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SUMMARY:

THE ECONOMIC VALUE OF WATER

Prepared for the

Legislative Commission on Minnesota Resources

Department of Natural Resources

Division of Waters

September, 1987

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1985 - 1986

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SUMMARY: THE ECONOMIC VALUE OF WATER

BACKGROUND

The Water Allocation and Management project was funded by the Legislative Commission on Minnesota Resources for the 1985-1987 biennium. It was an ambitious project which combined two independent project proposals. The first was a cooperative effort between the Department of Natural Resources (DNR) and the University of Minnesota-Duluth's Natural Resources Research Institute (NRRI) to assess the value of Minnesota's water. This report, (Volume 1) prepared by the DNR, summarizes the results of that effort. The second project proposal involved assessment of the utility of existing models of elements of the hydrologic cycle (*e.g.* ground water flow or stream flow) and assessment of the nature of the data required by these models to determine if a geographic information system (GIS) could be useful to such modeling efforts. The second phase was conducted by the University of Minnesota's Water Resources Research Center (WRRC). Volume 2, prepared by WRRC, is an executive summary of their effort.

An economic model (IPASS) was modified by the NRRI and used for simulation of the interplay among market sectors in order to determine a value for our water for economic production. The amount of water available, the amount withdrawn for offstream uses, and the amount needed to satisfy instream flow needs were the key inputs to the water module of this model. Water availability was determined by the U.S. Geological Survey; quantification of water withdrawals and instream flow was done by the DNR. Statewide analyses were completed as well as analyses for five economic regions.

A survey of water-related recreation activities in Minnesota was conducted and combined with the results of the 1978 State Comprehensive Outdoor Recreation Plan (SCORP) survey to evaluate the economic impacts and non-market benefits of water-related recreation in Minnesota. The Continuous Survey of Participation and Expenditures in Outdoor Recreation by Minnesota Residents (DNR Continuous Survey) was conducted in 1985 and 1986 by the Minnesota Center for Survey Research (MCSR) in association with the Center for Urban and Regional Affairs (CURA). Analyses of survey results using the contingent valuation and travel cost methods were conducted by the NRRI and the DNR Office of Planning.

THE GOAL

What is the value of Minnesota's water? The goal of this project is to answer this deceptively simple question. The answer changes as a function of "to whom" the value accrues. Water is necessary to sustain human life. It also has value when used as an input to economic production: it cools, heats, cleans, mixes, transports, and/or is incorporated into virtually all manufactured products. Water also has value while it is still in lakes and rivers. It is used for recreation, fish and wildlife habitat, navigation, water quality enhancement, and hydroelectric power generation.

It is important to recognize that the *value* of water to society is not reflected in its *price*. Value is a function of willingness and ability to pay; price is a measure of relative scarcity. Water is abundant in Minnesota. As a public good, it is not bought or sold as are most commodities. Thus, other than the cost of pumping or the entrance fees charged at state parks, water is available free of charge in Minnesota. While its price may be zero, its value is not.

No inherent problems arise from the fact that water is free as long as the supply of water is adequate to meet all the demands placed upon it. It is when these demands are not met that water, in economic terms, becomes *scarce*. While water may not now be scarce in Minnesota, conditions could change if the current demand for water increases or the supply decreases. In either case, scarcity implies the need to *allocate* water resources among competing uses.

Two allocation schemes are commonly used. The first scheme establishes a market for water so that the resource can be bought and sold like most other commodities. The price can be set by the market or established by law. The second method regulates water use through a set of laws administered by a public agency. Water is allocated according to an established priority of use based on the type of use or the length of time the user has been withdrawing water.

In recent years, there has been growing evidence that despite its apparent abundance, Minnesota is vulnerable to water scarcity. Hints of potential scarcity have come from a variety of sources. The drought of 1976-1977 reminded us that the State is susceptible to natural fluctuations in water supplies. Numerous examples of contaminated ground and surface water supplies have shown that human activities can also affect availability. Although infrequent, situations have occurred where the amount of water available from specific ground and surface water sources was not able to meet the needs placed upon them. Beyond Minnesota, increased instances of water shortage in many Western states have fanned speculation that we may be forced to pump our "surplus" water to meet the needs of others. Should water scarcity become a reality to Minnesota, there is a concern that our current allocation policies are inadequate to properly address the problems which would occur and would result in solutions which are inequitable or inefficient.

An outcome of these concerns was the understanding that a comprehensive evaluation of Minnesota's water allocation policy, water resources, and water uses was needed. Of primary significance was the recognition that the current water laws do not take into consideration the economic impacts of any allocation. This flaw, if it is one, is an inherent problem associated with an allocation based on law rather than a competitive market. If water were bought and sold in a public or private market economy, its price would automatically allow it to achieve an economically efficient allocation. *However, even if Minnesota retains its regulatory allocation policy, it is still possible to allocate water efficiently if the value of water for each competing use is known.* The value attached to the use of water can be used as one criterion in establishing the priorities of use employed in any allocation scheme.

In this study, economic efficiency was defined as the maximization of one of three economic objectives: gross output, earnings, or employment. It should not be inferred, however, that the project staff thus recommend that any water allocation policy have economic efficiency as its primary objective. In fact, it is likely that the DNR would recommend other objectives in its allocation policy which recognize instream uses of water and the use of water to sustain human life. Regardless of the objective chosen, though, the advantage of this analysis is that it is able to determine the loss in economic benefits which would occur by choosing an allocation which does not achieve an (economically) optimal solution. This ability to know the economic impacts of any allocation of water should then lead to better water use management.

The primary goal of this project, therefore, was to determine the value of water for economic production and for recreation, so that this knowledge could be used to determine whether current allocation schemes achieve an economically efficient result. The second goal was to be able to evaluate the potential economic impacts of any water shortage before it occurs, so that steps can be taken to minimize these impacts.

More specifically, this project sought to answer the following questions:

1. Is water a scarce resource in Minnesota?

2. Does the current allocation of water result in economic efficiency?

3. If not, what would be the most efficient allocation of water?

4. Is water scarcity a realistic threat to Minnesota?

5. What are the possible economic impacts of a constraint on water supplies?

6. What is the value placed on water for use in economic production?

7. What is the value of water used for recreation?

THE INPUTS

The economic analysis conducted by this study used a computer simulation model, the Interactive Policy Analysis Simulation System (IPASS), developed by the Agricultural Economics Department of the University of Minnesota and modified and updated by the Natural Resources Research Institute at the University of Minnesota - Duluth.

Before this analysis was possible, however, it was necessary to conduct the most comprehensive analysis of the supply and demand for water in Minnesota ever attempted. Water availability was analyzed by the U.S. Geological Survey, and both instream and withdrawal uses were evaluated by the DNR.

WATER AVAILABILITY

Water availability was analyzed statewide and regionally to determine the amount and availability of surface runoff. The regional perspective was based upon five economic regions for the economic model; data were also developed for hydrologic regions.

For the purpose of this study, *dry, normal* and *wet* years were defined as follows:

"*normal*" is the median of the mean annual daily flow
"*dry*" is the seventy-fifth percentile of the mean annual daily flow
"*wet*" is the twenty-fifth percentile of the mean annual daily flow

The flow statistics were calculated from the flow records of 101 continuous record discharge measurement stations with at least 10 years of record. Data sets were regionalized because gage data were not always of sufficient duration or proper location to allow specific analysis for each watershed or economic region.

The method of generalizing the flow characteristics uses contouring or isolines (lines of equal runoff) for the dry, normal and wet conditions (Figures 1 - 3). The surface water runoff volumes for the State under dry, normal and wet conditions are 14.6, 22.3 and 31.4 million acre-feet. The volume increases from west to east. The wettest area is Northeast Minnesota in each scenario. A wet year in the State is typical of the runoff for 1982, while 1976 conditions are generally comparable to a dry year.

WATER USE

Water use data were compiled for the seventy-five economic sectors and for households for each of the 39 principal watersheds, five economic regions and the State as a whole. The data sources were reported use from DNR water appropriation permit holders and DNR estimates of unreported use. Utilization of withdrawal data rather than consumptive use data was a conservative approach which increased the likelihood that potential water conflicts would be identified in the IPASS analysis.

Domestic water use was treated as a final demand for the IPASS simulation model. This procedure assigns domestic use a higher priority than all other uses by requiring that domestic water needs be satisfied first before any water is allocated to economic production.

Over three million acre-feet of water were withdrawn for use in Minnesota in 1985. Nearly one-half of this water was used by electric utilities for cooling. Other large industrial water users were iron ore mining, the pulp and paper industry, and fabricated steel manufacturing (see Table 1).

Table 1: Minnesota water withdrawals by type - 1985 (acre-feet).

	Ground Water	Surface Water	Total
Thermoelectric	36,068.6	1,555,666.5	1,591,735.1
Industrial/ Commercial	429,116.4	670,292.9	1,099,409.3
Irrigation	110,332.3	44,474.9	154,807.2
Livestock	59,794.2	10,551.9	70,346.1
Residential	302,858.8	134,741.0	437,599.8
Total	938,170.3	2,415,727.2	3,353,897.5

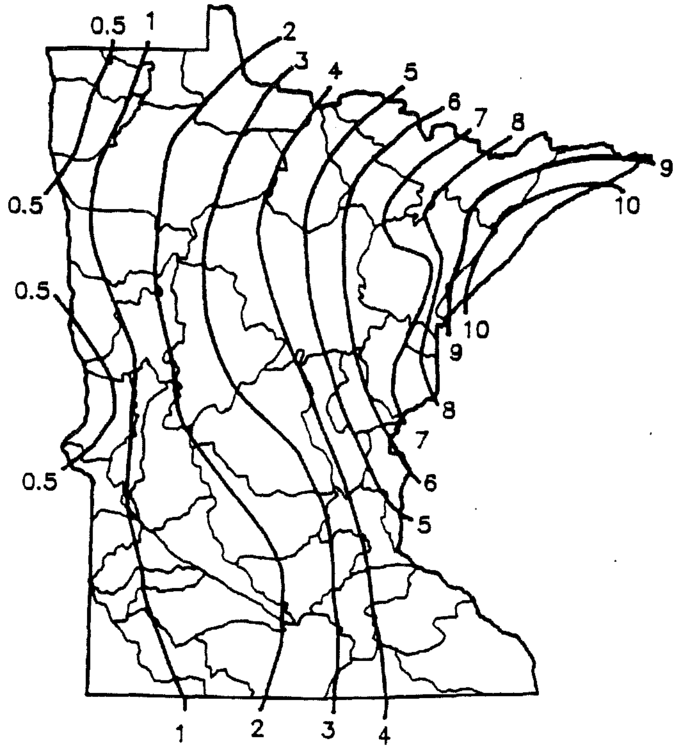


Figure 1: **Estimated Surface Runoff (in inches) for "DRY" Hydrologic Year.**

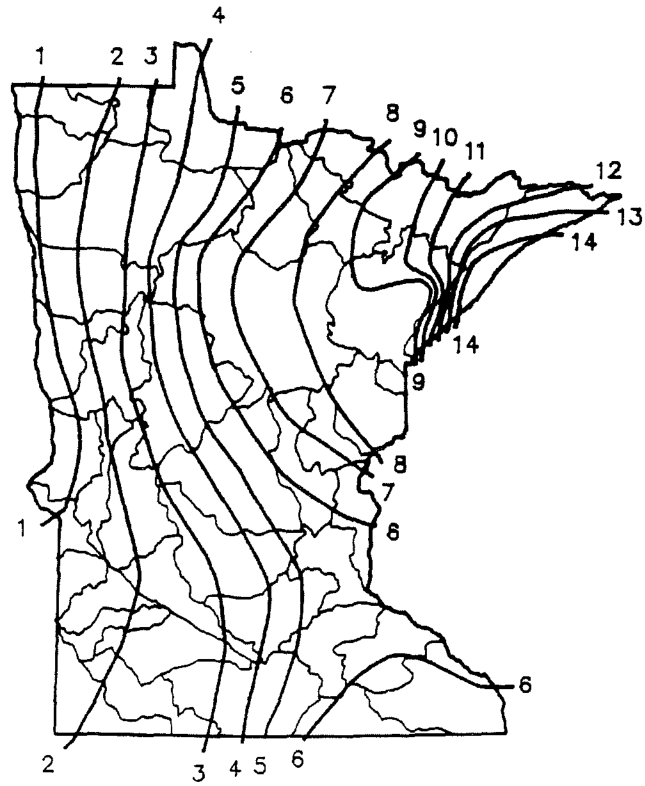


Figure 2:
Estimated Surface Runoff (in inches) for "NORMAL" Hydrologic Year.

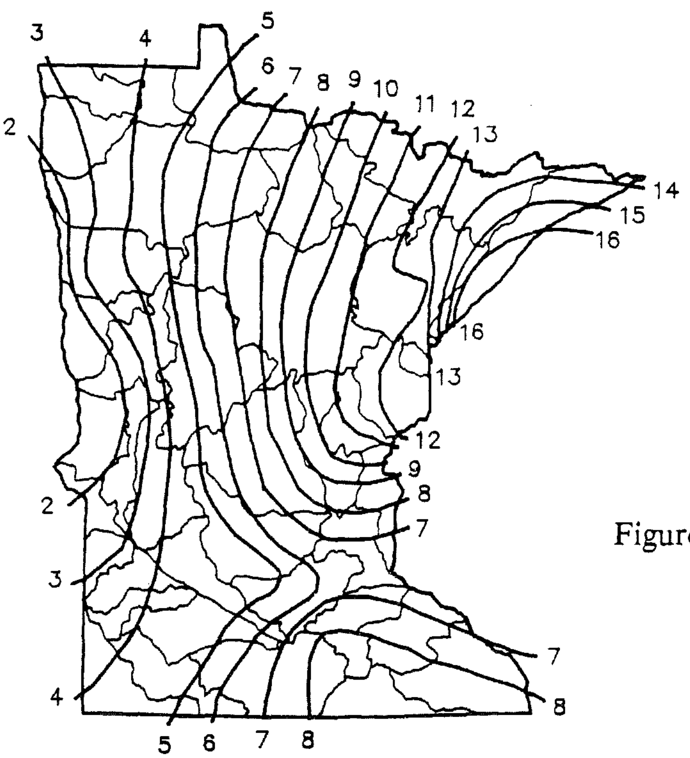


Figure 3: Estimated Surface Runoff (in inches) for "WET" Hydrologic Year.

On a regional basis (see Table 2), the Metro region used more water than any other region in 1985. Uses of water in the Metro region are varied. Electric utilities, pulp and paper mills, sand and gravel washing operations, a wide variety of manufacturing sectors, and private households used large volumes of water. In the Southeast, Central and West regions, water use was dominated by agriculture, electric utility, and residential uses. The West and Central regions include the major irrigation areas of the State. The Southeast had less irrigation but used a substantial amount for livestock production and food processing. Virtually all residential and agricultural users used ground water in these regions while electric utilities used mostly surface water. The Northeast region required large amounts of water to develop its natural resources, particularly iron ore and forest products. The Northeast was the only region which used more surface water than ground water for irrigation, primarily because of wild rice production which depends entirely on surface water.

Table 2: Minnesota water withdrawals by region - 1985 (acre-feet).

Region	Ground Water	Surface Water	Total
West	125,783.2	78,400.3	204,183.5
Northeast	115,691.4	631,054.1	746,745.5
Central	114,929.3	423,118.2	538,047.5
Metro	403,065.3	758,767.9	1,161,833.2
Southeast	178,701.3	524,386.6	703,087.9
Total	938,170.5	2,415,727.1	3,353,897.6

INSTREAM FLOW

Instream uses include fish and wildlife habitat, recreation, navigation, hydropower, waste water assimilation, aesthetics and conveyance to downstream users. The protection of these uses, under the assumption that the value of water accrues from being left in the stream rather than from being withdrawn, has been formally mandated by statute since 1977. Instream flow approximations were developed for the *dry* and *normal* years for the 39 watersheds, five economic regions and statewide (Table 3). They were developed using field measurements, knowledge of existing and potential instream uses, and hydrologic records. The instream flow approximations for wet conditions are assumed to be the same as for normal conditions.

Table 3: Instream flow approximations for five economic regions and the state (acre-feet).

	Normal Hydrologic Condition		Dry Hydrologic Condition	
	IFA (million acre-feet)	IFA (% of available water)	IFA (million acre-feet)	IFA (% of available water)
West	2.49	92	1.53	97
Northeast	11.48	90	8.30	90
Central	2.00	77	1.45	77
Metro	0.59	67	0.31	48
Southeast	2.41	72	1.72	74
State	18.97	85	13.31	86

Table 4: Priority areas for instream flow studies.

	Watershed	Issues
Priority 1:	St. Louis	hydropower relicensing, reservoir operations, mining, recreation
	Otter Tail	hydropower licensing, reservoir operations, existing conflicts, local water planning, recreation, fisheries
	Root	local water planning, hydropower, fisheries, recreation
	Cannon	hydropower, local water planning, recreation, fisheries
	Upper Minnesota	reservoir operations, water quality, local water planning, hydropower licensing, recreation, wildlife, fisheries
	Mississippi-Sauk	existing conflicts, reservoir operations, hydropower, local water planning, fisheries
	Mississippi Headwaters	reservoir operations, hydropower, local water planning, fisheries, recreation
Priority 2:		
	Crow Wing	existing conflicts, ground-surface water interactions, fisheries, recreation
	Red Lake	existing conflicts, proposed diversion, local water planning
	Blue Earth	hydropower operations, local water planning, recreation, fisheries
	Zumbro	hydropower, reservoirs, local water planning, recreation, fisheries
	Crow	local water planning, water quality, recreation
	Des Moines	local water planning, conflict potential, recreation
	Buffalo	existing conflicts, re-evaluate protected flow
Priority 3:		
	Wild Rice	proposed flood control, local water planning
	Cottonwood	water quality, local water planning, fisheries
	Lake Superior	hydropower, mining, fisheries, recreation
	Roseau	conflict potential, flood control, local water planning, wildlife

The instream flow component also provides a conservative, statewide scoping mechanism for developing management priorities for further study. DNR resource managers were surveyed to help identify areas of conflict. The results suggest that the resource potential for most river-based recreational activities is under-utilized. Improvements in the management of the State's rivers by controlling or eliminating such man-induced limiting factors as erosion, flow-fluctuations from dam operation and non-point source pollution would improve the potential for instream uses. Table 4 lists the watersheds of the State that have been identified by the DNR as tentative priorities for site-specific instream flow studies, based on potential for conflict, number of issues occurring, and recreation and fisheries potentials.

IDENTIFICATION OF POTENTIAL CONFLICT AREAS

In addition to the evaluation of potential economic impacts of water scarcity in Minnesota, the collection of water supply and demand data for this project provided the opportunity to conduct an empirical evaluation of potential water conflicts at the state, regional, and watershed levels. In simple terms, the total amount of water available was compared to the water requirements for instream and offstream uses. A determination that available supplies were less than the sum of these demands is an indication that there is a potential for water scarcity in the area studied. Implicit in this analysis is the assumption that the benefits accrued from providing water for instream flow uses are equal to the opportunity costs (benefits foregone) of diverting water for offstream uses.

This analysis was conducted using simple ratios ("water balance ratios") of total supply divided by total demand for water in each geographic area. Two ratios were evaluated for each area: one under normal hydrologic conditions and the second under dry conditions (75% exceedance levels). The geographic region is defined as having a positive water balance (+) if the water balance ratio is greater than or equal to 1.10. A neutral water balance (0) is defined as a ratio between 0.95 and 1.10. A ratio less than or equal to 0.95 is defined as a negative water balance (-). Water balance ratios for the five economic regions and the State are shown in Table 5 and for the 39 principal watersheds in Figure 4.

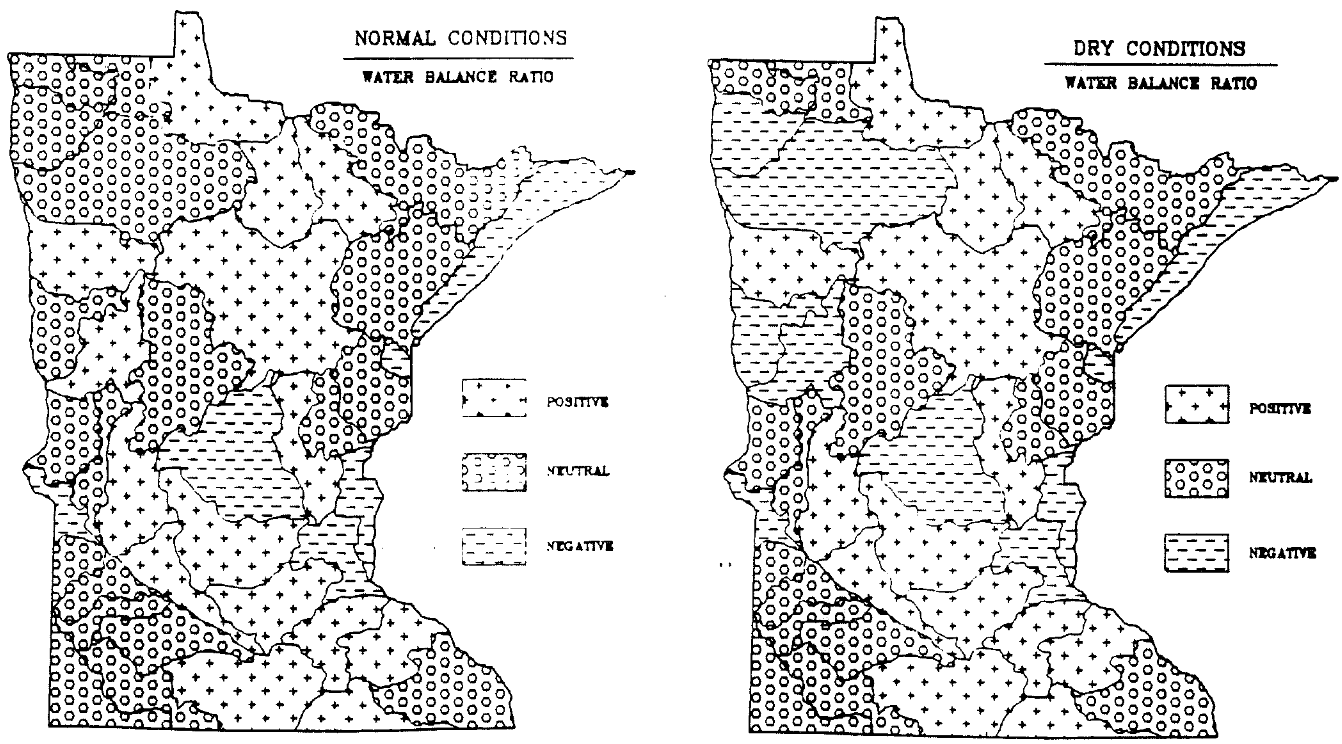
Instream requirements account for 85% of available supplies under normal conditions and 86% under dry conditions. Water withdrawals are only 11 percent of the water available under normal and 16 percent under dry hydrologic conditions. At the state level, there is no indication of conflict in a "normal" year. Given that water supplies and demands are not evenly distributed across the State and that supplies are highly variable, potential conflicts over water are possible at the regional and watershed levels, particularly in the western third of the State. Since this analysis does not take the quality of water supplies into account, total water available may be less that the amounts indicated. Nevertheless, the water balance ratios are a useful tool in identifying potential areas of water scarcity in the State.

Table 5. Water supply and demand and water balance ratios for five economic regions and the state.

Economic Region	Hydrologic Condition	Water Availability acre-feet (millions)	Instream Flow acre-feet (millions)	Water Use acre-feet (millions)	Water Balance
West	Normal	2.72	2.49	0.078	0
	Dry	1.57	1.53	0.078	0
Northeast	Normal	12.77	11.48	0.631	0
	Dry	9.17	8.30	0.631	0
Central*	Normal	2.59	2.00	0.423	+
	Dry	1.88	1.45	0.423	0
Metro *	Normal	0.86	0.59	0.759	-
	Dry	0.64	0.31	0.759	-
Southeast*	Normal	3.34	2.41	0.524	+
	Dry	2.31	1.72	0.524	0
Statewide	Normal	22.28	18.97	2.41	+
	Dry	15.51	13.31	2.41	0

* Water Availability does not include inflow from upstream watersheds

Figure 4: Water balance ratios for Minnesota's 39 principal watersheds.



VALUE OF WATER TO ECONOMIC PRODUCTION

Two analytical tools were used in the analysis of the value of water for economic production in Minnesota. The first, the Interactive Policy Analysis Simulation System (IPASS), is a dynamic input-output (I/O) simulation model. IPASS was used to develop alternative water allocation schemes and to evaluate the economic impacts of a constraint placed on available water supplies. The second is linear programming (LP), which estimates a value for water relative to some chosen objective function and subject to the constraints with respect to production technologies and resource availability.

IPASS was used to determine an allocation ranking for the seventy-five sectors in the state economy. This ranking is interpreted as follows: If there is not enough water to satisfy the production requirements of the state's levels of final demand and if the maximization of (say) earnings is the state's objective, then any additional water that might be found should be allocated first to that industry exhibiting the largest direct and indirect earnings effect per direct and indirect intake of one acre-foot of water. Once that sectors' final demand is satisfied (again, directly and indirectly), the next unit of new water should go to the industry exhibiting the next largest ratio, and so on.

To continue such an allocation across all industries would be to maximize the possible earnings out of a given supply of water. No other allocation would increase earnings, and in this sense the resulting water allocation would be deemed to be efficient.

Table 6 shows the ratio values relative to ground water along with industry rankings under three objectives: maximizing output, employment, and earnings. The relative rankings are the most important aspects to note out of those tables. For example, if the State objective is to maximize production in the form of gross output, the gas utility sector would be given the first new unit of ground water when ground water is short relative to demand. This same sector would continue to receive water until its own output and that of its direct and indirect suppliers increased to the point of satisfying final demand. However, if the objective is to maximize employment, the gas utility sector would be the thirty-third industry to start to receive new ground water. This same industry would be the forty-fifth industry if maximizing earnings were the objective.

The same computations were made with respect to surface waters. The results of these computations along with relative industry rankings appear in Table 7. Once again, the gas utility industry ranks number one with respect to the output objective. However, it can be seen that the different pattern of water use relative to output results in different rankings among the industries.

One industry that ranks fairly high for both ground and surface water is business services. While business services is not itself a major user of water, its interaction with other industries in the State in terms of output, employment, and earnings makes water which is supplied to this sector attain a higher value than for many competing industries.

Table 6: Economic sector ranking: ground water.

SECTOR	NAME	OUTPUT	EMPLOY-MENT	EARNINGS	AVERAGE RANKING
55	TRUCK TRANSIT	3	1	1	1.7
67	BUSINESS SERV.	5	2	7	4.7
64	FINANCE/INSUR.	9	4	2	5.0
58	COMMUNICATIONS	7	8	3	6.0
45	COM/OFFICE MACH	8	12	4	8.0
53	RAILROAD TRANS	4	7	16	9.0
62	WHOLESALE TRADE	11	15	8	11.3
24	APPAREL/FABRICS	10	14	15	13.0
72	EDUC/NON-PROFIT	20	3	17	13.3
54	LOCAL TRANSIT	14	5	23	14.0
15	ORDNANCE & REL	22	18	6	15.3
56	AIR TRANSPORT.	13	23	11	15.7
51	OPT.OPHTH.PHOT.	16	26	9	17.0
50	PROF/SCIENTIFIC	38	10	5	17.7
69	AUTO REPAIRS	12	19	22	17.7
71	HEALTH SERVICES	28	13	12	17.7
25	LOGGING	6	21	28	18.3
63	RETAIL TRADE	37	6	13	18.7
26	SAWMILLS	23	20	14	19.0
65	REAL ESTATE	2	24	31	19.0
43	MACHINE SHOPS	26	25	10	20.3
68	EAT/DRINK ESTBL	24	16	36	25.3
44	NONELECT. MACH.	30	30	18	26.0
60	GAS UTILITIES	1	33	45	26.3
52	MISC.MANUFACTUR	19	32	30	27.0
70	FILM/RECREATION	48	9	25	27.3
13	NEW CONSTRUCTN	15	34	34	27.7
27	WOOD PRODUCTS	36	28	20	28.0
14	MAINT. & REPAIR	18	35	32	28.3
28	FURNITURE	34	27	24	28.3
46	SERV. IND. MACH	21	40	27	29.3
42	FARM MACHINERY	40	31	19	30.0
47	ELECTRIC MACH.	31	36	26	31.0
35	LEATHER PRODUCT	43	22	29	31.3
23	TEXTILE GOODS	35	39	21	31.7
18	CANNED & FROZEN	29	29	44	34.0
4	OTHER CROPS	33	11	59	34.3
66	HOTELS/SERVICES	50	17	39	35.3
48	MOTOR VEHICLES	25	48	38	37.0
49	OTHER TRANSPORT	32	44	35	37.0
57	OTHER TRANSIT	27	43	41	37.0
5	FOR./FISH PROD.	51	37	33	40.3
20	BAKERY PRODUCTS	39	42	40	40.3
31	PRINT & PUBLISH	44	41	37	40.7
32	CHEMICAL/ALLIED	41	49	42	44.0
33	PETROL REFINING	17	63	57	45.7
21	BEVERAGES	46	50	46	47.3
34	RUBBER PRODUCTS	49	51	43	47.7
17	DAIRY PRODUCTS	45	47	54	48.7
16	MEAT PRODUCTS	42	52	55	49.7
22	OTHER FOOD/TOB.	47	45	58	50.0
36	CLAY/STONE/GLAS	56	53	49	52.7
1	DAIRY & POULTRY	53	46	60	53.0
19	GRAIN MILLING	54	55	51	53.3
30	PAPERBOARD CONT	52	59	50	53.7
6	AG/FOR/FISH SER	65	38	62	55.0
40	OTHER METALS	57	62	47	55.3
41	FABRIC. METALS	58	60	48	55.3
61	WATER & SANIT.	60	58	53	57.0
73	ALL GOVERNMENT	59	57	56	57.3
2	MEAT & ANIMAL	55	56	63	58.0
38	IRON/STEEL FOUN	61	61	52	58.0
39	PRIMARY COPPER	64	54	61	59.7
29	PULP & PAPER	62	65	64	63.7
3	FOOD/FEED GRAIN	63	64	65	64.0
8	NONFERROUS MINE	66	66	66	66.0
7	IRON ORE MINING	67	67	67	67.0
11	STONE & CLAY	69	68	68	68.3
37	PRIM STEEL PROD	68	69	69	68.7
59	ELECTRIC UTIL.	70	70	70	70.0
9	COAL & PEAT	NOT APPLICABLE			
10	OIL & NAT. GAS	NOT APPLICABLE			
12	OTHER MINING	NOT APPLICABLE			
74	SCRAP	NOT APPLICABLE			

Table 7: Economic sector ranking: surface water.

SECTOR	NAME	OUTPUT	EMPLOY-MENT	EARNINGS	AVERAGE RANKING
67	BUSINESS SERV.	5	1	1	2.3
62	WHOLESALE TRADE	11	3	3	5.7
55	TRUCK TRANSIT	3	8	8	6.3
13	NEW CONSTRUCTN	15	5	5	8.3
58	COMMUNICATIONS	7	13	7	9.0
25	LOGGING	6	6	16	9.3
45	COM/OFFICE MACH	8	15	6	9.7
26	SAWMILLS	24	4	2	10.0
53	RAILROAD TRANS	4	10	19	11.0
24	APPAREL/FABRICS	10	12	12	11.3
54	LOCAL TRANSIT	14	2	22	12.7
69	AUTO REPAIRS	12	14	15	13.7
43	MACHINE SHOPS	26	16	4	15.3
63	RETAIL TRADE	17	11	18	15.3
15	ORDNANCE & REL	23	19	9	17.0
64	FINANCE/INSUR.	9	20	24	17.7
72	EDUC/NON-PROFIT	21	7	25	17.7
57	OTHER TRANSIT	28	17	17	20.7
52	MISC.MANUFACTUR	20	22	23	21.7
46	SERV. IND. MACH	22	25	20	22.3
68	EAT/DRINK ESTBL	25	9	33	22.3
44	NONELECT. MACH.	31	24	14	23.0
56	AIR TRANSPORT.	13	27	29	23.0
51	OPT.OPHTH.PHOT.	16	33	21	23.3
50	PROF/SCIENTIFIC	39	21	13	24.3
5	FOR./FISH PROD.	52	18	11	27.0
14	MAINT. & REPAIR	19	30	32	27.0
23	TEXTILE GOODS	36	40	10	28.7
65	REAL ESTATE	2	42	44	29.3
48	MOTOR VEHICLES	27	38	27	30.7
27	WOOD PRODUCTS	37	28	28	31.0
49	OTHER TRANSPORT	33	37	30	33.3
60	GAS UTILITIES	1	46	53	33.3
42	FARM MACHINERY	40	35	26	33.7
28	FURNITURE	35	32	35	34.0
31	PRINT & PUBLISH	45	26	31	34.0
20	BAKERY PRODUCTS	38	31	34	34.3
71	HEALTH SERVICES	29	41	40	36.7
47	ELECTRIC MACH.	32	43	38	37.7
70	FILM/RECREATION	49	23	41	37.7
73	ALL GOVERNMENT	59	29	36	41.3
30	PAPERBOARD CONT	53	39	37	43.0
18	CANNED & FROZEN	30	49	51	43.3
32	CHEMICAL/ALLIED	43	45	42	43.3
35	LEATHER PRODUCT	44	44	46	44.7
33	PETROL REFINING	18	61	57	45.3
66	HOTELS/SERVICES	51	36	52	46.3
4	OTHER CROPS	34	47	62	47.7
39	PRIMARY COPPER	64	34	50	49.3
34	RUBBER PRODUCTS	50	50	49	49.7
19	GRAIN MILLING	54	55	41	50.0
40	OTHER METALS	57	54	39	50.0
17	DAIRY PRODUCTS	42	56	54	50.7
41	FABRIC. METALS	58	51	43	50.7
38	IRON/STEEL FOUN	61	53	45	53.0
61	WATER & SANIT.	60	52	48	53.3
21	BEVERAGES	47	59	56	54.0
22	OTHER FOOD/TOB.	48	57	58	54.3
1	DAIRY & POULTRY	46	60	59	55.0
16	MEAT PRODUCTS	41	63	61	55.0
36	CLAY/STONE/GLAS	56	58	55	56.3
29	PULP & PAPER	62	48	60	56.7
2	MEAT & ANIMAL	55	65	65	61.7
6	AG/FOR/FISH SER	65	62	68	65.0
3	FOOD/FEED GRAIN	63	64	69	65.3
7	IRON ORE MINING	67	67	63	65.7
11	STONE & CLAY	69	66	64	66.3
8	NONFERROUS MINE	66	68	66	66.7
37	PRIM STEEL PROD	68	69	67	68.0
59	ELECTRIC UTIL.	70	70	70	70.0
9	COAL & PEAT	NOT APPLICABLE			
10	OIL & NAT. GAS	NOT APPLICABLE			
12	OTHER MINING	NOT APPLICABLE			
74	SCRAP	NOT APPLICABLE			

The electrical utilities industry, a very important industry in the State that also uses a great deal of water, ranks at the bottom when it comes to all three objectives and for both ground and surface water requirements. In other words, the business service industry generates more output, employment, and earnings for the water it and its direct and indirect suppliers utilize to satisfy final demand than does the electric utility industry, and thus water has a higher value for the business services sector.

POLICY IMPLICATIONS

The policy implications of these results are intriguing. Simply put, these results indicate that if the goal of society is to maximize output, employment, or earnings, then the water demands for the smallest users (in general) should be satisfied first before allocating water to larger users. Fortunately, the top twenty-five sectors in the surface water rankings account for less than one percent of all water used. Given Minnesota's extensive water supplies, it seems unlikely that the water demands of the smaller users would be sufficient to prevent larger users from receiving any supplies during a water shortage.

Careful examination of the rankings also shows that many of the sectors at the top of the list, such as business services, wholesale and retail trade, and some manufacturing industries generally purchase their water from public utilities. This would indicate that any allocation scheme should include this sector as a high priority use of water.

When considering these results, remember that it is possible - even likely - that the state of Minnesota may wish to choose a water allocation scheme which maximizes some objective other than output, employment, or earnings. This study acknowledges other objectives by allocating water for residential use and instream flow needs before providing any water for economic production. Other objectives may also be valid. Minnesota has traditionally placed a high priority on its agricultural sectors. This objective is reflected in the current water allocation scheme which was established by the state legislature and gives agriculture a priority over all other industrial water uses. The State may also decide that it wishes to promote tourism and should therefore provide more water to those sectors related to recreation. The primary contribution of the model comes from its ability to predict the loss of output, employment, and earnings that would result from any allocation scheme which did not maximize these objectives. Given this information, it is hoped that policy-makers will thus be able to make better decisions regarding our water resources.

LINEAR PROGRAMMING

The principal value of water which is drawn for this approach is the shadow price of water. The shadow price represents the increasing value of water as it becomes more scarce. As can be seen in Table 8, water is not constraining in the statewide analysis until the level of water availability falls to 3,500,000 acre-feet. Up to that point, the shadow price of water is equal to zero. At that level, water must be allocated in order to get the highest level of gross output possible. Water's contribution to meeting that objective makes its value equal to $2,070 per acre-foot. This value makes sense only in relation to the gross output maximizing objective. It represents water's contribution towards meeting that objective.

Table 8: Water related shadow prices under alternative supply levels with moderate (5%) economic growth

Water Supply (acre-feet)	Water Used (acre-feet)	Gross Output ($Million)	Shadow Price ($)
5,444,434	3,544,925	125,572	0.00
3,811,104	3,544,926	125,572	0.00
3,500,000	3,500,000	125,479	2,070
2,000,000	2,000,000	108,057	30,830
1,000,000	1,000,000	73,411	37,760
50,000	50,000	53,380	51,140
25,000	25,000	38,093	73,150
10,000	10,000	9,739	329,000

As water supplies continue to be reduced, the value of water in meeting the objective increases substantially. In fact, once water is reduced to 2,000,000 acre-feet, the value jumps to $30,830 per acre-foot. It continues to jump quite rapidly to a high (out of the levels chosen for this analysis) of $329,000 per acre-foot. Note that under conditions of scarcity, gross output also declines as the shadow price increases.

ECONOMIC IMPACT OF DECREASING SUPPLIES

A dynamic value not unlike the *shadow price* from the linear programming model can also be generated using IPASS. To accomplish this, the model user notes the total water use and regional income level in the unconstrained baseline run and the same variables for the constrained case (using the best allocation scheme possible). The difference in regional income between the two runs divided by the difference in water use provides an indication of the value (measured with respect to the regional income objective) of additional water supplies. By further constraining the water availability and again finding the best allocation possible, a full set of shadow prices can be derived.

Figure 5 shows the results of this analysis for surface water. The X axis shows the percent of water required for production which is made not available (diverted out of state, contaminated, etc). Zero percent on the X axis means that there is adequate water for economic production and thus no impact on output (the Y axis). As you move to the right, water is taken out of production, and gross output is decreased by the amount shown on the Y axis. When all of the water is gone (100%, or about two million acre-feet), output is reduced by about $18 billion.

The results of the analysis for ground water are shown in Figure 6. Note that while the total amount of water required for unconstrained production, about 500,000 acre-feet, is one fourth the volume required for surface water, the total impact on output is much larger. In fact, the maximum reduction in output per acre-foot of ground water is 12.8 times the maximum reduction in output per

Figure 5: Value of surface water

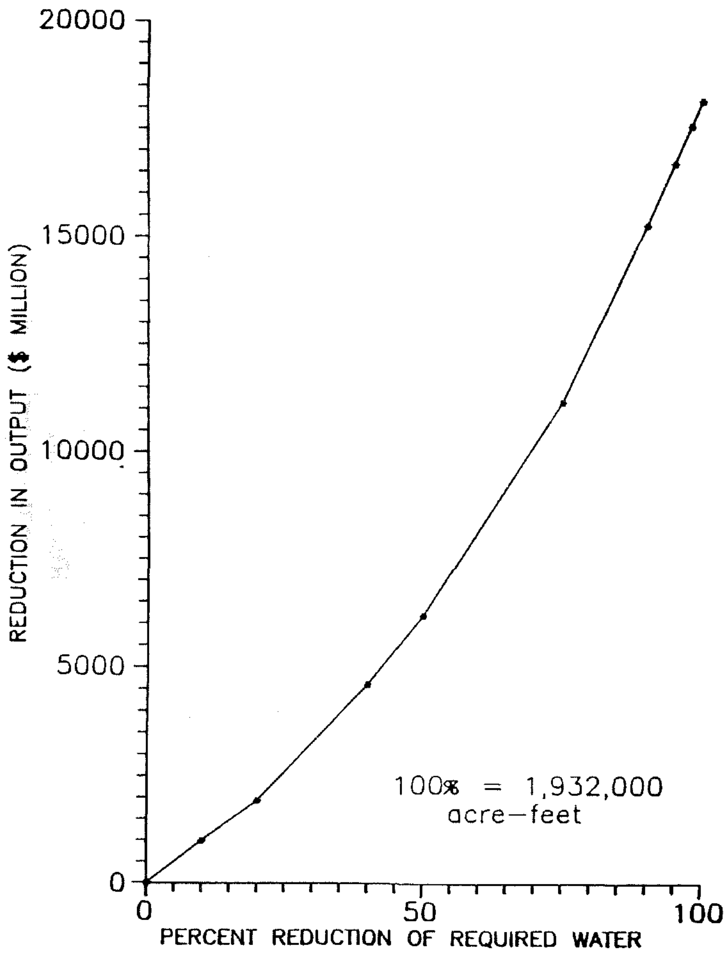
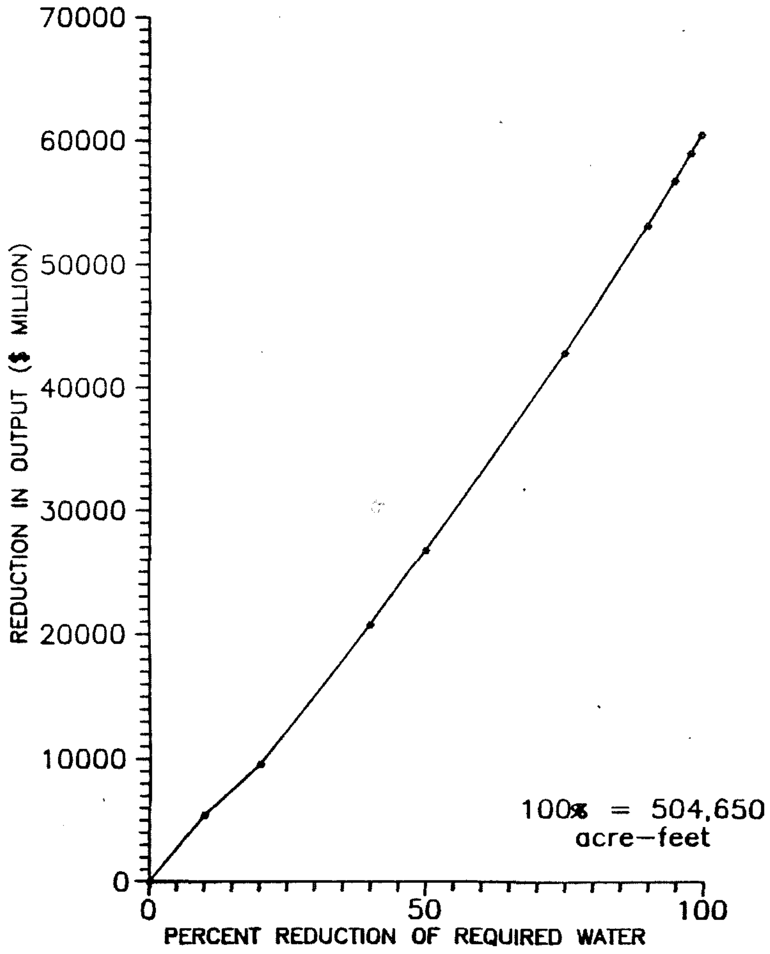


Figure 6: Value of ground water



acre-foot of surface water. In other words, each unit of ground water produces up to 12.8 times as much economic output as each unit of surface water.

These figures can be used to evaluate the impacts of a wide variety of constraints on water availability. From Figure 5, if ten percent of the demand for surface water is not met, due to drought, out-of-state diversion, or contaminated supplies, output would be reduced by about nine billion dollars. Similarly, from Figure 6, if forty percent of the demand for ground water is not met (approximately the amount of water required for the Twin Cities metropolitan area), output would be reduced by about thirty billion dollars.

A scenario was analyzed where the impacts of a moderately severe drought were identified. A fairly extensive drought can result in a loss of 150 jobs, a $5.7 million reduction in gross output, and a $3.1 million reduction in State exports.

ECONOMIC VALUE OF WATER FOR RECREATION

Perhaps one of the most difficult components to understand when estimating the value of Minnesota's water is the value of water for recreation. This is clearly a case where the perceived value of recreation is extremely high to society, much higher, in fact, than the actual dollar amount we spend on these activities. The difficulty in defining a recreation value for water arises from its status as a public or "free" good. Since no one "owns" the water, no direct payments are made for its use. For most privately-owned goods, value is defined by the price of the good in the marketplace. Payments made for the use of water--fishing licenses, state park stickers, boat launching fees - are negligible in relation to the value derived from the use of the resource.

The value of water for recreation is generally considered to be comprised of two distinct components. The market value of recreation is defined as the direct and indirect impacts of purchases made for goods and services used for water recreation. These impacts are a measure of the significance of recreational expenditures on the local, regional, or state economy. The non-market benefits of recreation are the intrinsic values placed on the recreational experience itself. Intrinsic benefits are accrued by users and non-users of the water resource, but only user benefits are analyzed in this study. Since non-user "option" benefits and existence (preservation) values were not measured, the economic value of water for recreation obtained in this analysis represents a <u>conservative</u> estimate of the total value to society. This fact should be recognized when making allocation and management decisions regarding Minnesota's water resources.

Both the market and non-market values were estimated using two surveys of recreational activities. The State Comprehensive Outdoor Recreation Plan (SCORP) survey of resident and non-resident tourists was conducted by the DNR in 1978. The Continuous Survey of Participation and Expenditures in Outdoor Recreation by Minnesota Residents (DNR Continuous Survey) was commissioned by the DNR to update and supplement SCORP, since the Water Allocation and Management Program required resident expenditure information not collected in the 1978 survey.

MARKET VALUE DIRECT BENEFITS

Nearly $1.2 billion, or $300 per Minnesota citizen, was spent annually by recreators in the pursuit of water-related activities. The amount spent for travel was 74% of the total; and, 36% was spent for equipment. Residents make up 59% of travel expenses, non-residents 40%. The bulk of travel expenses is accounted for by food, lodging and transportation (mainly gasoline). Non-residents allocate a much smaller share of the food dollar to groceries than residents, and a greater share to restaurants. Non-residents spend a larger share of their travel dollar on shopping and personal goods than residents. Resident equipment purchases are dominated by boats, trailers and boat accessories (77% of total equipment dollars). The next largest expense category is boat motors (6.9%).

Most of the water-related recreation activity time is spent, not surprisingly, on water-based activities. For all recreators, fishing is the largest activity. It is followed by swimming, boating and camping. Fishing is also the largest activity for both residents and non-residents. Non-residents spend a greater share of activity time on fishing, camping and canoeing than residents. Residents spend a greater share of activity time on remaining activities, especially swimming.

Residents account for 81% of statewide activity time, but they only account for 59% of travel expenses. The closer-to-home recreation trips of residents are less expensive, for the same amount of recreation, than the longer distance trips of non-residents.

The six economic sectors most affected by direct recreational expenditures are retail trade, petroleum refining, hotels, etc., other transportation manufacturing, eating and drinking establishments, and wholesale trade. Together these sectors account for almost 71% of the direct impacts of water-related outdoor recreation.

INDIRECT IMPACTS

The dollar value of all consumer expenditures does not represent the total impact of water-related recreation on the economy. In order to provide a good or service, a business must purchase goods and services which are inputs to its final products. These intermediate purchases also generate economic activity as the business suppliers require inputs to produce their goods and services, and those businesses must purchase inputs for their goods, . . . and so on throughout the economy. The combined effects of these inter-business purchases are the indirect impacts of consumer purchases for water-related recreation.

IPASS was used to analyze the direct and indirect impacts of water-related recreation. The total impacts represent 1.7% of the State's gross output, 1.5% of the State's value added and 1.9% of State's employment. Most of these impacts are concentrated in three major sectors: manufacturing wholesale, and retail trade, and services.

The economic impacts per acre of lakes with permanent fish populations, which are the State's prime water resource for outdoor recreation, are shown in Table 9.

Table 9: Direct and indirect impacts of recreation expenditures

	1982 Dollars per Acre*
Consumer purchases (direct impacts)	479
Direct and Indirect Impacts on:	
Total Gross Output	771
Total Value Added	334
Direct and Indirect Impacts on:	Jobs per Thousand Acres
Total Employment	16.5

*Acreage is 2,274,669: excludes acreage of Lake Superior, Upper and Lower Red Lake, and any portion of a lake outside of the State; includes acreage of river lakes and pools.

NON-MARKET VALUE OF RECREATION

Economists refer to the value placed on recreation over and above the costs of participation as "consumer surplus". The two methods used to determine consumer surplus are the travel cost method (TCM) and contingent valuation method (CVM). CVM provides a conservative value estimate on responses to hypothetical questions such as "what is the most additional amount of money you would be willing to pay if you were to take a specific recreational trip again?" TCM provides a more liberal value estimate based on willingness to travel (and incur the costs of travel) to experience the recreational opportunities at a specific site.

The following findings are the result of survey analysis using the contingent valuation method:

* The average dollar value of the benefits received from water-related recreation in excess of out-of-pocket expenditures (the consumer surplus) was $9.36 per recreation day for activities which involve an overnight stay.
* The average consumer surplus for water-related recreation for day trips and trips involving an overnight stay (combined) was $3.95 per recreation day.
* The total value of the consumer surplus for water-related recreation in Minnesota is $377 million.
* The average consumer surplus per acre of lake area in the State is $166.
* In Minnesota, consumer surplus values are approximately 44% of consumer expenditures per recreation day.
* The average consumer surplus for non-Minnesota residents is significantly larger than the surplus for Minnesotans, and the average consumer surplus for trips involving an overnight stay is significantly larger than that for day trips.
* The Northeast region accounts for almost sixty percent of the total value of the consumer surplus for water-related recreation in the State. Over one-half of all recreation trips involving an overnight stay occur in this region.

* Over one-half of all water-related recreation day trips in Minnesota occur in the Metro region.
* The average consumer surplus per recreation day is highest in Northeast region and lowest in the Metro region.
* The average consumer surplus per acre of lake area is highest in the Metro region ($922 per acre) - more than three times the average surplus per acre of any other region of the State.
* The values obtained for the average consumer surplus for water-related recreation using the travel-cost method are similar to those obtained using the contingent valuation method.
* No significant difference in consumer surplus was found among the various types of water-related recreation activities in Minnesota.

POLICY IMPLICATIONS

Although they are difficult to measure and therefore often ignored, the economic and non-economic benefits of water for recreation are significant. These benefits should be considered when making decisions regarding the allocation of water among competing uses.

Water provides more economic and non-economic recreational benefits to Northeast Minnesota than to any other region in the State. Policy options which protect or enhance the water resources in this region should be given high priority.

When considered in terms of the benefits provided per unit area, the lakes of the Twin Cities metropolitan region are significantly more important than are any other water bodies in the State. Great caution must be observed before allowing these water resources to be diverted to other uses.

The values obtained by this study to describe the benefits of water recreation are not directly comparable to those obtained to describe the impacts of water on economic production. Efforts should be made to enhance their comparability by evaluating the significance of the volume of water in lakes and streams on their value as sources of recreation.

Other benefits of water recreation, such as existence and option values, are important but were not evaluated here. These benefits should be analyzed, particularly with regard to the relative value of urban and non-urban water resources.

RECOMMENDATIONS

1. Re-evaluate the current water allocation framework.
While no water allocation policy can be expected to resolve all problems arising from a constraint on water supplies, Minnesota's combination of water laws under the riparian doctrine and established priorities of use have proven to be inadequate in addressing a wide variety of water constraints. Therefore, current statutes and rules should be re-evaluated and more appropriate guidelines and procedures should be established.

Any new allocation policy must:

a) *Include an objective*, clearly stated, which can be used as a guide in resolving conflicts for which explicit procedures have not been established and in providing justification for policies and procedures which are defined by statute or rule.

b) *Incorporate a degree of flexibility* sufficient to reflect the diversity in the availability and use of water in the state.

These two requirements are important enough to warrant further discussion.

One possible objective, economic efficiency, is discussed at length in this report. However, a water allocation policy guided solely on the concept of economic efficiency would inevitably conflict with other stated goals of the DNR as well as commonly accepted principles of equity. For instance, if economic efficiency, defined here as the maximization of gross output, employment, or earnings, were the primary objective of Minnesota's water allocation policy, one could not justify the dedication of 85% of all surface water supplies for instream flow uses. The value of these uses, as measured by the direct and indirect impacts of water related recreation, accounts for less than two percent of the state's output employment and earnings. Strict adherence to the principal of economic efficiency would also imply giving a low priority to the use of water for agricultural production. While such a policy could be justified at the state or even regional level, it ignores the great importance of the agricultural economy in many rural communities in the state. Finally, it is difficult to imagine where water for domestic use would fit into an economically efficient allocation plan, other than opening the possibility for higher prices for drinking water.

The incorporation of some flexibility in Minnesota's water allocation policy would expand the number of options available in addressing the diversity in the State's water supply and demand. For instance, significantly variations in water use among the State's economic regions could require different priorities of water use. Differences in the relative availabilities of surface and ground water among the regions could also demand different priorities of use. Greater flexibility could permit the possibility for designating individual ground or surface water sources to specific uses. A precedent for such a step was taken with the designation of certain streams in the state for trout production. Other possible options include the designation of pumpage from entire aquifers, such as the Mount Simon-Hinckley, to municipal utilities exclusively. This restriction would greatly reduce the possibility for overuse and contamination of this valuable aquifer. Similarly, surface water sources with little or no instream use potential could be allocated almost completely to withdrawal uses.

In many ways, the results of the Water Allocation and Management Program substantiates and reinforces the recommendations made by the Water Planning Board in 1979. In its report, *Toward Efficient Allocation and Management: A Strategy to Preserve and*

Protect Water and Related Land Resources, the Board suggested the following priorities of use in Minnesota:

1. Water for basic necessities (domestic use);
2. Water for environmental protection (primarily maintenance of instream flows and lake levels); and
3. Water for economic production.

While these categories of use are quite broad, they reflect many of the concerns raised in this report. Obviously, category three must be refined, possibly by incorporating many of the findings resulting from our rankings of economic sectors and an appreciation for regional differences in the supply and demand for water in the state.

The Water Planning Board also described several modifications of the riparian doctrine which would allow for the sale or leasing of "water rights" in Minnesota. At the time of their report, there was serious question as to the constitutionality of such a transfer of rights. Recent actions in the courts regarding similar transfers in some Western states imply that such sales are possible.

2. Improve data collection activities.
The availability of primary data is crucial to informed and effective planning and management of water resources. The current emphasis on local water planning serves to reinforce this need. The DNR should strive to improve its basic data collection activities in the following areas:

a. A minimal understanding of surface water supplies requires the establishment of a stream flow gage at the outlet of each of Minnesota's thirty-nine principal watersheds.

b. With the exception of several sand plain aquifers in central Minnesota and the Twin Cities metropolitan area, the yield potential of most ground water sources in the state have not been thoroughly explored. There is a need for detailed mapping of surficial and buried aquifers of the entire State of Minnesota.

c. An understanding of the instream flow requirements for a stream requires the collection and analysis of site-specific hydrologic, biological, and use data. The DNR should maintain its support for the collection of these data which is essential for the establishment of protected flows on streams with important instream uses. Funding provided by the LCMR for the continuation of this project is an important step toward this goal.

d. The methods used in the collection, storage, and analysis of water withdrawals in Minnesota are exemplary, as evidenced by the number of state and federal agencies which are using our procedures. The DNR should ensure that the momentum established over the last five years is not lost as the appropriation permitting responsibilities are decentralized to the six DNR regional offices. Instead, this recent shift should be used as an opportunity to improve the agency's enforcement of statutory requirements for water withdrawal.

3. Review the allocation of State resources.
The allocation of the state's financial resources should be reviewed to assure that the much higher value placed on ground water in comparison to surface water is reflected in management and regulatory activities. This recommendation is reinforced in light of the hydrologic, social, and economic impacts of reduces supplies due to contamination or depletion of available supplies.

4. Expand drought contingency planning.
The concept of drought contingency planning should be expanded in order to incorporate plans for responding to water supply contamination and increased water demand caused by economic growth.

5. Require efficient use of water.
While water is relatively plentiful in the state, supplies are not infinite and water shortages have occurred. Before seeking new or additional water supplies, water users should be encouraged to investigate water efficient technologies, conservation, and substitution of other resources of water.

6. Explore further use of the economic model.
The analytical capabilities of the computer models developed for this project have yet to be fully exploited. Since these models have shown promise for useful results, the DNR Division of Waters should allocate staff and funds so that improvements can be made to the model and many more analyses carried out.

7. Recognize the economic benefits of recreation.
Although they are difficult to measure and therefore often ignored, the economic and non-economic benefits of water for recreation are significant. These benefits should be considered when making decisions regarding the allocation of water among competing uses.