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THE ECONOMIC IMPACTS OF WATER SHORTAGE
AND WATER ALLOCATION POLICIES

Prepared for the:

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(1A) Minnesota Water Planning Board

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PREFACE

The following paper has been prepared as a detailed background report for use in development of the Framework Water and Related Land Resources Plan. The Plan is being prepared under the direction of the Minnesota Water Planning Board. Funds for the project and the project Work Plan were approved by the Legislative Commission on Minnesota Resources.

The Framework Water and Related Land Resources Plan project is an interagency activity, directed by the Board. Reports in the "Technical Paper" services are prepared for interagency work groups by staff persons in one or more agencies. The final "Technical Paper" is a joint project and does not necessarily reflect the views of the agencies represented by the individual preparers.

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The paper has been reviewed by and benefited from comments of the Supply, Allocation, and Use Work Group of the planning project; the Water Planning Board Technical Committee; the Regional Development Commissions throughout the state; the Water Interests Advisory Committee; and other interested groups and persons. In such reviews and resultant changes, the positions of the individual and/or of their agencies may have been altered.

This paper was approved by the Minnesota Water Planning Board on _____.

Thomas Kalitowski, Chairman
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Table of Contents

Summary

I. Background and Overview	i
II. Objectives	ii
III. Methodology	iii
IV. Summary and Conclusions	iii
V. Recommendations	xvi

Main Report

Introduction	1
A. Preliminary Definitions	1
B. Specific Water-Shortage Problems in the State of Minnesota	3
C. Economic Impacts	4
D. Organization of Report	5
Part I. Problems of Water Shortage in Minnesota	6
A. Surface Water Problems	6
B. Ground Water Problems	12
Part II. The Economics of Water Shortage -- Withdrawal Uses	16
A. A Generalized Model of Industrial Water Use	16
B. Heavy Water-Using Industrial Sectors In the State of Minnesota	18
C. Overview: Channels of Economic Impacts	20
D. Economic Impacts in Specific Industrial Sectors	36

1. Agriculture	36
2. Food Processing	45
3. Pulp and Paper Manufacturing	49
4. Iron Mining	58
5. Electric Power Generation	61
Part III. The Economics of Water Shortages -- Non-Withdrawal Uses	72
A. Commercial Navigation	72
B. Hydroelectric Power	74
C. Recreation	75
Part IV. Conclusions and the Role of the Public Sector	90
A. Conclusions from Previous Sections	90
B. Role of the Public Sector	91

SUMMARY

I. Background and Overview

The Minnesota Water Planning Board has adopted the following goal as an objective for the Framework Water and Related Land Resources Plan:

To outline alternatives to maximize the benefits of available water supplies at the present and in the future through (1) development of an assessment of the present and future water supplies and needs of the state; (2) the preparation of a system for equitably allocating the scarce resource in situations where quantities appear in danger of becoming inadequate to meet all state needs; (3) identification of means to efficiently utilize water resources; (4) cognizance of instream water uses and their relationships to water resources planning; (5) the development of management recommendations consistent with the options identified; (6) identification of mechanism by which policies and decisions can be integrated so that agencies do not work at cross purposes; (7) the completion of special analysis and projects essential to the planning effort; and (8) the submission of recommendations and proposals to the Legislature.

Parts (2) and (3), and (7) of this goal provide the impetus for this report. In order to "equitably allocate" a limited resource or "efficiently utilize" water resources, it is necessary to seek answers to the following questions:

- (1) How can problems of water scarcity of "water shortages" manifest themselves in concrete problems faced by water resource users?
- (2) How might these water users react to such problems in terms of their economic decisions?
- (3) How do the reactions of these users affect measures of economic well-being such as employment and earnings in their surrounding region and throughout the state?

- (4) How will public policy alternatives designed to allocate water during water shortages affect the economic decisions of water users and what are the wider economic ramifications of these decisions?

II. Objectives

The basic objectives of the research reported here is to seek answers to the four questions listed above in so far as they relate to the economic decisions of firms in heavy-water-using industrial sectors of the Minnesota economy. The heavy-water-using industries considered are as follows:

- (1) Agriculture,
- (2) Food Processing,
- (3) Pulp and Paper Manufacturing,
- (4) Taconite Mining, and
- (5) Electric power production.

Together, these industrial sectors account for roughly 82.6 percent of the water withdrawn and 92.2 percent of the water consumed among all users of water in Minnesota.

In addition, this paper will be concerned with the economic impacts of water shortages and of policies designed to cope with water shortages through the following activities which are heavily dependent upon water, but which do not remove water from its source.

These non-withdrawing uses are:

- (6) Commercial navigation,
- (7) Hydro-electric power production, and
- (8) Water-related outdoor recreation.

Although the specific industries considered in this report do not include all economic activities dependent upon water, the basic conclusions derived should be applicable to industries not covered. This is all the more likely to be true because the results reported here for the most part are non-quantitative in nature. The reason these results are largely non-quantitative is best described by the following quotation:

"...to a large extent industrial water utilization problems are unique to each particular plant and to each plant site. Only gross generalizations are possible. Each situation involving plant site, production site, production process, product mix, and the water environment tends to be unique. At least this is the expressed viewpoint of many people in industry. Although this point of view is probably valid with respect to specific data it is not valid with respect to generalizations about the nature and direction of responses of industrial water users to various factors." 1/

The basic objective of the research reported in this paper therefore, is to seek to identify "the nature and nature of (these) responses" to problems of water shortage and to public policies designed to deal with water shortages.

III. Methodology

The methodology followed in preparing this report was simply to draw upon available published sources and information obtained from experts in the field of hydrology, water quality, and regional economic analysis. This report is largely a synthesis of available literature concerning hydrological and water quality problems in the State of Minnesota, regional economic analysis, and micro-economic theory.

IV. Summary and Conclusions

A. Specific Water-Shortage Problems

Specific problems of water shortage which have occurred or potentially could occur in the state of Minnesota are identified in this study to be the following:

- (1) Low flow in rivers and streams resulting in:
 - (a) Higher concentrations of pollutants and of suspended and dissolved substances of natural origin in the water thereby increasing the costs of treating water for withdrawal purposes, interfering with recreational use of the water, and spoiling wildlife habitat;
 - (b) Increased competition for available water among water withdrawers and non-withdrawal users;
 - (c) Threats to wildlife habitat due to insufficient river or stream flows;
 - (d) Possible limitations on the navigational use of rivers;
 - (e) Conflicts between users of river and stream water and recreational and other uses on reservoir lakes;

- (f) Increased costs of building waste treatment facilities in order to meet more stringent effluent standards; and
 - (g) Reduced recharge to ground water supplies thereby affecting ground water uses.
- (2) Lower lake levels resulting in the depreciated value of lakes for recreational and other purposes because of:
- (a) Deteriorating water quality;
 - (b) More restricted access for boating as water recedes from the shore;
 - (c) Deterioration of the market value of lake-shore properties, especially if there is a trend for the average annual lake level to fall over time;
 - (d) Decreased aesthetic value of the lake environment;
 - (e) Reduced recharge to ground water supplies;
 - (f) Water temperature changes which could have adverse effects on aquatic life and habitat; and
 - (g) Increased turbidity on lakes used for aquatic recreation which could adversely affect recreation and aquatic life and habitat.
- (3) Ground water problems such as:
- (a) Wells going dry necessitating the expenses of deepening existing wells, installing new pumps, adding more sections of drop pipe, digging new wells, or using alternative water sources;
 - (b) Increased energy costs of pumping water as water levels fall;
 - (c) Increased well-interference problems;
 - (d) Reduced discharge of ground water to surface water thereby affecting surface water users; and
 - (e) Increased drawdown of lake levels through the withdrawal of groundwater.

B. The Economic Impacts of Water Shortage

In general, we would expect the economic impacts resulting from these problems to operate through the following channels:

- (1) Water shortage problems affect the costs of firms thereby affecting the output, profits, employment and earnings of each firm.
- (2) Each firm and its employees have impacts upon other firms and individuals in the economy through both market and non-market relationships.
- (3) Public policies and institutions affect the allocation of and availability of water to firms and individuals and, therefore, affect the impacts discussed in (1) and (2) above.

Water-withdrawing firms may be affected by water-shortage problems as follows:

- (1) The costs of intake water could increase because:
 - (a) Falling ground-water levels and increased well-interference problems could result in increased energy requirements for pumping ground water and could force users to invest in lower drop pipes, in new pumps, in deepening their existing wells, or in drilling new wells in order to retain their access to groundwater.
 - (b) The price charged for delivered water could increase.
 - (c) A charge for self-supplied water could be imposed or increased.
 - (d) Limits could be imposed on the quantity of water which the firm may withdraw from the source. The price of water used beyond the limit would become infinite or equal to a per-unit penalty charge for exceeding it.
- (2) In order to allocate water on a river, limits on water consumption or per-unit charges for water consumed could be imposed.
- (3) Because of increasing competition for water or because of a drought, the concentration of pollutants and suspended and dissolved substances of natural origin in a river or lake could increase. Then a firm withdrawing water could incur costs upgrading the quality of its intake water, seeking alternative supplies, or make other adjustments.

- (4) To assure that water quality standards were being met in a surface source, in the face of chronically worsening water-shortage conditions, stricter effluent-wasteload or thermal-pollution standards could be imposed.

In response to these initial effects, firms may, in the short run, have the following options at their disposal:

- (1) They may emphasize more heavily in their operations those processes which depend less upon water or which produce less effluent wastes. This may involve both product and input substitution since the processes involved will probably use inputs and produce outputs in different proportions.
- (2) They may be able to exercise tighter controls on leaks, wastes, and/or spills. This can reduce withdrawals, consumption, and/or effluent waste concentrations.
- (3) In some circumstances firms may be able to reduce their unit costs by reducing their rates of output.
- (4) In some circumstances firms may be able to raise their prices to at least partially cover the increases in their costs.
- (5) In some circumstances, firms may be able to reduce the prices they pay for raw materials.
- (6) Firms may close down.
- (7) Firms may do nothing.

If water-shortage problems appear to be recurring or chronic firms may be able to invest in various types of capital equipment such as new wells, pumps, piping, pollution abatement equipment and/or industrial processes which require less water or which give off less pollutants.

This could include the more extensive use of water recycling. Water recycling is expected to be widely adopted in industry in response to Federal pollution control legislation. However, firms which have adopted extensive recycling to comply with this legislation will have less scope to react to increases in the cost of intake water by conserving water. Such firms may be more vulnerable to the adverse economic effects of water intake cost increases. A firm will make investments in water or waste saving equipment only if the expected present value of alleviating the expected problems plus any other expected benefits are equal to or greater than the costs of the investment required. If this is not the case, the firm will not make the investment. Then the firm may continue to operate at a lower level of earnings or alternatively it may shut down.

Responses of individual firms to water problems have economic ramifications upon the rest of the economy through secondary impacts. These impacts occur through forward linkages, those market channels through which products

of the affected firm travel, and through backward linkages, those market channels through which the affected firm purchases its supplies of goods and services, through which suppliers of the affected firm obtain their supplies, and so forth. The importance of backward linkages for firms in various industrial sectors is shown in Table 6 (p. 58) in the main text of this report.

Mitigating Factors

The magnitude of the economic impacts of a water shortage may to some extent be mitigated with the passage of time or over space. In general, the larger the geographical perspective, the less severe will be the monetary value of economic losses. If, for example, output, employment, and earnings in a particular area decline due to a drought, these losses may at least in part be made up in another area of the state or country where conditions of water availability are relatively more favorable.

The adverse economic effects of a drought may also be mitigated with the passage of time. Reductions in output may be made up by operating at higher rates at a later date. Reduced demand by individuals and firms adversely affected by the water shortage may in part be deferred demand which will be exercised later. The demand for certain products such as irrigation equipment, pumps, and the services of well drillers are stimulated during water-shortage conditions. Eventually investments in water-saving capital equipment, cooling towers, process-water recycling equipment and the like will stimulate the industries supplying these products as well as other industries which support them.

The degree to which increased output in alternative times or places and water-shortage-induced investments will offset economic losses in the water-short area will depend upon the availability of unemployed resources (primarily labor) in the alternative times or places. If the increased output draws resources from other activities in the alternative times or places, the offsetting affects will be reduced as input prices are driven up. 2/

Finally, if the output of heavy-water-using sectors decreases in an area, and heavy-water-using firms close down, they may eventually be replaced with new industries seeking to take advantage of idled resources in the area. This would in some respects be a desirable outcome since it would reduce the pressure on water resources in the area while still providing economic benefits.

C. Economic Impacts in Specific Sectors

1. Withdrawal Sectors

(a) Agriculture

Agriculture is vitally dependent upon reliable supplies of good quality water at all production, processing and distribution levels. An economic

analysis of water shortages requires a careful analysis of the timing, location, and duration of the shortage. Due to the economic complexities within the agricultural sector and the numerous interrelationships between agriculture and the rest of the economy, it is extremely difficult to isolate the extent of water-related economic loss. In the most general terms, water shortages adversely affect crop yields, farm income, and regional economic stability. Furthermore, insufficient water supplies can lead to the bankruptcy of both farms and processing firms, food shortages and increased prices of agricultural commodities to consumers. Even when the physical aspects of drought have disappeared, the economic and social affects linger on. Measures which have been taken in the state to cope with the possibility of water shortages include the development of new conservation practices, improved farm management techniques, irrigation, and more liberalized farm credit and insurance programs.

(b) Food Processing

Although the food processing sector is characterized by the existence of large, multi-plant, multi-product firms, there is still enough competition among these and thousands of small and medium size firms to make this a highly competitive sector. Firms located in any region of the country are potential competitors to firms in any other region producing the same products. thus, the opportunity for passing on water-cost increases to consumers is limited because of the ability of unaffected firms to undercut affected firms' price increases. If the rise in water-costs makes a firm unable to cover its variable costs, it will be forced to close down temporarily or even permanently, depending upon the duration of the water shortage. This in turn will have a detrimental effect upon supplying farms. If the farmers are able to find other purchasers for their products, they will have to settle for lower prices or pay increased transportation costs. Even if a local food-processing firm continues to operate, supplying farmers may receive lower prices for their products if the affected food-processing firm seeks to pass back to them some of its water-cost increases.

The ability of food and food processing firms to adjust their water consumption and intake in response to an increase in the cost of using water will be addressed in a forthcoming report. (Technical Paper No. 12). Several firms have already begun instituting water conservation practices in response to increases in water, sewer, and energy costs.

(c) Pulp and Paper Manufacturing

During severe low-flow conditions, the cost of using water for pulp and paper plants could rise as a result of policies designed to induce these plants to internalize any costs their water use imposed upon others. Although much more information would be needed concerning technical and financial aspects of Minnesota pulp and paper plants to make definitive and quantitative statements about firm reactions to policies designed to cope with low-flow conditions on Minnesota rivers, the following observations can be tentatively made: the ability of firms in the pulp and paper industry to partially deflect increases in the costs of using water by decreasing their water intake or consumption is diminishing as they increase their dependence upon water recycling in order to comply with pollution-control regulations. Furthermore, there is little leeway for pulp and paper manufacturers to recoupe water cost increases by raising product prices. There may be some scope for reducing prices paid to producers of pulp wood, however, this avenue is limited by the fact that some mills use their own wood source, that, in most instances, wood is purchased under contract, and that producers of wood may be able to find other buyers. Thus, it seems likely that temporary cost increases would be absorbed primarily by the industry itself in the form of reduced profits, employment, and earnings. It appears, however, that even very small charges for intake water can wipe out the profits of the firm because of the large amounts of water required to generate one dollar's worth of profits. Thus, temporary water-related cost increases can result in temporary plant shut downs with resulting unemployment, loss of earnings, and undesirable secondary effects. More permanent cost increases or recurring temporary ones could be expected to slow the expected growth of the industry in the state.

(d) Iron Mining

The most recent projections of water availability in the northeastern part of the state where taconite mining operations are located, and projected water use of the taconite mining operations and potential and existing competing uses indicate that significant, wide-spread water-shortage problems affecting these operations are unlikely in the foreseeable future. However, the possibility of localized conflicts of demand between iron mining operations and municipal water utilities and other localized conflicts involving iron mining operations cannot be ruled out. Such problems could result in allocation policies which could increase the costs of water use to some iron mining operations. Rising water costs could induce firms to adopt water-saving technologies. In the unlikely event that

significant wide-spread, long-term increases in the cost of using water materialized, the parent firms of iron-mining operations are in a position to pass on a large portion of these cost increases to their customers. If, however, the cost increases were believed to be temporary, the iron mining companies could temporarily cut back or suspend their operations. This would have temporary adverse economic impacts on the area. If a single processor encountered significant increases in the costs of water use which did not affect other operations, employment in that operation could be adversely affected with consequential adverse secondary economic effects to the surrounding area. In general, however, there appears at this time to be no significant threat to the economy of the area due to increased costs of water use in iron mining operations.

(e) Electric Power Production

Electric utility power production is the largest single withdrawal use of water in Minnesota, accounting for 54.4 percent of all water withdrawn in 1976. However, most of the water is returned to its source; only 3.0 percent of all water withdrawn by power plants in 1976 was consumed. Pollution-control regulations have mandated that cooling towers replace once-through cooling in all future power plants. Cooling towers require the withdrawal of much less water, but consume most of the water withdrawn. Thus the amount and nature of power plant water use will change markedly in future years. Electric-power plants may face water supply problems in years of low surface-water flow because of their high water requirements and their low priority as appropriative water users. In short-term drought conditions, under which a plant would be required to curtail production, the producing utility might have the following available options:

(1) To increase generation at other baseload or intermediate plants, (if possible); (2) to bring on line peaking plants, which require little water but are more expensive to operate; or, (3) if the above are not possible, to buy power from other utilities. The second and third options would result in higher operating costs and higher costs of electricity to the consumer. If excess power from other sources were not available (a possible situation in the case of a wide-spread drought), there would be economic ramifications through all sectors of the economy which depend upon electric power. A longer-term approach would be to take into account opportunities for building storage reservoirs in the siting of new electric power generating plants. Such reservoirs could be used to store water during periods of relatively high flow for use during

periods of low flow. In some circumstances, groundwater back up systems might be established for the use of ground water for cooling purposes during periods of extreme low flow. A long-term planning goal must be the establishment of emergency allocation systems for water and electricity which would minimize disruption during a severe low-flow condition.

2. Non-Withdrawal Uses

Among the non-withdrawal water-using economic activities, water related recreation is the one most likely to be affected by water-shortage problems. Among the specific problems affecting recreation are the following:

- (1) Low flow in rivers and streams and low lake levels may cause water quality to deteriorate adversely affecting aquatic life and habitat, recreation activities, supporting economic interests, and recreational property values.
- (2) Pressures to supplement low flows in rivers and streams with water from reservoir lakes can result in lowered reservoir lake levels adversely affecting recreational activities there.
- (3) Increased use of ground water for agricultural irrigation and other uses can in some locations lower lake levels or reduce stream flows thereby having inimical impacts on aquatic life and habitat, recreational activities, supporting economic interests, and recreational property values.

It is estimated that in 1976 tourist and traveler expenditures in the state resulted in over 1.713 billion dollars worth of sales and over 100,000 jobs. It seems likely that a large proportion of these tourists and travelers are attracted to Minnesota because of its water-related recreation opportunities. Thus, anything impacting upon the quality of water-related recreational experience is of great economic concern to the state.

Commercial navigation at the port of Duluth and related industries could be adversely affected if clearance in the Harbor were reduced due to a fall in the level of Lake Superior. The level of the lake is to a large extent artificially controlled by means of control works at Sault Ste. Marie on the St. Marys River. Management of the lake levels is under the purview of the International Joint Commission. The maintenance of adequate channel depth in the harbor and the deepening of channels of insufficient depth for large vessels is the responsibility of the U.S. Army Corps of Engineers.

The likelihood of a severe enough low-flow condition to affect commercial navigation in the Twin Cities ports is low. The minimum flow necessary to operate Locks and Dam Number 1 and the St. Anthony Falls locks on the Mississippi River in the Twin Cities is about 225 million gallons per day. The estimated 30-day, 100-year low flow at both locks is about 300 million gallons per day. The main economic impacts resulting from any temporary halt in navigation would be secondary impacts through forward linkages. Such delays would affect the customers of the barge companies who would have to pay higher transportation costs and/or incur higher storage costs.

Hydroelectric power production is relatively insignificant in this state. If hydro power were reduced for any reason, the deficit would be made up by operating other facilities such as steam electric or internal combustion plants at higher load factors. Or if that were impractical, or not possible, power could be purchased from outside the system. In either case the substituted power would probably be more expensive than the hydropower. However, since the amount of electricity involved is small compared to the statewide total, such costs would be minimal.

3. General Conclusions Concerning Economic Impacts

Several (more general) conclusions and observations may be derived from the foregoing which have relevance for government policy designed to cope with water shortages and their economic effects. Concerning water-shortage problems, it is evident that they :

- (1) Are found in specific locations;
- (2) May be temporary, recurring, or chronic in nature; and
- (3) Become potentially worse as economic and population growth take place in an area.

Concerning economic impacts, the following general conclusions may be made:

- (1) Our knowledge concerning the specific actions that firms will take and the quantitative nature of economic impacts is at best highly limited.
- (2) Individual water users usually act in their own interests and take into account only those costs which they perceive to apply to themselves.
- (3) Specific water-shortage problems can affect individual firms adversely. It can cause them to reduce output, close down temporarily, or even permanently. These effects will of course adversely affect employment and earnings in the affected plants themselves and will adversely affect other firms and individuals in the economy through secondary impacts.

- (4) Charges for water withdrawals or consumption, or for effluent concentrations or more stringent limitations on withdrawals, consumption or on effluent concentrations can also have adverse effects in some sectors. On the other hand, if such policies promoted more efficient water allocation, the benefits forthcoming from such charges would outweigh the costs to adversely affected sectors. As discussed below, such policies should be designed to induce firms to internalize the costs they impose on others through their use of water. If firms do not internalize such costs they are in effect, exacting subsidies from those who must bear the costs. Obviously, if an unwarranted subsidy is removed, the ones who benefited from the subsidy are worse off. But those who have in effect paid the subsidy are less severely affected by the water shortage.
- (5) The severity of economic impacts depends upon the geographical and time perspectives considered. Part of the adverse economic impacts may be made up through investments in other places and other times, or through production deferred to other places or to later times. The extent to which the adverse economic impacts will be mitigated will depend upon the availability of idle resources in the alternative times or places.

D. Role of the Public Sector

There are basically two roles the public sector can take in dealing with the adverse economic impacts of water shortages. In one role, the public sector can seek to prevent or to minimize adverse economic impacts from water shortages through allocative policy. In the other, the public sector can seek to compensate those who have suffered losses. This report is concerned with the first role but only on a superficial level. A more detailed consideration of allocation options will be discussed in a forthcoming technical report.

(1) Objectives of Allocative Policy

The purpose of government allocative policy is to seek a distribution of available water among consumptive and non-withdrawal uses which promotes the maximum achievement of implicit and explicit government objectives. Usually such objectives include the following:

- (1) Maximizing economic well-being according to such indicators as employment and/or earnings;
- (2) Maintaining or achieving an acceptable distribution of income;
- (3) Maintaining water quality to support recreational and other activities;
- (4) Maintaining flow levels to support recreational and other activities; and

(5) Preserving the integrity of the environment.

In some cases, these objectives are compatible with each other. For example, the more flow there is in a river, the greater the capacity of the river to assimilate wastes. Thus, (3) and (4) are clearly complementary. On the other hand, maximizing employment and earnings is not necessarily compatible with maintaining water quality since employers' costs for pollution abatement may reduce the profitability of their operations, and therefore, may reduce their incentive to employ labor. The recent controversy concerning restrictions on multiple use in the Boundary Waters Canoe Area indicates that there is some question as to whether (2) and (5) are compatible. Thus, public policy makers must decide how these different objectives must be weighed in determining the allocation policy they will follow.

(2) Levels of Allocation

There are three levels at which allocation can be carried out. These are:

(1) Allocation between sources.

On a large scale, these may involve "interbasin transfers" whereby water is carried over large distances between rivers or lake basins. Such large-scale transfers are usually impractical because of the costs and intergovernmental controversies involved.

On a smaller scale, allocation between sources may involve the transfer of water between nearby surface sources between nearby ground-water sources, or between surface and ground-water sources. In some circumstances such transfers may be desirable, but only if it can be demonstrated that their benefits can justify their costs.

(2) Allocation at the source.

This involves the distribution of water among those who withdraw and/or who use water from or in a single source or several hydrologically related sources in an area. Thus, this would include the distribution of water among municipal water utilities, industrial withdrawers, agricultural withdrawers, private domestic wells, and water left in surface-water sources to maintain levels for non-withdrawal uses. It would also include structural measures to reallocate water in time at a particular source. For example, reservoirs and dams can be used to store water during periods of

relatively high flow (on a stream) for use during periods of relatively low flow.

(3) Allocation by Intermediate Suppliers.

This concerns the distribution of water by municipal water utilities and rural water systems to their customers.

(3) Approaches to Allocation

When water availability is limited, the consumption of water by one user or the retention of water in a surface source denies the use of water to other users. Thus, the use of water by some results in costs to others in the form of benefits foregone.

For example, during a low-flow period, an upstream user may be able to obtain all the water he wants at no cost to himself. Yet his use of water will impose costs on users downstream in the form of foregone earnings due to a lack of sufficient water, higher intake treatment costs due to higher concentrations of pollutants, and so forth. Thus, even though the upstream user perceives no costs to himself, there are external costs imposed upon others through his use of water.

In order to obtain the maximum social benefits from water consumed from a surface or ground-water source or left in a surface-water source for non-withdrawal uses, it is necessary that the benefits derived from each unit in a particular use exceed or equal the benefits lost through its denial to alternative uses.

One way of accomplishing this is to cause users to internalize all of the costs of their water consumption including the costs imposed on others. In other words, to cause them to treat these costs of their water use as if they were their own private costs. There are several ways to induce users to internalize all of the costs of their water use. These may be dichotomized into per-unit pricing schemes and non-price rationing although combinations of these approaches are also conceivable and may be desirable in some circumstances. Per-unit pricing schemes can take the form of pricing per unit of intake water or per unit of water consumed. It is also possible to ration the use of water for waste assimilation purposes by means of per-unit waste-load charges whereby charges are levied on concentrations of particular pollutants or classes of pollutants.

Non-price rationing can take the form of absolute limits on the amount of water withdrawals or consumption per time period with penalty charges for over-withdrawals or over-consumption. Combinations of pricing and non-price rationing would include such arrangements as per-unit pricing by municipal water utilities with

minimum water allotments at low cost to accommodate low income families and non-price rationing with the right to trade ration allotments in a free market.

It is possible to achieve similar allocations of water by using either pricing or non-price rationing; therefore, the issue of which to use comes down to determining which approach involves less costs in seeking to achieve the desired goals.

V. Recommendations

The basic objective of water allocation policy is to maximize the net social benefits of water use in the face of water shortages. Net "social benefits" should be defined in terms of explicitly stated goals of public policy. The broad conclusions obtained from this study give rise to the following recommendations for formulating allocation policy.

Consideration of specific allocation options based on these recommendations would require in-depth study of the hydrological, economic, environmental, social, and legal implications of the options.

- (a) Policy makers should explicitly state the goals of their allocation policies.
- (b) Policy makers should make explicit the geographic and time perspectives from which they make their assessments of economic impacts for allocation purposes. Policies concerned with an immediately affected area may differ from those with a broader geographic scope.
- (c) Allocation policies should be operable even in the face of limited information on the part of the allocating authority. Such policies should depend, as much as possible, upon the decentralized decisions of individual users made on the basis of their own conditions of water use and on the basis of the real costs of their use of water.
- (d) Allocation policy should allow the economy the flexibility to adjust as quickly as possible to changes in the conditions of water use with as little government intervention as possible.
- (e) Allocation policy should reflect the recognition that to subsidize some water users by not requiring them to internalize all of the costs of their water use may not be justified in terms of the costs imposed on others and in terms of the social benefits of such subsidization. If for some reason it is deemed desirable to subsidize these water users, then the subsidization should take the form of explicit governmental cash payments.

In other words, such subsidization should be brought out front where it is subject to public scrutiny instead of being hidden behind higher water-use costs imposed upon a select group of other water users and their customers.

INTRODUCTION

A. Preliminary Definitions

Drought conditions in the state of Minnesota during the year 1976 gave rise to concern about the "economic impacts" of "water shortages".

Often those who express such concern do not have precise ideas of what "water shortages" or "economic impacts" are. In order to clearly understand what questions are worth asking and answering, it is necessary to make these notions more precise.

Water "Shortages"

The concept of "water shortage" is both an economic one and a political one. It may be defined as follows:

Water Shortage: A water shortage exists in an area when the consumptive and non-withdrawal demands for water relative to available supplies is such that the real costs of obtaining and/or using water become unacceptable to the public.

To understand this definition, it is necessary to consider what is meant by the terms "consumptive and non-withdrawal demands", and why public perceptions determine whether or not a water shortage exists. The following five definitions should be helpful:

Water Withdrawal: A quantity of water which is removed from a source for some purpose.

Water Discharge: That part of the water withdrawal which is made available again to alternative uses within the area of consideration, or which flows out of the area.

Water Consumption: That part of the water withdrawal which is made unavailable to other uses in the area.

The last two definitions require some elaboration. After water is withdrawn from a source and used by the withdrawer, part of it may be discharged back to the source from which it came or to some other source where it may be made available to some other use in the area of concern. This constitutes the user's discharge. The remainder may be incorporated into a product, may evaporate, or may flow out of the area of consideration without being available to other uses there. This part of the water withdrawal is said to be consumed.

Consumptive demand for water is the amount of water withdrawers wish to consume given their costs of obtaining it.

It is important to clarify whether the phrase "demand for water" refers to the demand for water withdrawals (withdrawal demand), or for water consumption (consumptive demand). In some contexts it may refer to both. If a particular discussion refers to the demand for water from a particular aquifer and all water discharged from withdrawing uses flows away from the area and none is returned to the aquifer, then from the standpoint of that particular area, consumption and withdrawals are identical. On the other hand, if the discussion concerns uses along a river, then it is the consumption of upstream users that affects

the water available for downstream users, not their withdrawals. In this context, it is more appropriate for "demand" to refer to the demand for water consumption.

Non-withdrawal demands for water are demands for surface water volumes or flows to carry out activities which use water where it is and do not remove it from its source.

This definition would include demands for lake levels or stream flow for recreation, commercial navigation and hydroelectric power production.

In addition to these definitions, the following distinction should be kept in mind. This is the difference between a "water shortage" and a "drought". In this report, a drought shall be defined to be a prolonged absence of precipitation which results in a "water shortage" in an area.

The Real Costs of Water Use

The basic problem of water shortages is that as consumptive and non-withdrawal demands upon a water source increase, the real costs of using water in (and/or from) that source begins to rise. These costs may take the form of increased pumping costs for obtaining ground water, increased costs for the treatment of intake water as the concentration of pollutants and of suspended and dissolved substances from natural sources in the water rises, inconvenience to swimmers as water becomes murkier and more polluted, higher electricity rates if power must be curtailed and electricity imported because of insufficient flows in a river, and so on. Alternatively, a drought may cause a reduction in the supply of water which can also cause the real costs of using water to rise. A special case is that in which the costs of obtaining or using water for an activity is so prohibitive that for all practical purposes the water is unavailable. This would be the circumstance for a farm whose well has run dry during a drought. Theoretically, he could pay to have water hauled in, but the cost of his doing so may rule out this alternative.

In fact, there is always some cost for using water, and this cost will rise as the demand for water from a given source increases or as the available supply of water decreases. How then do we decide when there is a water shortage? The answer to this question depends on what the public perceives and is willing to accept. If only a few individuals in an area are inconvenienced, no widespread problem of water shortages will be seen to exist. On the other hand, if many individuals have noticed unacceptable costs of obtaining or using water, a general water shortage will be seen to exist by the public at large.

The use of the word "real" in the phrase, "real costs", is intended to distinguish a general rise in the types of costs discussed in the previous paragraphs from situations in which the cost of using water shifts among groups of users. An example of the latter situation is one in which users of here-to-fore underpriced municipal water receive an increase in their water rates. The water may have previously been underpriced because the water works were subsidized with local tax revenues or because of hidden costs of municipal water use, such as reduced or terminated yields in other (non-municipal) wells, which have been imposed on non-municipal users. There may be no change in the availability of water or in the overall use of water from the ground water source which precipitates the rate increase, and, in general, there may be ample availability of water in the area. What happens is that there is a redistribution in the costs of using water but not an overall rise in the real costs as required by the definition.

Water shortages are characterized by time and space dimensions. They may be restricted to a particular region of the state or they may occur in several regions simultaneously as did those occurring during the drought of 1976. They may be brought about by seasonal dry weather conditions or by occasional (or periodic) droughts. They may be of limited duration or they may last for several seasons. Or, they may become a chronic condition brought about by increasing demands upon the water resources of an area due to population growth and industrial (including agricultural) development. One effect of increasing demands over time is to make the consequences of droughts and seasonal dry periods more severe.

The real costs of water shortages are to a great extent determined by the degree to which water demands are over-extended in relation to the timing and spacing of precipitation. Critical water shortages represent a complex interaction between the natural variations in moisture availability and the particular resource utilization demands of human systems on variable supplies of water. The severity of a water shortage depends upon the degree to which human water demands exceed the long-run availability of moisture and man's ability to adapt institutions and technologies to these conditions. "Ultimately, the heart of much of the drought problem lies in particular land uses and their sensitivity to periodic fluctuations in precipitation amounts."³

B. Specific Water Shortage Problems in the State of Minnesota

The public's perceptions of water shortages are crystallized by specific problems which exist or can potentially exist in the state of Minnesota. Among these are the following:

- (1) Low flow in rivers and streams resulting in:
 - (a) higher concentrations of pollutants and of suspended and dissolved substances of natural origin in the water thereby increasing the costs of treating water for withdrawal purposes, interfering with recreational use of the water, and spoiling wildlife habitat;
 - (b) increased competition for available water among withdrawal and non-withdrawal uses;
 - (c) threats to wildlife and wildlife habitat due to insufficient river or stream flows;
 - (d) possible limitations on the navigational use of rivers;
 - (e) conflicts between users of river and stream water and recreational and other uses on reservoir lakes;
 - (f) increased costs of waste treatment facilities in order to meet more stringent effluent standards; and
 - (g) reduced recharge to ground water supplies, thereby affecting ground water users.
- (2) Lower lake levels resulting in the depreciated value of lakes for recreational and other purposes because of:

- (a) deteriorating water quality;
 - (b) more restricted access for boating as the water recedes from the shore;
 - (c) deterioration of the market value of lakeshore properties, especially if there is a trend for the average annual lake level to fall over time;
 - (d) decreased aesthetic value of the lake environment;
 - (e) reduced recharge to ground water supplies;
 - (f) water temperature changes which could have adverse effects on aquatic life and habitat; and
 - (g) increased turbidity on lakes used for aquatic recreation which could adversely affect recreation and aquatic life and habitat.
- (3) Ground water problems such as:
- (a) wells going dry necessitating the expense of deepening existing wells, installing new pumps, adding more sections of drop pipe, digging new wells, or using alternative water sources.
 - (b) increased energy costs of pumping water as water levels fall;
 - (c) intensification of well-interference problems;
 - (d) reduced discharge of ground water to surface water, thereby affecting surface water users; and
 - (e) increased drawdown of lakes through the withdrawal of ground water.

C. Economic Impacts

The question investigated here is, "How do these problems of water shortage and their possible solutions affect the economy of the affected regions?". More specifically, "How do they affect such indicators of economic well-being as employment and earnings?".

In general, we would expect the economic impacts to operate through the following channels:

- (1) Water shortage problems affect the costs of firms, thereby affecting the output, profits, employment and earnings of each firm.
- (2) Each firm and its employees have impacts upon other firms and individuals in the economy through both market and non-market relationships.
- (3) Public policies and institutions affect the allocation of and availability of water to firms and individuals and, therefore,

affect the impacts discussed in (1) and (2) above.

Firms most likely to be significantly affected by water shortage problems are, of course, those which are heavily dependent upon water. Many of these are classified in the following industrial sectors:

- (1) agriculture,
- (2) food processing,
- (3) pulp and paper production,
- (4) iron mining, and
- (5) electric power production.

Firms in these sectors withdraw water from particular water sources for use in their production processes. Thus, they will be referred to as withdrawal uses.

Some economic activities are heavily dependent upon surface water, but do not withdraw it from its source. These include:

- (1) navigation,
- (2) recreation, and
- (3) hydroelectric power production.

These will be referred to as non-withdrawal uses.

D. Organization of Report

This report is organized into four main parts. Part I. presents a more detailed discussion of the problems brought about by water shortages in Minnesota; Part II. deals with the economic impacts of these problems and policies designed to cope with them on and through withdrawal uses; Part III. considers the economic impacts on and through non-withdrawal uses; and Part IV. discusses broad conclusions which may be derived from the previous parts and how these might be applied to public policy.

Part I. Problems of Water Shortage in Minnesota

Problems involving water shortages in Minnesota can conveniently be dichotomized into those related to ground water and those related to surface water provided that one keeps in mind that surface water and ground water are both hydrologically and economically linked.

From a hydrological perspective, it should be recognized that for most surface waters there is an annual interchange with ground water sources. During periods of low or deficient precipitation, most streams are largely dependent upon the discharge of shallow ground water to maintain their flows. During periods of higher stream flows, the shallow ground water system is often dependent upon discharge of surface water to recharge the ground water system and raise levels.

Water sources are economically linked in that the use of water from one source affects the value of water in others and, therefore, the rate at which water from the latter is used. Rational users of water will obtain water from the cheapest source first and then draw from an alternative source if the supply of water from the first is insufficient for their needs or becomes more expensive than water from the alternative source. For example, the city of Moorhead used to obtain all its water from ground water sources. Because it was observed that water levels in these aquifers were falling, the city began to withdraw most of its water from the Red River. Growth projections indicate that the water in the river might not be sufficient to meet the city's growing demand, so the city is considering expanding its reliance on ground water again.⁴ Thus, drawdown of ground water and the adequacy of surface water flows are linked by human economic activities.

I-A. Surface Water Problems

Several types of problems resulting from low flows in rivers and streams and declining lake levels were identified in the introduction. These will now be discussed in somewhat greater detail.

(1) Water Quality and Surface Water Shortages

(a) Water Quality and Low-Flow Conditions in Rivers and Streams

Water quality problems in rivers and streams are exacerbated during water shortages when less water is available to dilute industrial and other wastes. Among the possible consequences of this are:

1. degradation or further degradation of wildlife habitat and the recreational opportunities afforded by rivers and streams;
2. increased costs of treating intake water by downstream users or the necessity and expense of turning to other sources for intake water; and
3. the eventual imposition of more stringent

effluent waste load standards, in response to long-term problems of decreasing flows resulting in increased costs of building or retrofitting and operating waste treatment plants.

An indication of the geographical extent of water pollution problems in Minnesota may be found by referring to the Minnesota Pollution Control Agency's report to the United States Congress under Section 305b of the Water Pollution Control Act.⁵ This report used data collected during the year 1976 — a drought year. Thus, it provides an indication of the extent of water quality problems under widespread conditions of water shortage.

In their report, the Minnesota Pollution Control Agency identified several rivers in which water quality was judged below standards for fishing and swimming.

Fishable Waters

To determine whether a waterway was meeting the fishable goal of federal pollution control legislation, the average frequency of violations between October 1, 1973, and September 30, 1976, of current MPCA (Class 2b) standards for six selected parameters was calculated. When the average frequency exceeded 10 percent, the goal was considered as not being met.

"Of the 75 water quality monitoring stations, 12 percent were not in general compliance with the fishable aspect of the 1983 national goal [that, where attainable, all waters must be fishable and swimmable]. The following locations were in non-compliance with the goal.

- Buffalo Creek below Glencoe
- Mississippi River below Minneapolis-St. Paul
- Zumbro River below Rochester
- Center Creek below Fairmont
- Cedar River below Austin
- Des Moines River, East Fork
- Okabena Creek
- Pipestone Creek
- Rock River

"The causes of this non-compliance are considered to be due to the combined effects of non-point sources, such as agricultural runoff, and point source discharges from industries and municipalities. The monitoring stations located on these rivers magnify the impact of human influence since the stations are commonly located downstream from municipalities."⁶

Swimmable Waters

In their report, the MPCA relied upon the "fecal coliform" count for determining if Minnesota waters are on track for meeting the 1983 goal. Their results suggest that:

- "1. Swimming may not be advisable in a majority of the rivers in Minnesota discussed in this report. This indication is pointed out by the fact that the fecal coliform standard is exceeded at a frequency greater than 10 percent of the time at 76 percent of the stations assessed.
- "2. In 20 percent of the 75 water quality monitoring stations in this report, the fecal coliform standard is exceeded more than 50 percent of the time. It is in these five rivers — the Twin Cities metropolitan segments of the Mississippi River, the Crow River, the Cottonwood River, the Des Moines River headwater tributaries and the Missouri River headwater tributaries — that the bacteriological integrity is so poor as to prompt the MPCA to classify these rivers as not being in compliance with the swimmable aspect of the 1983 goal of the Act.

"The causes for these excessive levels of fecal coliform in the metro segment of the Mississippi River appear to be due primarily to urban runoff, combined sewer overflows and point source discharges. In the other four areas, which are nearly entirely rural in character, the causes of the high fecal coliform levels are more likely due to agricultural runoff and, to a lesser degree, the discharges of municipal and industrial point sources. The natural bacteriological quality of the waters in these areas would be poor due to rural runoff, and it is speculated that were it not for man's activities, these areas would boast substantially improved bacteriological water quality."⁷

(b) Water Quality and Lowered Lake Levels

Drought conditions, or increasing withdrawal

demands upon lakes or their sources (ground water, rivers or streams) can lead to declining lake levels. This can lead to deteriorating water quality as the concentration of pollutants and nutrients in the water increases. This deterioration of lake water quality could adversely affect recreational activities in the lake (as more fully discussed in Part III).

A particularly troublesome problem involving the deterioration of water quality in lakes is that of lake eutrophication. Lake eutrophication is a process whereby enrichment of the water or lake soil with nutrients stimulates the growth of organisms in the lake. Over time, this can lead to a filling of the lake with organic material so that the lake ceases to exist as a body of water. Figure 1. illustrates this process.

Eutrophication may occur naturally in lakes which exist in regions with highly fertile soils. Runoff from lands surrounding the lakes brings the nutrients to the water.

When this process is induced or speeded up by man's activities, it is called cultural eutrophication. In this case, the nutrients may come from point source discharges such as those from industrial, municipal or commercial sources or from confined agricultural feedlot discharges. Alternatively, or in addition, they may come from non-point sources such as agricultural and urban runoff.

Non-point source pollution may be exacerbated during drought as a result of increased irrigation. Mismanagement and/or poor planning and unpredictable precipitation can lead to increased surface runoff due to the practice of sprinkler irrigation. If lake levels are lower than normal, this could lead to increased nutrient loading.

Economic and population growth can lead to more discharges and greater concentrations of nutrients, thus hastening eutrophication of some lakes. Figure 1. illustrates how man can speed up the process of eutrophication.

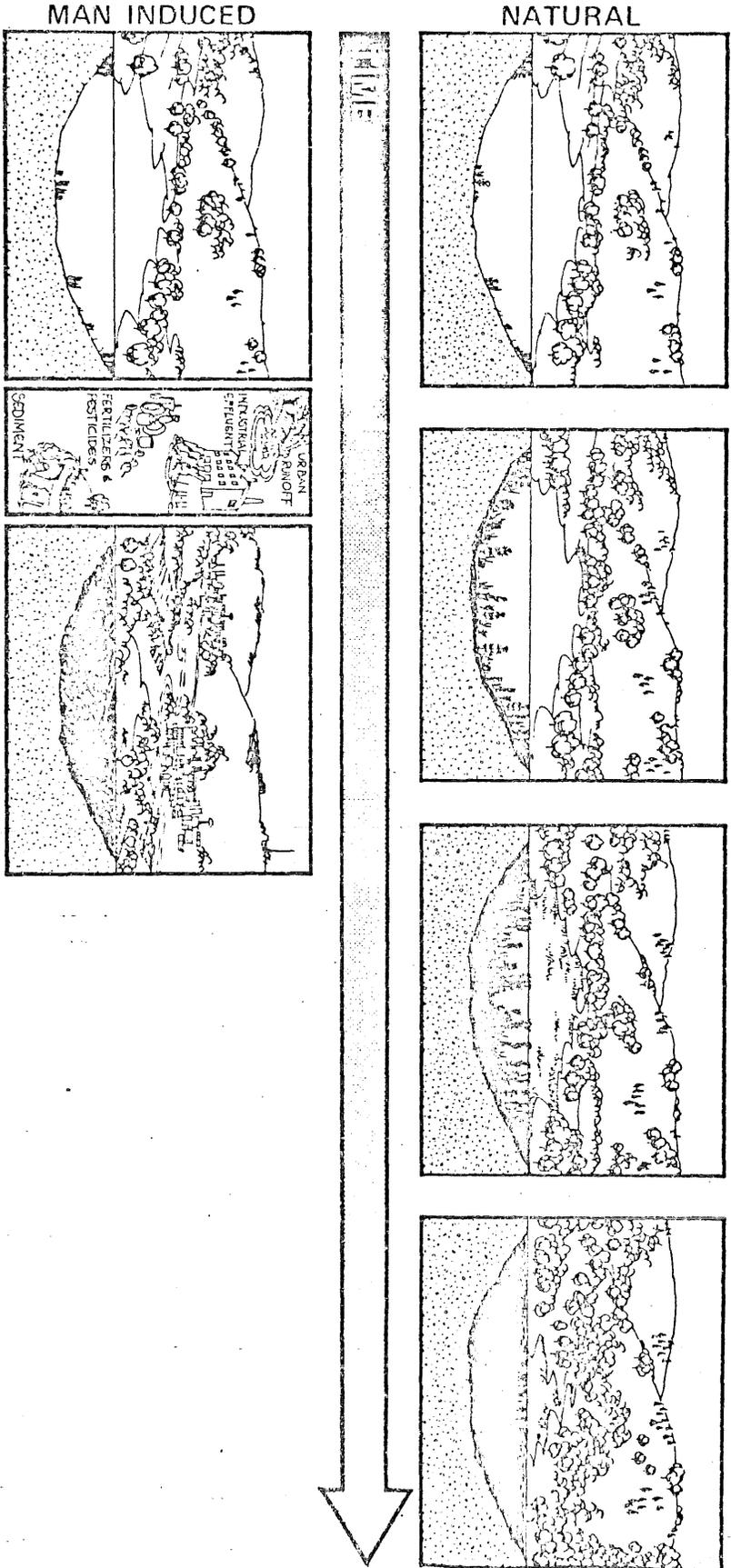
(c) Conclusions Concerning Surface Water Shortages and Water Quality

Three observations may be made on the basis of the foregoing:

1. Water quality problems occur throughout the state.
2. These problems can be exacerbated by low

EUTROPHICATION

Figure 1.



Source: Minnesota Pollution Control Agency, Minnesota Water Quality, June, 1977, Figure 4, p. 32.

flows in rivers and streams and low lake levels because there is less water to assimilate the pollutants and other suspended and dissolved substances.

3. These problems represent, to a large extent, conflicts between consumptive uses of water and water-related recreation. Many of the pollutants come from point dischargers such as municipal water utilities and industrial water users. Others come from non-point sources such as agricultural runoff. Part III. contains a more complete discussion of such conflicts.

(2) Low-flow Conditions and Consumptive Demands

During the drought of 1976, the levels of flow in the Mississippi River in the Twin Cities area and in the Red River at Fargo-Moorhead were so low that curtailment of withdrawal and non-withdrawal uses seemed a distinct possibility.

Twin Cities Area

According to the Metropolitan Council development policy plan, during a drought of similar magnitude to that of the 1930s (30-day, 100-year low-flow record), low flow in the Mississippi and Minnesota Rivers would force the Black Dog power plant on the Minnesota River and the Riverside power plant in Minneapolis to curtail power production.⁸ Thus, Northern States Power would have to import power into the region. This would entail higher costs for Northern States Power since the rates it would have to pay for the imported power would be higher per unit than its per unit costs of producing electricity. These rates would be passed on to its customers.

Two plants at the Black Dog site, and three at the Riverside site using once-through cooling may be phased out between 1984 and 1987. The power produced by these plants would be replaced by that produced by plants in Sherburne County which use cooling towers. This would mitigate the pressure of low flows on power production needs.

On the other hand, future population and economic growth in the Twin Cities area can be expected to put increasing pressure on the river during low-flow periods for municipal and industrial needs.⁹ Competition among Twin Cities' water users and between Twin Cities' users and users upstream can be expected to intensify as overall consumptive demands for water in the Mississippi River increase.

Fargo-Moorhead Area

During the drought of 1976, the Fargo-Moorhead area depended upon a diversion from the Sheyenne River in North Dakota to supplement water in the Red River in order to satisfy demands by the Fargo and Moorhead municipal waterworks, and

by self-suppliers. Flow in the Red River is of critical concern since the city of Fargo obtains all of its water from the River while the city of Moorhead obtains about 60 percent of its water there. Had the drought continued longer, diversions from Lake Ashtabula in North Dakota would have been required. This could eventually have caused the lake level to fall, adversely affecting recreational activities and supporting economic interests there.¹⁰

(3) Withdrawal Demands, Recreation and Commercial Navigation

During extreme low-flow periods, withdrawal uses will be competing with non-withdrawal uses such as recreation and commercial navigation on the Mississippi River and its tributaries. Minimum flows are required to operate locks and dams on the Mississippi River. The U. S. Army Corps of Engineers operates dams on the headwater lakes of the Mississippi River which can be used to supplement flows during low-flow periods. This can be done to augment the supply of water for consumptive demands downstream and to assure adequate flows for commercial navigation; however, to do so could threaten levels of the reservoir lakes and, thereby, recreational activities and their supporting economic interests.

I-B. Ground Water Problems

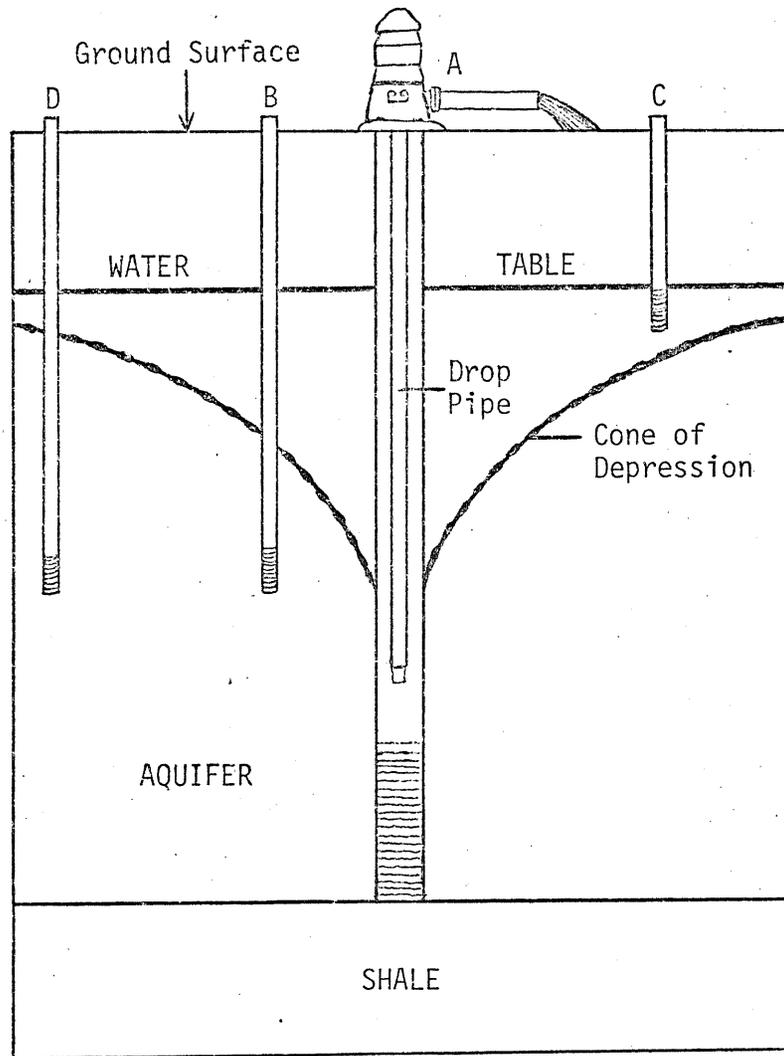
The most common problem involving Minnesota ground waters are well-interference conflicts between irrigators and other users. These conflicts can occur in an area even if there is no generally recognized water-shortage problem; however, they do reflect a limitation on ground water resources because, holding other factors constant, such as well spacing and well construction, the more ground water there is available, the less serious these problems are likely to be.

Figures 2A. and 2B. illustrate the nature of the problem. Figure 2A. illustrates a well drawing water from a water-table aquifer. In this type of aquifer, all material below the water table is fully saturated with ground water. As the well draws water out of the aquifer, the water table drops and forms what is called a cone of depression. The boundaries of this cone are shown in the figure. Within these boundaries is an area which has been dewatered by the pumping. It is not uncommon for the radius at the top of the cone of depression (caused by an irrigation well) to be 500 to 1,000 feet. Thus, the ability of any other well to withdraw water within the circumference of the cone of depression of well A (in Figure 2A.) will depend on the depth of the well and the length of its drop pipe. In the figure, well C will not be able to withdraw water because it is too shallow, and the cone of depression extends below the well. On the other hand, wells B and D will still be able to draw water provided their drop pipes still extend below the created cone of depression when they themselves are pumping.

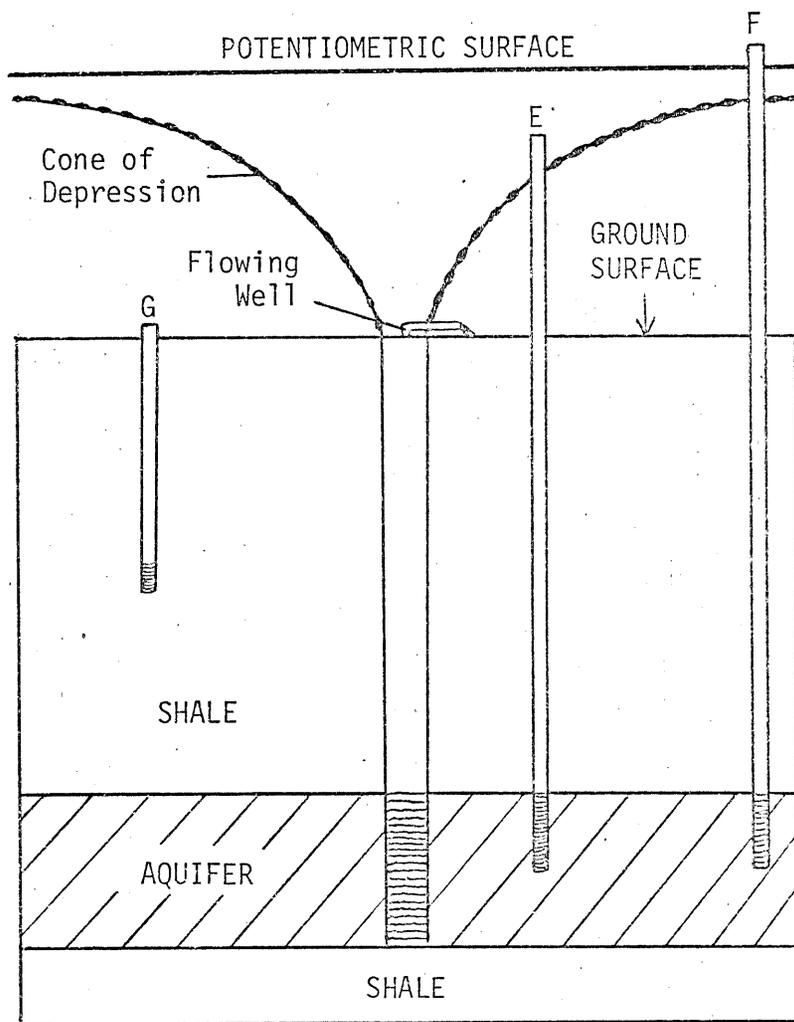
Note that if the water table were initially higher, well C would still have been able to withdraw water. On the other hand, if the initial water table were lower, even well B and well D would not have been able to retain their water supply. This illustrates that if during a dry period water tables are lowered, or if over time aquifers are mined, well-interference problems can become magnified.

Figure 2. Well Interference Problems - Water-Table and Artesian Aquifers

A. Water Table (Unconfined) Aquifer



B. Artesian (Confined) Aquifer



Source: Groundwater Group, Division of Waters, Minnesota Department of Natural Resources

Figure 2B. illustrates well-interference problems with artesian aquifers. There is a relatively impermeable material above the aquifer which keeps it under greater-than-atmospheric pressure. The potentiometric surface shown in the figure is the height the water would rise in a well due to the pressure in the aquifer. Thus, any well whose top is below the potentiometric surface will have flowing water, such as well E illustrated in the figure.

When a well taps an artesian aquifer, the withdrawal of water forms a cone of depression around that well reflecting a lowering of the potentiometric (pressure) surface. Consequently, any well whose wellhead is above the boundaries of this cone of depression will not have flowing water. This would be true for wells at F and E. Well G is not constructed in the outlined artesian aquifer and, thus should not be affected by the cone of depression created during the operation of the pumping well.

Holding other factors constant, the more water there is in the aquifer, the more pressure there will be and, therefore, the higher the potentiometric surface and the cone of depression.

There are, therefore, two ways in which a water shortage situation can exacerbate well-interference problems:

- (1) by decreasing the level of water in water-table aquifers and reducing the pressure and quantity of water in artesian aquifers; and
- (2) by inducing more people to drill wells (e.g., for irrigation), thereby creating more cones of depression and more interference problems.

Well-interference problems have occurred and potentially can occur whenever a new well has been put into an aquifer already used by others. Although almost all reported problems of this nature have involved new irrigators whose wells have affected domestic wells, similar problems can occur with, for example, new rural water systems, or a new industrial well.¹¹

In economic terms, the problem may be described as follows: When an individual or firm decides to invest in a well or, in the case of farmers, irrigation facilities, it is because they expect a stream of benefits to arise over time due to their investment. If they believe the present value of this stream to be greater than that of the costs involved, they will make the investment. But such investors may often not take into account all the costs of their investment. If others have wells in the area, then they too have made investments in the past assuming that they would receive a stream of benefits. If the new well causes well-interference problems so that the original wells no longer yield water, then the original well owners will have lost the remaining stream of benefits they have expected from their wells. The cost of reacquiring these benefits may involve lengthening their drop pipes, deepening their wells, drilling a new well, scheduling the pumping intervals, reducing their withdrawal rates, or pumping water from previously flowing artesian wells. However, this is really part of the cost of the investment in the new well. So the question is, "Who should bear these costs?"

Several of these conflicts have been settled out of court. The nature of the solutions has been that the new well owners have paid all or part of the costs of keeping the old wells operational. Thus, the cost of irrigation to these irrigators is higher than just the cost of drilling the wells and pumping

the water so that their net benefits are reduced.

Southwestern Minnesota is one area particularly dependent upon ground water supplies for municipal, industrial and agricultural use.

"During extended dry periods, the entire region will feel the effects of reduced recharge. Wells will become less productive and many wells may dry up all together. In general, each small community in the region has a potentially deficient supply. The regional and county service centers are particularly susceptible to deficient supplies because of their potential high rate of use. The City of Worthington has the worst potential deficiency. This is partly due to a poorly defined source of supply but also is due to the fact that the recharge area for their existing supply source is comparatively small and the existing supply source is probably being utilized at very nearly its maximum capacity. Worthington is the most probable location where recycling might be a feasible alternative for meeting future water demands. Similar deficiencies can be expected near Marshall in the future if additional large water demands occur. The Marshall area probably has more potential ground water supply than is now developed."¹²

Another potential trouble spot is the Fargo-Moorhead area where declining ground water levels have been observed. Originally, the city of Moorhead obtained all its water from a deep aquifer within the city limits. Because steadily declining water levels were observed, the city began to obtain most of its supplies from the relatively shallow Buffalo aquifer. However, because the water level in this aquifer was also declining, because of uncertain estimates of potential maximum sustained yield, and because of an increase in mineralization in the Buffalo aquifer, the city turned to the Red River as its main source of supply in the early 1960s. Expected growth of water demand in the area has prompted a study of the Buffalo aquifer to determine, in part, the effects of and potential for increased ground water development in the Buffalo aquifer and the effects and potential for its artificial recharge. The study will also seek to determine the effect of city withdrawals on other uses of the aquifer such as for domestic and irrigation wells.¹³

PART II. THE ECONOMICS OF WATER SHORTAGE - WITHDRAWAL USES

The uses of water considered in this part are withdrawal uses which involve the removal of water from its source. This is to be distinguished from non-withdrawal uses whereby the water is used where it is found. Examples of the latter are recreational water use, navigational use and hydroelectric power production.

In this chapter, we use the term "industrial" in a very broad sense. Thus, it is meant to include the agricultural industry as well as manufacturing industries and electric power production.

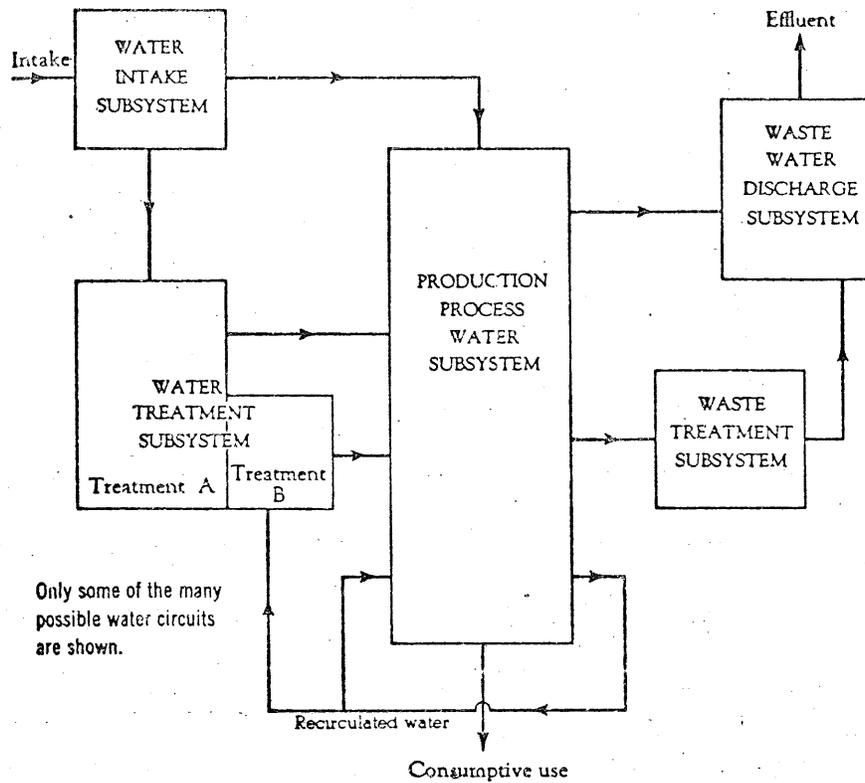
Using a definition supplied by Blair Bower, industrial water utilization may be defined as the "totality of water and steam flows - including intake water and waste water treatment - for all water uses within a production unit, from one or more points of intake through the one or more points of discharge of the final effluents."¹⁴

II-A. A GENERALIZED MODEL OF INDUSTRIAL WATER USE

Figure 3 below is a generalized abstract diagram of the main ways in which water is used in industry.¹⁵ Obviously, this model is not to be interpreted too literally. Not all of the subsystems shown are relevant to every industrial situation. For example, a farm may consist of a water intake subsystem (the well and pump), and a production process water subsystem (sprinklers and pipes), but no water treatment subsystem and no waste treatment subsystem. Brief descriptions of each component of this generalized model are as follows:

- (1) The water intake subsystem includes the equipment necessary to capture water from its sources and to transmit the water either directly to the production process subsystem or to the water treatment subsystem. Thus, for self-supplying firms, the water intake system would consist of such equipment as pumps, wells, transmission lines and/or pipes. For those obtaining water from an intermediate water supplier such as a municipal water utility, it would consist of equipment such as water intake pipes and the meters.
- (2) The water treatment subsystem is the equipment necessary to make the quality of intake water and/or recirculated water compatible with the requirements of the production process.
- (3) The production process water subsystem is that equipment necessary to circulate water and steam to where it is needed in production process itself. This would include water used for cooling purposes.
- (4) The waste treatment subsystem is that equipment necessary to make the quality of water to be discharged back to the environment compatible with externally imposed effluent standards.
- (5) Finally, the waste water discharge subsystem is the equipment necessary to physically discharge the water from the plant.

Figure 3. Generalized Industrial Water Utilization System



Source: Blair T. Bower, "The Economics of Industrial Water Utilization", in Allen V. Kneese and Stephen C. Smith (editors), Water Research. Resources for the Future, Inc., Baltimore. The John Hopkins Press, 1966. Figure 1., p. 145.

II-B HEAVY WATER-USING INDUSTRIAL SECTORS IN THE STATE OF MINNESOTA

Table 1, below, gives very rough estimates of the total quantities of water withdrawn and consumed by selected heavy water-using industrial sectors which in the aggregate account for roughly 84.6 percent of the water withdrawn and 88.6 percent of the water consumed.

According to these estimates, the electric utility industry alone accounts for 54.4 percent of the water withdrawn for industrial and residential use. Most of this water is used to supply steam for generators or for cooling purposes and most of it is discharged back to its water sources. Thus, this industry accounts for only 10.10 percent of consumption. Since most power plants are dependent upon river water, they are potentially susceptible to shortages during low-flow periods. However, new plants being built to replace others that are being retired and to expand power capacity will be relying primarily upon cooling towers rather than on once-through cooling. This will entail substantial recycling of cooling water. Thus, although water consumption will increase largely due to evaporative losses, water withdrawals will decrease. Future power plants will be less susceptible to power output cutbacks during low-flow periods. However, because of the increase in their consumption, their use of water during low-flow periods will tighten the supplies available for competing users down stream.

TABLE 1: Water Withdrawal and Consumption,
Heavy Water-Using Industries, 1976
(billion gallons)

<u>Sector</u>	<u>Withdrawals</u>	<u>Percent of Total Withdrawals</u>	<u>Consumption</u>	<u>Percent of Total Consumption</u>
Livestock	20.157	1.48%	20.157	9.22%
Crops	59.664	4.38	47.731	21.83
Food and Kindred Products	26.787	1.97	2.042	.93
Pulp and Paper	26.799	1.97	1.275	.58
Iron Mining	77.234	20.37	100.450	45.96
Electrical Utilities	740.585	4.42	22.075	10.10
<hr style="border-top: 1px dashed black;"/>				
Total, Heavy Water-Using Industries	1,151.226	4.60	193.730	88.63
<hr/>				
Total, All Withdrawal Uses	1,360.759	100.00	18.571	100.00

Source: Minnesota Energy Agency

The second heaviest withdrawing sector is iron (primarily taconite) mining which accounts for 20.37 percent of all withdrawals and 45.96 percent of consumption. Taconite and natural ore mining operations are located in the Northeastern part of the State. An expected future development in that area is the mining of copper and nickel and smelting operations. Both the taconite mining activities and the expected copper-nickel mining activities are in the vicinity of the Boundary Waters Canoe Area, an important recreational and wilderness asset. Projections made to date of water demand and water availability in the area seem to indicate that overall water availability to support these activities will be more than adequate in the foreseeable future.¹⁶ However, the possibility exists for localized conflicts of demand between iron mining operations and municipal water utilities and other localized conflicts involving iron mining operation.

Taken together, the food producing and food processing sectors (crops, livestock, and food and kindred products) account for 31.05 percent of water consumption. Pulp and Paper accounts for 1.97 percent of the water withdrawn. The figures given for the crop sector refer to irrigation water applied. It is assumed that 80 percent of this water is consumed.

II-C. Overview: Channels of Economic Impacts

As stated in the introduction to this report, water shortage problems and policies designed to cope with them affect the costs of firms. These, in turn, affect the rest of the economy through the market relationships between buyers and suppliers.

The nature and extent of firm reactions to changes in the availability and costs of using water will depend on factors peculiar to each firm.

"...to a large extent industrial water utilization problems are unique to each particular plant and to each plant site. Only gross generalizations are possible. Each situation involving plant site, production site, production process, product mix, and the water environment tends to be unique. At least this is the expressed viewpoint of many people in industry. Although this point of view is probably valid with respect to specific data, it is not valid with respect to generalizations about the nature and direction of responses of industrial water users to various factors."¹⁷

The purpose of this section, therefore, is to give an overview of the "nature and direction" of these responses and of their reverberations throughout the rest of the economy.

1. Specific Causes of Firm Reactions

The discussion of specific water problems in Part I identified several situations which can affect the costs of withdrawing firms. These include the following:

1. The cost of intake water could increase because:
 - a. Falling ground-water levels and increased well-interference problems could result in increased energy requirements for pumping groundwater and could force firms to invest in wells, or in drilling new well in order to retain their access to groundwater.
 - b. The price charged for delivered water could increase.
 - c. A charge for self-supplied water could be imposed or increased.
 - d. Limits could be imposed on the quantity of water which the user may withdraw from the source. The price of water used beyond the limit would become infinite or equal to a per unit penalty charge for exceeding it.
2. In order to allocate water on a river, limits or per-unit charges for water consumed could be imposed.
3. Because of increasing competition for water or because of a drought, the concentration of pollutants and of other dissolved and suspended substances from natural sources in a river or lake could increase. Then a firm withdrawing water could incur costs upgrading the quality of its intake water, seeking alternative supplies, or making other adjustments.

4. To assure that water quality standards were being met in a surface - water body characterized by increasingly worse low-flow periods over time, stricter effluent wasteload or thermal pollution standards could be imposed. If this occurred, the firms would incur increased costs in treating their wastes or in making other adjustments to reduce their effluent waste concentrations. An alternative approach to pollution control which would induce firms to intensify their pollution-abatement efforts would be the levying of or increasing of per unit charges against effluent waste concentrations of specific substances or classes of substances.

2. Long and Short Term Responses

The types of adjustments which firms can be expected to make to significant increases in their costs of using water will depend on the length of time considered and whether the cost increase is temporary or permanent. Certain adjustments can be made relatively quickly such as the number of hours worked, the amount of electricity and other types of energy forms used, and the amounts of chemicals applied. These inputs are sometimes referred to as variable inputs since they vary with the amount of output produced. The costs associated with them are variable costs. They include such things as hourly wage rates and overtime pay, electricity and other utility rates, and the cost of chemicals.

On the other hand, it takes longer to bring new wells, new production machinery, new pollution abatement equipment into operation, and even to hire salaried labor. These inputs are sometimes referred to as fixed inputs because, although they are associated with particular output capacities, they do not vary with day-to-day production. The costs they involve include fixed interest charges, depreciation, and fixed salaries. Such costs are called fixed costs.

A period of time long enough to allow changes in the amounts of variable inputs applied, but not long enough to allow for changes in fixed inputs, is called the short run. A period of time long enough to allow for changes in fixed inputs is the long run. Obviously, this is an oversimplification because different fixed inputs require different amounts of time to get on line and because some inputs have both fixed and variable aspects such as skilled labor and energy and water inputs from utilities. Nevertheless, the simplified dichotomy is useful for understanding the nature of possible firm responses.

3. Short Term Response Possibilities

It is convenient to divide short term response possibilities into two categories: 1) those which depend upon what part of the water use system of a plant is affected (specific responses), and 2) more general responses to increases in the per-unit costs of the plant.

a. Specific Responses

One course of action for firms affected by intake, consumption,

or effluent limitations, or by increases in the costs of intake, consumption or effluent discharge is to substitute. The exact nature of the substitution will, in part, depend upon the nature of the limitation or cost increase.

If such charges or more stringent limitations are imposed, one response may be to exercise tighter controls on leaks, wastes, and/or spills. This can reduce withdrawals, consumption, and/or effluent waste concentrations. This essentially would involve the substitution of labor for water and/or waste disposal. It has been suggested, for example, that in small meat packing plants, some refuse could be removed by using brooms and shovels rather than by hosing them away.¹⁸

In some circumstances, plants may have available more than one process to produce goods and services. The processes will vary according to the proportions of different inputs used and products and by-products produced. When limitations are imposed or made more stringent or when charges are increased, one response is to emphasize in the production process those processes which are less affected by the increased costs or limitations. For example, one paper mill in the state uses both groundwood and kraft processes for producing wood pulp. Fiber from the kraft process adds strength to the finished product. However, the kraft process requires more water than the groundwood process. Thus, one possible response to increased water-intake costs or limitations might be to emphasize a cheaper grade of paper (using a higher proportion of groundwood pulp) during a period when water intake is more restricted. Thus, in some circumstances, it may be possible to emphasize processes involving less water consumption or less waste production. Because these processes employ different combinations of inputs and outputs, shifting emphasis from one process to another involves input and output substitutions.

If more stringent pollution controls are imposed, one response might be to hold effluents in ponds or reservoirs and release them when river flows were back at higher levels. This would be very difficult to implement in situations where there were large volumes of discharge since the impoundment facility would have to be very large. Furthermore, while this might help the impounders to meet their pollution standards, it would result in reduced flows downstream. This would adversely affect withdrawal or flow uses of downstream users.

b. General Responses to Cost Increases

The institution of or increase of limitations on water intake, consumption, or effluent waste concentrations or the institution or increase of per-unit charges for these either directly or indirectly increase the per-unit costs of outputs of the firm. In response to such increases in unit cost, the firm may:

1. Reduce its rate of output.
2. Increase its prices.

3. Do nothing.

4. Close down.

When a firm is operating near full capacity, it is often operating under conditions of increasing unit costs; that is, as it produces at rates closer to capacity, its cost per unit (or dollar) output increases. Thus, one way for such a firm to reduce unit costs is for it to reduce its rate of output and cut back on variable factors of production including labor.

For plants with very high fixed costs such as utilities the region of increasing costs occurs only very close to plant capacity. Over most of the range of its output, the plant's operations are characterized by decreasing costs. When such a plant is operating in this range, reducing output will increase its unit costs.

The ability of a firm to raise product price depends upon its market position. If it sells in an industry where it faces a fair amount of competition, such as the pulp and paper industry, (and if its competitors are not facing similar problems), it may not be able to increase its price sufficiently to cover its increased costs.

In certain circumstances, a firm may not respond at all to an increase in the unit costs of the plant. For example, the unit-cost increase may be judged temporary and insignificant relative to unit profits. There may be discontinuities in production (for example, the firm may not be able to cut back on a small fraction of labor hours because it is committed to paying for so many hours per week from each of its employees for a certain period of time). The plant may be supplying inputs to higher levels of production, and it may be cheaper for the parent firm to obtain its inputs from this subsidiary, even though the subsidiary operates at a loss, than to obtain the inputs from another company.

If unit costs in the affected plant rise to the point that it cannot cover its variable costs, so that there is no surplus with which to pay off at least part of its fixed costs, the plant will shut down (unless it were still the cheapest source of supply of inputs to a higher level of production in the parent firm). If the water shortage or policy responsible for the increase in units costs were judged to be temporary, the plant closing might also be temporary. If the plant belonged to a multi-plant firm, the loss of production could be made up at some other plant of the firm, or the firm might try to recoup its lost production by operating at higher rates (running more shifts, etc.) at a later date.

Table 2 gives a rough indication of the ability of firms in selected manufacturing sectors to cope with increases in the costs of using water. The reason these indications are "rough" is because they are constructed using national data instead of primary data from Minnesota industries. In addition, the ratio net profits/net sales is compiled from 1977 data while intake/sales, consumption/sales, and gross water use/sales are compiled from data in the 1972 U.S. Census of Manufactures. Since 1972, some industries may have come to rely less on water intake because of more extensive use of water recirculation in order to meet federal and state anti-pollution legislation. Thus, the ratio intake/sales may be too high. Since recycling sometimes results in greater consumption, the ratio consumption/sales may be too low.

It seems doubtful, however, that the relative rates of water intake, consumption, or gross water use would have changed significantly among the industrial sectors. Thus, this table should give an indication of the relative sensitivity of these industries to changes in the costs of using water. For example, the data for paper mills indicates that the "average firm" used 5.51 thousand gallons of water for every dollar of profit in 1977. Assuming that such a firm can deduct the full increase in the cost of intake water from its federal and state corporate income tax liability (i.e., at a combined rate of 60 percent), the price of intake water need merely rise 30 cents per thousand gallons for the entire profits of the firm to be wiped out. On the other hand, if the same increase in the price of intake water were charged to "the average" soft drink plant, its profits would be reduced by 2.0 percent, i.e., for every dollar it had netted before, it would now net \$.98. This is because the soft drink plant is more profitable and uses less water. A similar comparison can be made for the relative impact of consumption charges.

TABLE 2

INTAKE, CONSUMPTION, AND GROSS WATER USE PER \$1 PROFIT
 SELECTED HEAVY WATER USING SECTORS, 1977

	$\frac{\text{Net Profits}}{\text{Net Sales}}$	$\frac{\text{Intake}}{\text{Sales}}$	$\frac{\text{Intake}}{\text{Profits}}$	$\frac{\text{Consumption}}{\text{Sales}}$	$\frac{\text{Consumption}}{\text{Profits}}$	$\frac{\text{Gross Water Use}}{\text{Sales}}$	$\frac{\text{Gross Water Use}}{\text{Profits}}$
	(Percent)------(1,000 gallons/dollar)-----						
Bakery Products	1.86	.002	.13	.0004	.021	.006	.30
Canned and Preserved Fruits & Vegetables	2.00	.016	.82	.0011	.055	.030	1.48
Dairy Products	1.47	.007	.46	.0004	.026	.012	.83
Malt Liquors	4.36	.017	.38	.0036	.082	.060	1.32
Meat Packing	0.75	.004	.58	.0001	.008	.007	.99
Soft Drinks	5.38	.006	.11	.0012	.022	.007	.13
Paper Mills	3.59	.198	5.51	.0072	.202	.594	16.55
Petroleum Refining	3.13	.010	.32	.0040	.128	.032	1.01

Source: United States Department of Commerce, Water Use in Manufacturing, 1972, Census of Manufactures.

"The Ratios of Manufacturing," Dun's Review, December, 1977, pp. 92-100.

4. Long-Term Response Possibilities

These include investments in various types of capital such as new wells, pumps, piping, pollution abatement equipment, and industrial processes which require less water or which give off less pollutants. Other long-term responses would be to shut down the plant completely or to move the plant to a new location.

Whether or not a firm will effect long-term responses to a change in the cost of using water will depend upon the size and duration of the change in costs and whether and how frequently it is expected to recur. In order to induce a firm to invest in pollution abatement equipment, new process machinery, or new wells, the present value of the benefits stream of that investment must exceed the cost of the investment. The present value of the benefit stream would, of course, include the costs of the problems to be alleviated. In other words, the present value of alleviating the problem, plus any other benefits, must exceed the cost of the investment. This may not seem to be the case if the problem were judged to be temporary and not likely to occur frequently in the future. Even the losses incurred by temporarily shutting down might not justify expenditure in additional equipment. If, on the other hand, the problem were judged to be permanent or recurring in nature, then investment in equipment might be judged appropriate.

5. The Federal Water Pollution Control Act and the Price/Cost Sensitivity of Water Use in Manufacturing Industries

Results of a study conducted by the Bureau of Domestic Commerce, U.S. Department of Commerce, indicate that efforts by manufacturers to comply with the water effluent standards imposed by federal pollution control legislation will result in such extensive water recycling that there will be little leeway for manufacturers to reduce their water withdrawals per gross water applied in response to increases in the cost of intake water.¹⁹ The phrase "gross water applied" means the total quantity of water needed to produce a stated quantity of output. Thus, it is the sum of water intake plus the amount of recirculated water necessary to produce that quantity.

In their study, the authors take the gross water applied for non-contact cooling and for the three industries studied to be constant. This weakens their conclusions that:

1. Under this legislation, manufacturers will be "much less sensitive to intake water prices since the cost-conscious manager of the manufacturing plant of the future will be employing all of the obvious methods of water conservation such as recycling as well as many of the not-so-obvious ones."²⁰
2. "If the goal of intake water pricing is to allocate net demands on stream flow in a river basin, then recycling water within the plant does not further this objective, since it's impact on consumption of water is negligible."²¹

The reasons these conclusions are weakened is that the authors do not take into account the possibility that a plant manager might be able to alter the gross water applied per unit of output, or to reduce total withdrawals and consumption by reducing the level of output. For example, if the plant were

operating in a zone of increasing unit costs, it could reduce its unit costs by reducing its output, even if the ratio of gross water applied to output or withdrawals per unit output were constant. Unit costs may be reduced because the firm can realize savings on other factors of production such as labor and/or energy costs.

Although their conclusions are weakened, they are at least to some extent viable since limitations on the ability to increase water recirculation do, in fact, close one avenue for reducing water intake. On the other hand, increased recirculation of water can actually result in increases in consumption. This is true, for example, when cooling towers replace once through cooling. More water is lost to evaporation with the former.

To analyze the effects of federal pollution control legislation, the staff of the BDC prepared simulation models of four manufacturing operations: 1) non-contact cooling, 2) cotton textile finishing, 3) kraft papermaking, and 4) steelmaking. Of these four, non-contact cooling and kraft papermaking have most relevance for Minnesota. The operations simulated employed current manufacturing technologies. Since they were done for hypothetical new plants, the results "may not be applicable for existing plants where the difficulties encountered in retrofitting and spacing of equipment and piping would greatly increase the costs over those developed for the study models."²²

Because non-contact cooling can be applied in several manufacturing industries and for power generation, results of the BDC study for this operation will be discussed in this section.

Processes which require or result in the generation of large amounts of heat will require some means of cooling their equipment and/or in-process outputs. In many cases, such heat may be dissipated through stacks by air connection or by radiation. Cooling by water, however, tends to be a more rapid method of cooling and allows for more accurate temperature control.²³

In 1973, about 47 percent of withdrawals of water in Minnesota manufacturing establishments reporting withdrawals of over 20 million gallons were for cooling purposes. Table 3 gives a breakdown of intake for cooling purposes for selected industries.

TABLE 3

WATER INTAKE FOR COOLING -- MINNESOTA
BILLION GALLONS

	COOLING AND CONDENSING			
	Total Water Intake	Steam Electric Power Generation	Air Conditioning	Other
Paper and Allied Products	43.6	14.6	(D)	5.3
Petroleum Re- fining	2.8	----	----	2.0
Rubber and Mis- cellaneous Plastics	.1	----	----	.1
Stone, Clay, and Glass Products	.5	----	----	.2
Primary Metal Industries	1.3	----	----	.5
Fabricated Metal Products	8.2	(D)	(D)	2.3
Electric and Electric Equipment	1.2	----	(D)	.5
TOTAL				
MANUFACTURING	90.2	6.5	2.1	24.2

D = Not Disclosed.

Source: Water Use in Manufacturing, Census of Manufactures, 1972.

Two basic approaches to cooling exist. In contact cooling, water is directly applied to the material to be cooled. This approach is used in taconite and primary metal production. One disadvantage of this method of cooling is that the water may absorb pollutants from the materials it cools.

A more common approach is non-contact cooling. With this method, water circulates through pipes, tubes, and jackets and does not come into direct contact with the substance being cooled.

"In past years, when water was plentiful, manufacturers took their cooling water from a surface stream or lake, passed it once through the cooling system, and returned the heated waste water to the source. More recently, induced by environmental and economic considerations, manufacturers have employed recirculating cooling water systems in which the heated water is cooled by evaporation in cooling towers or ponds and returned to the system rather than discharged."

To determine the impact of the federal pollution-control legislation on manufacturers using non-contact cooling, the BDC staff simulated a non-contact cooling water system with a flow through rate of 15 million gallons per day (mgd) which absorbs 2.5 billion BTU's of heat per day. Water withdrawn from the source serves to make up losses from "blowdown." Blowdown is the discharging of part of the water in circulation in order to control the build-up of dissolved solids due to scaling and corrosion.

The model is used to calculate the total costs per 100 gallons of gross water use that would be associated with different prices of raw water intake. Changes in these prices can, of course, also be taken to mean changing costs of pumping intake water from its source or of treating intake water caused by the problems discussed in previous sections.

The results of their study indicate that the sensitivity of water withdrawals per gross water applied to price changes is low under the assumed conditions. Thus, overall withdrawals will also be less sensitive to some increases.

"Since the manufacturer would be recycling 97.5 percent of his gross use anyway, intake is only equal to about 2.5 percent of his gross use. Prices charged for water withdrawals will not further improve recycling rates unless the price is over \$1.30 per 1,000 gallons. At this price, it would be more economical to demineralize the blowdown and recycle it rather than to discharge it. This would lower intake from 2.5 percent to about 2.0 percent of gross use."

The authors point out that this price would greatly raise system costs. This is shown in Table 4.

TABLE 4

SIMULATED NON-CONTACT COOLING SYSTEM (15 mgd)

Plant Operating at Most Cost-Effective Recycling Level

Price of Intake Water (Per 1,000 Gal)	Water Intake	Water Recycled	Water Consumption	Total Water-Related Costs Per 1,000 Gal. of Gross Water Use	Total Water-Related Costs Per Day
\$ 0 *	15.0 mgd	0 mgd	**	\$.045	\$ 675
0	.375 mgd	14.6 mgd	.300 mgd	.070	1,050
.10	.375 mgd	14.6 mgd	.300 mgd	.073	1,095
.50	.375 mgd	14.6 mgd	.300 mgd	.083	1,245
1.00	.375 mgd	14.6 mgd	.300 mgd	.095	1,425
1.25	.375 mgd	14.6 mgd	.300 mgd	.102	1,530
1.30	.300 mgd	14.7 mgd	.300 mgd	.103	1,545
1.50	.300 mgd	14.7 mgd	.300 mgd	.107	1,605

*Special Case. Costs and recycling practice indicated in the absence of water pollution control requirements. All other cases assume plant is meeting PL 92-500 standards. (Best Available Technology).

**Consumption in once-through cooling systems without cooling towers or lagoons occurs after discharge and is dependent upon the nature of the receiving body of water.

Source: Bureau of Domestic Commerce, An Analysis of Price/Cost Sensitivity of Water Use in Selected Manufacturing Industries (June, 1976), Table NC-1.

According to Table 4, the effect of an intake water price increase on water consumption per unit gross water applied is nil.²⁴ From the point of view of water allocation, this point is of crucial importance. If the problem during a low flow period is to allocate water between downstream and upstream users on a river, then allocation must take place over consumption.

There is, however, at least one way in which the quantity of water evaporated per unit of gross water applied may be reduced. This is by sending less material to cool through the system; that is, to reduce the rate of product output of the plant. This would also serve to reduce the amount of water withdrawn to make up for the water evaporated.

Although extensive recycling to comply with pollution-control legislation reduces withdrawals over what they would have been otherwise, it does not necessarily reduce consumption. On the contrary, less water is evaporated when once-through cooling is applied. Table 5 gives the water requirements for electricity generation in gallons per BTU generated. Note that the water withdrawn with a wet tower (the type of system simulated by the BDC) is much less than that withdrawn with a once through cooling system, but that the water consumed is much greater. In fact, the once-through system consumes less water than either of the two methods designed to abate thermal pollution--the cooling tower and the cooling pond.

TABLE 5

WATER REQUIREMENTS FOR ELECTRICITY GENERATION

IN GALLONS PER BTU GENERATED

(National Averages)

	Water Withdrawn	Water Consumed
Fossil - Once Through	1.97×10^{-2}	1.23×10^{-4}
Fossil - Wet Tower	$.50 \times 10^{-2}$	2.99×10^{-4}
Fossil - Cooling Pond	1.29×10^{-2}	2.52×10^{-4}

Source: Federal Power Commission

Nevertheless, one should not discount the importance of reducing withdrawal needs. A power plant with a cooling tower is less vulnerable to low-flow conditions in a river than if the same plant were to use once-through cooling. Thus, its customers are less likely to face higher rates during low-flow conditions.

6. Secondary Impacts

This section deals with how the response of individual firms to changes in the conditions of using water affects the rest of the economy. These impacts may be conveniently divided into two categories:

- a. Those impacts which occur through forward linkages.

b. Those impacts which occur through backward linkages.

a. Forward Linkages

Forward linkages are those market channels through which products of the affected firm travel. Thus, impacts through forward linkages involve such things as the impact on buyers of a cutoff in supply or an increase in the price of the product.

For example, the impact of increased costs of electricity production due to low-flow water conditions is largely through forward linkages since the economy as a whole is affected by the increase in electricity prices. Similarly, delays in barge traffic due to low-flow conditions impact upon the customers of the barge companies who must pay higher transportation costs or higher storage costs. This, in turn, may affect the prices of their products and affect the costs of their customers--be they consumers or other producers.

In general, the importance of impacts through forward linkages of water shortages for any particular firm will depend upon the availability of alternative sources of supply and the costs of transporting these alternative supplies to customers of the firm. If the availability of alternative supplies is limited, or the cost of transportation is high, then the impact on customers of the affected firm to a cutoff of the firm's output or to increased prices charged by the firm will be relatively more significant.

b. Backward Linkages

Backward linkages are those market channels through which the affected firm purchases its supplies of goods and services, through which suppliers of the affected firm obtain their supplies, and so forth. Economic impacts through these channels occur when the affected firm reduces its purchases of supplies from other firms and these firms, in turn, must reduce their purchases. Included in the category of impacts through backward linkages are changes in tax revenues and consumer purchases due to changes in the earnings of households. Households are also suppliers (of labor services) to the affected firms. When payments to households are reduced, household payments to government and household purchases of goods and services must similarly fall. Thus, a reduction in the output of any one firm is magnified throughout the economy. With the help of input/output analysis, impacts through backward linkages are in general more easily estimated than those through forward linkages. Table 6 indicates how events in any one sector are magnified throughout the economy due to backward linkages. This table gives multipliers computed using the Minnesota Energy Agency's MINTOM input/output model. Column 1 shows the amount by which every dollar change in output is magnified throughout the economy due to backward linkages. For example, if a drought caused output in the food processing industry to fall by \$1 million, total output in all industries (including the food and food processing industry) would fall by \$1.830 million. Note that the backward linkage effects for all the identified heavy water-using industries are substantial.

Column 2, 3, and 4 show the amount by which demand, employment, and income changes are magnified throughout the economy. Again, note the substantial backward linkage effects of the heavy-water-using industries.²⁵

TABLE 6

OUTPUT, DEMAND, EMPLOYMENT, AND INCOME MULTIPLIERS BY SPECIFIED INDUSTRY GROUPS

MINNESOTA, 1972

Industry Group	Multipliers (Direct and Indirect Effects)			
	Output	Demand -dollar-	Employment -number-	Income -dollar-
Agriculture				
1 Livestock*	1.840	2.253	4.990	6.234
2 Crops*	1.503	1.553	1.226	3.823
3 Other Agric.*				
Mining	1.548	1.553	1.330	1.315
4 Iron Ferro*	1.357	1.432	1.683	1.752
5 Non-Ferrous	1.336	1.362	1.390	1.348
6 Other, Quarry	1.362	1.370	1.250	1.220
7 Construction				
Manufacturing	1.523	1.523	2.049	1.555
8 Food & Kindred*	1.830	2.299	5.042	2.678
9 Lumber, Furn.	1.296	1.591	1.720	1.655
10 Pulp & Paper*	1.329	1.844	2.181	2.040
11 Print. & Publ.	1.484	1.759	1.660	1.536
12 Chemical, etc.	1.344	1.635	2.305	2.129
13 Petrol Refin.*	1.319	1.367	3.663	2.331
14 Stone, Clay, Gl.	1.366	1.480	1.574	1.642
15 Primary Metal	1.297	1.384	1.417	1.337
16 Fabric. Metal	1.331	1.420	1.479	1.432
17 Machinery	1.324	1.582	1.733	1.647
18 Electrical	1.306	1.559	1.637	1.526
19 Other Mfg.				
Transportation	1.311	1.630	1.561	1.451
20 Railroad	1.354	1.431	1.250	1.208
21 Trucking	1.238	1.300	1.141	1.221
22 Other Trans.	1.329	1.434	1.503	1.320
23 Communication				
Utilities	1.172	1.189	1.206	1.137
24 Electric Util.*	1.428	1.498	2.701	1.938
25 Gas Utilities	1.231	1.675	2.099	1.842
26 Other Util.*				
Trade	2.139	2.140	7.329	2.784
27 Wholesale	1.292	1.311	1.192	1.232
28 Retail	1.250	1.253	1.074	1.220
29 Finance (Fire)				
Services	1.223	1.360	1.864	1.612
30 Motels, Pers.	1.385	1.425	1.242	1.410
31 Business Serv.	1.570	1.605	1.321	1.410
32 Medical, Educ.	1.319	1.340	1.164	1.173
33 Other Service	1.246	1.251	1.185	1.215
34 Fed. Govt. Ent.	1.416	1.416	1.348	1.147
35 State-Loc. Ent.	1.549	1.550	1.159	1.603

*Indicates Identified Heavy-Water-Using Section.

Source: Minnesota Energy Agency

7. Mitigating Factors

The magnitude of the economic impacts of a water shortage may to some extent be mitigated with the passage of time or over space. In general, the larger the geographical perspective, the less severe will be the monetary value of economic losses. If, for example, output, employment, and earnings in a particular area decline due to a drought, these losses may at least in part be made up in another area of the state or country where conditions of water availability are relatively more favorable.

The adverse economic effects of a drought may also be mitigated with the passage of time. Reductions in output may be made up by operating at higher rates at a later date. Reduced demand by individuals and firms adversely affected by the water shortage may in part be deferred demand which will be exercised later. The demand for certain products such as irrigation equipment, pumps, and the services of well drillers are stimulated during water-shortage conditions. Eventually investments in water-saving capital equipment, cooling towers, process-water recycling equipment and the like will stimulate the industries supplying these products as well as other industries which support them.

The degree to which increased output in alternative times or places and water-shortage-induced investments will offset economic losses in the water-short area will depend upon the availability of unemployed resources (primarily labor) in the alternative times or places. If the increased output draws resources from other activities in the alternative times or places, the offsetting affects will be reduced as input prices are driven up.²⁶

Finally, if the output of heavy-water using sectors decreases in an area, and heavy-water-using firms close down, they may eventually be replaced with new industries seeking to take advantage of idled resources in the area. This would in some respects be a desirable outcome since it would reduce the pressure on water resources in the area while still providing economic benefits.

II-D. The Economic Impacts of Water Shortages in Specific Industrial Sectors

1. Agriculture

The potential effects of water shortages resulting from a drought on the agricultural economy include financial loss, bankruptcy, geographic dislocation of the farmer, regional economic disruption and migration, government relief and loan programs, food shortages, and rising food prices. Even when the physical aspects of a drought have disappeared, its economic and social effects linger on. Farmers may have to wait additional years for soil moisture to accumulate to the levels necessary for crop production. Similarly, livestock farmers may face lengthy delays in rebuilding their herds. Loans taken out to allow farmers to continue operations will have to be repaid long into the future.

The great drought of the 1930's prompted many social, economic, and technical drought adjustments in this country. These include the development of new conservation practices and drought resistant crops, the increasing use of irrigation, the adoption of more diversified and improved farm management techniques, and the creation of more liberalized farm credit and crop insurance programs. A portion of the adverse financial effects of a drought can be modified by strong farm prices and a healthy economy. Also, the large amount of research that has been done on water conservation and augmentation, weather prediction and modification, irrigation and river basin development has also led to diminished impacts. However, due to the ever growing international dependence upon limited food reserves, droughts in prime agricultural regions can have more far reaching effects than ever before.

Because of the basic inability to precisely determine the beginning and end of a water shortage, it is equally difficult to categorically state the full economic impact of a drought on agriculture. Additional factors complicating the analysis include the fact that droughts have different impacts upon various sectors of the agricultural and general economy and that each of these sectors is financially related in different ways. For example, a drought-related crop failure in one region may work to the benefit of unaffected farmers and to the detriment of consumers due to resulting increased market prices. However, drought damages can roughly be broken down into two basic categories--primary and secondary. The primary damages are the initial financial setbacks faced by the farmer. The secondary damages are a measurement of the degree to which these financial adjustments are transferred throughout other sectors of the economy.

The initial impact of a drought on the farm-level is a reduction of per acre crop yields. Tables 7 and 8 show ten year average yield figures for corn and wheat for the nine crop reporting districts in Minnesota.²⁷ These tables reveal two major points. The first factor is that the majority of crop reporting districts witnessed sizable decreases in yields beginning in 1974 and ending in 1976, the years which correspond to Minnesota's most recent drought. Although there were other climatologic factors involved in the low yields of these three years, the drought was almost entirely responsible for the low yields of 1976. The second major point of these tables is that the decreased output was by no means uniform throughout the State. In fact, some areas in the State actually had better harvests during 1974 through 1976 than they had ever had. This again illustrates the variable impacts a drought can have throughout a given area.

TABLE 7

CORN YIELDS PER HARVESTED ACRE BY CROP REPORTING DISTRICT

Years	North West	North Central	North East	West Central	Central	East Central	South West	South Central	South East	State
1967	43.1	38.6	27.0	54.3	69.9	64.7	70.1	86.2	76.9	72
1968	45.2	46.9		67.2	78.4	73.3	80.1	94.4	81.7	81
1969	52.5	41.4	35	70.8	79.2	59.7	87.4	98.7	88.5	85
1970	44.5	58.7	0	65.8	82.5	79.7	81.3	100.5	92.9	85
1971	56.9	52.2	0	71.8	78.0	76.9	79.9	94.2	92.6	83
1972	59.8	57.6	0	70.4	86.8	82.5	96.6	106.7	99.8	93
1973	59.6	57.8	0	83.5	91.2	83.4	85.8	106	104.6	93
1974	45.7	38.5	0	49.2	54.4	47.9	55.5	78.1	68.7	61
1975	45	35	30	56.1	67.8	61.3	60.1	82.3	84.7	70
1976	36.9	33.6		32.9	50.6	45.8	44	78.8	76.4	59
1977	61.1	63.4		82.5	95.9	89.5	97.1	111.1	114	100

SOURCE: Compiled From Minnesota Crop and Livestock Reporting Service

TABLE 8

WHEAT YIELDS PER HARVESTED ACRE BY CROP REPORTING DISTRICT

Year	North West	North Central	North East	West Central	Central	East Central	South West	South Central	South East	State
1967	32.4	24	19.8	31.5	33.1	28.1	32.8	32.7	29.5	32.1
1968	32.9	25	21.3	32.9	34.4	29.3	32	35.3	31.4	32.9
1969	30.6	18.7	17	27.3	28.2	21	26.5	27.9	27.8	29.4
1970	27.5	21.1	19	27	29.8	25.8	28.3	30.7	27.4	27.6
1971	39.8	30.5	25	34.6	29.8	27.2	33.7	30.8	28.4	37.9
1972	36	29.8	24	25.7	27.3	26.8	29.8	33.6	31	32.9
1973	38.7	32.6	24	39.7	39.9	31.8	32.7	38.4	35.7	28.9
1974	27.5	22.4	20	29	35.8	31.5	33.4	39.3	36.1	38.9
1975	33.4	26.4	22.9	27	30.6	27.0	32.5	30.5	28	30.8
1976	36.5	32.6	30.1	22.1	36.7	30.7	31	44.5	37.2	32.2
1977	34.9	31.5	37	42.4	47.6	37.8	48.4	49.5	41.6	39.6

SOURCE: Compiled From Minnesota Crop and Livestock Reporting Service

A decrease in farm yields immediately translates itself into farm income losses. Minnesota's recent drought experience offers some insight into the financial impact of droughts on farmers in this State. The Minnesota Farmers' Union Drought Task Force made drought loss estimates for crops in 1976, shown on Table 9. The Task Force, in cooperation with the Minnesota Department of Agriculture, completed these estimates by surveying county Agricultural Stabilization and Conservation Service disaster committees throughout the State. The \$1.45 billion dollar loss in 1976, is based upon mid-September crops prices. However, this \$1.45 billion dollar crop loss estimate only begins to touch upon the full extent of the financial dislocations brought about by the drought. Other factors besides crop loss must be considered when assessing drought losses.

As of February 24, 1977, approximately 1,900 wells had gone dry. This means that farmers all over the State either had to drill new wells, begin hauling water, or simply stop operations. Livestock, poultry, and dairy farmers also witnessed damaging financial setbacks during the drought. Early 1976 hay crops were extremely marginal. Dried out pastures allowed only minimal grazing, and low yields on field crops provided little relief. Livestock farmers were forced to pay very high prices for feed and hay when it was available. Many farmers resigned themselves to total or partial herd liquidation due to lack of feed, hay and pasture. Also, many operations were forced to begin hauling water for livestock consumption needs. When one considers that it takes approximately three years from breeding to get a new cow on the milking line, one can begin to see the long term impact of drought hardship.²⁹

Farms throughout the State were forced to rely on their feed and cash reserves to stay in business. Many farmers were unable to meet their already high debt payments. Most of these businesses required many new loans to meet their costs of operation and debt repayment. As of July, 1977, the Minnesota Department of Agriculture estimated that outstanding debt of Minnesota Farmers was in excess of \$4.3 billion. This figure is 77 percent higher than the 1974 debt figure of \$2.4 billion. The debt was owed to a combination of commercial banks, Bank of Cooperatives, Federal Land Bank(s), Production Credit Associations, and the Farmers Home Administrations. Table 10 shows the results of a farm credit survey taken by the Minnesota Department of Agriculture.³⁰

Another source of debt is the purchases of fertilizers, pesticides, machinery, fuel, and other farm supplies. This debt is generally held by private individuals and the agricultural service industry. No current estimate of the size of that debt is presently available.

It is important to realize that farm establishments facing serious cash flow and credit problems cannot consume the usual quantities of goods and services from their community business dealers. This means that new tractors are not going to be bought, homes are not going to be improved, and families will do without the new car they were planning to buy. This has an extremely deleterious effect on the local business community. Local business dealers will be forced to cancel their orders for merchandise from suppliers and forego other goods and services. The impacts ripple throughout the entire State economy. Tax revenue is lost, farm transfers and bankruptcies are magnified and migration from the affected area commences.

TABLE 9

MINNESOTA FARMERS UNION DROUGHT TASK FORCE ESTIMATES
ON 1976 DROUGHT LOSSES
FOR CROPS BY COUNTY

1. Redwood	\$68,791,080	45. Traverse	\$13,958,675
2. Renville	56,389,900	46. Sherburne	12,519,350
3. Ottertail	48,648,495	47. Chisago	12,000,639
4. Yellow Medicine	45,021,800	48. Waseca	10,028,927
5. Lyon	43,149,600	49. Wright	10,574,762
6. Lac Qui Parle	41,484,424	50. Freeborn	10,210,000
7. Murray	39,734,112	51. Carver	9,966,405
8. Olmsted	37,993,220	52. Scott	8,813,144
9. Jackson	36,895,213	53. Blue Earth	8,634,700
10. Big Stone	35,615,160	54. Wadena	8,509,342
11. Stearns	35,532,280	55. Benton	8,428,591
12. Nobles	33,961,650	56. Faribault	8,255,000
13. Chippewa	33,145,930	57. Washington	7,582,625
14. Cottonwood	32,318,800	58. Cass	7,573,004
15. Martin	32,232,516	59. Isanti	6,946,880
16. Mower	32,189,360	60. Mille Lacs	6,670,128
17. Rock	31,509,360	61. Rice	6,390,141
18. Brown	31,032,985	62. Kanabec	4,813,816
19. Wilkin	27,574,640	63. Crow Wing	4,602,954
20. Winona	26,862,765	64. Hubbard	4,597,340
21. Kandiyohi	25,643,310	65. Pine	4,419,850
22. Pipestone	25,601,450	66. Aitkin	3,793,581
23. Dakota	25,128,130	67. Hennepin	3,691,280
24. Le Sueur	23,960,600	68. St. Louis	2,970,109
25. Swift	23,806,503	69. Beltrami	2,939,555
26. Steele	22,492,000	70. Carlton	2,937,585
27. Stevens	22,217,325	71. Marshall	2,724,500
28. McLeod	22,122,070	72. Clearwater	2,716,570
29. Pope	22,103,884	73. Mahnomen	2,193,168
30. Lincoln	21,233,235	74. Itasca	1,672,087
31. Douglas	20,979,970	75. Norman	1,625,000
32. Watonwan	20,862,330	76. Houston	1,585,890
33. Morrison	20,650,236	77. Red Lake	1,482,000
34. Clay	18,741,740	78. Goodhue	1,247,839
35. Fillmore	18,178,100	79. Pennington	520,000
36. Dodge	17,806,650	80. Wabasha	392,550
37. Sibley	16,550,370	81. Ramsey	234,285
38. Grant	15,606,220	82. Lake	130,000
39. Becker	15,319,552	83. Cook	0
40. Polk	15,132,190	84. Kittson	0
41. Nicollet	14,979,350	85. Koochiching	0
42. Meeker	14,611,000	86. Lake of the Woods	0
43. Anoka	14,078,868	87. Roseau	0
44. Todd	14,059,275		
		TOTAL	\$1,450,299,920

TABLE 10

JULY 29, 1977 SPECIAL FARM CREDIT SURVEY BY THE MINNESOTA DEPARTMENT OF AGRICULTURE

OUTSTANDING MINNESOTA FARM DEBT, 1974-1977 COMPARISONS, HELD BY MAJOR LENDERS

(All balances outstanding shown are for June 30, taken from official agency and federal government reports, except for the June 30, 1977, balances shown for Commercial Banks and the Insurance Industry. These two balances **are estimates based on official December 31, 1976 debt outstanding and data obtained in a special survey of spokespersons for the banking and insurance industries. *The Insurance Industry balance for 1974 also is a December 31 official figure, as this industry reports only annually to the U. S. Department of Agriculture on farm real estate loans outstanding.)

	<u>1974</u>	<u>1976</u>	<u>1977</u>	<u>1977 GAIN OVER</u>	
				<u>1974</u>	<u>1976</u>
Federal Land Bank	\$ 415,243,682	\$ 632,221,333	\$ 796,916,525	91.9%	26.1%
Bank For Cooperatives	283,526,000	501,394,000	723,149,000	155.1%	44.2%
Farmers Home Administration	148,716,973	215,054,000	296,618,000	99.5%	37.9%
Commodity Credit Corporation	78,711,630	28,166,781	135,124,510	71.7%	379.7%
Production Credit Associations	315,958,701	488,653,000	543,653,000	72.1%	11.3%
Commercial Banks	\$ 993,055,000	\$1,373,182,000	\$1,560,000,000**	43.0%	13.6%
Insurance Industry*	<u>194,600,000</u>	<u>217,375,000</u>	<u>250,000,000**</u>	<u>28.5%</u>	<u>15.0%</u>
TOTALS	\$2,429,811,986	\$3,466,046,114	\$4,305,461,035	77.2%	24.2%

(The December 31, 1976, farm debt outstanding in Commercial Banks of Minnesota was \$1,420,281,000---including \$217,617,000 on farm real estate and \$1,202,664,000 on chattel. The December 31, 1976, farm debt held by the Insurance Industry in Minnesota was officially reported at \$199,985,000. Insurance spokespersons emphasized that until the recent change of the usury law by the Minnesota Legislature, the insurance industry had been reducing its farm loan volume in this State; that the recent change has resulted in unprecedented and continuing demand for farm loans.

NOTE: The above table contains no official figures or estimates on two important areas of outstanding farm debt: a) Supply and service accounts of fuel, fertilizer, seed, feed, pesticide, and equipment dealers for the current production season; and b) The farm real estate debt held by individuals and private investors on contract for deed land sales.

One of the more immediate impacts of the drought was the tremendous increase in the growth of irrigation in the State. Irrigation dealers and experts were inundated with requests for information on irrigation practices. While other farm equipment dealers suffered, irrigation dealers were experiencing a boom.

Drought can have many positive and negative benefits on irrigated agriculture in Minnesota. Due to the intensified crop stress, larger volumes of water will probably be applied to existing acreage to maintain optimum production potential. Irrigation enables farmers to obtain normal yields while their neighboring dryland farmers' crops are withering. However, increased pumping volumes may lead to serious side effects. For example, an increased demand on shallow groundwater aquifers may lead to aquifer depletion and necessitate the drilling of deeper wells. There is also increased potential for well interference between domestic, irrigation, industrial and municipal supplies, conceivably leading to costly legal contests. An increased pumping rate requires increased energy consumption. This can dangerously affect the ability of local generating utilities to meet peak electrical demands. There is additional potential for deteriorating ground and surface water quality due to increased leaching of soil nutrients, increased run off and increased erosion.

With a dramatic increase in interest in irrigation, there is always a potential for irrigating non-suitable soils. Farmers must be increasingly aware of the soil, climate, labor, and economic requirements of operating modern irrigation equipment. When used under the appropriate circumstances, irrigation can be a boom to the local economy.

The increase in irrigation in the State has been coupled with an increased use of conservation techniques to cope with variable moisture conditions and to protect the local environment. Much research has already been done to promote the most efficient irrigation practices. Many new innovations have been employed throughout the country with excellent results. It has been repeatedly shown that water conservation not only saves water, but money as well.

Drought adjustments can broadly be classified into two major categories: adjustments which alter agricultural water requirements; and, adjustments which attempt to modify the natural resource cycle. Obviously, irrigation has been one of the major features in adjusting to varying moisture levels. However, there has also been a tremendous amount of research done on developing new cultivation practices for dryland farming which can better cope with severe water shortages. Some of these adjustments include the use of summer fallow, stubble mulching, strip cropping, contouring and land leveling.

Another large-scale effort has been the improvement of the operational flexibility in the modern agricultural system. There has been a concerted attempt to make farm operations less susceptible to variations in the amount and distribution of precipitation. One method for reducing the need for water on the farm is to reduce the rate of water consumption. This can be achieved by adjusting crop and livestock varieties and cultivation techniques to the available water supplies. Flexibility in cropping patterns can also be an aid in preventing complete crop failure. Diversification of farming activities is another mode of agricultural adjustment. This may help to lessen the impact of a water shortage. When one enterprise fails, farmers will have others to fall back on.

Livestock operations have numerous options to pursue. This includes grazing rotation systems, range reseeding, supplemental feeding, creation of rural water systems, the adjustment of livestock numbers and the liquidation of part or all of the stock.

Land use regulation may be used to help regions adjust to variation in moisture levels. Regulation can be employed to control the land development rate, to stimulate the return of agriculturally marginal land to idle land and to encourage the adoption of various types of drought adjustments.³²

Attempts to modify the natural resource cycle has fallen into the realm of weather modification projects and improved weather prediction and forecast techniques. Although the control of the water cycle still lies far into the future, more accurate weather predictions can serve to eliminate some of the risk and uncertainty in agricultural production. Greater knowledge about the potential for moisture variation can aid farmers in the adoption of new operating techniques.

Agricultural adjustments to water shortages often take the form of financial aid to farmers. Financial protection devices can help supplement income and mitigate the direct financial impact on the agricultural system. Drought insurance is the primary mechanism for reducing monetary loss from drought. Insurance is a method by which a certain fixed cost is paid to reduce the possibility of a future drought related loss. Insurance usually allows farmers to recover most of their production expenses and a portion of the value of the lost crop. Feed and grain reserves are another method of protection and self insurance. Feed reserves can be used to feed livestock when other crop supplies are low. Excess feed can be sold during dry periods to provide additional sources of income.

Credit is an additional mechanism by which losses can be budgeted over time. Credit serves to smooth out the variability of income from drought reduced yields. It can be used as a direct adjustment during periods of financial stress or to finance conservation techniques used on the farm.

Government relief and rehabilitation is another primary mechanism for relieving financial stress. Government aid spreads the cost of the drought throughout society by providing supplemental support to stricken farmers. Specific government programs include sale of feed grain at reduced prices, freight cost sharing on hay shipments, cost sharing on water conservation measures, emergency loans, and loans of emergency water equipment.³³

Table 11. Industry Statistics for Food Processing in Minnesota, 1976

CODE	STATE AND INDUSTRY GROUP	1976									
		ALL EMPLOYEES		PRODUCTION WORKERS			Value added by manufac- ture (million dollars)	Cost of materials (million dollars)	Value of industry ship- ments (million dollars)	Capitol expendi- tures, new (million dollars)	End-of- year invent- ories (million dollars)
		Number	Payroll	Number	Man- hours	Wages					
		(1,000)	(million dollars)	(1,000)	(millions)	(million dollars)	F	G	H	I	J
	MINNESOTA	321.0	4,141.6	197.9	380.9	2,127.5	8,473.0	12,147.3	20,439.5	494.9	2,625.8
20	FOOD AND KINDRED PRODUCTS	43.5	485.1	33.3	61.8	343.1	1,513.5	5,096.4	6,559.6	104.7	483.8
201	MEAT PRODUCTS	14.6	117.9	12.2	22.0	142.1	503.2	1,663.5	2,160.5	10.8	80.9
2011	MEATPACKING PLANTS..	8.0	131.0	6.4	12.0	106.5	411.5	1,328.9	1,739.9	5.3	40.8
202	DAIRY PRODUCTS	6.6	70.7	5.1	9.7	50.0	261.9	1,461.1	1,720.5	13.6	80.6
2022	CHEESE, NATURAL AND PROCESSED	2.9	27.7	2.6	4.9	24.1	98.9	715.3	813.0	3.1	56.3
203	PRESERVED FRUITS AND VEGETABLES	6.5	47.6	5.9	10.3	37.8	152.4	230.6	385.0	8.4	96.3
2033	CANNED FRUITS AND VEGETABLES	3.2	20.0	2.9	4.4	15.7	74.2	107.2	181.5	3.6	67.1
204	GRAIN MILL PRODUCTS..	3.2	41.5	2.3	4.6	26.5	154.2	578.5	731.6	4.7	49.3
205	BAKERY PRODUCTS	2.6	32.9	1.5	2.6	18.1	60.6	46.1	106.5	2.4	4.1
206	SUGAR, CONFECTIONERY PRODUCTS	2.6	27.6	2.3	4.6	22.6	67.1	162.3	224.6	26.9	28.6

SOURCE: ANNUAL SURVEY OF MANUFACTURERS, U.S. DEPT. OF COMMERCE, 1976

2. Food Processing

Agricultural processing plays a vital role in Minnesota's economic structure. In 1975, Minnesota was ranked first nationally in the production of turkeys, butter and non-fat dry milk; agricultural commodities which all require a high degree of processing. Minnesota is also a significant producer of processed commodities such as beet sugar, sweet corn, green peas, dairy and poultry products, beef, and veal. Water of sufficient quality and quantity is a major necessity in the continued safety, efficiency, and growth of the agricultural processing industries in the State.

Table 11 provides summary statistics on various financial aspects of agricultural processing in Minnesota. The total number of employees of the food and kindred products sector of the economy reached 43,500 in 1976. The total payroll for this same year was \$485.1 million dollars. It is important to note that of the \$12,147 billion dollars spent for "the cost of materials," roughly half was spent by the food and kindred products sector. This figure illustrates the mutual dependence between agricultural processing and agriculture production, and the impact which both of these sectors have on the overall economy. Food and kindred products were responsible for approximately 13 percent of the total employees in the State and 21 percent of the new capital expenditures.³⁴

Table 12 is a summary review of the estimated water withdrawals for some agricultural processing in Minnesota for 1976. These selected industries accounted for approximately one-half of the total annual withdrawals in food processing. For each of the six agricultural sectors, an estimate has been provided for average gallons per day and total gallons per year usage. Gallons per year water requirements were calculated by multiplying average daily water use times the number of days the plant operates per year. The days per year of operation depends upon the nature of the industry, the production capacity of the firm, and the total output. The following sections give a brief description of each of the six processing sectors and the nature of their water use.

TABLE 12

ESTIMATED WATER WITHDRAWALS FOR SELECTED AGRICULTURAL
PROCESSING INDUSTRIES IN MINNESOTA - 1976

<u>Sector</u>	<u>Gallons Per Day in Million Gallons</u>	<u>Gallons Per Year In Million Gallons</u>	<u>Percent of Annual Total Processing Water</u>
Sugarbeets	3.57	598.60	2.23
Processed Vegetables	18.21	2,632.97	9.83
Livestock Slaughter & Manufacture	14.39	3,741.60	13.96
Poultry Slaughter	6.96	1,545.40	5.76
Eggs Processing	0.81	209.29	.78
Dairy Products	<u>16.04</u>	<u>4,487.28</u>	<u>16.75</u>
Total Selected Industries	59.98	13,215.14	49.34
Total All Food Processing	*	27,787.04	100.0

Source: Water Requirements and Issues in the Minnesota Agricultural System, 1976, p. 129.

SUGARBEETS

According to the Minnesota Crop and Livestock Reporting Service, approximately 248,000 acres of sugarbeets were harvested with a total yield of 3,026 tons in 1976. Beet sugar is currently processed in five major plant locations in the State. The period in which the raw beets are processed into sugar, known as the campaign, lasts from 120 to 140 days, and typically runs from mid-September to mid-February or early March. This is the period during which the bulk of 598.60 million gallons of water (Table 12) is used in the processing operations. Some of the plants do, however, engage in the processing of the liquid beet sugar on a yearly basis.

Water has five major roles in the beet processing operations: it acts as a carrying agent in the transportation of beets into the plant; it is used in the diffusion process during processing for boiler feed water; cooling equipment; sanitation; and, general cleanup. The amount of water used in a campaign will depend upon the condition of the beets, the size of the harvest, the time of the harvest, the equipment wear, and the type of engineering the plant employs. The industry, in general, attempts to recirculate as much water as possible. From Table 12 we can see that sugarbeet processing uses approximately 2.2 percent of the total water withdrawn in agricultural processing.

PROCESSED VEGETABLES

Minnesota agri-business firms process and can a vast array of State grown vegetables. A listing would include asparagus, green beans, pumpkins, cucumbers for pickles, potatoes, sweet corn and peas. According to the Minnesota Crop and Livestock Reporting Service, Minnesota produced 5,654,000 hundred weight of processing potatoes, 503,200 tons of sweet corn, and 82,000 tons of peas in 1976. This study identified 35 plants which were involved in some aspect of the vegetable processing industry.

The majority of the 2,632.97 million gallons of water used in 1976 for processed vegetables were used in canning operations (Table 12). The two major crops canned in Minnesota are peas and sweet corn, and most canneries have the production capacity to can both products. Peas are usually packed from mid-June to mid or late July. Corn is typically canned from early or mid-August to mid or late September. Plants that can both products are usually shut-down for one to two weeks between canning operations. Pumpkins, asparagus, beans, and potatoes are also canned in this State, but on a very marginal level. Pickles and potatoes are both processed on a large scale in this State, with most of the plants operating on a year long basis. Some of the potato products, however, only require a processing season from six to eight months.

There are numerous functions that water fulfills in vegetable processing operations. It is used in the washing and intra-plant transport of the vegetables, for cooling and washing cans in the canning operations, for sanitation and cleanup of equipment and facilities, and for the making of brine. The amount of water needed will depend upon the type of processing equipment, the engineering set-up of the plant, the amount of recycling of water permitted, the type and amount of the vegetable processed, and the size of the plant.

According to Table 12 approximately 9.8 percent of the total water withdrawn by the food processing industry is for vegetable processing. It should be remembered, however, that most of the water is needed during the summer and fall months for canning.

LIVESTOCK SLAUGHTER AND MANUFACTURE

This class of agricultural processing includes the slaughter of cattle, calves, sheep, lambs, and hogs that takes place in Minnesota licensed meat packing companies and the manufacture of sausage. It does not include the meat processing that occurs in custom slaughter houses or in wholesale or retail meat operations. We have identified ten sausage manufacturers and 19 meat packing companies currently operating in Minnesota.

This sector of processing is the second largest water user accounting for 14 percent of the total water withdrawals of the food processing industry. Although sausage manufacture required 130.98 million gallons of water in 1976, it only accounted for approximately four percent of the total water used in meat processing. The huge amounts of water needed for meat slaughter are due to the large scale of the industry and immense amount of water required for cleaning operations. Minnesota Crop and Livestock Reporting Service estimated that the total livestock slaughter in 1976 was 2.86 billion liveweight pounds.

As in the other agricultural sectors, water serves many vital functions in the meat processing industry. It is used to feed livestock during the holding period before slaughter; for washing carcasses; for cleaning the slaughtering floor and walls; for cleaning livestock holding pens; carcass coolers; tools and equipment, and for scalding operations prior to hog slaughter.

Slaughtering and sausage manufacture is a five day a week, year-round operation. The daily water requirements were estimated at 14.39 million gallons in Table 12. If we exclude vegetable processing, which is mostly a seasonal operation, livestock slaughter and manufacture is the largest water user on a daily average basis.

POULTRY

The Minnesota Crop and Livestock Reporting Service estimated that in 1976, 96.4 million pounds of chicken and 437.2 million pounds of turkey were slaughtered in federally inspected poultry plants in Minnesota. In 1976, Minnesota ranked first nationally in the production of turkeys.

Table 12 shows that poultry slaughter accounts for 5.8 percent of the average daily water use and 11 percent of the total water withdrawals of the food processing industry. There is a wide range in the number of production days for different plants, running from 140 to 260 days per year, depending upon the size and nature of the slaughtering plant. A yearly total was determined by multiplying average gallons per day usage for each plant times the average number of days each plant operates.

The largest use of water in this industry is for cleaning operations. Most plants are thoroughly cleaned four times a day, with the feathers and entrails constantly flushed out during and after evisceration. Water is also required for scalding the birds to remove feathers and dirt, for washing the interior and exterior of the birds during slaughter, for ice manufacture, and for refrigeration.³⁵

EGG PROCESSING

There are presently 19 federally inspected egg processing plants in operation in the State of Minnesota. They use approximately 209.29 million

gallons of water per year and typically operate on a year-round basis. From December, 1975, through November, 1976, Minnesota produced 2,289 million eggs.³⁶

The water requirements for this sector are again basically for cleaning and sanitizing the product and equipment. All eggs must be carefully washed with a water and detergent solution, and the plant and equipment must be kept sanitary at all times. There is also a need for water to maintain the boilers and for refrigeration.

DAIRY PRODUCTS

The final sector in this analysis is dairy products. In 1975, Minnesota produced 8.9 million pounds of milk. All of this milk must be processed in some manner before it reaches the consumer. There are six basic milk products which are manufactured in this State: butter, cheese (and whey), dry milk, evaporated milk, ice cream and packaged milk (bottles or cartons). These products are processed in approximately 284 dairy plants throughout the State. We examined the water requirements for the shipment and processing of milk and milk products on a daily and yearly basis.

Table 12 shows that dairy products consumed 16.8 percent of the total water withdrawn by the food processing industry. This total reflects the size and scope of the industry, the fact that many dairy plants and receiving stations are operating seven days a week, and the large volume of products they are handling.

Water is required for cleaning dairy equipment such as vats, pipelines, cans, bottles, and tanker trucks. It is also used in the processing of milk for such tasks as pasteurization, cooling, and separating whey. Water is the key element in maintaining the safe and sanitary conditions under which milk is processed in this State.³⁶

Ability of Food Processors to Absorb or to Pass on Water Related Cost Increases

According to Table 2, water intake per dollar profit among the food-processing industries shown ranges from 820 gallons for canned and preserved fruits and vegetables to 110 gallons for soft drinks. Thus, assuming that a food processor can fully deduct from its state and federal income taxes an increase in the cost of its intake water (at a combined rate of 60 percent), if the price of intake water rises \$3.05 per thousand gallons, the profits of a "typical" canner will be wiped out unless the canner can pass the increase in costs onto its customers or its suppliers, or can find some way to reduce its reliance upon water. For a soft drink manufacturer, the price of water would have to rise \$22.72 to produce a similar result. It is apparent, therefore, that within the food-processing sector there is a broad range of sensitivity to water-cost increases.

Although the food-processing sector is characterized by the existence of large, multi-plant, multi-product firms, there is still enough competition among these firms and thousands of small and medium size firms to make this a highly competitive sector. Firms located in any region of the country are potential competitors to firms in any other region producing the same products. Thus, the opportunity for passing on water-cost increases to consumers is limited because of the ability of unaffected firms to undercut affected firms' price increases. If the rise in water-costs makes a firm

unable to cover its variable costs, it will be forced to close down temporarily or even permanently, depending upon the duration of the water shortage. This, in turn, will have a detrimental effect upon supplying farms. If the farmers are able to find other purchasers for their products, they will have to settle for lower prices or pay increased transportation costs. Even if a local food-processing firm continues to operate, supplying farmers may receive lower prices for their products if the affected food-processing firm seeks to pass back to them some of its water-cost increases.

The ability of food and food-processing firms to adjust their water consumption and intake in response to an increase in the cost of using water will be addressing in forthcoming report. Several firms have already begun instituting water conservation practices in response to increases in water, sewer, and energy cost increases.

3. Pulp and Paper Manufacturing

How Water is Used in Pulp and Paper Manufacturing

Celulose fibers derived from a varied of softwoods and hardwoods are the primary raw material used for paper and paperboard making. The fibers are separated from the wood by one of several pulping processes. These processes vary in terms of the quantities of water they use; however, even the most water-conserving of them, the groundwood process, requires considerable quantities of water as indicated by Table 13.

Table 13 also indicates that nationally there has been a dramatic decline in water usage per kkg (ton). This is largely attributable to a combination of incentives which have caused pulp and paper mills to conserve and recycle water.³⁸ These include the economic advantages of resource recovery and federal and state pollution control legislation. As early as 1973, the average ratio of recycled water to gross water applied in paper manufacturing was .50.³⁹

TABLE 13
 WATER USE
 1965 vs. 1973

<u>Type of Mill</u>	<u>Flow</u> 1965	<u>Kl/kkg/(kgal/ton)</u> 1973*
Groundwood	200 (48)	91.5 (22)
Bleached Kraft	180 (43)	146 (35)

*Data from Surveyed Mills

Source: U.S. Environmental Protection Agency, Development Document for Effluent Limitations Guidelines for the Bleached Kraft, Groundwood, Sulfite, Soda, Drink, and Non-Integrated Paper Mills Segment of the Pulp, Paper, and Paperboard Mills Source Category, December, 1976, Table 30, p. 155.

There are nine pulp and paper mills in Minnesota. Five of these are located on the Mississippi River, one on the St. Louis River (Potlatch), and one (Boise Cascade) is located on the Rainy River. One plant, Hoerner Waldorf in St. Paul, uses ground water for its operation.

In their pulping operations, most of these mills use the relatively water-saving groundwood or mechanical pulping process. In this process, pulp is made by grinding fiber from pieces of wood which may be pretreated either chemically or with heat. Paper made from groundwood pulp tends not to be long-lasting, but this disadvantage is offset by the fact that it is less expensive to produce than other products and is useful for disposable products such as tissues, towels, and paper plates.

Two mills in Minnesota, Boise Cascade at International Falls and Potlatch in Cloquet, use bleached kraft pulp in their operations while Blandin, at Grand Rapids, blends its own bleached kraft pulp and purchased bleached kraft pulp with its own groundwood pulp in its paper making operations. Kraft (or sulfate) is the dominant pulping method in the United States. In this process, wood is treated with caustic soda and sodium sulfite to dissolve non-cellulosic materials and leave residual cellulose. It is the non-cellulosic materials in groundwood pulp which account for its impermanence. Kraft is the least expensive chemical woodpulp and also the strongest. Furthermore, it can utilize a wider variety of woods than any other pulping process. An important feature of the Kraft process is by-product recovery, the recovery and regeneration of spent chemicals, and the recovery of energy from vapors and from the combustion of liquid and solid wastes. Such recoveries are necessary to make the process economically feasible.

Water Shortage and Possible Allocation Strategies

Even during extreme low flow periods, there would probably be ample water to meet the withdrawal demands of the Minnesota plants. In an extreme situation, some of the costs of their water usage could be borne by other users downstream in the form of reduced flows or increased concentrations of pollutants. The only way the paper companies could be induced to internalize such costs would be through governmental policies such as:

1. Instituting or increasing water intake or consumption charges.
2. Limiting the amounts of water the plants could withdraw according to some non-price rationing scheme.
3. Imposing more stringent effluent limitations.
4. Imposing and/or increasing effluent charges.

Possible Firm Reactions

Let us consider what scope a firm has to react to policies designed to alleviate water shortages. In the short run, in response to limitations on water withdrawals, consumption, or waste concentrations, or in response to charges for these, a firm may be able to reduce its water intake, consumption, or wastes by seeking to reduce leaks and spills. Alternatively, the plant might be able to place more emphasis on production processes which require less

water intake or consumption, or which involve less wastes. For example, a plant with both kraft and groundwood pulping processes could rely more heavily on the groundwood processes which produce less wastes and require less water. As discussed above, this would involve a product shift since paper made with higher percentages of groundwood pulp will be less durable. Detailed information concerning the production processes of Minnesota pulp and paper manufacturers would be required before the scope for process substitution and tighter control could be accurately assessed.

One alternative for dealing with stricter effluent controls would be to hold waste water in reservoirs during low flow periods and release them when the low-flow condition has subsided. The quantities of water discharged by pulp and paper manufacturers would seem to cast doubt upon the practicality of this option. In addition, this would further reduce the flows available to downstream users.

If the policies described are judged to be either permanent in nature or recurring, then the firm may have to invest either in water-saving, or less waste-producing processes, in additional capital for water recycling, or possibly in some non-recycling alternatives. Whether or not the firm will do so will depend upon the expected benefits and costs of the investments considered as described in Section II, C-4.

The economic advantages of resource recovery and federal water pollution legislation have already induced pulp and paper manufacturers to be efficient water users. Water recycling is widely practiced in both groundwood and kraft mills.⁴⁰ As the mid-1980's approach, more intense recycling may be expected as firms seek to comply with the 1972 and 1977 amendments to the Federal Water Pollution Control Act.

The BDC simulation study described in Section II, C-5 above included a simulation study of a hypothetical unbleached kraft pulp mill. The conclusions drawn were similar to those drawn from the non-contact cooling simulation.

"Even with zero price, it is cost effective for the mill to recycle at a high rate with a small blowdown discharge to prevent a build-up of dissolved salts from damaging equipment. To achieve a higher level of recycling would require ion-exchange demineralization. This would not ordinarily be economical. It can be seen that a price of \$.25 per 1,000 gallons would not provide enough incentive to recycle further. The paper mill would simply pay the price and continue the same water use practices as before. It would not be cost effective to recycle the blowdown unless the price of water were at least \$.75 per 1,000 gallons. At these high prices, the percentage of recycled water to total gross water use would increase from 91.8 percent to 97.3 percent. The plant would then be operating on approximately a zero discharge basis. The only water intake would be to replace water lost by evaporation, incorporation in products and by-products, leaks, or other losses. (An analysis of the Kraft Mill's non-contact cooling system would be very similar to the non-contact cooling system described in the previous section)."

Table 23 presents the results in tabular form. According to this table, an intake water price of \$.75 per thousand gallons would be necessary to induce the hypothetical mill to reduce its water intake by more extensive

recycling. "At this price level, the model predicts it would minimize costs to demineralize and recycle the blowdown discharges from the process water system. If the water prices were as high as \$1.30, it would be economical to recycle the blowdown from the non-contact cooling system."⁴¹

Thus, according to this study, compliance with federal pollution control law leaves little scope for further recycling of water. The estimated price necessary to induce this hypothetical plant to increase its rate of recycling (\$.75) is of some interest in view of the discussion of Section II, C-3b. According to the information presented in Table 2, a price of only \$.30 per thousand gallons would completely wipe out the profits of the "average" paper mill unless a drastic reduction in water use could be effected.

The authors discuss six, non-recycling options for reducing water withdrawal and consumption. These include:

1. Dry cooling towers.
2. Dry fume scrubbing.
3. Tighter control of leaks and waste.
4. Substitution of other solvents for water.
5. Additional vapor recovery condensers.
6. Dry forming of paper.

The authors state that in general these "would involve higher costs, and some of them would also increase energy consumption, cause air and water pollution, create occupational safety hazards, and/or consume resources more scarce than water. In some cases, a reduction in process water use would be offset by increased water needs in the power plant system."⁴²

All of these policies designed to deal with quantity and quality aspects of water shortages will either directly or indirectly increase the unit costs of the firm. Charging for water withdrawals, consumption, or for effluent waste concentrations directly affects the costs of the firm. Some of these cost increases may be offset by process substitution or tighter control on leaks and wastes but, if the firm is operating efficiently in the first place, its unit costs must rise. Similarly, if the firm is operating efficiently before more stringent limitations on waste effluents or limitations on water intake are imposed, its unit costs will increase as it tries to make adjustments to take these into account. Among the options available to pulp and paper manufacturers to cope with these increases in unit costs are the following:

1. If the plant is running relatively close to capacity, it may be able to reduce its unit costs by reducing its rate of output. However, if unit costs rise to the extent that the firm can no longer cover its variable unit costs at any level of output (those costs which vary with the amount of output produced), the firm will have to close down. If the policy is temporary in response to low-flow problems, the firm can start up production when the crisis passes.

TABLE 14
KRAFT MILL COMBINED WATER SYSTEMS*

Plant Operating at Most Cost-Effective Recycling Levels

Water Price (Per 1,000) Gal. of Intake	Water Intake	Water Reused	Water Consumed	Costs Per 1,000 Gal. of Gross Water Use	Water Related Water- Related Costs Per Day	Water** Costs as Percent of Value of Production
0***	28.9 mgd	51.9 mgd	NA	\$.085	\$ 6,789	3.5%
0	5.6 mgd	74.4 mgd	2.0 mgd	.158	12,618	6.5%
\$.10	5.6 mgd	74.4 mgd	2.0 mgd	.165	13,177	6.8%
.50	5.6 mgd	74.4 mgd	2.0 mgd	.193	15,445	7.9%
.70	5.6 mgd	74.4 mgd	2.0 mgd	.207	16,563	8.5%
.75	2.1 mgd.	77.9 mgd	2.0 mgd	.211	16,851	8.6%
1.25	2.1 mgd	77.9 mgd	2.0 mgd	.223	17,857	9.2%
1.30	2.0 mgd	77.9 mgd	2.0 mgd	.224	17,938	9.2%
1.50	2.0 mgd	78.0 mgd	2.0 mgd	.230	18,425	9.4%

*Gross Water Use = 80.0 mgd. This includes 63.8 mgd for the process system and 16.2 mgd for the non-contact cooling system. It does not include water used for log handling or in the power plant.

**Hypothetical mill produces 1,000 tons per day of unbleached kraft linerboard. Value = \$195 per ton. Costs and prices based on March, 1975, price levels.

***Special Case. Costs and recycling practices indicated in the absence of water pollution control requirements. All other cases assume plant is meeting P1 92-500 standards (Best Available Technology).

Source: Bureau of Domestic Commerce, An Analysis of Price/Cost Sensitivity of Water Use in Selected Manufacturing Industries (June, 1976), Table K-1.

2. Alternatively, the firm may try to pass on the increased unit costs to its customers. Its ability to do this will depend upon the market power of the firm. In general, the market power of firms in the pulp and paper industry to control prices is limited. The bulk of the sales of the industry tend to be concentrated in relatively few companies. In 1972, for example, the top four producers accounted for 59 percent of all paper shipments.⁴³ However, there are still hundreds of companies. Efforts by any one firm to raise prices have in the past been undercut by competitors. An example of this occurred in 1976 when International Paper Company, the World's largest paper company, tried to raise prices above those its competitors charged.

"By some calculations, IP lost more than 100,000 tons of production to competitors who were willing to cut prices during that final quarter of 1976, and a smaller--but still substantial--tonnage slipped away in the first quarter of 1977. The company's grip on many key markets eased correspondingly. In 1974, IP's share of total U.S. paper and paperboard production was 12.7 percent; last year it dropped to 11.3 percent. And, as its production fell, so did profits. The company's earnings were off 36 percent in the fourth quarter of last year, compared with a year earlier, and its profits in the first quarter of 1977 were 24 percent lower than in the same quarter of 1976."⁴⁴

3. An alternative approach might be for the pulp and paper mill to reduce the prices it pays for pulp wood. This would apply to companies which unlike Blandin, Potlatch, and Boise Cascade do not have their own forest lands. The ability of firms to do this will, in part, depend upon the duration of the cost increases and whether or not they are under contract to their suppliers. The firms may be able to immediately reduce the price paid to some small suppliers not under contract. If a contract is involved, then the company will have to wait until it expires. The ability of the company to unilaterally lower the price it pays for wood from a given supplier will depend on that supplier's ability to sell to other sources. This will partly depend on the location of the supplier and on the demand for wood in other uses such as for saw mills.

The future ability of firms in the pulp and paper industry to absorb unit-cost increases due to water policy will depend on future profits relative to costs. Their willingness to invest in water-saving equipment will depend upon expected future costs and upon profit expectations of the industry as a whole. This is due to the relatively competitive nature of the industry and to the fact that most of the plants in Minnesota are part of national firms and serve national markets.

Table 2, Section II, C-3b, gives a rough indication of the ability of paper mills to absorb increases in unit costs due to charges for water consumption or intake. According to that table, on the average, U.S. paper mills require 5,510 gallons of intake water for every dollar of profit and consume 202 gallons. Assuming that an increase in the cost of intake water was fully deductible from the company's state and federal corporate income tax liability (at a combined rate of 60%), it would require a water intake charge of only \$.30 per thousand gallons to totally eliminate the profits of the "average" mill. On the other hand, it would take a consumption charge of \$8.25 per thousand gallons to have the same effect. Of the nine industry groups shown, clearly paper mills is the most sensitive to increases in the price of intake water or of water consumption.

Profits of the pulp and paper industry have in the past been less than those of most other manufacturing industries, although in recent years there has been some improvement in this situation.⁴⁵ This is shown by Table 15 and Figures 4a and 4b.

Opinion on demand prospects for the industry are mixed. According to the U.S. Industrial Outlook.

"A broad based growing domestic market, coupled with expanding foreign demand, presents favorable prospects for continued growth in the U.S. paper and board industry. Shipments, expressed in 1977 dollars, are expected to approach \$27 billion in 1982, representing a 4.1 percent annual rate of growth in the 1977-82 period. While the industry may be challenged in the future by changing foreign markets, the foreseen balance between domestic supply and demand should provide the opportunity to forge a more beneficial cost/price relationship and enhance profitability."⁴⁶

On the other hand, there is a body of opinion that believes that the growth in the demand for paper will be limited by such factors as:

1. Increased industry-wide prices needed to cover higher energy costs and pollution-control expenditures.
2. Maturing markets, i.e., markets in which the demand for the paper products levels off.
3. Competing technologies.

Included in the last categories are such items as plastic clear wrappings, wider use of microfilm for storing information, and wider use of electronic communication.⁴⁷ Even if demand does grow significantly, the relative ease of entry into the industry could keep profits down.

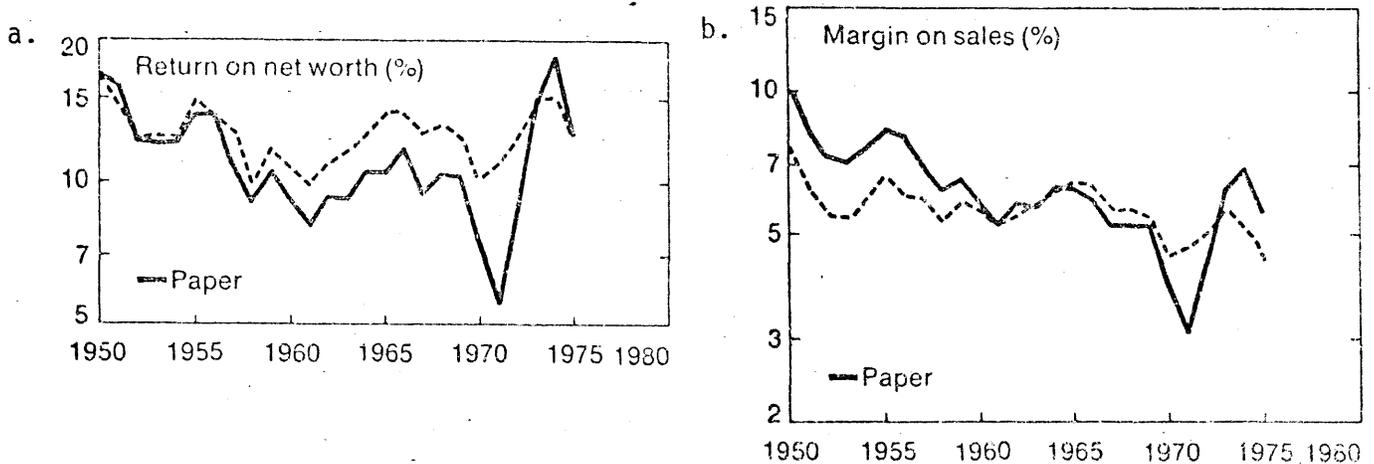
Table 15

ANNUAL FINANCIAL RESULTS OF PUBLICLY-HELD PAPER COMPANIES, 1967-1975

	No. of Companies	Percent Change, Year-to-Year Net Income	Margin on Sales	Return on Net Worth
Paper Companies				
1967	68	-10.8	5.2	9.5
1968	60	12.6	5.2	10.7
1969	60	10.8	5.2	11.1
1970	62	-22.8	3.9	7.4
1971	62	-23.0	2.9	5.6
1972	60	56.0	4.3	8.8
1973	60	67.0	6.2	14.2
1974	61	37.0	6.8	18.3
1975	61	-22.0	5.5	12.5
All Manufacturing Companies				
1967	2,250	- 4.6	5.6	12.6
1968	2,068	11.4	5.7	13.3
1969	2,127	2.1	5.4	12.4
1970	2,319	-12.1	4.5	10.1
1971	2,414	12.8	4.7	10.8
1972	2,136	31.0	5.1	12.1
1973	1,866	13.0	5.7	14.9
1974	1,757	13.0	5.2	15.2
1975	1,757	-11.0	4.4	12.3

Source: First National City Bank Monthly Economic Letter; and Rauch, James (editor), The Kline Guide to the Pulp and Paper Industry, 1976, Tables 1-3.

Figure 4. Profits in Paper and All Manufacturing, 1950-1975



Source: First National City Bank Monthly Economic Letter; and Rauch, James (editor), The Kline Guide to the Pulp and Paper Industry, 1976, Figures 1-3.

Conclusions

During severe low-flow conditions, the cost of using water for pulp and paper plants could rise as a result of policies designed to induce these plants to internalize any costs their water use imposed upon others. Although much more information would be needed concerning technical and financial aspects of Minnesota pulp and paper plants to make definitive and quantitative statements about firm reactions to policies designed to cope with low-flow conditions on Minnesota rivers, the following observations can be tentatively made. The ability of firms in the pulp and paper industry to partially offset the increase in the costs of using water by decreasing their water intake or consumption is diminishing as they increase their dependence upon water recycling in order to comply with pollution control regulations. Furthermore, there is little leeway for pulp and paper manufacturers to recoup water-cost increases by raising product prices. There may be some scope for reducing prices paid to producers of pulp wood, however, this avenue is limited by the fact that some mills use their own wood sources, that, in most instances, wood is purchased under contract, and that producers of wood may be able to find other buyers. Thus, it seems likely that temporary cost increases would be absorbed primarily by the firms themselves in the form of reduced profits, employment, and earnings. It appears, however, that even very small charges for intake water can wipe out the profits of the firm because of the large amounts of water required to generate one dollar's worth of profits. Thus, temporary water-related cost increases can result in temporary plant shut downs with resulting employment, loss of earnings, and undesirable secondary effects. More permanent cost increases or recurring temporary ones could be expected to slow the expected growth of the industry in the State.

4. Iron Mining

Iron mining, or more specifically, taconite production is the second largest withdrawer of water in the State after electric power production. According to Table 1, it accounts for roughly 20.37 percent of the water withdrawn. Reserve Mining Company alone accounts for 61 percent of iron mining withdrawals and 12 percent of total withdrawals. When Reserve changes to on-land tailings disposal (instead of disposing of the tailings into Lake Superior) in 1980, its withdrawals of water will fall considerably since it plans to change to a closed-cycle water system for its processing operations.

Water is used in the taconite-mining process itself to flush and flake out holes caused by jet-piercing machines. Within the taconite beneficiation process water is used in substantial quantities as a suspension agent in grinding, as a transportation agent for crude ores, concentrates and tailings, and as a cooling agent for equipment and product.

"Water to support the operation is gained from the recycling of water in the plant, and from the thickening processes, and the recycling of water from the tailings basin. The use of water from natural resources is from rivers, reservoirs, mine pit dewatering operations, and direct precipitation captured by the reservoirs and tailings basins. In that the tailings basins and clearwell reservoirs cover large areas of land, the capture of direct precipitation provides significant input of water to the processing operations."48

Comparisons of estimated water availability with projections of water demand by the U.S. Army Corps of Engineers and by the Barr Engineering Company have indicated that, in general, water supply will be more than adequate to meet the consumptive needs of various users in the area including the taconite processors. Both of these studies tried to take into account the probable development of the copper/nickel mining industry in the same general area.⁴⁹ A study concerning the impact of the copper/nickel mining and smelting on water resources in the area is being undertaken by the Minnesota Environmental Quality Council's Regional Copper/Nickel Study.

The potential exists, however, for local water-use conflicts between the demand for water for taconite mining and processing and municipal water demand. In particular, during severe droughts, municipalities which obtain their water from old mine pits located on mining company owned lands could face cutbacks in their water supplies if the mining companies decided to withhold some of this water for their own use. There is one case in which a taconite mining company (Erie Mining Company) sought to exchange land with the federal government so that it could construct a reservoir. The DNR voiced its opposition to this proposal on the grounds that the reservoir would be built on lands for which there were potentially conflicting demands including that of possible future copper-nickel development and that preferred alternative sources of water were available for the taconite mining company's use. This case indicates a potential for land use conflicts associated with efforts to secure dependable water supplies.

Obviously there is a need to secure equitable and efficient water and land use allocation procedures and mechanisms in order to prevent or to resolve conflicts such as these and to allocate water among other possible competing demands (including environmental considerations) which might materialize in specific localities within the region. The allocation approaches used could increase the costs of some mining operations.

All of the taconite firms in the state are subsidiaries of firms located outside the State -- mainly steel manufacturers. The steel industry is highly concentrated with more than 50 percent of production accounted for by four companies and 75 percent of output by the eight largest companies. Customers of the steel industries include such durable goods industries as automobiles, capital goods industries, and the construction industry. Historically steel prices have been rigid in an upward direction and price increases have been administered via price leadership.⁵⁰

Thus, the steel industry is in a position to recoupe a large percentage of increased costs due to wide-spread, long-term occurrences in the cost of rising water on the iron range, should these ever be significant, unless there is a temporary downturn in the demand for steel. If, however, the cost increases were believed to be temporary, the iron mining companies could temporarily cut back or suspend their operations. This would have temporary adverse economic impacts on the area. If a single processor encountered significant increases in the costs of water use which did not affect other operations employment in that operation could be adversely affected with consequential adverse secondary economic effects to the surrounding area.

In fact, the demand for steel is subject to cyclical swings. A particularly bad year for steel was 1977, partly due to competition from foreign imports. However, the U.S. Industrial Outlook predicts that "the long run growth (in shipments) is likely to approximate the nations' historic growth in steel consumption which since 1960, has averaged 2.5 percent annually."⁵¹

Even if the steel industry is able to pass on a large portion of its costs to its customers, it must still deal with foreign competition and with the ability of final customers of goods made with steel to delay gratification or do without certain products. Thus, if the cost of using water goes up it behooves the mining operations to use water more efficiently.

How this can be accomplished is, of course, an engineering problem which would require detailed technical information for each mining and taconite processing operation. Currently, the mining operations already employ considerable water recycling. However, in the short-run, some conservation may be feasible. In the long-run, investment in water-saving processes might be necessary. Given current projections of water availability and the capacity of existing company reservoirs, it is not clear that there will be sufficient economic incentive to induce companies to make such changes.

5. Electric Power Production

In 1976, the electric utility industry withdrew roughly 740.59 billion gallons of water for power generation. At 54.42 percent of the state's water withdrawal, this was by far the largest single withdrawal use. In consumption (water evaporated and thus unavailable to downstream users) the industry ranked behind irrigation and mining. An estimated 22.08 billion gallons (approximately three percent of water withdrawn) were consumed; the remainder was returned to its source.⁵²

Steam-electric power plants accounted for over 96 percent of all electricity generated in 1976. Most of the utility-related water withdrawals were required for cooling. Water required by internal combustion and gas turbine plants (smaller installations used as peaking capacity) is negligible.⁵³ Hydroelectric power, which delivers a small proportion of Minnesota's power, is considered an "instream" use and is discussed in Part III. Water requirements for steam-electric generating plants are the major concern of this section.

The nature of power plant water use is expected to alter in the future because of changing technologies for cooling. Power-plant water withdrawal will decrease, and consumption will increase, due to the retirement of older facilities which used once-through cooling (which withdraws large quantities of water but consumes little) and the addition of larger plants using wet-tower cooling (which withdraws much less water but consumes most of the water withdrawn).⁵⁴

In 1976, the generation of 27.472 trillion kilowatt-hours (kwhr) of electricity by steam-electric facilities required the withdrawal of 2,029.0 million gallons per day (740.585 billion gallons per year), and the consumption of 60.48 million gallons per day (22.075 billion gallons per year). For 1990, the following capacity and water use has been estimated:

- (1) Utility steam-electric generating capacity will increase from 5511.5 MW to 9580.5 MW.
- (2) Associated water withdrawal will decrease, from 2029.0 million gallons per day (mgd) to 1624.9 mgd, while
- (3) Associated water consumption will almost double, from 60.48 mgd to 109.22 mgd.⁵⁵

Thus steam-electric power plants are the major area of concern, especially since their proportion of total power generated is expected to increase.

Water is required in steam-electric plants for several purposes: boiler feedwater, domestic use, fly ash control, pollution abatement and condenser cooling. Coal-fired generating plants use the energy from combustion to convert water to steam. This high-pressure steam then drives turbines which turn the generators. Steam leaves the turbines and passes through a condenser, where it is condensed back into water and then returned to the boiler in a closed-circuit system. Water losses in this circuit are negligible.

Some water also is required for pollution control, but the major use of water in steam plants occurs in the separate flow of water through the condenser, required to carry away the waste heat of condensation. The amount of water withdrawn and consumed by power plants depends upon the temperature rise across the condenser, the thermal efficiency of the plant, and the type of cooling system employed. The thermal efficiency of most modern fossil fuel steam-electric

plants is around 33-35 percent; the remaining 65-67 percent of the energy derived from the burning of fuel is waste heat and must be dissipated, either up the smokestack or to the cooling system. Nuclear steam plants, which operate at a lower thermal efficiency (31%), have a higher percentage of waste heat which must be dissipated through the cooling system. Dissipation of this waste heat is the major requirement for water in steam-electric power plants.⁵⁶

Until recently, once-through cooling was the most widely-used cooling method. Using this method, water is withdrawn from a river or lake, run over the steam condensers, and returned to its source. This requires the withdrawal of large quantities of water, but very little of that water is consumed. The rest is returned to the source. For example, the NSP Riverside plant in Minneapolis (1976) required the withdrawal of 178.2 million gallons per day (mgd), and consumed approximately 1.6 mgd, or less than one percent of total withdrawal.⁵⁷ Concern about the effects on river ecosystems of hot water discharges have resulted in federal thermal water quality regulations, on which Minnesota thermal regulations are based. These new regulations require that future power plants use off-stream cooling. Off-stream cooling is most commonly achieved using cooling towers or cooling ponds, which transfer heat to the air by evaporation.

In a wet-tower system, the heated water, as it comes from the condenser, is trickled down a set of baffles inside the tower with a draft of air rising upward. The water is cooled by evaporation and is returned to the condenser to complete the cycle. With a cooling pond the heated water is discharged into a pool, where the heat is dissipated by surface evaporation. Then the cooled water is withdrawn from the pond to recirculate through the condenser.⁵⁸ Although less expensive than cooling towers, cooling ponds require large land area and favorable topography; they are not expected to be widely used in Minnesota.

Beginning with NSP's Sherco 1 and 2 plants (which began operation in 1976 and 1977, respectively), all new facilities are being planned with 100 percent closed cycle wet-tower cooling. Since this system is a closed loop, it requires a much lower water withdrawal than once-through cooling; on the other hand, most of the water withdrawn is consumed.⁵⁹ (For example, the combined 1360-MW Sherco 1 and 2 units withdraw 13.2 million gallons per day and consume 12.0 mgd; or 91 percent of withdrawal. Sherco 3 and 4 (800 MW each) are each expected to withdraw 11.4 mgd and consume 11.3 mgd, or 99 percent of withdrawal).⁶⁰

The per-megawatt water consumption of the planned 3000-MW Sherco complex can be considered representative of coal plant proposals of similar size in the next decade. The four units combined will typically withdraw 36.0 million gallons per day (mgd) and consume 34.6 million gallons per day, with maximum consumption of approximately 49 mgd. This peak demand amounts to about 7.6 percent of the low flow of the Mississippi River recorded in September, 1976 at the Anoka gauging station downstream from the plant site.⁶¹

Table 16 shows all steam-electric generating plants operated by utilities in Minnesota in 1976.⁶² The accompanying map and key shows locations of all steam-electric plants with capacity greater than 50 MW.

Tables 17 and 18 represent, respectively, projected additions and retirements of electric generating facilities to the Minnesota area system.⁶³ The exact timing of these additions and retirements is subject to change, but the likelihood is that the locations and sizes of additions is relatively stable. All of the additional fossil-steam plants in Minnesota will have wet-tower cooling; the retiring fossil-steam plants are facilities which currently require once-through cooling.

TABLE 16
STEAM-ELECTRIC PLANTS LOCATED IN MINNESOTA IN 1976

<u>Plant Name</u>	<u>County</u>	<u>Type</u> <u>Cool*</u>	<u>Capacity</u> <u>(KW)</u>	<u>Generated</u> <u>Power (MMH)**</u>	<u>Cooling</u> <u>Water Source</u>
Alexandria	Douglas	OT	5250	0	Lake
Benson	Swift	OT	520	0	Wells
Detroit Lakes	Becker	WT	6000	4	City Water
Marshall	Lyon	OT	3000	-120	City Water
Moorhead	Clay	OT	34000	387	Red River
Hoot Lake	Otter Tail	OT	136900	763795	Otter Tail River
Ortonville	Big Stone	OT	16500	100089	Big Stone Lake
Hibbing	St. Louis	WT	19000	85941	City Water
Litchfield	Meeker	WT	3000	-759	City Water
Luverne	Rock	WT	3000	38	City Water
Syl Laskin	St. Louis	OT	116100	479280	Colby Lake
Clay Boswell	Itasca	CB	514500	3296637	Mississippi River
M.L. Hibbard	St. Louis	OT	122500	179348	St. Louis River
New Uln	Brown	WT	29500	114895	Wells
Black Dog	Dakota	CB	486655	1841726	Minnesota River
Allen S. King	Washington	CB	598400	3197027	St. Croix River
Minnesota Valley	Chippewa	OT	46000	109366	Minnesota River
Red Wing	Goodhue	OT	23000	72073	Mississippi River
Riverside	Hennepin	OT	383850	1533354	Mississippi River
High Bridge	Ramsey	OT	396835	1406854	Mississippi River
Wilmarth	Blue Earth	OT	25000	56494	Minnesota River
Sherburne	Sherburne	WT	720000	2827723	Mississippi River
Redwood Falls	Redwood	OT	2000	0	Redwood River
North Broadway	Olmsted	OT	12500	-2333	SD FK Zumbro River
Silver Lake	Olmsted	CB	98400	432000	SD FK Zumbro River
Elk River	Sherburne	OT	45000	16924	Mississippi River
Virginia	St. Louis	OT	36200	74996	Silver Lake
Willmar	Kandiyohi	WT	30350	68712	Wells
Windom	Cottonwood	WT	3000	49	City Water
Worthington	Nobles	OT	14000	26984	Lake Okarena
Jackson	Jackson	OT	2000	0	Des Moines River
Sleepy Eye	Brown	WT	3250	5281	Wells
Springfield	Brown	WT	7750	14747	Cottonwood River
Two Harbors	Lake	OT	6000	10153	Lake Superior
Austin	Mower	WT	27500	51235	Red Cedar River
Northeast Stat.	Mower	WT	31950	138766	Wells
Blue Earth	Blue Earth	WT	4000	5008	Wells
Fairmont	Martin	OT	22000	49364	Lake George
Fox Lake	Martin	OT	104600	307291	Fox Lake
Albert Lea	Freeborn	WT	18500	6285	Wells
Owatonna	Steele	WT	34500	110195	City Water
Monticello	Wright	CB	568800	3986380	Mississippi River
Prairie Island	Goodhue	CB	1186200	5924217	Mississippi River

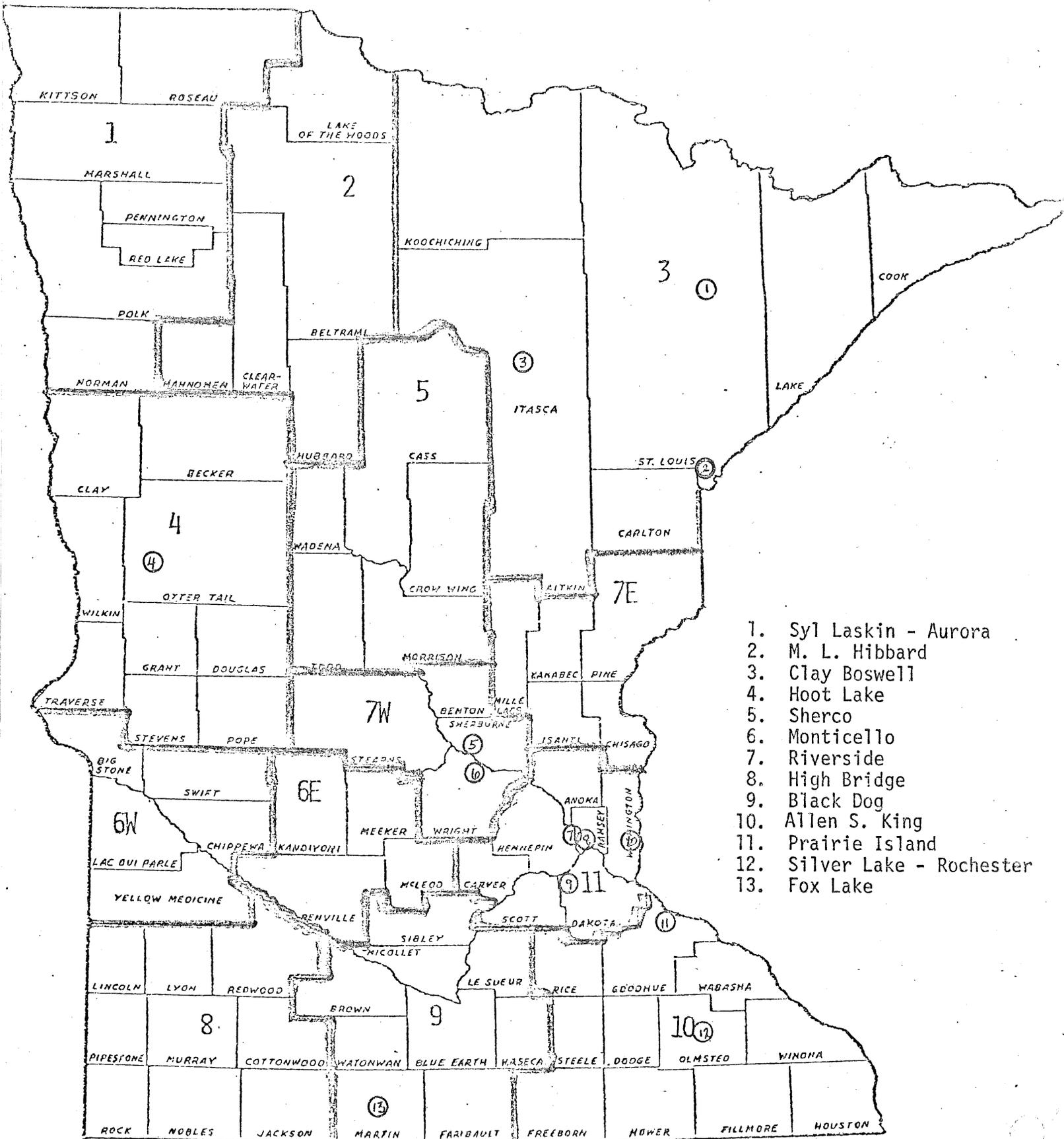
*OT = once-through; WT = wet tower; CP = cooling pond; CB = combination

**Negative value indicates net imports of power.

Source: Federal Energy Regulatory Commission, 1978

Map 1.

Large Steam Electric Plants in Minnesota
Electric Generating Plants with Capacity > 50 MW



1. Syl Laskin - Aurora
2. M. L. Hibbard
3. Clay Boswell
4. Hoot Lake
5. Sherco
6. Monticello
7. Riverside
8. High Bridge
9. Black Dog
10. Allen S. King
11. Prairie Island
12. Silver Lake - Rochester
13. Fox Lake

TABLE 17. PROJECTED FACILITY ADDITIONS

Utility	Unit	Location	Earliest In-Service Date	Rated Capacity - MW			
				Summer	Winter	Type	Fuel
Within Minnesota							
CPA	St. Bonifacius	St. Bonifacius	5/78	47	47	C.T. ^a	Oil
UPA	Cambridge	Cambridge	5/78	21	23	C.T.	Oil
UPA	Maple Lake	Maple Lake	5/78	21	23	C.T.	Oil
UPA	Pine City	Pine City	5/78	21	23	C.T.	Oil
MP&L	Clay Boswell #4	Cohasset	5/80	500	500	F.S. ^b	Coal
NSP	Sherco #3	Becker	5/83 ^c	800	800	F.S.	Coal
MP&L	Floodwood	Floodwood Fine Lakes	-/86	500	500	F.S.	Coal
NSP	Sherco #4	Becker	5/87 ^c	800	800	F.S.	Coal
NSP		Unsite	5/89 ^c	800	800	F.S.	Coal
Outside Minnesota							
MP&L	Milton R. Young	Center, ND	5/77	408	408	F.S.	Lignite
UPA/CPA	Coal Creek 1	Coal Creek, ND	11/78	469	470	F.S.	Lignite
UPA/CPA	Coal Creek 2	Coal Creek, ND	11/79	466	466	F.S.	Lignite
NSP	Manitoba Hydro Transmission Line	Winnipeg	5/80	575	-345		

Key: CPA = Cooperative Power Association
 UPA = United Power Association
 MP&L = Minnesota Power and Light
 NSP = Northern States Power
 MPC = Minnkota Power Cooperative

Notes: a: C.T. = Combustion Machine
 b: F.S. = Fossil Steam
 c: In-service dates according to NSP February, 1978 statement.
 Dates subject to Minnesota Energy Agency Review.

Source: Minnesota Energy Agency Data Base. Energy Policy and Conservation Report, MEA, Biennial Report to the Legislature, April, 1978. and other information from MEA Certificate of Need files.

TABLE 18. PROJECTED FACILITY RETIREMENTS

Utility	Unit	Location	Retirement Date	Rated Capacity - MW			
				Summer	Winter	Type	Fuel
MPC	Warroad	Warroad	83	2.3	2.3	Diesel	Oil
MPC	Little Fork	Little Fork	83	1.0	1.0	Diesel	Oil
NSP	Dodge Center	Dodge Center	12/82	1.8	1.8	Diesel	Oil
NSP	Excelsior	Excelsior	12/82	4.0	4.0	Diesel	Oil
NSP	Glenwood	Glenwood	12/82	3.9	3.9	Diesel	Oil
NSP	New Richland ^d	New Richland	12/82	1.7	1.7	Diesel	Oil
NSP	Red Wing 1 & 2 ^d	Red Wing	12/82	28.0	28.0	Fossil	Coal
NSP	St. James	St. James	12/82	2.0	2.0	Diesel	Oil
NSP	Wilmarth 1 & 2 ^d	Mankato	12/82	28.0	25.0	Fossil	Coal
NSP	Pipestone	Pipestone	12/83	2.9	2.9	Diesel	Oil
NSP	Tracy	Tracy	12/83	1.8	1.8	Diesel	Oil
NSP	High Bridge 3 & 4 ^d	St. Paul	12/84	113.8	100.0	Fossil	Coal
NSP	Riverside 1, 2 & 6 ^d	St. Paul	12/84	150.0	107.0	Fossil	Coal
NSP	Mobile	Winona	12/86	1.6	1.6	Diesel	Oil
NSP	Black Dog 1 ^d	Minneapolis	12/87	75.0	70.0	Fossil	Coal
NSP	Minnesota Valley ^d	Granite Falls	12/88	47.0	47.0	Fossil	Coal
NSP	Black Dog 2 ^d	Minneapolis	12/89	100.0	81.0	Fossil	Coal
				<u>564.0</u>	<u>478.0</u>		

Key: MPC = Minnkota Power Cooperative
 NSP = Northern States Power Company

d: A portion of the summer generating capacity will be lost prior to retirement due to the unavailability of natural gas for electric generation.

Source: Minnesota Energy Agency Data Base. Energy Policy and Conservation Report, MEA, Biennial Report to the Legislature, April, 1978.

According to the Metropolitan Council's Development Guide for the Twin Cities Metropolitan Area, "the surface water resources of the Metropolitan area are now being used to such an extent that a supply adequate to meet peak demands will not be available if a drought of magnitude similar to the 1930's (30-day, 100-year low flow) recurs in this region." 64 In particular, there would be an insufficient supply of cooling water to the Black Dog plant on the Minnesota River to maintain electric power production at current levels. The Northern States Power Minneapolis-Riverside plant is another which could be forced to curtail operation during a drought of such magnitude. Dry weather conditions in 1976 caused problems for some facilities. Notable was the NSP Allen S. King plant at Bayport, which was forced to limit generation because of low flows in the St. Croix River.

Two factors influence the electric utilities' water position: 1) their demand for large amounts of water; and 2) their low priority in the water allocation system. Utility-related water demand has already been discussed. Current Minnesota appropriation law sets electric power generation as a fourth priority water use-- after domestic use (including municipal water utilities' domestic obligations), irrigation, and other small uses under 10,000 gallons per day. 65 In addition, the Minnesota Department of Natural Resources is currently studying instream flow requirements necessary to support navigation, recreation, fisheries, and other nonwithdrawal activities in order to determine "protected flow" levels for major waterways. Thus, utilities' water needs can be accommodated only after the "protected flow" criterion is met and the needs of higher priority users have been satisfied. Hence, the "protected flow" and appropriative priorities will determine a limit to water withdrawal before any "absolute limit" (i.e., less volume in the river than required for condenser flow) is reached.

UTILITY RESPONSES/ECONOMIC IMPACTS OF WATER SHORTAGES

Both utility responses and economic impacts of water shortages for electric power generation are difficult to measure. The options, and costs, depend largely upon the severity and extent of these low flow conditions and upon the extent to which these conditions have been anticipated.

Short-term utility responses

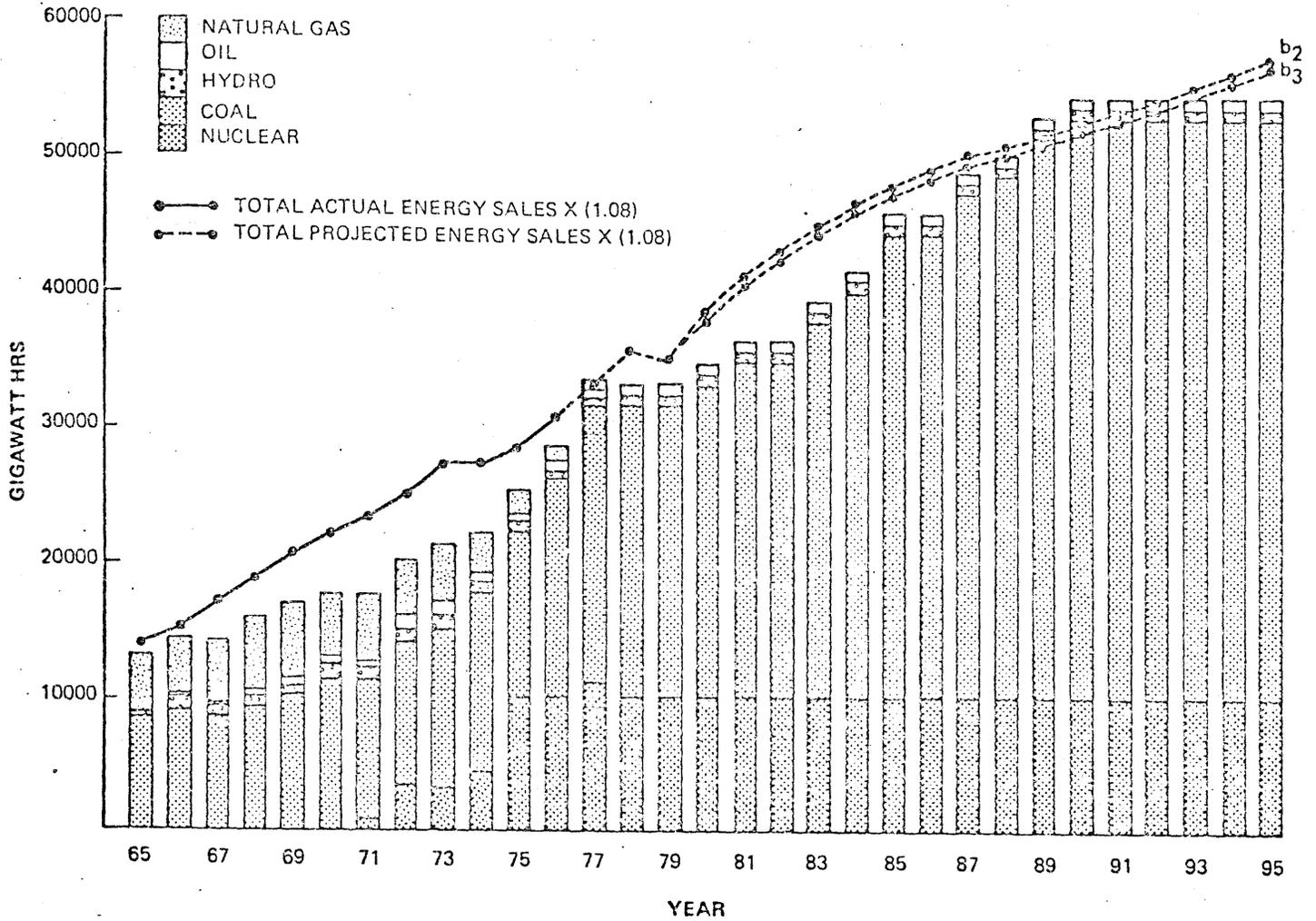
In the absence of flows sufficient to operate a plant at normal capacity, the utility must derate that plant (operate at lower capacity which is sustainable given the water flow.) If the low-flow condition is localized (for instance, on the Minnesota River, which historically experiences very low flows), then the utility may be able to make up for the lost generating capacity by operating other intermediate and baseload plants at higher capacity. If such excess capacity is not available, then the utility might be able to make up the difference by bringing on line peaking plants, which are kept in reserve to handle peak electric demand. These plants are more expensive to operate, but they generally are internal combustion or gas turbine plants which do not require much water for operation. In the absence of sufficient capacity within the utility, it might be possible to buy electricity at higher price from other utilities. Historically, Minnesota has been an importer of electricity, at times buying as much as 25 percent of its power needs from outside the state.

Figure 12 illustrates this generation deficit. In this figure, the height of the rectangles represents the amount of electric energy produced in the state. The solid black line represents total energy sales in the state while the two dotted lines represent sales projections under two different growth scenarios. The dotted line labeled b_2 represents projected electric energy consumption under the assumption that energy demand will be somewhat reduced (relative to an alternative scenario b_1 (not shown)) due to both the short-term effects of rising fuel prices and the effects of existing mandatory federal and state conservation programs. Under the scenario represented by dotted line b_3 , additional government conservation programs and consumer investments in energy-saving equipment are added to the effect of rising fuel prices and existing mandatory federal and state conservation programs to further reduce energy demand.⁶⁶ The distance between the solid and dotted black lines and the height of the rectangles represents the amount of electricity which must be imported into the state.

From 1967 through 1976, Minnesota utilities bought considerably more power than they generated within the state. A significant deficit is also expected in the 1980's. In the past the Bureau of Reclamation has been a source of Minnesota's imported power. In the future, summer peaking capacity will be supplemented by a transmission connection with the Manitoba Hydro-Electric Board.⁶⁷

Imported power is generally more expensive than self-generated power; however, if a drought condition were widespread, there might not be excess power in the system to supplement a drought-induced deficit.

Figure 5. Minnesota Total Energy Generation and Sales to 1977 and Projected Generation and Sales to 1995 (No Electrical Substitution)



Source: Energy Policy and Conservation Report, Minnesota Energy Agency, April 1978

LONG-TERM RESPONSE

Many of the same options hold for existing as for future plants, but in most cases, what makes sense for facilities in the planning stage is financially unfeasible for an existing plant, with limited remaining in-service life. For instance, all new power plants will be constructed with wet tower cooling. Retrofit of older plants to wet-tower cooling systems is not expected, because of the expense involved.

The construction of reservoir capacity is seen as a likely response to periodic water shortfalls. In fact, a preliminary evaluation of streamflow records indicates that the Mississippi River below the Twin Cities may be the only water source near population centers capable of sustaining an 800-MW coal plant during extreme low flows without supplementary water storage capacity.⁶⁸

The Department of Natural Resources (in conjunction with the Minnesota Energy Agency and the Environmental Quality Board Power Plant Siting Staff) has developed a "mass analysis" model - which will be used to calculate storage capacity necessary to supplement low flows, given certain site-specific data: plant size and water requirement, historic low flow data, established protective flow, and higher priority appropriative uses. Construction of reservoir capacity will add to the cost of a power plant. As with wet towers, the addition of such capacity at existing plants is unlikely, especially in urbanized areas.⁶⁹

An alternative to on-site reservoir capacity would be upstream reservoir storage for the purpose of streamflow augmentation in case of low flows. The Mississippi Headwaters reservoir capacity, originally developed as an aid to downstream navigation, is an example of such a system. However, any plans to use the headwater reservoir for streamflow augmentation would have to take into account recreational and other interests on these lakes which depend upon stable water levels.

Dry cooling towers have been suggested as an alternative, but their technology is as yet unproven and the expected costs so great that it is expected that only in areas where water is very expensive will they ever be financially feasible.

It has been suggested that groundwater could be used to supplement low flows for short periods of time. Because of their vast water requirements, large power plants do not use groundwater for cooling purposes. Information on aquifer extent, capacity, and recharge capability is lacking in most areas, making it impossible to judge the extent of impact of such use. Nonetheless, it is thought that the impact of a short-term "mining" of certain aquifers might be less than the impact of withdrawing surface water below "protected flow" levels (although such pumpage could not be sustained over the long term). Such an option should only be pursued with a much more comprehensive understanding of groundwater hydrology than presently exists.

Economic Impacts

The use of peaking plant capacity or the purchase of electricity from other producers to make up for water-related capacity loss would increase the price of electricity to all classes of consumers. This would have some ramifications throughout the economy.

Much more serious, however, would be the ramifications of insufficient power to meet demands. Very short-term deficiencies would entail some economic losses. Unavailability of electricity for longer periods of time would eventually mean losses of jobs and earnings.

The industrial sector would be affected since there are many processes for which electricity is essential (no substitution options are available); most establishments have no back-up facilities of their own. Some types of commercial establishments could not operate without electricity; in others, business could be greatly affected.

Two utilities (Northern States Power and Minnesota Power and Light) have emergency allocation plans, designed to minimize the impacts of shortage of electricity, given their own particular mix of customers. At present there is no statewide allocation plan. There is a good possibility that such a plan will be developed in the near future. Any such plan will have to examine, sector by sector;

- the energy-intensiveness of the sector (relationship of electricity used per employee and per dollar output, both direct and indirect)
- the ability of the sectors to substitute primary fuels for electricity.

These and other factors would have to be examined to determine what services could be curtailed in the short term, with the least disruption to the well-being of the state.

Part III. The Economics of Water Shortage - Non-Withdrawal Uses

Non-withdrawal uses of water are those uses which do not require the removal of water from its source. Included in this category are recreation, commercial navigation, and hydroelectric power production.

III-A. Commercial Navigation

Water freight transportation in Minnesota is centered at two port areas: the Port of Duluth on Lake Superior and on the Mississippi, St. Croix and Minnesota Rivers in the vicinity of the Twin Cities.

The Port of Duluth

The ability of ships to use the harbor at Duluth and Superior (Wisconsin) depends upon the level of Lake Superior and the depths of channels in the harbor. One inch of draft represents up to 110 tons of cargo on large freighters now in use and more than 200 tons on new 800 - and 1,000 - foot ships.⁷⁰ Table 19 gives some crude estimates of the value of the direct (not including secondary effects) impacts of a ton of each of seven classes of cargo handled at the Duluth-Superior harbor on revenues of harbor-related businesses. According to this table, a decline in the lake level of one inch could affect the revenues generated by a single outgoing vessel carrying cargo classified as "general" by \$1,944.80 (using the low estimate of \$17.68 per ton of cargo and assuming that cargo carrying capacity diminished by 110 tons). This, of course, is a very crude estimate for only one ship.

TABLE 19. Estimated Economic Impact of Commercial Shipping at Duluth-Superior Harbor, 1972

<u>Type of Cargo</u>	<u>Primary Impact per ton of Cargo</u>	
	(low)	(high)
General	\$17.68	\$30.00
Bulk Liquid	3.32	11.00
Iron Ore	2.76	4.00
Coal	3.32	4.00
Grain-Export (Overseas)	6.63	8.50
All Other Grain	3.34	4.00
Misc. Bulk	3.32	4.00

Source: U.S. Army Corps of Engineers, Draft Environmental Impact Statement, U.S. Statement, U. S. Army Corps of Engineers Project, Duluth-Superior Harbor, St. Paul, March, 1974, Table 11, p. 104.

The level of Lake Superior is determined by precipitation over the lake, run-off from surrounding land areas through various tributaries and the Long Lake and Ogoki Diversions in Canada, evaporation and outflow through the St. Marys River to Lakes Huron and Michigan. The level of Lake Superior is controlled to a large extent by control works at Sault Ste. Marie on the St. Marys River.

Clearance for vessels in the Duluth-Superior harbor is determined by the overall level of the lake and the depth of channels in the harbor.

Responsibility for the overall level of the lake is vested in the International Joint Commission. Responsibility for channel deepening and depth maintenance resides with the U.S. Army Corps of Engineers. The Corps of Engineers must weigh the economic advantages to expanding and maintaining channel depths with the economic, ecological, and social costs of such activities. The management of Great Lake levels is largely an interstate and international issue which lies beyond the scope of a single state's water-management plan.

Twin Cities Ports

Commodities exported downstream from the Twin Cities ports include agricultural products, grains, scrap iron, and low sulfur coals from the Dakota's, Montana and Wyoming.

The shipment of grain by barge from ports in the Minneapolis-St. Paul area has been steadily increasing in recent years. These grain shipments have historically represented a large proportion of all barge traffic leaving these ports. In 1975, 2.8 million tons of grain were loaded on barges from elevators in the Minneapolis-St. Paul area. That accounted for 41.3 percent of the total shipments.

Corn and soybeans represent the largest increase in grain moved on the Mississippi from the Twin Cities. In 1969, 677,378 tons of corn were shipped from the Minneapolis-St. Paul area. By 1975, the shipment of corn had increased to 750,469 tons. Likewise, soybean shipments increased from 95,949 tons in 1969 to 171,494 tons in 1975.⁷¹

Shipments of grain on the Mississippi River from ports in the Minneapolis-St. Paul area have become principally shipments for export. The greater portion of the grain shipments on the River move to the Gulf Coast, mostly to Baton Rouge and New Orleans where they are transshipped for export.⁷² In 1973, for instance, approximately 70 percent of the total grain shipped on the Mississippi from all ports was exported to foreign countries.⁷³

Located north of Lock and Dam 1 on the Mississippi River in Minneapolis are facilities for loading low-sulphur western coal onto barges and for unloading miscellaneous bulk commodities. This coal is used by many plants adjacent to the Mississippi River and its tributaries downstream. This coal is cheaper and more easily obtained than most eastern coal. Thus, it is expected that even if air quality regulations were relaxed or air pollution control equipment became cheaper, the burning of this coal would expand.

Important commodities coming to the Twin Cities ports include petroleum products, coal, chemicals and cement. In 1975, shipments into the Twin Cities ports included 2,832,450 tons of coal, 692,866 tons of burner oil and 955,800 tons of gasoline. Table 20 shows barge traffic into and out of the Twin Cities ports from 1971 through 1976.⁷⁴

TABLE 20: Barge Traffic in Tons - All Ports, St. Paul District

<u>Year</u>	<u>Receipts, All Commodities</u>	<u>Shipments, All Commodities</u>	<u>Receipts and Shipments</u>
1971	7,593,266	4,861,805	12,455,071
1972	9,439,209	6,921,965	16,361,174
1973	7,504,777	7,767,634	15,272,411
1974	7,170,159	8,555,030	15,725,189
1975	7,561,092	7,062,614	14,623,706
1976	10,053,506	7,462,196	17,525,702

Source: U.S. Army Corps of Engineers

Although remote, the possibility exists that during an extreme drought there would not be enough water flowing in the Mississippi River to operate Lock and Dam 1 and the St. Anthony Falls locks. The minimum flow necessary to operate these locks is 225 million gallons per day. The estimated 30-day 100-year low-flow at both locks is about 300 gallons per day.⁷⁵ In order to maintain sufficient flow for navigational purposes, the U.S. Army Corps of Engineers built six dams on the Mississippi River headwater lakes. However, the welfare of the recreation industry on these lakes is dependent on the maintenance of adequate lake levels. Thus, during a very extreme drought, the potential exists for water use conflicts of interest between recreation, commercial navigation and withdrawal uses on the Mississippi River and its tributaries.

Since commercial navigation is a relatively inexpensive mode of transportation, anything which delays barge traffic will result in increased costs not only to the barge companies, but to its customers who will either pay higher rates or be forced to use other modes. Many of the customers are along the river and have facilities for using barges. Thus, using other modes can significantly affect their transportation costs. On the other hand, if they wait for the interruption to subside, they must undertake significant expense of storage.

Low-sulfur western coal is used by many plants adjacent to the river and its tributaries. If a drought situation resulted in delayed shipments, these firms might have to decrease production, use more expensive transportation modes, or possibly violate air quality standards by using greater amounts of eastern high-sulphur coal. This would, of course, depend on the length of the drought and the size of their stockpiles. In any case, eastern coal is more expensive and obtaining it would entail greater transportation costs.

III-B Hydroelectric Power

Hydroelectric facilities make use of the kinetic energy of falling water to produce electricity. Unlike some Western States, Minnesota's hydroelectric

facilities make up only a small proportion of its total electric capacity. In 1976, hydroelectric plant accounted for 132 megawatt (MW) capacity out of a State total capacity of 6,911 MW, that is 1.9 percent. In the future, this proportion is expected to decline as more steam electric plants are build and older hydro plants are retired.

Of the hydroelectric total capacity of 132 MW - 87 MW is in Region 3, 17 MW in Region 5, and 19 MW in Region 11. The remaining capacity is dispersed around the State.

Even in Region 3, the 87 MW of hydro capacity only accounts for 10 percent of the Region's total electric generating capacity. In 1976, the entire State produced 473,466 megawatt hours of hydro power, out of a total for all facilities of 28,541,561 megawatt hours, which is 1.65 percent.

If in any particular year the water flow is reduced due to a drought or the water being diverted, it could have a very serious effect on an individual hydroelectric facility. Its ability to produce electricity would be reduced or completely stopped.

The reservoirs behind the hydroelectric dams may serve other purposes for which it may be necessary to maintain a water level, for example, recreational boating or municipal water supply. During a low-flow period, these other purposes may have priority over the production of electricity so that even a small reduction in water flow could affect electric generation.

Even though low-flows would have a serious effect on individual hydro plants' ability to produce power, this reduction of hydroelectric generation would have a minimal effect on the State's total electric production. If hydro power were reduced for any reason, the deficit would be made up by operating other facilities such as the steam electric or internal combustion plant at a higher load factor. Or if that was impractical, or infeasible power could be purchased from outside the system. In either case, the substituted power would probably be more expensive than the hydro power. Since the amount of electricity involved is very small compared to the statewide total, such costs would be minimal.

III-C Recreation

Water-related recreation consists of recreational activities associated with a particular surface water entity (i.e., a river or a stream), the interface between the land and the water, and the land immediately surrounding the water. It consists of a set of mental and physical activities that range from the active to the passive, from the consumptive to the non-consumptive use of recreational resources. Thus, it includes such activities as aesthetic enjoyment, nature study and appreciation, sailing and canoeing, fishing, and power boating. It produces both intangible benefits such as enjoyment, and tangible economic benefits to citizens of the State.⁷⁶

A water shortage may bring about economic impacts through recreation in the following ways:

- (1) It may exacerbate conflicts between recreational and nonrecreational uses.
- (2) It may exacerbate conflicts among recreational uses.

- (3) It may have detrimental effects on recreational activities in dependent of other uses.

1. Conflicts between Recreational and Non-Recreational Uses of Water - Water Quality

In Section I-A, 1 above problems of water shortage and water quality in lakes and streams were discussed in the context of the 1972 Amendments of the federal Water Pollution Control Act. It was pointed out that the water in rivers and streams at 12 percent of 75 water quality monitoring stations operating by the Minnesota Pollution Control Agency were not in compliance with the fishable aspect of the 1983 national goal and swimming might not be advisable in a majority of the rivers in the State considered due to excessive concentrations of fecal coliform. Problems of lake eutrophication were also discussed.

It was pointed out that these quality problems were attributable to both point source and non-point sources of pollutants and that concentrations of these substances were greater during low-flow periods.

The Barr Engineering Company has associated water quality ranges with three levels of lake use. The recreational activities in each level are:

Level I

Scuba Diving and Snorkeling
Swimming

Level II

Sailboating
Canoeing
Water-skiing
Motorboating
Hiking-Picnicing

Level III

Fishing

Figure 6 present a hypothetical relationship between time, the deterioration of lake quality, and each use level.⁷⁷

It would also be possible to imagine a similar relationship between water quality and recreational use in rivers and streams. In this case, the relevant water quality parameters would include BOD's turbidity, and fecal coliforms.

2. Conflicts Between Recreational and Non-Recreational Uses of Water - Water Quantity

Problems of this type are as follows:

- (1) Between 1881 and 1913, the Corps of Engineers constructed six dams on lakes in the headwaters area of the Mississippi River primarily

to maintain minimum flows in the Mississippi River for navigation purposes. Of course, adequate flows are also needed for withdrawal uses.

All of the headwaters lakes are used extensively for recreational purposes. Stable lake levels are desirable for recreational purposes, in particular for recreational boating and boat launching facilities. Thus, during an extreme drought, there is a potential conflict between maintaining adequate flow levels for activities on the Mississippi River and recreational activities on these lakes.

- (2) During droughts, conflicts can develop between the need to maintain lake levels for recreational use and the drawing down of lake levels due to ground water withdrawals for agricultural irrigation, other industrial use, and by municipal water utilities. These problems can become chronic if ground water usage grows steadily over time due to population growth or increasing withdrawals for industrial uses.

3. Other Problems of Water Shortages for Recreation

Receding lake levels have obviously detrimental impacts on recreational activities. Lakes are simply uglier to look at. Aquatic life and habitat may be adversely affected. The value of private property adjacent to the lake falls. Access to the water becomes less convenient because boats must be transported beyond piers to reach the water. Hazardous objects are closer to the surface. Objectional odors and other ill effects of increased pollutant concentrations reduce the desirability of the water for recreational purposes.

4. Overcrowding

Recent and not-so-recent projections of the demand for water-related recreational activities made by basin commissions and by the Metropolitan Council all indicate that the demand for water-related recreational activities may be expected to increase through the year 2000. This is likely to result in serious problems of overcrowding at some recreational water sites which can be avoided only by judicious rationing (price or non-price) of the available space. Overcrowding increases conflicts among recreational uses and can result in degradation of the environment.

Tables 21 through 26 present estimates and projections for recreational demand for regions of the State and for the Twin Cities metropolitan area. For the specific methodologies used, the reader is referred to the referenced sources. Some of these projections did not take into account the increases in gasoline prices which rose sharply during the 70's. Nevertheless, increasing demand for water-related recreational activities is a distinct possibility.

5. Water-Related Recreation and the Economy

The importance of water-related recreation to the Minnesota economy may in part, be realized by considering a breakdown of expenditures attributed to tourists and travelers in the State.⁷⁸ Obviously, not all tourist-travel expenditure is devoted to recreation, since part of the travel is for business purposes and not all tourism is related to water recreation. It seems likely, however, that a substantial portion of these expenditures are related to water-related recreation in this "land of ten thousand lakes." Tourist-travel

Table 21: Projected Demand for Water-Related Recreation Activity Occasions -
Northeastern Minnesota and Four Northwestern Wisconsin Counties

		Annual Activity Occasions (in thousands)							
		1970		1980		2000		2020	
Activity		Annual	Summer	Annual	Summer	Annual	Summer	Annual	Summer
LAND-BASED WATER ORIENTED	Swimming	2,637	2,294	3,649	3,164	5,299	4,593	7,300	6,328
	Beach (55%)*	1,450	1,262	2,007	1,740	2,914	2,526	4,015	3,480
	Picnicking	1,793	1,154	2,144	1,378	2,711	1,745	3,380	2,172
	Camping	369	226	558	342	850	624	1,196	735
	Nature Walking	344	84	408	102	512	128	630	156
	Hiking	135	81	201	119	291	177	433	261
	Sightseeing	1,591	650	2,060	841	2,822	1,151	3,776	1,541
TOTAL ACTIVITY OCCASIONS		6,869	4,489	9,020	5,946	12,485	8,318	16,715	11,193
TOTAL ACTIVITY OCCASIONS (55%)		5,682	3,457	7,378	4,522	10,100	6,251	13,430	8,345
TOTAL RECREATION DAYS**		2,748	1,796	3,608	2,378	4,994	3,327	6,686	4,477
TOTAL RECREATION DAYS (55%)		2,273	1,383	2,951	1,809	4,040	2,500	5,372	3,338
WATER SURFACE	Boating	1,132	759	1,597	1,060	2,330	1,561	3,254	2,180
	Water Skiing	195	150	331	259	548	427	848	658
	Canoeing	81	38	104	56	149	79	217	119
	Sailing	42	31	58	41	87	62	120	85
	TOTAL ACTIVITY OCCASIONS	1,450	978	2,090	1,416	3,114	2,129	4,439	3,042
TOTAL RECREATION DAYS		580	391	836	566	1,245	852	1,776	1,217
PLANNING AREA TOTALS***									
WATER-ORIENTED ACTIVITY OCCASIONS		7,132	-	9,468	-	13,212	-	17,870	-
WATER-ORIENTED RECREATION DAYS		2,853	-	3,787	-	5,285	-	7,148	-

* It is assumed that 45 percent of all swimming is associated with pools and 55 percent is associated with beaches. For planning purposes, activity occasions and recreation days for land-based water-oriented activities are presented in two manners, one including all swimming and the other including only beach-associated swimming.

**It is assumed that a recreation day consists of 2.5 activity occasions.

***Total water-oriented recreation days are the sum of land-based water-oriented recreation days (55 percent) and water surface recreation days.

Table 22: Estimated 1975 and Projected 2000 Demand
for Water-Related Recreation Activity Occasions,
Minnesota River Basin.

<u>Activity</u>	<u>1975</u>	<u>2000</u>
Swimming	159,568	215,871
Fishing	38,800	51,352
Boating	14,150	16,292
Canoeing	7,860	14,854
Water Skiing	35,944	77,628
Sailing	2,286	2,633
Waterfowl Hunting	13,941	17,005

Source: Southern Minnesota River Basin Commission,
Minnesota River Basin Report, Tables II-16,
p. II-19, and IV-13, p. IV-26.

Table 23: Estimated and Projected Demand for Water-Related Outdoor Recreation,
Rainy River Basin

(Recreation Days - In Thousands)^{1/}

Activity	1968		1980		2000		2020	
	Annual	Summer	Annual	Summer	Annual	Summer	Annual	Summer
Swimming	129	112	185	160	286	248	360	313
Boating (Gen.)	65	42	94	62	145	97	185	122
Water Skiing	12	9	21	16	38	30	53	41
Fishing ^{2/}	<u>1,653</u>	<u>-</u>	<u>1,788</u>	<u>-</u>	<u>1,992</u>	<u>-</u>	<u>2,246</u>	<u>-</u>
Totals - Water-Related Recreation Days	1,859	163	2,088	238	2,461	375	2,844	476

^{1/} Includes persons 12 years of age and older, with the exception of swimming. For this activity, the effective population was considered to be those persons six years of age and older.

^{2/} In fisherman days.

Source: Souris-Red-Rainy River Basins Commission. Souris-Red-Rainy River Basins Comprehensive Study, Vo. 5, Appendix I: Recreation and Preservation, Table I-21, p. I-99.

Table 24: Estimated and Projected Demand for Water-Related Outdoor Recreation,
 Red River Basin
 (Recreation Days - In thousands)^{1/}

<u>Activity</u>	<u>1968</u>		<u>1980</u>		<u>2000</u>		<u>2,020</u>	
	<u>Annual</u>	<u>Summer</u>	<u>Annual</u>	<u>Summer</u>	<u>Annual</u>	<u>Summer</u>	<u>Annual</u>	<u>Summer</u>
Swimming	1,634	1,416	2,314	2,008	3,403	2,950	4,302	1,733
Boating	812	544	1,174	780	1,729	1,150	2,204	1,461
Water Skiing	154	118	264	208	454	353	628	487
Fishing ^{2/}	<u>2,084</u>	<u>-</u>	<u>2,623</u>	<u>-</u>	<u>2,947</u>	<u>-</u>	<u>3,097</u>	<u>-</u>
Totals - Water-Related Recreation Days	4,684	2,078	6,375	2,996	8,533	4,453	10,231	3,681

^{1/} Includes persons 12 years of age and older with the exception of swimming. For this activity, the effective population was considered to be those persons six years of age and older.

^{2/} In fisherman days.

Source: Souris-Red-Rainy River Basins Commission. Souris-Red-Rainy River Basins Comprehensive Study, Vol. 5
 Appendix I: Recreation and Preservation, Table I-11, p. I-56.

Table 25: Projected Recreation Demand,
Mississippi Headwaters
(thousand recreation days)

<u>Year</u>	<u>Quantity</u>
1964	58,486
1980	101,476
2000	165,961
2020	233,946

Source: U. S. Department of the Interior, Bureau of Outdoor Recreation. Recreation, Appendix K, Upper Mississippi River Comprehensive Basin Study, 1968. Table K-24, p. K-110.

Table 26: Projected Recreation Water Surface Demand
by Activity, Metropolitan Area

<u>Activity</u>	<u>1970</u>	<u>1980</u>	<u>1990</u>	<u>2000</u>
Waterskiing - Lakes (acres)	11,711	14,656	16,352	16,632
Waterskiing - River (miles)	39	46	49	48
Fishing - Lakes	23,419	30,267	31,001	41,344
Fishing - Rivers	21	25	25	26
Sailing	4,454	6,827	6,879	4,989
Canoeing - Lakes	279	733	785	702
Canoeing - Rivers	132	165	161	145
Boating - Lakes	5,964	6,738	7,747	10,411
Boating - Rivers	14	17	19	26

Source: Upper Mississippi River Basin Commission. Minneapolis-St. Paul Water and Land: Future Perspectives and Plans, June 1977, Table VII-8, p. VII-20.

in the state.

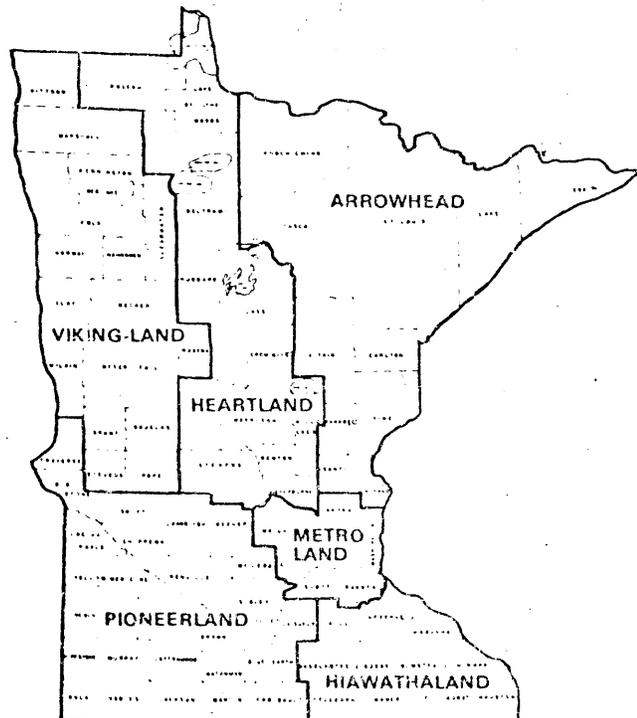
Table 27: Tourist-Travel Expenditures
Minnesota, 1976

<u>Industry Segment</u>	<u>Percent of Total</u>	<u>Receipts</u>
Transportation	26.0%	\$ 345,299,000
Commercial Accommodations	18.1	240,868,000
Food and Beverage	29.4	390,108,000
Other Retail	23.0	305,667,000
Amusements and Other Services	3.5	45,865,000
TOTALS	100.0%	\$1,327,807,000

Source: Minnesota Department of Revenue, Tax Research
and Minnesota Department of Economic Develop-
ment, Research Division

Map 3

Minnesota Tourism Regions



expenditure in Minnesota is shown in Tables 27 and 28. Map 3 identifies tourism regions.

TABLE 28: Effect of Travel Dollars
in Minnesota by Region, 1976

<u>Tourist Region</u>	<u>Expenditures (dollars)</u>	<u>Percent of State</u>
Arrowhead	\$ 167,304,000	12.6%
Heartland	159,337,000	12.0
Hiawathaland	193,860,000	14.6
Metroland	616,102,000	46.4
Pioneerland	82,324,000	6.2
Vikingland	108,880,000	8.2
Regional Totals	<u>\$1,327,807,000</u>	<u>100.0%</u>

Source: Minnesota Department of Economic Development, Research Division

According to the National Tourism Resources Review Commission, on a national-level the total income generated by tourist-travel expenditures is equal to one-third the expenditures.⁷⁹ Applying this ratio to Minnesota's total travel expenditure of \$1.3 billion, we obtain \$443 million as the amount of income generated by tourist-travel expenditures in 1976.

The Department of Economic Development has estimated that in 1976 each \$14,793 in receipts produced one job. Table 29 shows estimated income and employment derived from travel expenditures in 1975 and 1976. The reader should keep in mind that these estimates are very rough and only indicate the order of magnitude.

TABLE 29: Benefits Derived from
Travel in Minnesota

	<u>1975</u>	<u>1976</u>
Total Receipts	\$1.2 billion	\$1.3 billion
Income	\$400 million	\$443 million
Employment	83,000	90,000
Average Income Per Worker	\$4,822	\$4,944

Source: Minnesota Department of Economic Development Research Division

Tables 30 and 31 give estimates of expenditures and employment at a more detailed industrial level. Table 32 gives sales tax revenue generated.

TABLE 30: Minnesota Travel Expenditures by
Major SIC Classification, 1976

SIC Code	Segment	Tourist-Travel Portion (000)
54	Food Stores	\$ 120,905
58	Eating and Drinking	269,203
554	Automotive Service	314,830
40, 41, 45, 47	Transportation	30,469
53	General Merchandise	89,740
56	Apparel and Accessory	17,968
59	Other Retail	197,959
70	Hotels, Lodging	240,868
72	Personal Service	16,880
79	Amusements and Recreation	28,985
	TOTAL	\$1,327,807

Source: Minnesota Department of Revenue, Tax Division, Sales and Use Tax Data by Industry; and Minnesota Department of Economic Development, Research Division

Secondary Impacts

Since, for the most part, personal enjoyment has no resale value, most of the secondary impacts of tourist-traveler expenditure are through backward linkages. The multipliers of the MINTOM model are applied to the expenditures and employment figures shown in Tables 30 and 31 to obtain rough estimates of the total dollar output and employment generated as shown in Tables 34 and 35. Dividing the indirect plus direct totals in each table by the direct totals gives the overall tourist-travel multipliers. Thus, every \$1 loss in direct revenues in the tourist-travel industry causes an additional \$.29 loss in revenues to supporting industries. Every 100 jobs loss causes the loss of about 17 jobs in supporting industries.

Table 31 : - Estimated Minnesota Employment
in the Travel Industry by Segments, 1976

<u>SIC Code</u>	<u>Segment</u>	<u>Total Full-Time Employment</u>
	<u>Food and Drink</u>	
54	Food Stores	2,024
58	Eating and Drinking	25,870
	<u>Transportation</u>	
554	Automotive Services	5,496
40	Transportation	12,491
	<u>Retail</u>	
53	General Merchandise	2,370
56	Apparel and Accessory	745
59	Other Retail	5,687
	<u>Commercial Accommodations</u>	
70	Hotels and Lodging	27,912
	<u>Amusements and Other Services</u>	
72	Personal Service	3,531
79	Amusement and Recreation	<u>3,434</u>
	TOTALS	89,560

Footnote: Seasonal employment times 1/3 equals full-time equivalents.

Sources: Minnesota Department of Economic Security, Research and Planning Branch; County Business Patterns, U. S. Department of Commerce; Minnesota Department of Revenue, Tax Research Division; and Minnesota Department of Economic Development, Research Division

Table 32
Minnesota Sales Tax Revenue from Travel Industry, 1976
by Industry Segment

SIC Code	Segment	Percent Distri- bution	Total Tax Receipts	Portion Attributed to Travel Industry
54	Food Stores	5%	\$ 10,773,241	\$ 538,662
58	Eating and Drinking	25	37,766,413	9,441,603
554	Automotive Service	25	9,312,431	2,328,108
40,1,5,7	Transportation	85	754,562	641,378
53	General Merchandise	5	36,194,716	1,809,736
56	Apparel and Accessory	5	1,115,452	55,773
59	Other Retail	10	36,433,700	3,643,170
70	Hotels, Lodging	100	9,612,350	9,612,350
72	Personal Services	20	1,402,827	280,565
79	Amusements and Recreation	15	5,650,825	847,624
	Totals	19%	\$151,154,169	\$29,199,169

Source: Minnesota Department of Revenue, Tax Research Division; and Minnesota Department of Economic Development, Research Division

Table 33
Minnesota Alcoholic Beverage Taxes Attributed to Tourist-Travel Industry
1975-76

<u>Total Tax Collected</u>	<u>1975</u>	<u>1976</u>
Distilled Spirits	\$40,382,076.14	\$40,499,311.32
Malt Tax Collected	<u>9,098,444.02</u>	<u>9,854,409.45</u>
Total Tax Collected	\$49,480,520.16	\$50,353,720.77
25 Percent Apportioned to Travel Industry	\$12,370,000.00	\$12,588,430.00
Percent Change		+1.8%

Source: Minnesota Liquor Control Commission, Minnesota Department of Public Safety; and Minnesota Department of Economic Development, Research Division

Table 34: Direct and Indirect Impacts
of Tourist Expenditures in Minnesota - 1976

SIC Code	Segment	Sales	MINTOM Sector	Multiplier Applied	Direct and Indirect Output Due to Expenditures
54	Food Stores	120,905	28	1.253	151,494
58	Eating and Drinking	269,203	28	1.253	337,312
554	Automotive Service	314,830	28	1.253	394,482
40,41, 45,47	Transportation	30,469	20,22	1.430	43,571
53	General Merchandise	89,740	28	1.253	112,444
56	Apparel and Accessory	17,968	28	1.253	22,514
59	Other Retail	197,959	28	1.253	248,043
70	Hotels, Lodging	240,868	30	1.425	343,237
72	Personal Service	16,880	30	1.425	24,054
79	Amusements and Recreation	28,985	33	1.251	36,260
TOTALS		1,327,807	--	-	1,713,411

Overall multiplier: 1.29

Source: Minnesota Department of Economic Development, Research Division; and
Minnesota Energy Agency

Table 35: Direct and Indirect Employment Impacts
of Tourist Expenditures in Minnesota - 1976

<u>Code</u>	<u>Segment</u>	<u>Employment</u>	<u>MINTOM Sector</u>	<u>Multiplier Applied</u>	<u>Direct and Indirect Employment</u>
54	Food Stores	2,024	28	1.074	2,174
58	Eating and Drinking	25,870	28	1.074	27,784
554	Automotive Service	5,496	28	1.074	5,903
40,41, 45,47	Transportation	12,491	20,22	1.320	16,488
53	General Merchandise	2,370	28	1.074	2,544
56	Apparel and Accessory	745	28	1.074	800
59	Other Retail	5,687	28	1.074	6,108
70	Hotels, Lodging	27,912	30	1.242	34,666
72	Personal Service	3,531	30	1.242	4,386
79	Amusements and Recreation	<u>3,434</u>	<u>33</u>	<u>1.185</u>	<u>4,069</u>
TOTALS		89,560	--	-	104,922

Overall multiplier: 1.17

Source: Minnesota Department of Economic Development, Research Division; and
Minnesota Energy Agency

PART IV: CONCLUSIONS AND THE ROLE OF THE PUBLIC SECTOR

IV-A. Conclusions from Previous Sections

Several conclusions and observations may be derived from the foregoing which have relevance for government policy designed to cope with water shortages and their economic effects. Concerning water shortage problems, it is evident that they:

- (1) Are found in specific locations;
- (2) May be temporary, recurring, or chronic in nature; and
- (3) Become worse as economic and population growth take place in an area.

Concerning economic impacts, the following general conclusions may be made:

- (1) Our knowledge concerning the specific actions that firms will take and the quantitative nature of economic impacts is at best highly limited.
- (2) Individual water users usually act in their own interests and take into account only those costs which they perceive to apply to themselves.
- (3) Specific water-shortage problems can affect individual firms adversely. It can cause them to reduce output, close down temporarily, or even permanently. These effects will of course adversely affect employment and earnings in the affected plants themselves and will adversely affect other firms and individuals in the economy through secondary impacts.
- (4) Charges for water withdrawals or consumption, or for effluent concentrations or more stringent limitations on withdrawals, consumption or effluent concentrations can also have adverse effects in some sectors. On the other hand, if such policies promoted more efficient water allocation, the benefits forthcoming from such charges would outweigh the costs to adversely affected sectors. As discussed below, such policies should be designed to force firms to internalize the costs they impose on others through their use of water. If firms do not internalize such costs, they are in effect exacting subsidies from those who must bear the costs. Obviously, if an unwarranted subsidy is removed, the ones who benefited from the subsidy are worse off. But those who have not are less severely affected by the water shortage.

- (5) The severity of economic impacts depends upon the geographical and time perspectives considered. Part of the adverse economic impacts may be made up through investments in other places and other times and through production deferred to other places or to later times. The extent to which the adverse economic impacts will be mitigated will depend upon the availability of idle resources in the alternative times or places.

IV-B. Role of the Public Sector

There are basically two roles the public sector can take. In one role, the public sector can seek to prevent or to minimize adverse economic impacts from water shortages through allocative policy. In the other, the public sector can seek to compensate those who have suffered losses. This section will be concerned with the first role but only on a superficial level. A more detailed consideration of allocation options will be discussed in a forthcoming technical report.

(1) Objectives of Allocative Policy

The purpose of government allocative policy is to seek a distribution of available water among consumptive and non-withdrawal uses which promote the maximum achievement of implicit and explicit government objectives. Usually such objectives include the following:

- (1) Maximizing economic well-being according to such indicators as employment and/or earnings;
- (2) Maintaining or achieving an acceptable distribution of income;
- (3) Maintaining water quality to support recreational and other activities;
- (4) Maintaining flow levels to support recreational and other activities; and
- (5) Preserving the integrity of the environment.

In some cases, these objectives are compatible with each other. For example, the more flow there is in a river, the greater the capacity of the river to assimilate wastes. Thus, (3) and (4) are often complementary. On the other hand, maximizing employment and earnings is not necessarily compatible with maintaining water quality since employers' costs for pollution abatement reduces the profitability of their operations, and therefore, may reduce their incentive to employ labor. The recent controversy concerning restrictions on multiple use in the Boundary Waters Canoe Area indicates that there is some question as to whether (1) and (5) are compatible. Thus, public policy makers must decide how these different objectives must be weighed in determining the allocation policy they will follow.

(2) Levels of Allocation

There are three levels at which allocation can be carried out. These are:

(1) Allocation between sources.

On a large scale, these may involve "interbasin transfers" whereby water is carried over large distances between river or lake basins. Such transfers are fairly common in the west. The city of Los Angeles, for example, receives its water from northern California and from the Colorado River. In Minnesota, it has been suggested that water from Lake Superior be transferred to the Mississippi River Basin to supplement water supplies in the Twin Cities area.⁸⁰ Such transfers involve huge governmental investment costs and may have profound effects on the area from which water is obtained. For example, water drawn from the great lakes by means of interbasin transfers could have detrimental effects on recreational and commercial docking facilities, the operations of locks and dams between the lakes, and would result in political imbroglios among the various political entities which border on the lakes. In any case, it is at best, extremely difficult to judge when the expenditures of resources necessary to effect such transfers are justified by their benefits, and to establish fair methods to compensate all who bear the costs of the transfers.

(2) Allocation at the source.

This involves the distribution of water among those who withdraw and/or who use water from or in a single source or several hydrologically related sources in an area. Thus, this would include the distribution of water among municipal water utilities, industrial withdrawers, agricultural withdrawers, private domestic wells, and water left in surface-water sources to maintain levels for non-withdrawal uses. It would also include structural measures to reallocate water in time at a particular source. For example, reservoirs and dams can be used to store water during periods of relatively high flow (on a stream) for use during periods of relatively low flow.

(3) Allocation by Intermediate Suppliers.

This concerns the distribution of water by municipal water utilities and rural water systems to their customers.

(3) Approaches to Allocation

When water availability is limited, the consumption of water by one user, or the retention of water in a surface source denies the use of water to other users. Thus, the use of water by some results in costs to others in the form of benefits forgone.

For example, during a low-flow period, an upstream user may be able to obtain all the water he wants at no cost to himself. Yet his use of water will impose costs on users downstream in the form of foregone earnings due to a lack of sufficient water, higher intake treatment costs due to higher concentrations of pollutants, and so forth. Thus, even though the upstream user perceives no costs to himself, there are external costs imposed upon others through his use of water.

In order to obtain the maximum social benefit from water consumed from a surface or ground-water source, or left in a surface-water source for non-withdrawal uses, it is necessary that the benefits derived from each unit in a particular use exceed or equal the benefits lost through its denial to alternative uses.

One way of accomplishing this is to cause users to internalize all of the costs of their water consumption including the costs imposed on others. In other words, to cause them to treat these costs of their water use as if they were their own private costs.

There are several ways to induce users to internalize all of the costs of their water use. These may be dichotomized into per-unit pricing schemes and non-price rationing although combinations of these approaches are also conceivable and may be desirable in some circumstances.

Per-unit pricing schemes can take the form of pricing per unit of intake water or per unit of water consumed. Ideally, the charge for water consumed at the source should be equal to the shadow price of the water consumed; that is to the value in the best alternative use of the last unit of water consumed. The charge for water withdrawn should be equal to the shadow price times that fraction of the last unit of water withdrawn which is consumed. Of course from a practical point of view, shadow price can never be measured accurately. However, it may be possible to circumvent this problem by charging an initially low price for water and adjusting it by trial and error. The effect of the charge could be monitored by observing its impact on estimates of the quantity of water conserved. It is also possible to ration the use of water for waste assimilation purposes by means of per-unit wasteload charges whereby charges are levied on concentrations of particular pollutants or classes of pollutants.

Non-price rationing can take the form of absolute limits on the amount of water withdrawals or consumption per time period with penalty charges for over-withdrawals or over-consumption.

Ideally, such limits would be equal to the amounts of water each withdrawer would consume if they were forced to internalize the costs of their water use with consumption in withdrawal charges. Determining such limits with any degree of accuracy would probably not be feasible.

With either approach, someone must justify the social cost of the water used by the benefits obtained in each use. With pricing, the user himself must make the justification. With non-price rationing it is the government which must make it.

Combinations of pricing and non-pricing rationing would include such arrangements as per-unit pricing by municipal water utilities with minimum water allotments at low cost to accommodate low income families, and non-price rationing with the right to trade ration allotments in a free market. It is possible to achieve similar allocations of water by using either pricing or non-price rationing; therefore, the issue of which to use comes down to determining which approach involves less costs in seeking to achieve the desired goals. In light of the conclusions of the previous parts of this report, it would seem that the following principles should be followed in devising an allocation plan for dealing with water shortages:

- (1) Policy makers should state explicitly what their goals are and should rank these goals in order of importance.
- (2) The plan should take into account the fact that there is at present limited quantitative knowledge concerning how firms will react to water shortages and to policies designed to cope with them. From an economic point of view, water should go to those uses in which it is more highly valued first and then to other uses as the value of water in those satisfied first declines. Under a pricing scheme, users, themselves identify how much they value water by what they are willing to pay for it. Under non-price rationing, the rationing authority must determine where the value of water is greatest. This requires detailed knowledge of how water is used in firms and how these firms will adjust to changes in the availability of water. Thus, in general, more information is required under non-price rationing than under pricing. Under non-price rationing, greater expense must be incurred by the rationing authority to secure the necessary information. This must be done well in advance of an actual water shortage.

- (3) Whatever allocation scheme is adopted must take into account the fact that firms respond only to costs which they believe affect themselves. For example, if the costs of an upstream user's consumption of water affect only downstream users, then the only way to get the upstream user to take these into account is to charge him a per-unit consumption charge equal to the costs of downstream users or to limit his consumption (using non-price rationing) to what it would have been if such a price were charged to him.
- (4) The costs and adverse effects on firms affected by water allocation policies which force them to internalize all of the costs of their water use and the adverse secondary impacts of such effects must be weighed against the social costs (costs imposed on others plus costs to the firms themselves) of the firms' use of water.
- (5) Allocation policy should be limited to those places where and times when water shortages exist.
- (6) The policies chosen should be flexible and should allow water users to respond quickly to changes in the conditions of water use. In general, pricing is thought to be more flexible.⁸¹ For example, a change in market conditions or the technical conditions of a water-using firm can affect the value of water in particular uses of the firm. This would be recognized faster by the firm itself than by a non-price rationing authority. Thus, if water-pricing were used as an allocative policy, the firm could adjust by changing the quantity of water it uses. On the other hand, changing the amount of water allotted to the firm under a non-price rationing scheme would require further deliberation and study by the rationing authority.
- (7) In determining the cost of water-shortages and of economic policies designed to deal with them, policy makers must determine the geographical and time perspective from which to consider the costs involved. Employment, earnings, and output losses in one area may be at least partially recouped in another as firms make up production in areas not as severely affected by a water shortage. Similarly, employment, earnings and output losses in a time of water-shortage may be at least partially offset in time when water is more abundant (relative to the demands for it). Overestimating the costs of water shortages may result in unnecessary or overly-emphasized policies for dealing with them. It must be remembered that the policies themselves have their own costs.

(4) Recommendations

The basic objective of water allocation policy is to maximize the net social benefits of water use in the face of water shortages. Net "social benefits" should be defined in terms of explicitly stated goals of public policy. The broad conclusions obtained from this study give rise to the following recommendations for formulating allocation policy. Consideration of specific allocation options based on these recommendations would require in-depth study of the hydrological, economic, environmental, social, and legal implications of the options.

- (a) Policy makers should explicitly state the goals of their allocation policies.
- (b) Policy makers should make explicit the geographic and time perspectives from which they make their assessments of economic impacts for allocation purposes. Policies concerned with an immediately affected area may differ from those with a broader geographic scope.
- (c) Allocation policies should be operable even in the face of limited information on the part of the allocating authority. Such policies should depend as much as possible, upon the decentralized decisions of individual users made on the basis of their own conditions of water use and on the basis of the real costs of their use of water.
- (d) Allocation policy should allow the economy the flexibility to adjust as quickly as possible to changes in the conditions of water use with as little government intervention as possible, and
- (e) Allocation policy should reflect the recognition that to subsidize some water users by not requiring them to internalize all of the costs of their water use may not be justified in terms of the costs imposed on others and in terms of the social benefits of such subsidization. If for some reason it is deemed desirable to subsidize these water users, then the subsidization should take the form of explicit governmental cash payments. In other words, such subsidization should be brought out front where it is subject to public scrutiny instead of being hidden behind higher water-use costs imposed upon a select group of other water users and their customers.

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