Economic Values of Freshwater in the United States

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Abstract

This report presents nearly 500 water value estimates for four withdrawal uses (domestic, irrigation, industrial processing, and thermoelectric power generation) and four instream uses (hydropower, recreation/fish & wildlife habitat, navigation, and waste disposal). The first section discusses important caveats for interpreting the data and the relevance of water values for achieving efficient use of the resource. The second section discusses the presentation of the data. Tables and graphs are used to summarize and help interpret the water value data that have been converted to constant 1994 dollars. Section 3 presents the data by geographic region to illustrate how the values within a region vary among uses. Section 4 presents the data for individual water uses to illustrate how the values for specific uses vary within each of the 18 water resources regions that comprise the conterminous United States. Information such as the location, year, and methodology used to derive each of the values are presented in the appendices along with each of the water value estimates. The data are organized by water resources region in Appendix B and by type of use in Appendix C.

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ECONOMIC VALUES OF FRESHWATER IN THE UNITED STATES

1. INTRODUCTION

Water is essential for all life; consequently, its total value is infinite. But for purposes of allocating scarce resources efficiently among competing uses, marginal water values (that is, the additional value contributed by the last unit of water to a particular use) are of particular interest. An economically efficient allocation requires that the marginal value of water is equal in all uses.

In addition to being critical for the health of both humans and ecological systems, water is an important element in many of our recreational and economic activities. It is used in virtually everything we make and do. Water is the most widely used resource by industry; it is used both directly and indirectly to produce energy; it provides the basis for much of our outdoor recreation; it is an important part of our transportation network; it serves as a vehicle for disposing of wastes; and it provides important cultural and amenity values. Irrigation water can increase crop yields and expand the area where crops can be grown commercially. Economic and recreational opportunities and the overall quality of life depend in part on how water is allocated among these competing uses.

Freshwater is becoming increasingly scarce as the growth of demand, driven largely by population and economic growth, exceeds that of supply, which is constrained by limited opportunities and sharply rising costs for developing additional sources of freshwater. As supply and demand conditions change, the efficient allocation of the resource changes. The absence of market institutions to reallocate supplies in response to changing conditions and the importance of goods and services provided by water resources that are not traded and priced in markets are sources of potential discrepancies in the marginal values of water in alternative uses.

Objective and scope

This report describes and presents estimated values for four water withdrawal uses (domestic, irrigation, industrial processing, and thermoelectric power generation) and four instream uses (hydropower, recreation/fish & wildlife habitat, navigation, and waste disposal). Irrigation estimates are further divided into 22 crops or crop types and the recreation/fish & wildlife habitat estimates are broken down by fishing, wildlife refuges, fishing and whitewater, whitewater, and shoreline recreation. The nature of each of these water uses is described briefly in the following section.

Water use definitions

- Domestic use includes water used for household purposes such as drinking, bathing, washing clothes and dishes, toilets, food preparation, and outdoor uses such as watering lawns and washing cars. Outdoor uses are likely to be the lower value domestic uses.

- Irrigation use includes water artificially applied to agricultural crops.

- Industrial processing includes water used in the processing of chemicals, paper, minerals, cotton, vegetables, and meat.

- Thermoelectric power includes water used in the generation of electric power with fossil fuel, nuclear, and geothermal energy. Steam power plants require a method of cooling to condense the steam after it is used to drive the turbines. Water value estimates are available only for fossil fuel power plants.

- Hydroelectric power generation uses water to generate electricity at plants where the turbines are driven by falling water. Hydropower is classified as an instream use in this report although it sometimes involves diverting water from a stream channel. The value per acre-foot depends on the head of the flow at the dam or the cumulative head if the water would pass through multiple dams, the production factor of the turbine, and the unit value of the electricity produced.

- Recreation benefits provided by the nation's streams and reservoirs include activities such as fishing, boating, rafting, and swimming that make direct use of the water as well as activities such as picnicking and hiking that are enhanced by their proximity to water resources. Of the five categories of recreational activities for which there are water value estimates, three -- fishing, wildlife refuges, and fishing and whitewater -- might be viewed as proxies that capture part of the value of water for fish & wildlife habitat. The first two of these activities account for about 96 percent of all the recreation value estimates. About three-fourths of the 211 recreation estimates (see

Table 4.2) are for fishing, and nearly all of these values are from a single national study by Hansen and Hallam (1990). Another 44 of the estimates are for waterfowl hunting, fishing, and wildlife viewing at wildlife refuges. The combined category of fishing and whitewater has 3 estimates and the remaining 6 recreation observations are for activities involving whitewater and shoreline recreation.

- Navigation on inland waterways is an important part of the transportation system in some areas of the country. The size of the cargo that can be transported at any given time and therefore the value of the transportation services provided depends on the depth of navigable rivers and lakes, which in turn varies with the quantities of water.

- Waste disposal is an important use of the nation's surface waters. The ability of a stream to assimilate wastes without exceeding water-quality standards depends on the quantity of flow, the nature of the waste, and the ambient meteorological conditions. Thus, releasing water from storage during critical periods can help maintain water quality. The value of water released for these purposes is calculated as either the downstream damages avoided or the waste-treatment costs foregone.

Interpreting the data

This report presents nearly 500 estimates, from 41 different studies, of the economic value of water in the above mentioned uses. The estimates come from both published and unpublished sources based on studies performed under a wide range of supply and demand conditions over the last several decades. For comparability, all estimates have been converted to 1994 dollars per acre-foot. However, a number of important caveats should be borne in mind in interpreting these numbers and applying them to current or future conditions.

- Water has a number of dimensions -- quantity, quality, timing, and location -- that influence its value in a particular use. Quantity is the dimension considered in the value estimates. Since water uses are subject to diminishing marginal utility, the larger the quantity available at any given time, the lower the marginal value.

- Water quality is important for most water uses. High quality water is critical for most domestic and industrial uses and some recreational activities, and the value of water for irrigation depends in part on the salinity level. Water quality considerations, however, are not directly captured in the estimated water values.

- Timing can have an important influence on a water value. Water is more valuable in the production of hydroelectricity when it is used for peaking power. Irrigation water is more valuable when it is applied during periods of critical plant growth and when crops are water-stressed. And instream flows for anadromous fish are especially important during the migration season of the smolts.

- Water values may vary widely among locations. Relative to its value in most uses, water is expensive to transport out of natural or existing channels. Even within the same basin, allowance should be made for the costs of transporting water from the stream to the site of use when comparing offstream and instream water values.

- A variety of methods have been employed to estimate the water values presented in the following tables, and these methods do not necessarily provide readily comparable estimates. Both average and marginal water values are included in this report although marginal values are the relevant measure for assessing the efficiency with which water is allocated among alternative uses. But estimates of marginal water values are not available for many water uses. For instance, some of the water value estimates for irrigation and recreation that are included in this report are average rather than marginal values. And in some cases it is not clear if the estimates are for marginal or average values. Irrigation water values are estimated from both crop-water production functions and farm crop budget studies that use linear programming analysis. The production function method can provide estimates of marginal values while the farm crop budget studies provide estimates of either the average value of water or the price of water at which it become profitable to irrigate a particular crop. In spite of the significant differences in the methodologies used, the primary factors underlying the wide variations in the estimated irrigation water values are the crop grown, the location, and the year of the estimate rather than the methodology employed. The water value estimates of nonmarketed water services such as fishing and rafting that are based on contingent valuation techniques are even more controversial and should be interpreted as only rough indicators of average water values.

- The data in this report confirm the expectation that domestic use is one of the more valuable applications of water. Nevertheless, the value of domestic relative to other uses may be understated by the data presented because, with negatively sloping demand functions, marginal values (which are estimated for domestic uses) are less than average values (which are estimated for some of the other water uses). Estimation of the domestic values start with derivation of a household demand curve for water. The area under the demand curve for the marginal unit of water represents the consumers' willingness to pay for a unit of pretreated, pressurized water delivered to the home. Subtracting the costs of treating and delivering the water to the home from the willingness to pay provides an estimate of the marginal value of water in municipal use that can be compared to the value of water in instream uses.

- Supply and demand conditions change over time. Large seasonal and annual variations in supplies can result in droughts or floods. In the absence of flow regulation and storage, the ratio of maximum to minimum streamflow within a year may exceed 500 to 1. Water demands for irrigation and domestic uses also vary seasonally. Natural climate variability results in interannual fluctuations; annual flows may vary by a factor of 3 or more, especially in arid areas. The marginal value of water for a particular use is likely to be higher during a period of drought than during a period of average or above average precipitation. And since demands are growing faster than supplies, marginal water values tend to rise over time.

- Water uses are rarely fully consumptive. Consequently, using water for one purpose does not necessarily preclude others from using the same water. However, allocating water for one use often, but not necessarily, adversely affects the quantity, quality, timing, and location of supplies for other uses. Ideally, water would be managed and allocated on a basin-wide level to maximize the total public benefits.

- Water provides both final goods and services that are used directly by consumers (e.g., domestic and recreational water uses) and inputs that are used in the production of other goods and services (e.g., crops and power). The value of water used as an input is derived from the value of the final goods and services. Thus, the values of water for irrigation and hydropower depend strongly on the prices of the crops and power produced.

- Conversion of the values to 1994 prices was accomplished using the price deflator (presented in appendix A) for gross domestic product from the 1995 Economic Report of the President. Changes in the prices of the various goods (such as crops and power) that influence the value of water in particular uses may differ considerably from those of the price deflator. And the values that society places on goods and services such as recreation and fish and wildlife habitat that are not priced in markets may change over time. The original values and the years in which the estimates were made are reported in the appendices to enable the user to make adjustments for variations in the price changes of specific goods.

- Technology can alter both the demand and supply of water and therefore its relative value over time. For example, technological developments early in this century led to the development and widespread use of hydroelectric power, thereby increasing the demand for water. In the 1930s improved pumps reduced the costs and, therefore, increased the economic supply of groundwater. More recently development of more efficient irrigation technologies that increased the returns to water in agriculture have had somewhat offsetting impacts on the demand for irrigation water; improved efficiency reduces the water applied per acre while lower water costs encourages the irrigation of additional land.

In spite of the many caveats that accompany the data, the systematic presentation of estimates of the economic value of water in alternative uses and locations provides important information for understanding the role of water in the economy and the potential benefits of institutions that facilitate the allocation of supplies to higher value uses as supply and demand conditions change over time.

2. PRESENTATION OF THE DATA

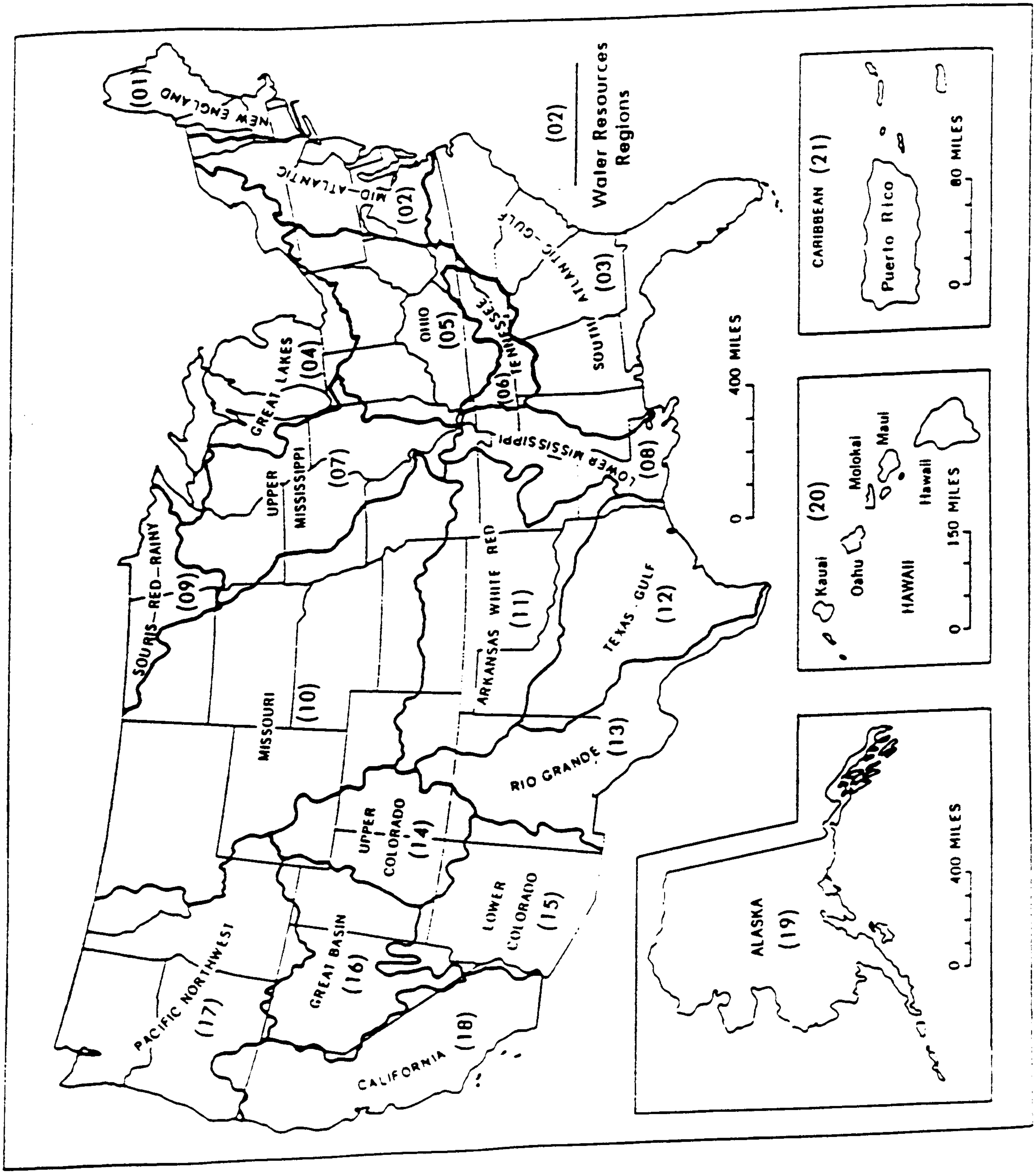
The individual water value estimates in this study are generally based on conditions relevant to specific locations, times, and water supply situations. Consequently, information such as the location, year, and methodology used to derive each of these values are presented in the appendices along with each of the individual water value estimates. For more complete information about a particular estimate and its applicability to other conditions, the user should refer to the original source. References for each estimate are provided in appendices B and C, and the list of references provides the necessary bibliographic information.

The appendices use a spread sheet format in which the information for each value estimate is presented in a single row. Many studies contain multiple water value estimates. Consequently, an estimate is uniquely identified by the combination of the study number and the number of the estimate within the study. When studies reported high, average, and low estimates for a single water use, all three values are included in the tables; the notes in column 'J' of appendices B and C describe each estimate.

To assist users in locating information for a particular region or use, the water value estimates are organized by water resources region in appendix B and then by type of use in appendix C. The United States is divided into the 21 water resources regions depicted in Figure 2.1. These regions are hydrologic areas that comprise either the drainage area of a major river such as the Missouri or the combined drainage of a series of rivers such as the South Atlantic Gulf Region. Water values for the various withdrawal and instream uses are presented for the 18 water resources regions within the conterminous 48 states.

The range of the estimated values for a particular use and region can be large because of the factors described in the introduction that affect both the actual and estimated values and because, when available, both high and low estimated values are included in the tables and figures. The small number of observations available for some of

Figure 2.1



Water Resources Regions
(02)
NEW ENGLAND (01)
MID-ATLANTIC (02)
SOUTH ATLANTIC-GULF (03)
GREAT LAKES (04)
OHIO (05)
TENNESSEE (06)
UPPER MISSISSIPPI (07)
LOWER MISSISSIPPI (08)
SOURIS-RED-RAINY (09)
MISSOURI (10)
ARKANSAS WHITE RED (11)
TEXAS GULF (12)
RIO GRANDE (13)
UPPER COLORADO (14)
LOWER COLORADO (15)
GREAT BASIN (16)
PACIFIC NORTHWEST (17)
CALIFORNIA (18)
400 MILES
ALASKA (19)
0 400 MILES
(20)
Kauai
Oahu
Molokai
Maui
Hawaii
HAWAII
0 150 MILES
CARIBBEAN (21)
Puerto Rico
0 80 MILES

the categories suggests that a single outlying value can have a large impact on the average of the estimated values for a particular use and region. Indeed, water value estimates are not available for all uses in all regions. As might be expected, there are many more estimates of water values for the more arid regions of the country where water conflicts are more common and long-standing and where marginal values are likely to be higher. The absence of water value estimates does not indicate that the marginal value of water in those uses and regions is zero. In some cases, however, the values may not have been sufficiently high to attract the interest of investigators.

The following two sections use tables and graphs to summarize and help interpret the nearly 500 values presented in the appendices. Section 3 presents the data for various geographic regions -- the conterminous 48 states, the humid East (water resources regions 1 to 9) compared to the more arid West (regions 10 to 18), and for each of the 18 water resources regions -- to illustrate how estimated water values within these geographic areas vary among uses. Section 4 presents the data for individual water uses to illustrate how the economic values of water in specific uses vary within each of the 18 water resources regions. The 18 estimates that are not identified with a specific region are included in the national estimates and in section 4.

3. NATIONAL AND REGIONAL WATER VALUES

Table 3.1 and Figure 3.1 present the national averages and medians of the water values for four instream uses (waste disposal, recreation/fish & wildlife habitat, hydropower, and navigation) and four withdrawal uses (irrigation, industrial processing, thermoelectric power, and domestic).[1] Industrial processing and domestic uses are the highest value uses based on both the average and median figures. Recreation/fish & wildlife habitat and irrigation, however, which together account for nearly 80 percent of all the estimates, have the highest individual estimated water values. The overall averages for each water use, which are considerably higher than the respective medians, are strongly influenced in some cases by a few unusually high outlier estimates. Unusually high

[1] Each estimate is given equal weight in calculating the averages.

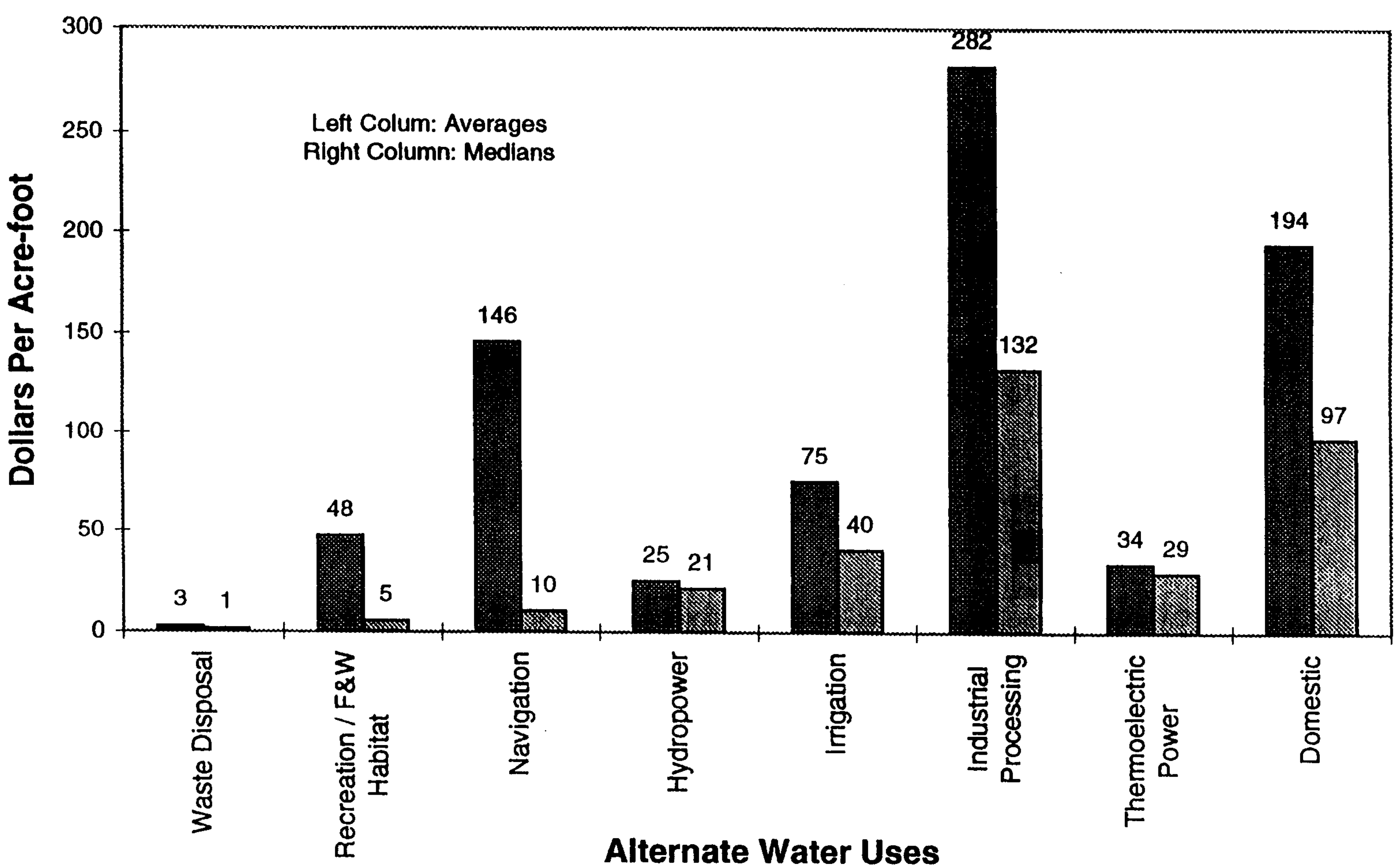
Table 3.1 National Water Values by Use, ($/Acre-foot)

Water Use Classification Major	Minor	Average	Median	Minimum	Maximum	Number of Values
Instream						
	Waste Disposal	3	1	0	12	23
	Recreation/F&W habitat	48	5	0	2,642	211
	Navigation	146	10	0	483	7
	Hydropower	25	21	1	113	57
Withdrawal						
	Irrigation	75	40	0	1,228	177
	Industrial Processing	282	132	28	802	7
	Thermoelectric Power	34	29	9	63	6
	Domestic	194	97	37	573	6
			Total Number of Values			494

Table 3.2 Water Values in the East vs the West, ($/Acre-foot)

Water Use	Average	Median	Maximum	Minimum	Number of Values
East					
Instream	16	4	483	0	89
Withdrawal	29	19	198	0	17
West					
Instream	56	8	2,642	0	203
Withdrawal	80	42	1,228	0	167
		Total Number of Values			476

Figure 3.1 National Water Values by Use, ($/Acre-foot)



estimates might reflect the methodology employed (particularly when contingent valuation techniques are employed to estimate nonmarketed goods) or the specific circumstances of the study. The marginal value of water for a particular use in a specific location can vary widely over time depending on changes in the availability of supply and the number and needs of users. The medians, on the other hand, may be strongly influenced by a single study with multiple estimates of the value of water in a particular use. Although there are shortcomings of both summary measures, at the national level the medians may provide a better indication of the relative values of water in various uses under relatively normal hydrologic conditions. The median values of the withdrawal uses are all higher than those of the instream uses.

Table 3.2 and Figure 3.2 compare instream and withdrawal water values for the East (water resources regions 1 to 9) and the more arid West (regions 10 to 18). As would be expected, water values are considerably higher in the drier, more water-scarce areas of the country. Within both regions, the values are higher for withdrawal than for instream uses. Moreover, the median value of water withdrawals in the East exceeds the median value of instream uses in the West.

Table 3.3 and Figure 3.3 show the averages and medians of the values of all water uses combined for the 18 water resources regions. The averages are (with the exception of region 9 for which there are only two estimates) much higher than the medians. As noted above, this result reflects the large influence on the averages of a few very high estimates. For instance, the maximum values exceed $1,200 an acre-foot in three regions and $400 per acre-foot in another four regions. In general, these data reinforce the message that water values are higher in the West. The minimum estimated water values of $1 per acre-foot (af) or less in all 18 regions may be the result of treating water as essentially a free resource for some uses. A resource that is provided free to the user will be used until either its marginal value is zero or the supply is exhausted.

Caution should be used in making comparisons as to the relative water values in the various water resources regions based on the averages and medians; these values depend in large part on the relative number of estimates that are available for high and low value water uses in a specific region. Table 3.4 indicates the number of estimated values

Figure 3.2 Water Values in the East vs the West, ($/Acre-foot)

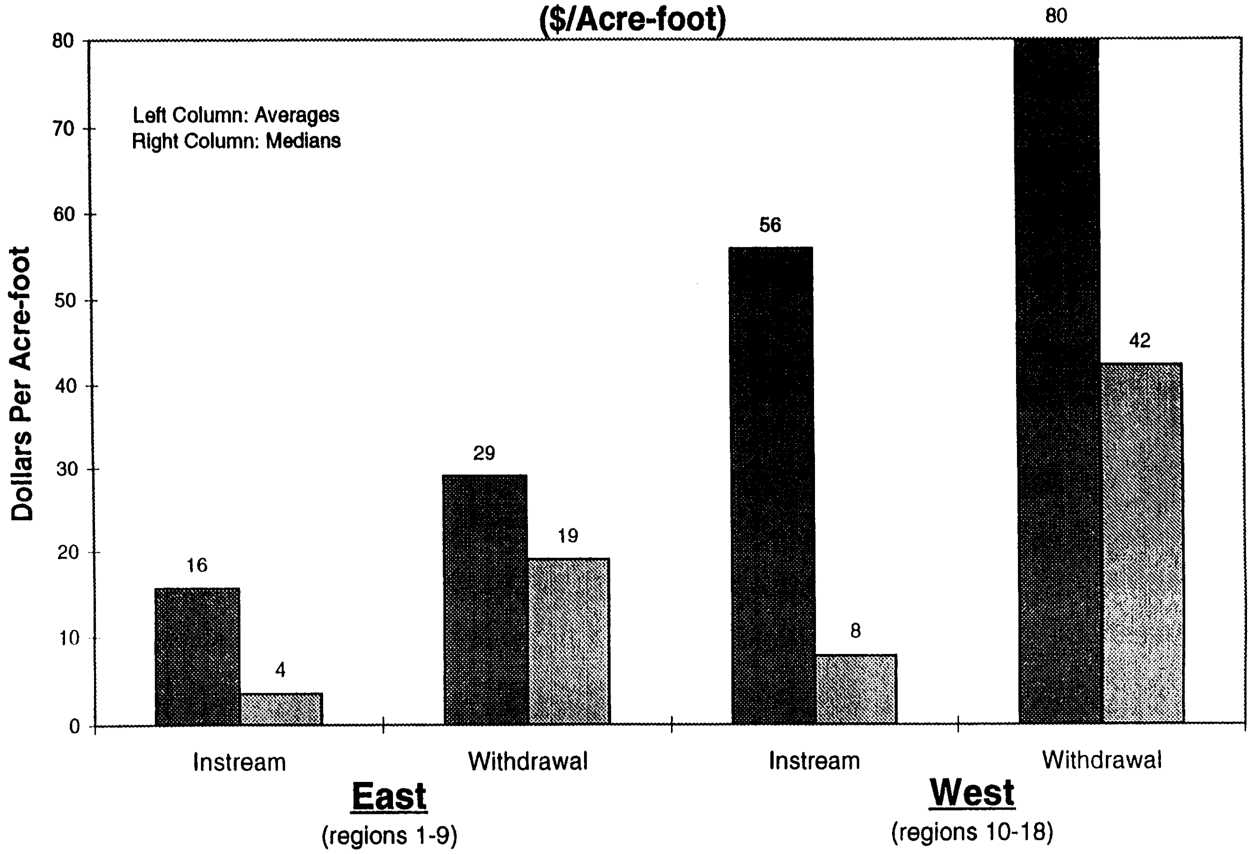


Table 3.3 Water Values by Region, ($/Acre-foot)

Resources Region Values	Average	Median	Maximum	Minimum	Number of
New England	4	2	12	0	7
Mid-Atlantic	25	5	198	1	10
S. Atlantic-Gulf	12	3	57	0	17
Great Lakes	7	4	42	1	10
Ohio	31	2	483	0	17
Tennessee	14	7	91	0	16
Upper MI	30	4	420	0	17
Lower MI	8	1	50	0	10
Souris-Red-Rainy	1	1	3	0	2
Missouri	13	4	95	0	49
AK-White-Red	31	3	187	0	24
Texas-Gulf	64	52	199	0	26
Rio Grande	191	36	1,615	0	21
Upper CO	32	27	70	0	29
Lower CO	122	49	2,642	0	70
Great Basin	38	4	461	0	14
Pacific NW	53	16	1,228	0	66
California	51	8	756	0	71
		Total Number of Values			474

Table 3.3 Water Values by Region, ($/Acre-foot)

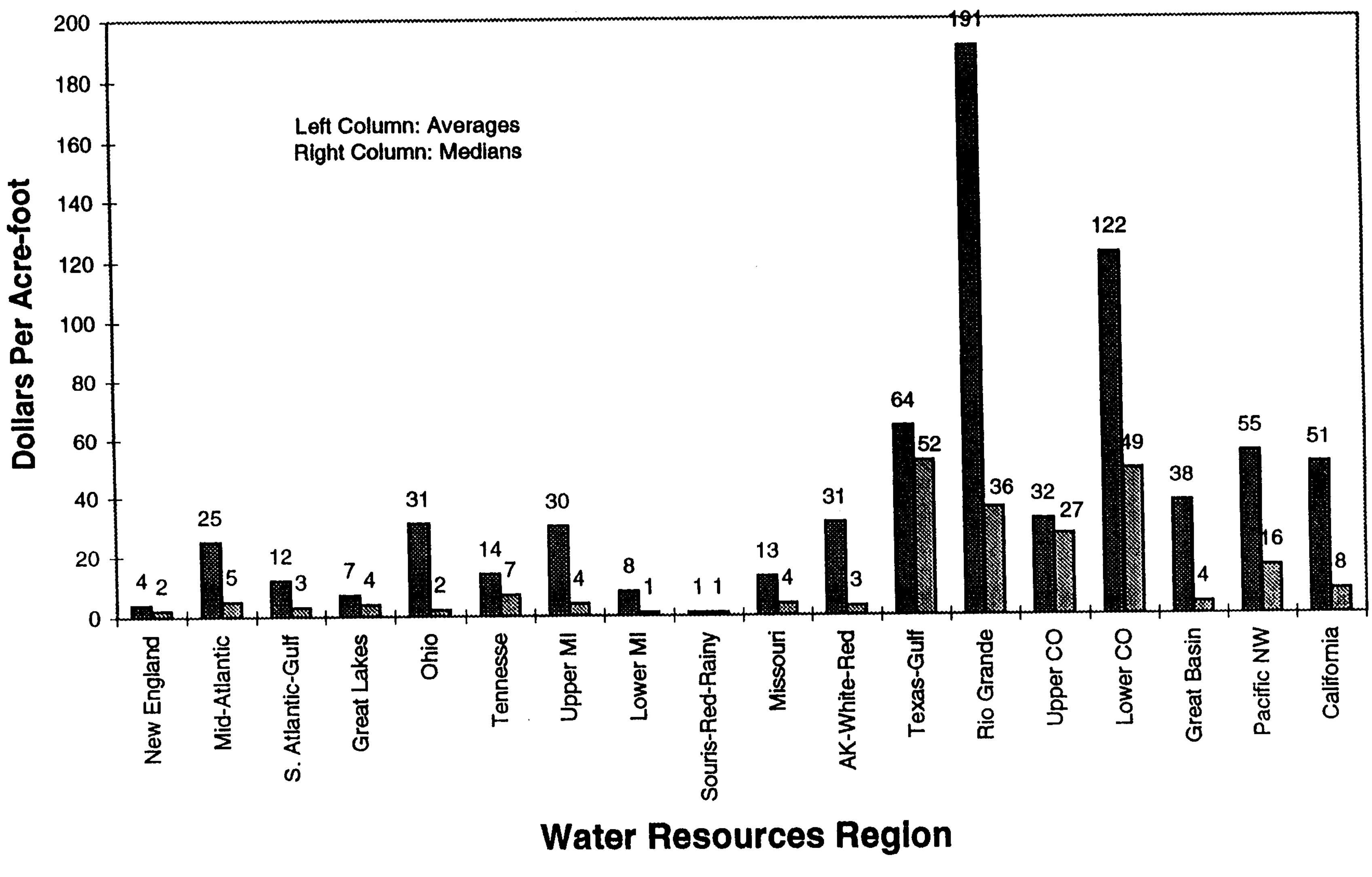


Table 3.4 Water Values by Region and Use, ($/Acre-foot)

Region 1: New England

Water Use Classification Major	Minor	Average	Minimum	Maximum	Number of Values
Instream	Waste Disposal	2	2	2	1
Instream	Recreation/F&W habitat	4	0	12	6

Region 2: Mid-Atlantic

Water Use Classification Major	Minor	Average	Minimum	Maximum	Number of Values
Instream	Waste Disposal	3	1	4	2
Instream	Recreation/F&W habitat	6	3	9	7
Withdrawal	Irrigation	198	198	198	1

Region 3: South Atlantic-Gulf

Water Use Classification Major	Minor	Average	Minimum	Maximum	Number of Values
Instream	Waste Disposal	1	1	1	1
Instream	Recreation/F&W habitat	3	1	7	9
Withdrawal	Domestic	37	37	37	2
Withdrawal	Irrigation	20	0	57	5

Region 4: Great Lakes

Water Use Classification Major	Minor	Average	Minimum	Maximum	Number of Values
Instream	Waste Disposal	1	1	2	2
Instream	Recreation/F&W habitat	9	1	42	8

Region 5: Ohio

Water Use Classification Major	Minor	Average	Minimum	Maximum	Number of Values
Instream	Waste Disposal	4	2	6	2
Instream	Recreation/F&W habitat	3	0	8	14
Instream	Navigation	483	483	483	1

Region 6: Tennessee

Water Use Classification Major	Minor	Average	Minimum	Maximum	Number of Values
Instream	Waste Disposal	0	0	0	1
Instream	Recreation/F&W habitat	2	1	4	4
Instream	Navigation	91	91	91	1
Instream	Hydropower	7	1	13	9
Withdrawal	Irrigation	19	19	19	1

Table 3.4 Water Values by Region and Use (Continued)

Region 7: Upper Mississippi

Water Use Classification Major	Minor	Average	Minimum	Maximum	Number of Values
Instream	Waste Disposal	8	8	8	1
Instream	Recreation/F&W habitat	4	0	12	10
Instream	Navigation	215	10	420	2
Withdrawal	Irrigation	10	0	41	4

Region 8: Lower Mississippi

Water Use Classification Major	Minor	Average	Minimum	Maximum	Number of Values
Instream	Waste Disposal	5	5	5	1
Instream	Recreation/F&W habitat	0	0	0	5
Instream	Navigation	10	10	10	1
Withdrawal	Irrigation	21	0	50	3

Region 9: Souris-Red-Rainy

Water Use Classification Major	Minor	Average	Minimum	Maximum	Number of Values
Instream	Recreation/F&W habitat	3	3	3	1
Withdrawal	Irrigation	0	0	0	1

Region 10: Missouri

Water Use Classification Major	Minor	Average	Minimum	Maximum	Number of Values
Instream	Waste Disposal	7	2	12	2
Instream	Recreation/F&W habitat	14	0	95	29
Instream	Navigation	0	0	0	1
Withdrawal	Irrigation	18	0	77	17

Region 11: Arkansas-White-Red

Water Use Classification Major	Minor	Average	Minimum	Maximum	Number of Values
Instream	Waste Disposal	3	3	4	2
Instream	Recreation/F&W habitat	21	0	187	12
Withdrawal	Irrigation	49	0	113	10

Table 3.4 Water Values by Region and Use (Continued)

Region 12: Texas-Gulf

Water Use Classification Major	Minor	Average	Minimum	Maximum	Number of Values
Instream	Waste Disposal	1	1	1	1
Instream	Recreation/F&W habitat	8	3	15	5
Withdrawal	Irrigation	81	0	199	20

Region 13: Rio Grande

Water Use Classification Major	Minor	Average	Minimum	Maximum	Number of Values
Instream	Waste Disposal	1	1	1	1
Instream	Recreation/F&W habitat	313	6	1615	12
Withdrawal	Irrigation	33	0	107	8

Region 14: Upper Colorado

Water Use Classification Major	Minor	Average	Minimum	Maximum	Number of Values
Instream	Waste Disposal	0	0	0	1
Instream	Recreation/F&W habitat	51	5	70	8
Instream	Hydropower	21	4	40	13
Withdrawal	Irrigation	5	0	18	4
Withdrawal	Thermoelectric Power	55	40	63	3

Region 15: Lower Colorado

Water Use Classification Major	Minor	Average	Minimum	Maximum	Number of Values
Instream	Waste Disposal	0	0	0	1
Instream	Recreation/F&W habitat	597	62	2,642	5
Instream	Hydropower	35	26	46	2
Withdrawal	Domestic	97	49	144	2
Withdrawal	Irrigation	88	0	1,071	60

Region 16: Great Basin

Water Use Classification Major	Minor	Average	Minimum	Maximum	Number of Values
Instream	Waste Disposal	1	1	1	1
Instream	Recreation/F&W habitat	60	0	461	9
Withdrawal	Irrigation	0	0	0	4

Table 3.4 Water Values by Region and Use (Continued)

Region 17: Pacific Northwest

Water Use Classification Major	Minor	Average	Minimum	Maximum	Number of Values
Instream	Waste Disposal	0	0	0	1
Instream	Recreation/F&W habitat	1	0	3	13
Instream	Navigation	5	5	5	1
Instream	Hydropower	31	2	113	33
Withdrawal	Irrigation	143	0	1,228	18

Region 18: California

Water Use Classification Major	Minor	Average	Minimum	Maximum	Number of Values
Instream	Waste Disposal	1	1	1	2
Instream	Recreation/F&W habitat	27	0	404	48
Withdrawal	Irrigation	111	0	756	21

by type of water use for the 18 water resources regions. There are relatively few estimates available for some regions, especially in the eastern United States, and no region has estimates for more than five of the eight water-use categories listed in Table 3.1. The unusually high averages for the Rio Grande (region 13) and the Lower Colorado (region 15) that are illustrated in Figure 3.3 are attributable to some very high estimated recreation values and the dominance of recreation in the number of water-value estimates.

4. WATER VALUES BY CATEGORY OF USE

Waste disposal

Waste disposal is a relatively low-value water use in the 17 regions for which estimates are available. The values average less than $1/af in six regions and less than $3/af in another six regions (see Table 4.1 and Figure 4.1). Even the highest single estimated value for waste disposal ($12/af in the Missouri Region) and the highest average value ($8/af in the Upper Mississippi Region) are low relative to the estimated values of water for most other uses.

Recreation/fish & wildlife habitat

Recreation, which includes fishing, wildlife refuges, fishing and whitewater, whitewater, and shoreline recreation, is the only water use category with estimates for all 18 water resources regions. The range of the estimated recreation values is very wide, both within and among regions. The highest individual water value estimates are for recreational activities – $2,642 for fishing in the Lower Colorado Basin and $1,615 for fishing and whitewater boating (rafting and kayaking) in the Rio Grande Basin (see Tables 4.2 and 4.3 and Figures 4.2 and 4.3). These high values reflect the increasing demands for water-based recreation as well as the scarcity of high-quality streams for recreational activities in these basins. The scarcity of water-based recreational sites is attributable to both the natural aridity of those basins and the extensive development of their water resources for withdrawal and hydropower uses. At the other extreme, nine regions had estimated recreation values of zero and all five estimates of the marginal value of water for

Table 4.1 Water Values for Waste Disposal by Region, ($/Acre-foot)

Resource Region	Average	Maximum	Minimum	Number of Values
New England	2.2	2	2	1
Mid-Atlantic	2.7	4	1	2
S. Atlanta-Gulf	0.7	1	1	1
Great Lakes	1.2	2	1	2
Ohio	3.9	6	2	2
Tennessee	0.3	0	0	1
Upper MI	8.0	8	8	1
Lower MI	5.2	5	5	1
Missouri	7.0	12	2	2
AK-White-Red	3.0	4	3	2
Texas Gulf	1.2	1	1	1
Rio Grande	1.4	1	1	1
Upper CO	0.3	0	0	1
Lower CO	0.3	0	0	1
Great Basin	0.7	1	1	1
Pacific NW	0.4	0	0	1
California	1.1	1	1	2

Figure 4.1 Water Values for Waste Disposal by Region
($/Acre-foot)

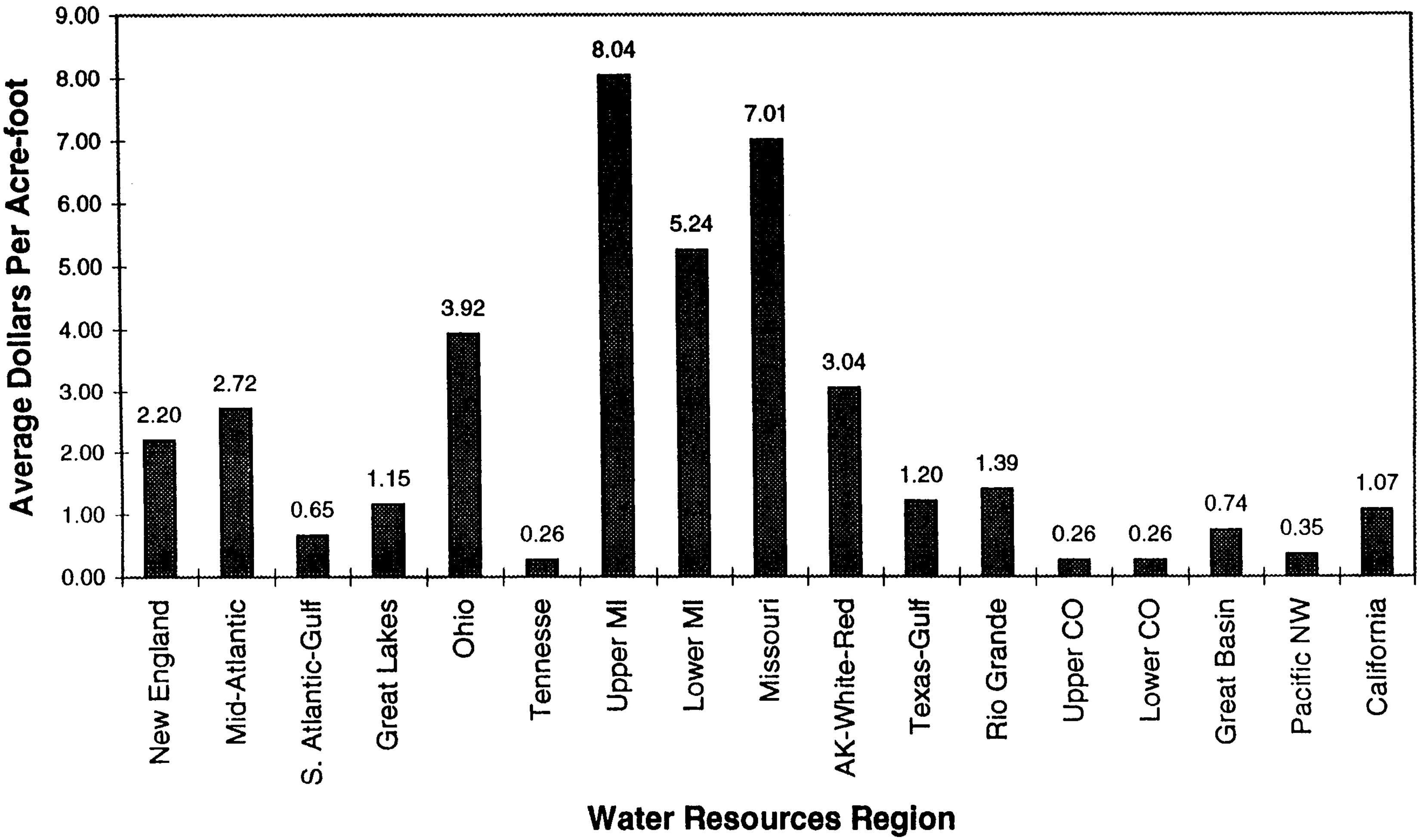


Table 4.2 Water Values for Recreation/Fish & Wildlife Habitat by Region, ($/Acrefoot)

Resource Region	Average	Maximum	Minimum	Number of Values
New England	4	12	0	6
Mid-Atlantic	6	9	3	7
S. Atlantic-Gulf	3	7	1	9
Great Lakes	9	42	1	8
Ohio	3	8	0	14
Tennessee	2	4	1	4
Upper MI	4	12	0	10
Lower MI	0	0	0	5
Souris-Red-Rainy	3	3	3	1
Missouri	14	95	0	29
AK-White-Red	21	187	0	12
Texas-Gulf	8	15	3	5
Rio Grande	313	1,615	6	12
Upper CO	51	70	5	8
Lower CO	597	2,642	62	5
Great Basin	60	461	0	9
Pacific NW	1	3	0	13
California	27	404	0	48
unspecified	19	32	12	6

Table 4.3 Water Values for Recreation/Fish and Wildlife Habitat, ($/Acre-foot)

Recreation Activity	Average	Median	Minimum	Maximum	Number of Values
Fishing	34	5	0	2,642	158
Wildlife Refuges	24	6	1	404	44
Fishing & Whitewater	1,042	1,505	6	1,615	3
Whitewater	9	9	5	12	4
Shoreline Recreation	19	19	17	21	2

Figure 4.2 Water Values for Recreation/Fish &Wildlife Habitat by Region, ($/Acre-foot)

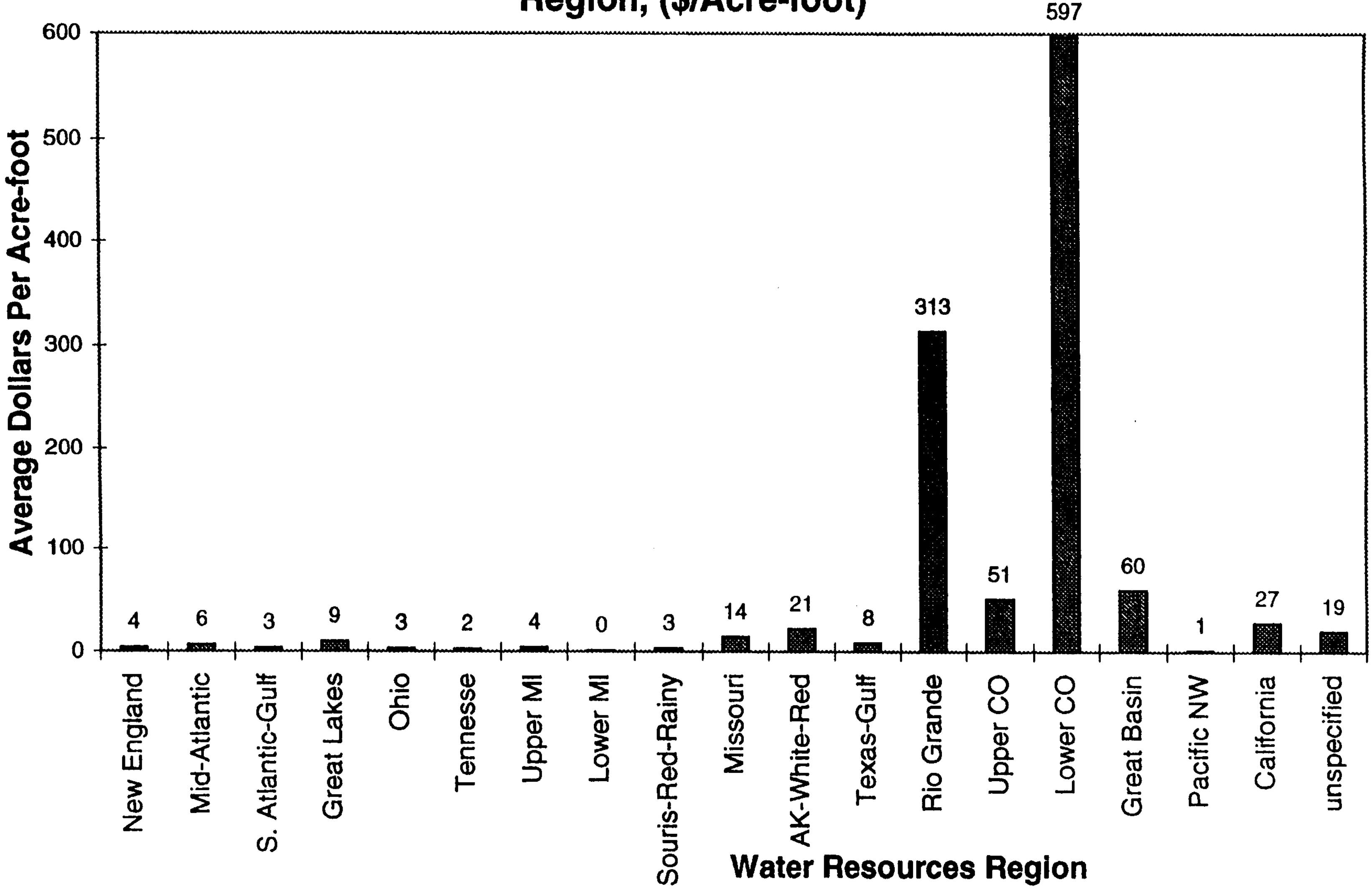
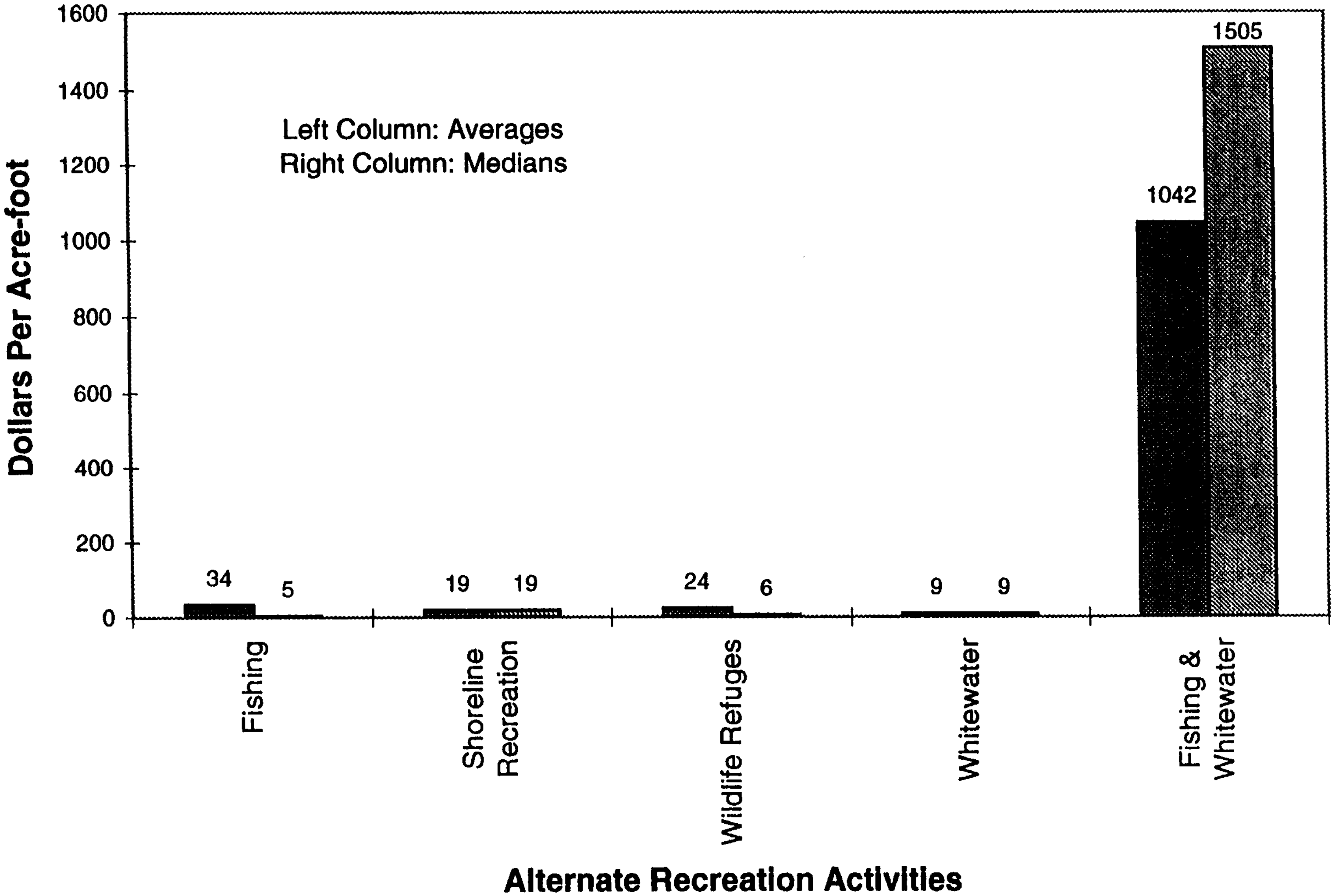


Figure 4.3 Water Values for Recreation/Fish & Wildlife Habitat ($/Acre-foot)



recreation in the water-rich Lower Mississippi Region were zero. The recreation values tend to be considerably higher in the western states. For example, the averages of the recreation water values range from zero to $9/af in the nine eastern regions. In the West, the range is from $1/af in the relatively water-rich Pacific Northwest to $597/af in the Lower Colorado Basin.

There is a strong complementarity between the conditions that provide good fish and wildlife habitat and those that provide for good fishing, waterfowl hunting, and wildlife viewing at refuges. Consequently, the values for fishing, wildlife refuges, and fishing and whitewater, which make up about 97 percent of all recreation water value estimates, provide proxies for important components of the value of water for fish and wildlife habitat.

Hydroelectric power

Hydroelectric power values are available for only four water resources regions, the Tennessee, Upper Colorado, Lower Colorado, and Pacific Northwest (see Table 4.4 and Figure 4.4). These regions are highly developed for hydropower with multiple dams and generating plants in place along their major rivers. The potential value of water for hydropower within a basin varies widely with the location of the water on the river because the power produced by an acre-foot of water is determined by the developed head (the height of a retained body of water) above the generating turbines. For instance, an acre-foot of water at the headwaters of the Snake River in the Pacific Northwest could pass through 16 dams before joining up with the Columbia River and then through another 4 dams before reaching the Pacific Ocean. The cumulative developed head of these dams is 2,159 feet. In contrast, the developed head of Bonneville Dam, the last dam along the Columbia River, is 59 feet. Consequently, the value for hydropower of an acre-foot of water at the headwaters of the Snake is more than 36 times the value just above Bonneville Dam. The averages of the marginal hydropower values listed in Table 4.4 are the averages of the cumulative upstream generating capability at each dam along the respective rivers. Hydropower is an important, although not the highest value, water user in these four water resources regions (see Table 3.4).

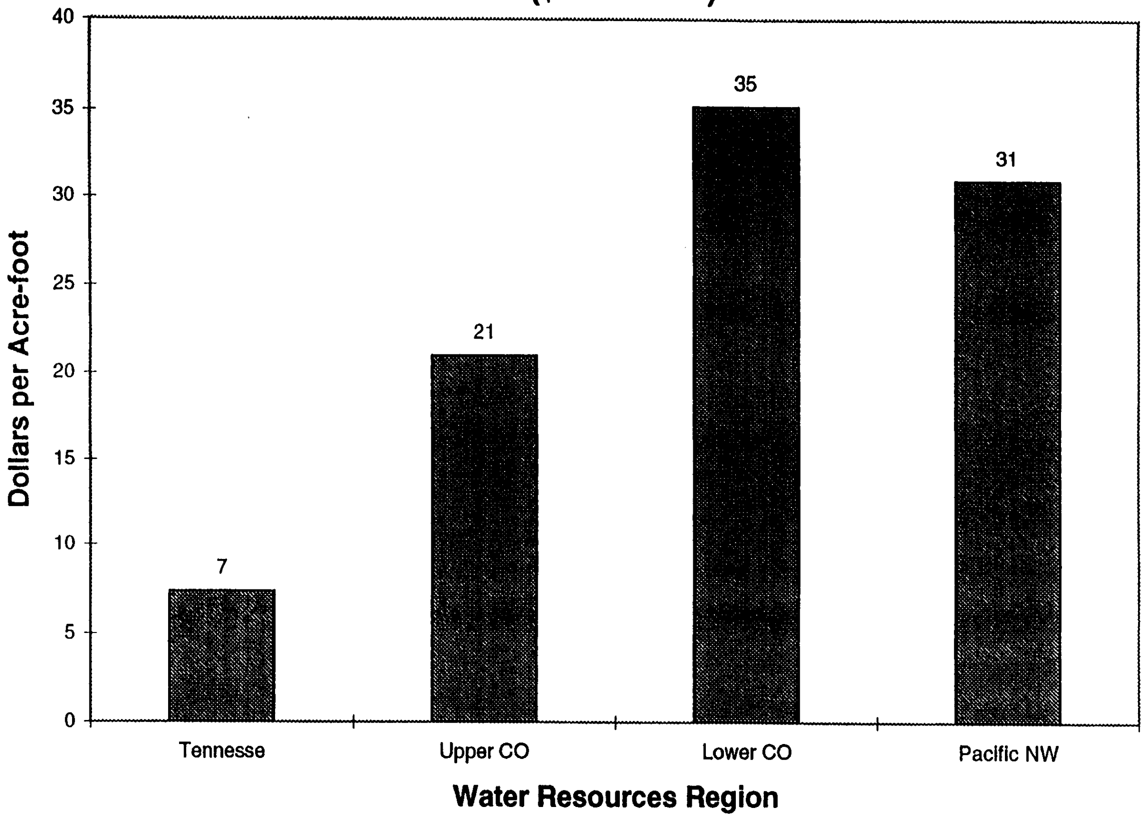
Table 4.4 Water Values for Hydropower by Region, ($/Acre-foot)

Resource Region	Average	Maximum	Minimum	Number of Values
Tennessee	7	13	1	9
Upper CO	21	40	4	13
Lower CO	35	46	25	2
Pacific NW	31	113	2	33

Table 4.5 Water Values for Navigation by Region, ($/Acre-foot)

Resource Region	Average	Maximum	Minimum	Number of Values
Ohio	483	483	483	1
Tennessee	91	91	91	1
Upper MI	215	420	10	2
Lower MI	10	10	10	1
Missouri	0	0	0	1
Pacific NW	5	5	5	1

Figure 4.4 Water Values for Hydropower by Region, ($/Acre-foot)



Navigation

Navigation is an important part of the nation's commercial transportation system. When ports are accessible and time is not a critical factor, barge transportation is generally the least expensive form of shipping large loads. Navigation is sensitive to the level and flow of water. Minimum water levels are required for navigation on free-flowing rivers while too much flow can create problems for loading and unloading barges. Water levels on the Great Lakes and other reservoirs affect the size of the load that can be transported on a barge and thus the profitability of navigation. Water is also used when ships pass through locks although the quantities are small in comparison to the quantities of water used to support navigation on a free-flowing stream. Government subsidies for navigation add to the problems of estimating navigation water values. Accordingly, the water values for navigation presented in Table 4.5 and Figure 4.5 should be viewed with caution. The averages of the estimated values for navigation water in the Ohio ($483/af), Tennessee ($91/af), and Upper Mississippi ($215) are by far the highest estimated values for water in these regions (see Table 3.4). In contrast, the estimated values for navigation in the Lower Mississippi, Missouri, and Pacific Northwest regions are $10/af or less.

Irrigation

Irrigation is the largest withdrawal user of water in the United States, accounting for 40 percent of all withdrawals and 77 percent of withdrawals in the 17 western states (Solley, Pierce, and Perlman, 1993). The range of water value estimates is wide (Table 4.6). On the low end, the minimum value is zero for 13 of the 15 regions for which there are estimates; the two regions with non-zero minimums have only one observation. On the high end, two regions -- the Lower Colorado and the Pacific Northwest -- have maximum irrigation values in excess of $1,000/af. The estimates suggest that water can have considerable value in irrigation in both humid and arid regions although the values are generally higher in the West (Tables 3.4 and 4.6 and Figure 4.6).

Irrigation water values tend to be higher for the higher value crops such as vegetables and fruits and lower for the grains and hay (see Tables 4.7 and 4.8 and Figures 4.7 and 4.8). For specific crops, the average values per acre-foot are $784 for potatoes,

Figure 4.5 Water Values for Navigation by Region, ($/Acre-foot)

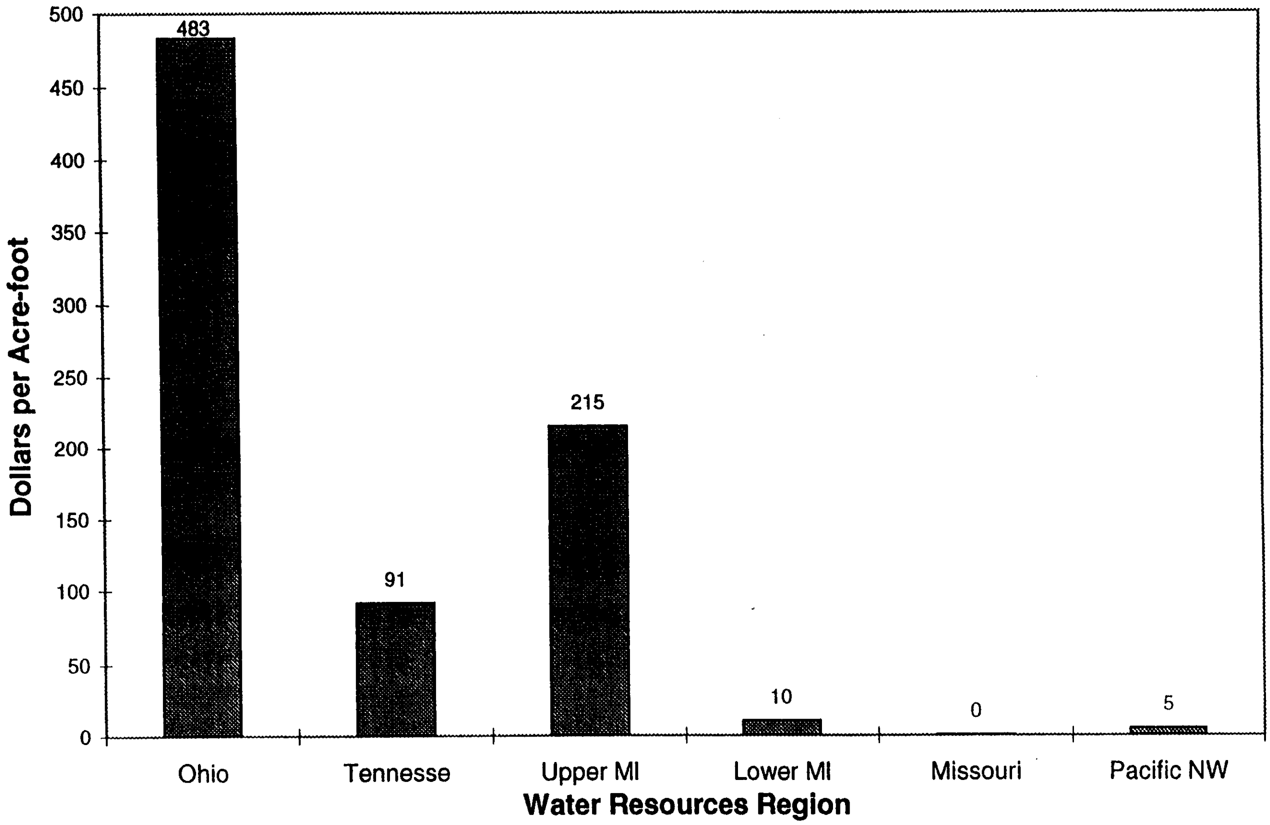


Table 4.6 Water Values for Irrigation by Region, ($/Acre-foot)

Resource Region	Average	Maximum	Minimum	Number of Values
Mid-Atlantic	198	198	198	1
S. Atlantic-Gulf	20	57	0	5
Tennessee	19	19	19	1
Upper MI	10	41	0	4
Lower MI	21	50	0	3
Souris-Red-Rainy	0	0	0	1
Missouri	18	77	0	17
AK-White-Red	49	113	0	10
Texas-Gulf	81	199	0	20
Rio Grande	33	107	0	8
Upper CO	5	18	0	4
Lower CO	88	1,071	0	60
Great Basin	0	0	0	4
Pacific NW	143	1,228	0	18
California	111	756	0	21

Figure 4.6 Water Values for Irrigation by Region, ($/Acre-foot)

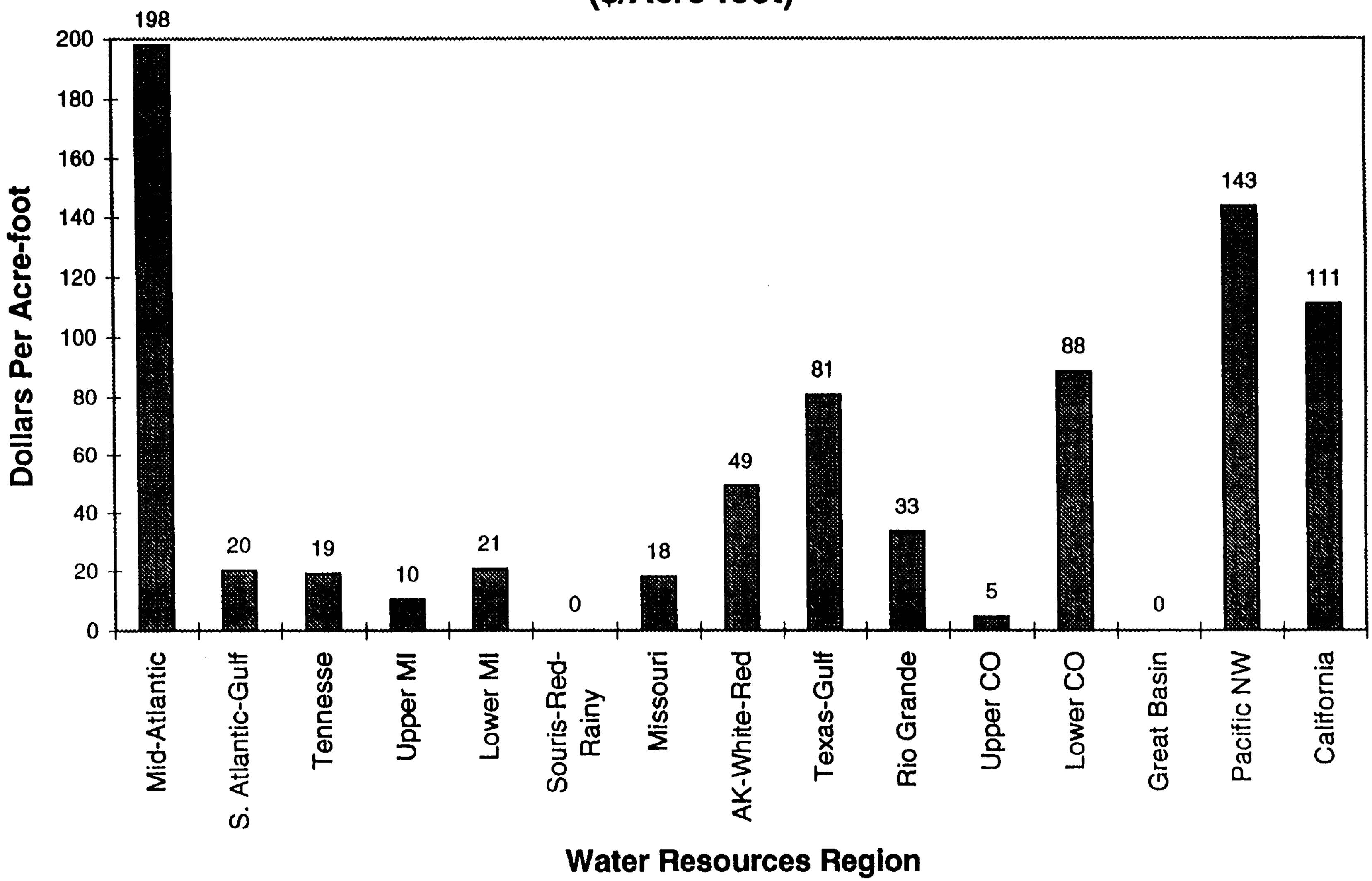


Table 4.7 Water Values by Crop, ($/Acre-foot)

Crop	Average	Median	Maximum	Minimum	Number of Values
Alfalfa	51	44	173	18	13
Apples	151	151	151	151	1
Barley	33	39	62	9	7
Beans	58	58	72	44	2
Carrots	550	550	550	550	1
Corn	91	98	134	44	7
Cotton	114	103	292	28	18
Grain Sorgham	57	44	199	5	11
Hay	36	36	49	23	2
Hops	18	18	18	18	1
Lettuce	208	208	208	208	1
Melons	54	54	70	37	2
Onions	40	40	40	40	1
Pears	137	137	137	137	1
Potatoes	710	784	1,228	46	4
Rice	86	86	86	86	1
Safflower	53	58	69	26	4
Soybeans	121	127	178	60	3
Sugar Beets	121	119	253	39	8
Tomatos	686	686	686	686	1
Vegetables	206	206	206	206	1
Wheat	51	47	104	14	13

Figure 4.7 Water Values by Crop, ($/Acre-foot)

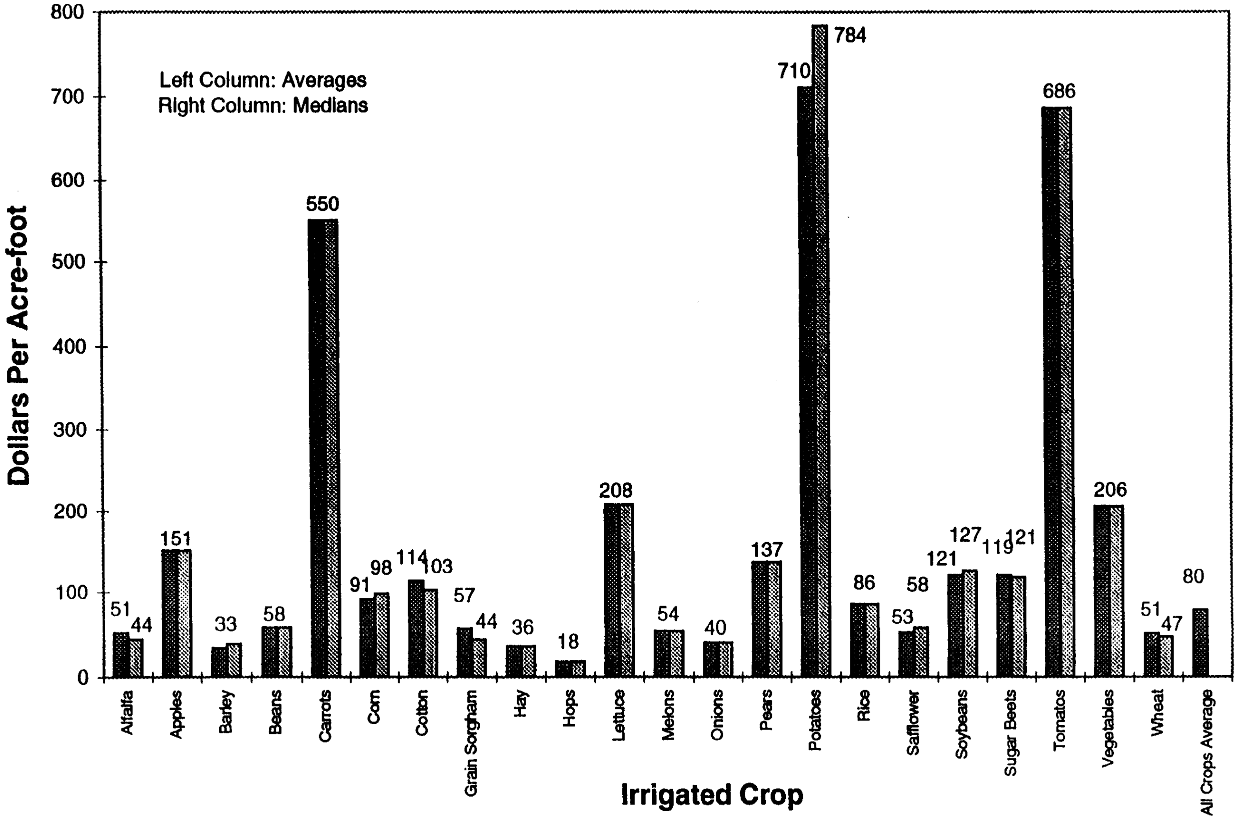


Table 4.8 Water Values for Categories of Crops, ($/Acre-foot)

Crop Category	Average	Maximum	Minimum	Count
Cotton	114	292	28	18
Grain	57	199	5	40
Hay	49	173	18	15
Oil Seeds	82	178	26	7
Vegetable and Orchard	261	1,228	37	23

Table 4.9 Water Values for Domestic Use by Region, ($/Acre-foot)

Resource Region	Average	Maximum	Minimum	Number of Values
S. Atlantic-Gulf	37	37	37	2
Lower CO	97	144	49	2
unspecified	448	573	324	2

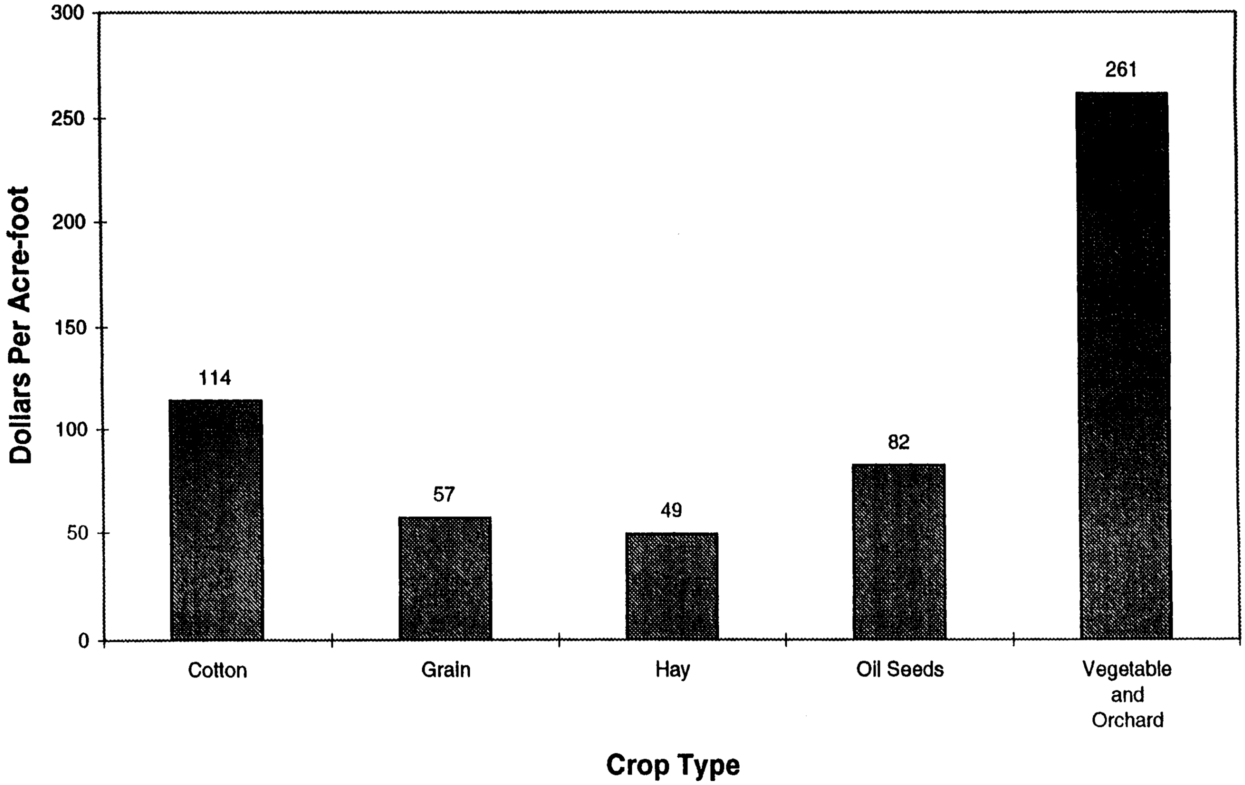
Table 4.10
Water Values for Thermoelectric Power by Region, ($/Acre-foot)

Resource Region	Average	Maximum	Minimum	Number of Values
Upper CO	55	63	40	3
unspecified	12	18	9	3

Table 4.11
Water Values for Industrial Processing, ($/Acre-foot)

Resource Region	Average	Maximum	Minimum	Number of Values
unspecified	282	802	28	7

Figure 4.8 Water Values for Categories of Crops, ($/Acre-foot)



$686 for tomatos, and $550 for carrots compared to $18 for hops, $33 for barley, and $36 for hay. For crop groups, the average value for vegetable and orchard crops is $261/af, more than five times the $49/af average for hay crops.

Domestic

Water for domestic purposes is one of the higher value uses. However, observations are available for only two regions and each of these regions has only two observations (Table 4.9). At $37/af domestic is the highest value use in the South Atlantic-Gulf region. In the Lower Colorado region, the average domestic value $97/af ranks second behind the recreation/fish & wildlife values.

Thermoelectric power

The value of water for thermoelectric power averages $55/af in the Upper Colorado region, the only region for which such estimates are available, and $12/af for three estimates with no identifiable location (Table 4.10).

Industrial processing

Industrial processing with an average estimated water value of $282/af has the highest estimated value of any of the water uses (Tables 3.4 and 4.11). The seven observations for industrial processing are not identified with a specific water resources region.

5. SUMMARY AND CONCLUSIONS

Economic and recreational opportunities and the overall quality of life depend in part on how increasingly scarce water supplies are allocated among competing uses. An economically efficient allocation requires that the marginal value of water is equal in all uses. But the absence of market institutions to reallocate supplies in response to changing conditions and the importance of goods and services provided by water that are not traded and priced in markets are sources of potential discrepancies in the marginal values of water in alternative uses.

This report presents nearly 500 water value estimates for four water withdrawal uses (domestic, irrigation, industrial processing, and thermoelectric power generation) and four instream uses (hydropower, recreation/fish & wildlife habitat, navigation, and waste disposal). Geographically, the data are organized into the 18 water resources regions that comprise the conterminous 48 states. Although a number of important caveats should be borne in mind in interpreting and applying the water value numbers, the systematic presentation of estimates of the economic value of water in alternative uses and locations provides important information for understanding the role of water in the economy and the potential benefits of institutions that would facilitate the allocation of supplies to higher value uses as supply and demand conditions change over time.

Tables and graphs are used to summarize and help interpret the nearly 500 water values presented in the appendices. There are wide variations in the estimated values of water for particular uses and locations. This variability reflects both differences in the estimating methodologies employed and variations in marginal water values over time resulting from changes in the availability of supplies and in the number and demands of users.

Nationally, withdrawal water uses, especially industrial processing and domestic, tend to have higher estimated values than instream uses. (See Figure 3.1). However, recreation/fish & wildlife habitat, and irrigation which together account for nearly 80 percent of all the estimates, have the highest individual estimated water values. Water values tend to be higher in the drier, more water-scarce areas of the country. (See Figure 3.3).