three recreational river sites on local economies surrounding the sites were estimated using an input-output model (IMPLAN). Expenditure data were from the Public Area Recreation Visitors Study (PARVS). Results indicate that visitor spending stimulates a considerable amount of economic activity and growth in local economies. Economic effects include increases in total gross output ranging from $2.6 million to $13.4 million, increases in total income ranging from $1.2 million to $5.6 million, and increases in employment ranging from 60 to 292.2 jobs.

Creel, M.; Loomis, J. 1992. Recreation value of water to wetlands in the San Joaquin Valley: linked multinomial logit and count data trip frequency models. Water Resources Research. 28: 2597-2606.

Abstract from journal: The recreational benefits from providing increased quantities of water to wildlife and fisheries habitats is estimated using linked multinomial logit site selection models and count data trip frequency models. The study encompasses waterfowl hunting, fishing and wildlife viewing at 14 recreational resources in the San Joaquin Valley, including the National Wildlife Refuges, the State Wildlife Management Areas, and six river destinations. The economic benefits of increasing water supplies to wildlife refuges were also examined by using the estimated models to predict changing patterns of site selection and overall participation due to increases in water allocation. Estimate of the dollar value per acre foot of water are calculated for increases in water to refuges. The resulting model is a flexible and useful tool for estimating the economic benefits of alternative water allocation policies for wildlife habitat and rivers.

Duffield, J.W.; Brown, T.C.; Allen, S.D. 1994. Economic value of instream flow in Montana's Big Hole and Bitterroot Rivers. Res. Pap. RM-317. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 64 p.

Abstract from report: Instream flow is valuable to recreationists who rely on flows for fishing, boating, and other forms of river recreation. Instream flow is also valuable to many members of society, whether they visit the rivers or not, because flows maintain ecosystem stability and associated fish and wildlife habitat. This study estimates the economic value of these recreation and preservation benefits along the Big Hole and the Bitterroot Rivers in Montana. Valuation and participation information was obtained from recreationists who were interviewed along the rivers, and from households that were sampled using mail and phone surveys. Both dichotomous-choice and open-ended contingent valuation questions were used in these surveys to estimate the value of instream flow. In addition, methodological issues of additivity of preservation values and apportionment of total value into use and nonuse categories were investigated. Results indicate substantial economic value for maintaining instream flows above minimum levels, with most of the value attributable to preservation motives.

Eiswerth, M.E.; Englin, J.; Fadali, E.; Shaw, W.D. 2000. The value of water levels in water-based recreation: a pooled revealed preference/contingent behavior model. Water Resources Research. 36: 1079-1086.

Abstract from journal: In this paper we present estimated recreation values for preventing a decline in water levels at, and even the total loss of, a large Western lake that is drying up. We use a Poisson version of the count data travel cost model; however, in addition to and in combination with revealed preference (RP) data, we employ contingent behavior (CB) responses to hypothetical questions on alternative water levels and number of trips. The pooled model used allows for tests of differences between results using RP and CB data. This particular pooled RP/CB approach has not to our knowledge previously been applied to examine the values of alternative water quantities in water-based recreation.

English, D.B.K.; Bowker, J.M. 1996. Economic impacts of guided whitewater rafting: a study of five rivers. Water Resources Bulletin. 32: 1319-1328.

Abstract from journal: This paper presents estimates of the statewide economic impacts of guided whitewater rafting on five rivers in six states: the Nantahala (North Carolina), Gauley (West Virginia), Kennebec (Maine), Middle Fork of the Salmon (Idaho), and the Chattooga (Georgia-South Carolina). Except for the Chattooga and the Middle Fork, rafting is dependent on upstream dam releases. Guide fees range from about $15 per trip on the Nantahala to over $1,000 on the

Middle Fork. Economic impacts per nonresident 1000 visitors increase along with the length of the rafting trip and remoteness of the river. Total industrial output per 1000 non-resident visitors ranged from $95,000 on the Nantahala to over $2.5 million on the Middle Fork. However, because of differences in annual visitation levels, total impacts were greatest at the Nantahala, at over $14 million in 1993. Multipliers for all economic measures were relatively consistent over the rivers. Employment multipliers (Type III) ranged from 1.67 to 1.90, income multipliers from 2.0 to 2.4, and industrial output multipliers from 2.1 to 2.5.

Forster, B.A. 1989. Valuing outdoor recreational activity: a methodological survey. Journal of Leisure Research. 21: 181-201.

Abstract from journal: This paper surveys the economic literature relevant to the monetary valuation of outdoor recreational activity. The paper examines issues that arise in the design and application of the Travel Cost Method, the Contingent Valuation Method, and the Hedonic Methods to valuing outdoor recreational activity and the response of researchers to these issues.

Johnson, R.L.; Bregenzer, N.S; Shelby, B. 1990. Contingent valuation question formats: dichotomous choice versus open-ended responses. In: Johnson, R.L.; Johnson, G.V., eds. Economic valuation of natural resources: issues, theory, and applications. Boulder, CO: Westview Press: 193-203.

The authors use a mail survey including both open-ended and dichotomous choice questions to examine peoples' willingness to pay for a trip on the Rogue River in Oregon. The dichotomous choice question yielded a mean response of $52.93 per trip and a median response of $48.32 per trip. The open-ended question yielded a mean response of $32.66 per trip with a 95 percent confidence interval between $28.30 and $34.87 per trip. The survey was conducted in 1985.

Johnson, R.; Moore, E. 1993. Tourism impact estimation. Annals of Tourism Research. 20: 279-288.

Abstract from journal: Economic impacts associated with whitewater recreation on the Klamath River in Oregon (USA) are estimated using a combination of primary expenditure data and the IMPLAN input-output system. Impact estimates are generated for a range of use levels. A "naïve" model, which assumes that all expenditures in the destination area are related to the river, is distinguished from an "adjusted" model, which includes only expenditures that would be lost without the river. Primary data regarding substitution behavior indicate that estimates of total impact may be overstated if an adjusted model is not employed. Overall, results show that whitewater recreation, even on a small scale, can help to diversify a region's economy.

Laughland, A.; Caudill, J. 1997. Banking on nature: the economic benefits to local communities of National Wildlife Refuge visitation. Washington, DC: U.S. Fish and Wildlife Service. 118 p.

The authors estimate income and employment effects recreational visitors to wildlife refuges have on local communities by using expenditure data from the national survey of fishing, hunting, and wildlife-associated recreation; visitation data obtained through the refuge management information system; and IMPLAN.

Leones, J.; Colby, B.; Cory, D.; Ryan, L. 1997. Measuring regional economic impacts of streamflow depletions. Water Resources Research. 33: 831-838.

Abstract from journal: Because of large upstream diversions for agriculture and an absence of policies to protect in-streamflows, flows in the Rio Grande near Taos, New Mexico, routinely are low by midsummer. The reach is a popular whitewater run in the southwestern United States when flows are adequate for river running. This article estimates the regional economic impacts attributable to summer streamflow depletions. Economic analysis indicates that while lower water levels affect the number of people coming to the region to raft on the river reach, low water levels had no effect on another nearby rafting area. Total expenditures and economic impacts were simulated for streamflows maintained at levels adequate for whitewater recreation throughout the summer season. These simulations indicate a 24 percent ($0.74 million) increase in rafting-linked expenditures and a 25 percent ($0.94 million) increase in value added from rafting, compared to actual 1992 expenditures and value added.

Loomis, J.B. 1989. Estimating the economic activity and value from public parks and outdoor recreation areas in California. Journal of Park and Recreation Administration. 7: 56-65.

Abstract from journal: This study compares traditional measures of the economic importance of parks and recreation, such as visitor expenditures, with direct economic benefits received by the participants. Visitor spending at parks and recreation areas in California supports 238,500 jobs and contributes $4.5 billion in personal income to Californians. Participant benefits are quantified in the form of net willingness to pay. Direct benefits to participants from camping and water sports are shown to be two to three times their actual expenditures. These direct benefits provide a more correct picture of the overall contribution of recreation to society. The average rate of return on investments in recreation facilities and programs is also estimated.

Loomis, J.B.; Gonzalez-Caban, A. 1997. How certain are visitors of their economic values of river recreation: an evaluation using repeated questioning and revealed preference. Water Resources Research. 33: 1187-1193.

Abstract from journal: We test the robustness of visitor dichotomous choice willingness to pay (WTP) for maintaining instream flow by challenging respondent's affirmative answers. This is followed by rephrasing the per trip WTP question into an annual dichotomous choice WTP question and re-asking the question. About 5 percent of visitors revised their “yes” answer to “no.” Estimated WTP changed from $12.81 per trip to $11.96 per trip. Using the method of convolutions, this is an insignificant difference. To further evaluate the robustness of contingent valuation method estimated WTP, these values are compared to WTP derived from the revealed preference travel cost model of the same visitors. No statistical difference was found.

Loomis, J.B.; Roach, B.; Ward, F.; Ready, R. 1995. Testing transferability of recreation demand models across regions: a study of Corps of Engineer reservoirs. Water Resources Research. 31: 721-730.

Abstract from journal: This research tests the interchangeability of two specifications of travel cost demand models for recreation at U.S. Army Corps of Engineer reservoirs in Arkansas, California, and Tennessee/Kentucky. Statistical tests of coefficient equality for both nonlinear least squares and Heckman sample selection models suggest rejecting a transferable model among all three regions. However, the nonlinear least squares models in Arkansas and Tennessee were similar enough to fail to reject the hypothesis of equal coefficients at the 0.01 significance level. Even so, interchanging the Arkansas and Tennessee nonlinear least squares coefficients produces visitor use and total benefit estimate that are more than 100 percent too high. However, interchanging coefficients does provide reasonably close estimates of the average consumer surplus per trip for both states using the nonlinear least square model (5 to 10 percent). This is due to similarity of the price coefficients in the two models. Thus a more limited form of transferability which focuses on average benefit per day, rather than on predicting total use and total benefits, appears promising.

McCollum, D.W.; Peterson, G.L.; Arnold, J.R. [and others]. 1990. The net economic value of recreation on the national forests: twelve types of primary activity trips across nine forest service regions. Res. Pap. RM-289. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 36 p.

Abstract from report: The Public Area Recreation Visitors Survey (PARVS) was used to estimate demand models, from the point of view of a site operator, for recreation on Forest Service lands for twelve types of primary activity trips in all nine Forest Service regions. The models were estimated using the travel cost method with a “reverse multinomial logit gravity model.” At the first stage, they are share models estimating the probability that a trip observed at a given recreation site originated in a particular county. This probability is equivalent to the expected proportion of total trips to a site coming from a particular origin. A second staging process, identical to that used in traditional travel cost models, was used to derive site demand functions from the point of view of a site operator. These functions were used to estimate average consumer surplus. The relative values for different primary activity trips across different regions of the country are examined, as are relative values for different primary activity trips within the regions.

Shelby, B.; Johnson, R.L.; Brunson, M. 1990. Comparative analysis of whitewater boating resources in Oregon: toward a regional model of river recreation. Washington, DC: U.S. Department of the Interior, Geological Survey; final Tech. Rep. G1609-07. 144 p.

The authors examine boaters' willingness to pay for boating trips on the Clackamas, Deschutes, Klamath, and Rogue Rivers in Oregon by using travel cost and contingent valuation methods.

Sorg, C.; Loomis, J.B. 1984. Empirical estimates of amenity forest values: a comparative review. Gen. Tech. Rep. RM-107. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 23 p.

The authors surveyed published and unpublished recreation economics literature that used primarily travel cost and contingent valuation methods. The authors attempted to adjust value estimates from each study to make them consistent with one another in terms of the proportions of in-state versus out-of-state visitors, travel time, and real dollars. Willingness-to-pay values are reported for anadromous fishing, coldwater fishing, warmwater fishing, big game hunting, camping, hiking, nonmotorized boating (rafting and kayaking), small game hunting, picnicking, waterfowl hunting, water sports, wilderness recreation, downhill skiing, motorized boating, and saltwater fishing.

Abstract from report: Comparisons of empirical estimates of the values of wildlife, wilderness, and general recreation require that the values be based on comparable methods and comparable units of measurements. Adjustments necessary to allow such comparisons are outlined and are applied to an extensive database of valuation studies.

Ward, F.A. 1987. Economics of water allocation to instream uses in a fully appropriated river basin: evidence from a New Mexico wild river. Water Resources Research. 23: 381-392.

Abstract from journal: In fully appropriated multiple-use river basins, a major potential competitor for a share of water may be publicly sponsored appropriation to supplement low streamflows for fish, wildlife and recreation, which generates economic values not revealed in the marketplace. Based on a survey of instream recreationists on New Mexico's Rio Chama a travel cost model is developed to identify the potential recreation demand for instream flows. A discrete optimal control model is formulated that solves for the intraseasonal allocation of reservoir releases which maximizes the yearly value of instream recreation benefits, net of values of competing uses in the basin. Results indicate that the New Mexico, reservoir releases which augment the low streamflows can return gross recreation benefits in the range of $900 to $1100 per acre-foot (ac ft) of water consumed (1 ac ft = 1.233 $\times 10^3$ m^3). This compares to a $40/ac ft cost of using the water. Consequently, results strongly support the hypothesis of potential economic payoff from public investments in and management of instream flow reservations.

Ward, F.A.; Roach, B.A.; Henderson, J.E. 1996. The economic value of water in recreation: evidence from the California drought. Water Resources Research. 32: 1075-1082.

Abstract from journal: A significant barrier to economically efficient management of most reservoir systems is lack of reliable information about how recreational values change with reservoir levels. This paper presents evidence on marginal values of water for recreation at Corps of Engineer reservoirs in the Sacramento, California District. Data on visitors were collected by origin and destination before and during the early part of the 1985-1991 California drought. Because lake levels varied widely during the sample period, water's effect on visits was isolated from price and other effects. An estimated regional travel cost model containing water level as a visit predictor provided information to compute marginal values per acre-foot (1234 m^3) of water vary from $6 at Pine Flat Reservoir to more than $600 at Success Lake. These findings are limited to use values of visitors who travel to the reservoirs and do not reflect passive use values to people who value the reservoirs but never visit them. Analysis could apply similar methods to other river basins in which a public agency controls the management of multiple water uses.

Environmental Amenities and Ecosystem Services

Blamey, R.; Gordon, J.; Chapman, R. 1999. Choice modeling: assessing the environmental values of water supply options. Australian Journal of Agricultural and Resource Economics. 43: 337-357.

Abstract from journal: Three criticisms of the contingent valuation method are considered in this article. One technique that would appear to answer such criticisms is choice modeling. Choice Modeling permits value estimates for different goods sharing a common set of attributes to be pieced together using the results of a single multinomial (conditional) logit model. The choice modeling approach to environmental value assessment is illustrated in the context of a consumer-based assessment of future water supply options in the Australian Capital Territory. Choice modeling is found to provide a flexible and cost effective method for estimating use and passive use values, particularly when several alternative proposals need to be considered.

Daily, G.C., ed. 1997. Nature's services: societal dependence on natural ecosystems. Washington, DC: Island Press. 392 p.

Abstract from publisher: Nature's Services brings together world-renowned scientists from a variety of disciplines to examine the character and value of ecosystem services, the damage that has been done to them, and the consequent implications for human society. Contributors present a detailed synthesis of our current understanding of a suite of ecosystem services and a preliminary assessment of their economic value. Nature's Services represents one of the first efforts by scientists to provide an overview of the many benefits and services that nature offers to people and the extent to which we are all vitally dependent on those services. The book enhances our understanding of the value of the natural systems that surround us and can play an essential role in encouraging greater efforts to protect the earth's basic life-support systems before it is too late.

Englin, J.; Netusil, N.; Hilger, J. [and others]. 1999. Non-market values associated with Stillwater National Wildlife Refuge. Prepared for U.S. Department of the Interior, Truckee-Carson Coordination Office, Carson City, Nevada. Reno, NV: Department of Applied Economics and Statistics, University of Nevada. 75 p.

The authors examine the nonmarket benefits of increasing and stabilizing wetland habitat in the Lahontan Valley, including the Stillwater National Wildlife Refuge, Fallon Indian Reservation, and Carson Lake by using expenditure data obtained from on-site surveys of waterfowl hunters and general recreationists.

Goulder, L.H.; Kennedy, D. 1997. Valuing ecosystem services: philosophical bases and empirical methods. In: Daily, G.C., ed. Nature’s services: societal dependence on natural ecosystems. Washington, DC: Island Press: 23-48.

The authors discuss different types of ecosystem services and methods for valuing them. Four types of ecosystem services are outlined: (1) provision of production inputs such as pest control, flood control, soil fertilization, and water filtration, (2) sustenance of plant and animal life, including consumptive and nonconsumptive uses of plants and animals, with direct and indirect use values, (3) provision of existence values, and (4) provision of option values. Valuation methods discussed include avoided cost, direct valuation based on market prices, indirect valuation using travel cost and contingent valuation methods, and empirical assessments of individual risk aversion. The authors discuss several applications.

Hamilton, C. 1995. The economics of logging high conservation value native forests. Economic and Labour Relations Review. 6: 159-79.

Abstract from journal: This paper analyses various aspects of the economics of logging high conservation value native forests. After outlining the multiple uses of these forests, evidence is reviewed that suggests that subsidization of logging is extensive. Next the paper reviews work that indicates that when account is taken of the environmental values lost due to logging (including the value of water with alternative uses) there are net social costs from logging high conservation native forests.

Hanley, N.; Wright, R.E.; Adamowicz, V. 1998b. Using choice experiments to value the environment. Environmental and Resource Economics. 11: 413-428.

Abstract from journal: This paper outlines the choice experiment approach to environmental valuation. This approach has its roots in Lancaster’s characteristics theory of value, in random utility theory and in experimental design. We show how marginal values for the attributes of environmental assets, such as forests and rivers, can be estimated from pair-wise choices, as well as the value of the environmental asset as a whole. These choice pairs are designed so as to allow efficient statistical estimation of the underlying utility function, and to minimize required sample size. Choice experiments have important advantages over other environmental valuation methods, such as contingent valuation and travel cost type models, although many design issues remain unresolved. Applications to environmental issues have so far been relatively limited. We illustrate the use of choice experiments with reference to a recent UK study on public preferences for alternative forest landscapes. This study allows us to perform a convergent validity test on the choice experiment estimates of willingness to pay.

Johnston, R.J.; Swallow, S.K.; Weaver, T.F. 1999. Estimating willingness to pay and resource tradeoffs with different payment mechanisms: an evaluation of a funding guarantee for watershed management. Journal of Environmental Economics and Management. 38: 97-120.

Abstract from journal: This study reports on a contingent choice survey in which respondents expressed their preferences for packages of watershed management outcomes, where these packages assessed alternative institutional characteristics of the funding mechanism. Specifically, this study addresses the issue of respondents' faith in the payment mechanism as an efficient and guaranteed funding source. Analyses of marginal willingness to pay for single variable changes, marginal rates of substitution among variable pairs, and willingness to pay for watershed management packages indicate the potential for significant impacts of payment mechanism attributes. Implications address ranking of policy packages and validity in estimating money-scaled welfare impacts.

Kline, J.D.; Alig, R.J.; Johnson, R.L. 2000. Forest owner incentives to protect riparian habitat. Ecological Economics. 33: 29-43.

Abstract from journal: Private landowners increasingly are asked to cooperate with landscape-level management to protect or enhance ecological resources. We examine the willingness of nonindustrial private forest owners in the Pacific Northwest to forego harvesting within riparian areas to improve riparian habitat. An empirical model is developed describing owners' willingness to accept an economic incentive to adopt a 200-foot harvest buffer along streams, as a function of their forest ownership objectives and socioeconomic characteristics. Results suggest that owners' willingness to forego harvest varies by their forest ownership objectives. Mean incentive payments necessary to induce owners to forego harvest in riparian areas are higher for owners possessing primarily timber objectives than for owners possessing both timber and nontimber objectives or primarily recreation objectives.

Kosz, M. 1994. Valuing riverside wetlands: the case of the "Donau-Auen" National Park. Ecological Economics. 16: 109-127.

Abstract from journal: For two decades, the establishment of the "Donau-Auen" national park east of Vienna has been on the political agenda in Austria. Since 1991, concrete proposals have been worked out for several variants of a national park including hydraulic engineering concepts and hydroelectric power stations. Within this planning process a cost-benefit analysis was carried out to estimate the economic impacts of the proposed projects. One crucial question was how to value the ecological quality of wetlands. These environmental goods were valued by means of a willingness-to-pay (WTP) survey. Two different kinds of variables were defined: (1) Costs and benefits depending on direct "anthropocentric" use including energy production with hydroelectric power stations, shipping, groundwater protections, stabilization of the river bed to stop channel erosion, visitors' benefits, forestry, farming, fishing, hunting and the costs of establishing a national park. Based on these variables the net present value for variants with hydroelectric power stations is higher than for variants without electricity production. On the contrary, the internal interest rate and the benefit-cost ratio is higher for a "pure" national park without electricity production. (2) Taking also the Austrians' WTP for the "Donau-Auen" national park as a substitute measure for ecological values into account, only 20 percent of the WTP which was measured by means of contingent valuation is needed to make the net present value of the "best" national park variant equal to that of the "best" hydroelectric power variant. This shows that the protection of national goods, like wetlands, in a natural state might be more efficient from an economic viewpoint than development projects.

Kramer, R.A.; Richter, D.D.; Pattanayak, S.; Sharma, N.P. 1997. Ecological and economic analysis of watershed protection in eastern Madagascar. Journal of Environmental Management. 49: 277-295.

Abstract from journal: Watershed protection is one of the many goods and services provided by the world's fast disappearing tropical forests. Among the variety of watershed protection benefits, flood damage alleviation is crucial, particularly in upland watersheds. This study is a rare attempt to estimate flooding alleviation benefits, resulting from the protection of upland forests in Eastern Madagascar. A three-stage model is used to examine the relationship between the economic concept of value and the bio-physical dimensions of the protected area. This approach combines techniques from remote sensing, soil and hydrologic sciences and economics. In stage one, the relationship between changes in land use practices and the extent of flooding in immediate downstream is established by using remotely sensed and hydrologic-runoff data. Stage two relates the impact of increased flooding to crop production by comparing the hydrologic data with agronomic flood damage reports for the same time period. In stage three, a productivity analysis approach is adopted to evaluate flood damage in terms of lost producer surplus. The presence of the Mantadia National Park, in Eastern Madagascar, is designed to prevent land conversions and changes in hydrologic patterns, thereby alleviating flood damage. This averted flood damage is a measure of the watershed protection benefits to society. Given that natural systems are subject to considerable stochastic shocks, sensitivity analysis is used to examine the uncertainty associated with the key random variables. The results of this analysis should help policymakers assess trade-offs between the costs and benefits of protecting tropical rainforest.

Loomis, J.B. 1996. Measuring the economic benefits of removing dams and restoring the Elwha River: results of a contingent valuation survey. Water Resources Research. 32: 441-447.

Abstract from journal: The contingent valuation method was used to obtain estimates of willingness to pay for removing the two dams on the Elwha River on the Olympic Peninsula in Washington State and restoring the ecosystem and the anadromous fishery. Using the dichotomous choice voter referendum format, the mean annual value per household is $59 in Challam County, $73 for the rest of Washington, and $68 for households in the rest of the United States. The aggregate benefits to residents of the State of Washington is $138 million annually for 10 years and between $3 and $6 billion to all U.S. households. These estimates suggest that the general public would be willing to pay to remove old dams that block salmon migration.

Sanders, L.D.; Walsh, R.G.; Loomis, J.B. 1990. Toward empirical estimation of the total value of protecting rivers. Water Resources Research. 26: 1345-1357.

Abstract from journal: The purpose of this paper is to develop and apply a procedure to estimate a statistical demand function for the protection of rivers in the Rocky Mountains of Colorado. Other states and nations around the world face a similar problem of estimating how much they can afford to pay for the protection of rivers. The results suggest that in addition to the direct consumption benefits of onsite recreation, total value includes offsite consumption of the flow of information about these activities and resources consumed as preservation benefits. A sample of the general population of the state reports a willingness to pay rather than forego both types of utility. We recommended that offsite values be added to the value of onsite recreation use to determine the total value of rivers to society.

Water Quality

Bocksteal, N.E.; Hanemann, W.M.; Kling, C.L. 1987. Estimating the value of water quality improvements in a recreational demand framework. Water Resources Research. 23: 951-960.

Abstract from journal: With the advent of Executive Order 12291, policymakers involved in water quality regulations are increasingly interested in assessing the benefits of their programs. Several methods for valuing water quality improvements using recreational demand models have been developed by economists, most of which depend on observing recreationists visiting an array of sites with varying water quality and costs of access. In this paper, three general types of models are described: systems of demands, discrete choice models, and hedonic travel cost approach; the latter two models are demonstrated using a common data set on water quality and swimming behavior in the Boston area. The models are contrasted and their relative usefulness in answering policy questions explored.

Caulkins, P.P.; Bishop, R.C.; Bouwes, N.W., Sr. 1986. The travel cost model for lake recreation: a comparison of two methods for incorporating site quality and substitution effects. American Journal of Agricultural Economics. 68: 291-297.

Abstract from journal: This paper empirically illustrates how different assumptions regarding recreationists' decision-making behavior affect the predicted changes in recreational activity given a water quality improvement. A multinomial logit model, which reallocates visits away from other sites to the improved site, predicts a smaller outward shift of the recreationist's demand curve than the more traditional travel cost model, which does not assume any reallocation of visits among sites.

Contant, C.K.; Duffy, M.D.; Holub, M.A. 1993. Tradeoffs between water quality and profitability in Iowa agriculture. Iowa City, IA: Public Policy Center, the University of Iowa. 67 p.

The authors define four types of policies with which to control ground and surface water contamination, including regulation, taxation, technological assistance and cost sharing, and research and education, and estimate potential changes in water quality and farming profitability if each policy were adopted.

Courant, P.N.; Porter, R.C. 1981. Averting expenditure and the cost of pollution. Journal of Environmental Economics and Management. 8: 321-329.

Abstract from journal: The paper considers the relationship between the willingness to pay for environmental quality and averting expenditures—that is, the costs of measures undertaken in efforts to counteract the consequences of pollution. The models used assume perfect mobility among locations with different levels of environmental quality. The major results are (1) averting expenditures are not in general a good measure of willingness to pay; (2) averting expenditures are not always even a lower bound on willingness to pay; (3) even when averting expenditures are a lower bound, the difference between the level of such expenditures and willingness to pay cannot be attributed to the unavertable aesthetic consequences of pollution.

Crutchfield, S.R.; Cooper, J.C.; Hellerstein, D. 1997. Benefits of safer drinking water: the value of nitrate reduction. Agric. Econ. Rep. 752. Washington, DC: U.S. Department of Agriculture, Economic Research Service. 158 p.

Abstract from report: Nitrates in drinking water, which may come from nitrogen fertilizers applied to crops, are a potential health risk. This report evaluates the potential benefits of reducing human exposure to nitrates in the drinking water supply. In a survey, respondents were asked a series of questions about their willingness to pay for a hypothetical water filter, which would reduce their risk of nitrate exposure. If nitrates in the respondent's drinking water were to exceed the EPA minimum safety standard, they would be willing to pay $45 to $69 per household per month, to reduce nitrates in their drinking water to the minimum safety standard. There are 2.9 million households in the four regions studied (White River area of Indiana, central Nebraska, lower Susquehanna, and Mid-Columbia Basin in Washington). If all households potentially at risk were protected from excessive nitrates in drinking water the estimated benefits would be $350 million.

Edwards, S.F. 1988. Option prices for groundwater protection. Journal of Environmental Economics and Management. 15: 475-487.

This paper reports results from a contingent valuation study of households' willingness-to-pay to prevent uncertain, future nitrate contamination of a potable supply of groundwater. The functional form of the corresponding logit model is derived from utility maximization theory. Probability of future demand, change in the probability of future supply, and an attitudinal score for interests in the well-being of future generations are significant, positive determinants of option prices. Several implications of these results for aquifer management policy are highlighted.

Malone, P.; Barrows, R. 1990. Groundwater pollution's effects on residential property values, Portage County, Wisconsin. Journal of Soil and Water Conservation. 45: 346-348.

Abstract from journal: Nitrate pollution of groundwater had no statistically significant effect on the price of residential property in a study in Portage County, Wisconsin. These results however, do not mean that groundwater pollution has no cost. Sellers may be forced to wait longer to sell to a buyer who is uninformed or simply does not care abut nitrate pollution, so the cost of pollution may be denominated in time rather than sale price. A closer examination of market process suggests that sellers may also absorb pollution costs by drilling new wells or purchasing filters in response to demands from realtors, lenders, or buyers. Groundwater pollution costs do not appear in property prices but are likely absorbed in other ways.

McCarthy, P.S.; Tay, R.; Fletcher, J.J. 1991. Estimating the value of water quality improvements from a fully discrete model of recreational fishing. Paper No. 1001. West Lafayette, IN: Institute for Research in the Behavioral, Economic, and Management Sciences, Krannert Graduate School of Management, Purdue University. 19 p.

The authors estimate travel demand for recreational fishing trips and compute potential welfare gains from improved water quality.

Phaneuf, D.; Kling, C.; Herriges, J. 1998. Valuing water quality improvements using revealed preference methods when corner solutions are present. American Journal of Agricultural Economics. 80: 1025-1031.

Abstract from journal: A general utility model of recreation choice is set up for use as a benchmark. This theoretical model, which can also be described as a quality differentiated goods model, is matched against three alternative empirical demand models using data on water-based recreation taken from the Great Lakes region. The data used in empirical analysis was obtained from two mail surveys on angling behavior conducted at the University of Wisconsin-Madison in 1990.

Shultz, S.D.; Lindsay, B.E. 1990. The willingness to pay for groundwater protection. Water Resources Research. 26: 1869-1875.

Abstract from journal: To determine the willingness to pay (WTP) for a hypothetical groundwater protection plan in Dover, New Hampshire, a mail contingent valuation survey was conducted. The median WTP value among Dover residents was estimated to be $40 per household, and the community WTP value is estimated to be at least $100,000 annually for a groundwater protection plan. The assessed land values of respondents as well as their incomes were shown to positively influence their WTP values, while their ages had a negative influence on WTP. A variety of other socioeconomic variables were shown to have no influence on individuals' WTP for groundwater protection. This research illustrates a methodology that other researchers, and water resource managers can use to estimate the value which people place on various water resources and can help to predict whether the public will accept water policies and projects.

Steinnes, D.N. 1992. Measuring the economic value of water quality: the case of lakeshore land. Annals of Regional Science. 26: 271-276.

Abstract from journal: The valuation of water quality has proved difficult for economists using hedonic methods. This study, by employing a sample of lakes and considering only land values, is able to overcome many methodological and empirical problems inherent in previous studies. One objective measure of water quality, secchi disc reading, is found to be significant for various alternative specifications of the hedonic model. However, the results suggest that economic value may be attached to a perceived, rather than actual, measure of water quality. This raises fundamental questions as to how economists and natural scientists can work together to formulate public policy regarding water quality.

Sun Henglun, J.C.B.; Dorfman, J.H. 1992. Estimating the benefits of groundwater contamination control. Southern Journal of Agricultural Economics. 24: 63-71.

Abstract from journal: In this paper, a conceptual model of estimating option price for groundwater quality protection is developed and the effects of subjective demand and supply uncertainty and other variables on option price are examined. A contingent valuation study to measure option price for groundwater quality protection was conducted in southwestern Georgia. Evaluation results suggest that the monetary benefits to citizens of protecting groundwater supplies from agricultural chemical contamination are quite large.

Sutherland, R.J. 1982. A regional approach to estimating recreation benefits of improved water quality. Journal of Environmental Economics and Management. 9: 222-247.

Abstract from journal: Recreation demand and value are estimated with the travel-cost method for fishing, camping, boating, and swimming on a site-specific regional basis. The model is regional in that 179 sites are defined for the Pacific Northwest. A gravity model is employed to estimate the number of trips from each origin to each destination in the region, and these data are the basic input in the travel-cost demand curves. The model is illustrated by estimating the recreation benefits that would result from meeting the national environmental goal of “fishable and swimmable” rivers. The main finding is that potential recreation benefits are concentrated in a few select areas, which are accessible to large population centers.

William, P.G.; Rabinowitz, H. 1993. Groundwater contamination: its effects on property values and cities. Journal of the American Planning Association. 59: 473-484.

Abstract from journal: This paper discusses the impact of groundwater contamination with toxic chemicals on the value of contaminated and surrounding property. The case studies indicate that groundwater contamination negatively affects the value of commercial and industrial properties, but not residential properties. This finding suggests that real estate markets may not be functioning properly. The risk of liability for contamination may differ by type of property. The paper explores the policy implications, especially for cities, where fear of liability may inhibit action to protect public health.

Examining Tradeoffs Among Uses

Aillery, M.; Moore, M.R.; Weinberg, M. [and others]. 1999. Salmon recovery in the Columbia River basin: analysis of measures affecting agriculture. Marine Resource Economics. 14: 15-40.

Abstract from journal: The effects of salmon recovery measures on the Northwest agricultural sector are evaluated. Relevant recovery measures, such as modified timing for dam releases, reservoir drawdown, and flow augmentation in the Columbia River basin, on the regional agricultural sector are evaluated. Combined, these measures would increase power rates, grain transportation costs, and irrigated water costs and reduce the supply of water to irrigators. We quantify these input cost and quantity changes and combine them into seven recovery scenarios for analysis. Results suggest that drawdown and/or minor reductions in irrigation water diversions would reduce producers' profits by less than 1 percent of baseline levels. However, the most extreme scenario—a long drawdown period combined with a large reduction in irrigation diversions would reduce producers' profits by $35 million (2.5 percent) annually. That effect is magnified at the local level; of the $35 million decline in annual profits, more than $27 million occur in southern Idaho and eastern Oregon. The federal government would bear these costs if it acquires water via voluntary transactions.

Aillery, M.; Shoemaker, R.; Caswell, M. 2001. Agriculture and ecosystem restoration in south Florida: assessing tradeoffs from water-retention development in the Everglades agricultural area. American Journal of Agricultural Economics. 83: 183-195.

Abstract from journal: Agricultural production decisions can affect ecosystem function and environmental quality. Environmental restoration policies can, in turn, affect profitability of the agricultural sector. A dynamic model of agricultural production, soil loss, and water retention in the Everglades Agricultural Area is developed to assess agricultural impacts under alternative water policy and land acquisition scenarios.

Bischoff, J.H.; Dobbs, T.L.; Pflueger, B.W.; Henning, L.D. 1995. Environmental and farm profitability objectives in water quality sensitive areas: evaluating the tradeoffs. In: Clean water, clean environment, 21st century: team agriculture working to protect water resources—conference proceedings. St. Joseph, MI: American Society of Agricultural Engineers: 25-28. Vol. 3.

Abstract from proceedings: This research project was designed to determine whether the economic incentives offered by recent environmental provisions of the federal farm program are sufficient to induce western Corn Belt/Northern Great Plains farmers in environmentally sensitive areas to adopt sustainable farming practices and systems. Particular attention is being focused on the Integrated Crop Management program and the Water Quality Incentive Program. Results of the participation of farmers in a three-county water quality demonstration project area of eastern South Dakota—The Big Sioux Aquifer Demonstration Project—indicate that 45 out of 400 farmers had enrolled in the Integrated Crop Management program or the Water Quality Incentive Program, or both by the end of 1993. The most popular practices under these programs were nutrient management, pest management, conservation cropping sequence, and crop residue use. There was very little change in either crop type or crop rotation. Preliminary economic results for three case study farms in the project area indicated no change in “typical-year” net profits “after” participation compared to “before” participation on one farm, modest increase on another, and substantial increase on the other. Simulation of possible additional practice changes thought to improve groundwater quality showed further possible modest increases in profits on all three case farms. Simulated system changes, involving changes to more diverse crop rotations, also appear to add to profitability; however, sensitivity analyses are yet to be carried out for the system changes to test the range of assumptions under which this conclusion is valid.

Gold, A.; Weaver, T.; Porter, E.; Opaluch, J. 1988. Potential water use conflicts generated by irrigated agriculture in Rhode Island. Northeastern Journal of Agricultural and Resource Economics. 17: 8-14.

Abstract from journal: This study constructs a simulation model to evaluate the potential for conflict among residential and agricultural users of water in southern Rhode Island. The model estimates the profitability of irrigation of turf farms and projects the total use and the economic value of irrigation water. The results indicate that the economic value of irrigation water compares favorably with current residential water prices in the area. In addition, substantial demand for irrigation water is projected. Given current rates of growth in turf acreage and residential water use, there appears to be a significant potential for conflict, particularly given the absence of well-developed institutions for allocating water among users.

Hansen, L.T.; Hallam, A. 1990. Water allocation tradeoffs. Washington, DC: U.S. Department of Agriculture, Economic Research Service. 21 p.

Abstract from report: Diverting water from streams for irrigation competes with its use as a recreational fishing resource. This report develops a procedure for estimating the marginal value of water used for fishing that includes effects of upstream diversions on all points downstream. The downstream effects are dispersed across a wide geographic area and, until now, have not been estimated. The procedure is applied to all 99 major river basins of the contiguous states. The tradeoffs in water allocation are detailed in the 67 river basins where irrigation competes for the water with recreational fishing. The results substantiate the role of water for recreational fishing and highlight the implications for a national perspective in water allocation decisions.

Hutchinson, W.G.; Chilton, S.M. 1999. Combining preference ordering and contingent valuation methods to assess nonmarket benefit of alternative afforestation projects. Journal of Rural Studies. 15: 103-109.

Abstract from journal: The application of the contingent valuation method in this paper incorporates a prior preference ordering of several alternative future afforestation programs which could be implemented in Ireland over the next decade. This particular experimental design is thereby shown to reveal the potentially conflicting preferences of different groups within society. These findings are used to devise appropriate contingent valuation method scenarios to take account, not only of the efficiency gains of choosing a single policy alternative over others, but also the effects on the distribution of non market benefit between different groups within society, arising from choice between alternatives.

Johnson, S.H., III. 1975. Optimal tradeoffs between reservoir and downstream recreation benefits. In: Proceedings: annual meeting of the Western Agricultural Economics Association. Fort Collins, CO: Department of Agricultural and Resource Economics, Colorado State University: 140-143.

The author develops benefit functions for reservoir recreation and open stream (downstream) recreation based on the amount of water allocated to each type of recreation, and suggests that complementary, competitive, and supplementary relations exist between the two activities depending on water levels. The benefit functions are combined in an optimization program to examine tradeoffs between reservoir and downstream recreational uses. The optimal tradeoff between the two occurs when the marginal benefits associated with water allocated to the reservoir are equal to the marginal benefits associated with water allocated to the stream. Furthermore, the optimal size of the reservoir can be determined where the marginal cost of construction of an increased acre-foot of capacity is just equal to the expected marginal benefits associated with the flow.

Oven-Thompson, K.; Alercon, L.; Marks, D.H. 1982. Agricultural vs. hydropower tradeoffs in the operation of the High Aswan Dam. Water Resources Research. 18: 1605-1613.

Abstract from journal: This paper defines a tradeoff relationship between hydropower and agriculture for the monthly operations of the High Aswan Dam under current water availability conditions. A stochastic dynamic programming model is employed which incorporates the physical constraints of the High Aswan Dam system. Variations of monthly reservoir releases for agricultural purposes are imposed on the system through this model, and consequent impacts on hydropower production at the high dam are studied. The results show that once operating rules are optimized for current agricultural demands an 11-20 percent increase in firm monthly hydropower production can be gained when summer irrigation allocations are reduced by 25 percent. A simple benefit/cost analysis concludes that potential benefits obtained by gains in firm monthly hydropower are nearly equal to potential losses in the agricultural sector when summer allocations are reduced by 5-10 percent. Operation questions raised by the introduction of a new emergency flood control spillway at Toska are addressed. Recommendations are made for the operating guidelines of the high dam releases in light of these results.

Qui, Z.; Prato, T.; Kaylen, M. 1988. Watershed-scale economic and environmental tradeoffs incorporating risks: a target MOTAD approach. Agricultural and Resource Economics Review. 27: 231-241.

Abstract from journal: This paper evaluates the economic and environmental tradeoffs at watershed scale by incorporating both economic and environmental risks in agricultural production. The target MOTAD model is modified by imposing a probability-constrained objective function to capture the yield uncertainty caused by random allocation of farming systems to soil types and by introducing environmental targets to incorporate environmental risk due to random storm events. This framework is used to determine the tradeoff frontier between watershed net return and sediment yield and nitrogen concentration in runoff in Goodwater Creek watershed.

Schaible, G.D. 2000. Economic and conservation tradeoffs of regulatory vs. incentive-based water policy in the Pacific Northwest. Water Resources Development. 16: 221-238.

Abstract from journal: In this paper, on-farm water conservation and agricultural economic tradeoffs between selected regulatory and conservation-incentive water-policy choices are evaluated for the Pacific Northwest. Five broad water-policy perspectives are analyzed using a total of 37 alternative policy scenarios. Policy analyses use a primal/dual-based, multi-product, normalized restricted-equilibrium model of Pacific Northwest field-crop agriculture. Results demonstrate that conservation-incentive water policy, when integrated within balanced policy reform, can produce upwards of 1.7 million acre-feet of on-farm conserved water for the region, while also significantly increasing economic returns to farmers. Producer willingness to accept water-policy change is lowest for regulatory policy, but highest for conservation-incentive policy that increases both irrigation efficiency and crop productivity. Conservation-incentive water policy also enhances decision-maker flexibility in meeting multiple regional policy goals (i.e., water for endangered aquatic species, water quality, Native American treaty obligations, and sustainable rural agricultural economies).

Willis, D.B.; Whittlesey, N.K. 1998. Water management policies for streamflow augmentation in irrigated river basins. Journal of Agricultural and Resource Economics. 23: 170-190.

Abstract from journal: The value of maintaining a minimum streamflow objective on average is lessened when there is considerable dispersion around the average. An integrated economic and hydrology model is presented which provides water policy planners with a way to accurately measure both the economic cost and hydrologic consequences of maintaining a minimum streamflow level in an irrigated river basin at alternative probabilities of maintaining the target flow level. Water markets for streamflow augmentation are shown to be the most cost-effective policy in the study area.

Water Policies
General

Clyde, S.E. 1989. Adapting to the changing demand of water use through continued refinement of the prior appropriation doctrine: an alternative approach to the wholesale reallocation. Natural Resources Journal. 29: 435-455.

Abstract from journal: The prior appropriation doctrine facilitated Western expansion and economic growth in the arid West. The doctrine rewarded those who were first by providing them with a relatively stable water supply by protecting them from unreasonable interference by junior appropriators. Beneficial use generally required both the diversion and consumption of water in some economic activity. Today, society recognizes other values in water. Some people fear that the prior appropriation doctrine may prevent the use of water for these non-consumptive purposes and are searching for novel legal theories to circumvent it. This effort is unnecessary. The doctrine is inherently flexible. Given time, it will be adapted to meet the competing needs and interests of society. The prior appropriation doctrine is not an obstacle to change. We do need, however, sufficient time to discern the true direction of our rapidly changing societal values.

Fleming, W.M.; Hall, G.E. 2000. Water conservation incentives for New Mexico: policy and legislative alternatives. Natural Resources Journal. 40: 69-91.

Excerpt from abstract: A broad range of options for encouraging municipal, industrial and agricultural water conservation are proposed for water-short New Mexico. Of particular interest are feasible options within the existing institutional and legal framework, focusing on measures that could be implemented without statutory changes by the Office of the State Engineer and the Interstate Stream Commission.

Lamb, B.L.; Lord, E. 1992. Legal mechanisms for protecting riparian resource values. Water Resources Research. 28: 965-977.

Abstract from journal: Riparian resources include the borders of rivers, lakes, ponds, and potholes. These border areas are very important for a number of reasons, including stream channel maintenance, flood control, aesthetics, erosion control, fish and wildlife habitat, recreation, and water quality maintenance. These diverse functions are not well protected by law or policy. We reviewed law and policies regarding endangered species habitat designation, land use planning, grazing management, water allocation, takings, and federal permits and licenses, along with the roles of federal, state, and local governments. We discuss the politics of implementing these policies, focusing on the difficulties in changing entrenched water and land use practices. Our review indicates a lack of direct attention to riparian ecosystem issues in almost all environmental and land use programs at every level of government. Protection of riparian resource values requires a means to integrate existing programs to focus on riparian zones.

Water Pricing

Haddad, B.M. 2000. Economic incentives for water conservation on the Monterey Peninsula: the market proposal. Journal of the American Water Resources Association. 36: 1-15.

Abstract from journal: Literature on price-based urban water conservation and on market-based mechanisms to manage natural resources suggests that market-based management of urban/suburban water use may be feasible. A market-based proposal that emerged from a water shortage on California's Monterey Peninsula is presented. In the proposal, conservation incentives arise both from an ability among end-users of water to reduce consumption and sell use-rights to water, and from a penalty price for consumption in excess of one's use rights. The amount of water associated with use rights is capped and varies according to hydrological, meteorological, ecological, and other criteria. Requirements for further study of the proposal are listed, and the role that similar market-based mechanisms could play in urban water management is discussed.

Hewitt, J.A.; Hanemann, W.M. 1995. A discrete/continuous choice approach to residential water demand under block rate pricing. Land Economics. 71: 173-192.

Abstract from journal: A discrete/continuous choice model of the residential demand for water under block rate pricing is presented, estimated, and compared to results of regression models. The empirical analysis uses a dataset from a previously published study, Nieswiadomy and Molina (1989) a household level panel data for Denton, Texas, for summer months from 1981 to 1985 with an increasing block rate in effect. The striking result is that the discrete/continuous choice model produces price elasticity estimates near -1.6, which are much more elastic than previously published results based on regression models where discrete choice is not explicitly modeled.

Huffaker, R.; Whittlesey, N.; Michelsen, A. [and others] 1998. Evaluating the effectiveness of conservation water-pricing programs. Journal of Agricultural and Resource Economics. 23: 12-19.

Abstract from journal: Charging farmers increasing block prices for irrigation deliveries is advocated as a means of encouraging agricultural water conservation in the West. We formulate a model of a hypothetical irrigated river basin to investigate the hydro-economic circumstances in which such pricing leads to water conservation. Our results indicate that increasing delivery prices may encourage irrigators to make adjustments with countervailing impacts on consumptive water use and conservation. Whether these countervailing impacts combine to conserve water or increase its consumptive use must be resolved empirically. An alternative resolution of this ambiguity is to assess water prices in terms of consumptive use.

Wichelns, D.; Cone, D. 1992. Tiered pricing motivates Californians to conserve water. Journal of Soil and Water Conservation. 47: 139-144.

Excerpt from Journal: California's Broadview Water District implemented an increasing block-rate pricing plan in October 1988 to motivate the use of water conservation practices. The goal of these practices: to reduce the volume of drain water collected beneath farm fields. The program's success was to be measured by observed changes in irrigation practices and reductions in water deliveries and collected drain water. The positive results obtained in subsequent years prompted the district's board of directors in 1990 to adopt tiered pricing as a permanent district policy.

Water Markets

Brennan, D.; Scoccimarro, M. 1999. Issues in defining property rights to improve Australian water markets. The Australian Journal of Agricultural and Resource Economics. 43: 69-89.

Abstract from journal: This article discusses the key practical issues associated with defining property rights to water use, in the context of broadening the scope of the market for transferable water entitlements. In particular, the third party impacts of water trade and the need for improved water trading rules are discussed. Some of the issues associated with defining the reliability of water rights, including the design of appropriate dam management policies, are also discussed. The article concludes with some positive suggestions for the policy debate.

Crase, L.; O'Reilly, L.; Dollery, B. 2000. Water markets as a vehicle for water reform: the case of New South Wales. The Australian Journal of Agricultural and Resource Economics. 44: 299-321.

Abstract from journal: Water reform in NSW is being undertaken using an adaptive approach in recognition of the uncertainty and imperfect knowledge embodied in the riverine environment. However, the reform process also relies, in part, on the ability of markets for tradable water entitlements to develop and thereby assist in allocating scarce water resources to their highest value use. This article explores impediments to the formation of efficient markets in permanent tradable water entitlements in NSW. The article concludes that more attention should be paid to market failures and related problems, which manifest themselves in thin markets for permanent water entitlements.

Duffield, J.W.; Neher, C. 1991. Market value of agricultural water leased for instream flows. Missoula, MT: Bioeconomic Associates; final report submitted to Montana Department of Fish, Wildlife and Parks. 138 p.

Abstract from report: The purpose of this report is to provide market values for leasing agricultural water for instream flow purposes and to develop a structure for lease agreements. This information is to assist Montana Department of Fish, Wildlife and Parks in implementing a pilot instream flow water-leasing program.

Fadali, E.; Shaw, W.D. 1998. Can recreation values for a lake constitute a market for banked agricultural water? Contemporary Economic Policy. 16: 433-441.

Abstract from journal: This paper presents estimates of the recreational use value to prevent the loss of a Western lake threatened by diversions of upstream waters that supply it. The recreation demand model used to estimate recreation-related values is the popular repeated nested multinomial logit model. The model is specified to allow an individual to choose when to visit various sites during the season, because site choice is likely to be influenced by water levels that change over the course of the season. The values are compared to agriculture values in order to assess whether the potential recreation demand side of a market for a water bank exists.

Gardner, B.D.; Warner, J.E. 1994. The Central Valley Water Project Improvement Act and water markets: two steps forward—one step back. Choices. 9: 4-9.

The authors discuss the Central Valley Water Project Improvement Act, which changed the rules for allocating federal water in California. The act aims to promote market transfers of federal water to promote efficiency. The act also introduced a tiered pricing scheme that depends on the contracted price of water, quantity of water used, and the full cost of water. The act includes certain safeguards for fish and wildlife habitat, including a mandate of 13 percent of project water to be dedicated annually for fish and wildlife habitat restoration. The authors argue that this favored position for fish and wildlife distorts market values for water and hinders the process of water markets. They suggest that such restrictions on market exchanges will cost far more in efficiency losses than any benefits they might provide.

Graff, T.J.; Yardas, D. 1998. Reforming Western water policy: markets and regulation. Natural Resources and Environment. 12: 165-169.

The authors discuss inefficiencies and environmental externalities caused by the prior appropriation doctrine. They suggest that water must be reallocated and this can best be accomplished through the development of water markets.

Hanley, N.; Fairchney, R.; Munro, A.; Shortle, J.S. 1998a. Economic and environmental modeling for pollution control in an estuary. Journal of Environmental Management. 52: 211-225.

Abstract from journal: This paper reports on results from an environmental-economic modeling exercise aimed at quantifying the potential cost savings from a Tradable Pollution Permits (TTPs) scheme in the Fourth Estuary, Scotland. Such a scheme might be introduced to control inputs of biological oxygen demand more cheaply than the current regulatory system. A MIKE 11 water-quality model is combined with step-wise integer and linear programming models representing firms' abatement costs. Cost savings under a deterministic scenario are compared with savings under a stochastic scenario, where transfer coefficients, relating discharges to ambient water quality, are allowed to vary. Potential cost savings appear to exist in both cases, although these cost savings are less in the stochastic case. The paper concludes by considering potential barriers to any real-life TPP market actually achieving these potential cost savings.

Howitt, R. 1994. Water markets, individual incentives and environmental goals. Choices. 9: 10-13.

This article is a response to Gardner and Warner (1994) who argue that environmental constraints imposed by the Central Valley Project Improvement Act will deter free trading of water in California. Howitt (1994), on the other hand, argues that other aspects of the act will stimulate water market sales. The underlying debate is whether or not environmental restrictions imposed by the act will restrict water sales more than new incentives will encourage them. Howitt (1994) argues that the restoration of water for fish and wildlife simply corrects the negative externalities that environmentalists believe stemmed from misallocation of water to agriculture by the Central Valley Project several decades ago. The act also attempts to control for third-party impacts of water trades by placing some restrictions on water trades, such as the restriction that fish and wildlife shall not be negatively impacted by water transfers. Howitt states that the provision in the act that allows farmers to sell up to 20 percent of their water without approval of their local water district, creates an incentive that will improve water markets. This provision basically (for the first time) gives a portion of the water property right directly to individual users. This prevents other users from interfering with or stopping individuals from selling water and making gains from trade. Howitt believes that the net effect of all the provisions in the Central Valley Project Improvement Act should be an increase in water traded despite the stronger environmental regulations.

Lovell, S.; Millock, K.; Sunding, D.L. 2000. Using water markets to improve environmental quality: two innovative programs in Nevada. Journal of Soil and Water Conservation. 55: 19-26.

Abstract from journal: Economists have long advocated the use of market mechanisms as a means to improve environmental quality at minimum cost. Voluntary water purchase programs are an example of such a policy. This paper examines the structure and performance of two water right purchase programs operating in Nevada: the Truckee River Water Quality Agreement and the Lahontan Valley purchase program administered by the U.S. Fish and Wildlife Service, the State of Nevada and The Nature Conservancy. Statistical analysis of the latter program indicates that it is performing efficiently. Notably, personal factors prompt water right sales, and the least productive rights (e.g., those appurtenant to poor soils) are sold to the government. Concluding comments offer suggestions about ways to improve program performance, including allowing the sale of fractional water rights.

Weinberg, M.; Kling, C.L.; Wilen, J.E. 1993. Water markets and water quality. American Journal of Agricultural Economics. 75: 278-291.

Abstract from journal: In addition to improving the allocative efficiency of water use, water markets may reduce irrigation-related water quality problems. This potential benefit is examined with a nonlinear programming model developed to simulate agricultural decision-making in a drainage problem area in California's San Joaquin Valley. Results indicate that a 30 percent drainage goal is achievable through improvements in irrigation practices and changes in cropping patterns induced by a water market. Although water markets will not generally achieve a least-cost solution, they may be a practical alternative to economically efficient, but informational intensive, environmental policies such as Pigouvian taxes.

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