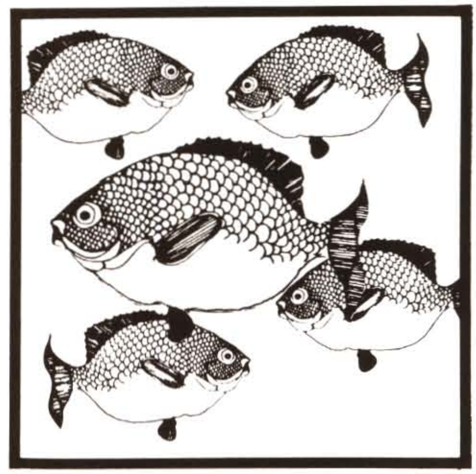
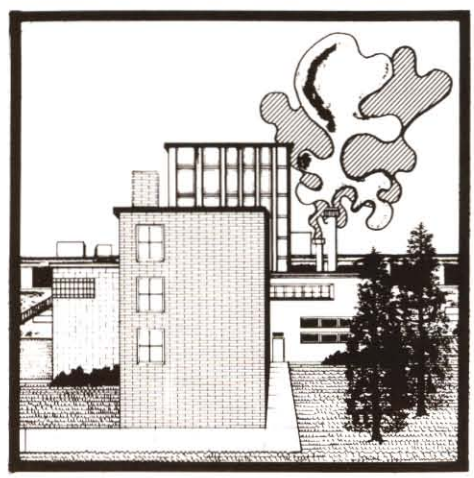


POLICY ISSUE STUDY ON

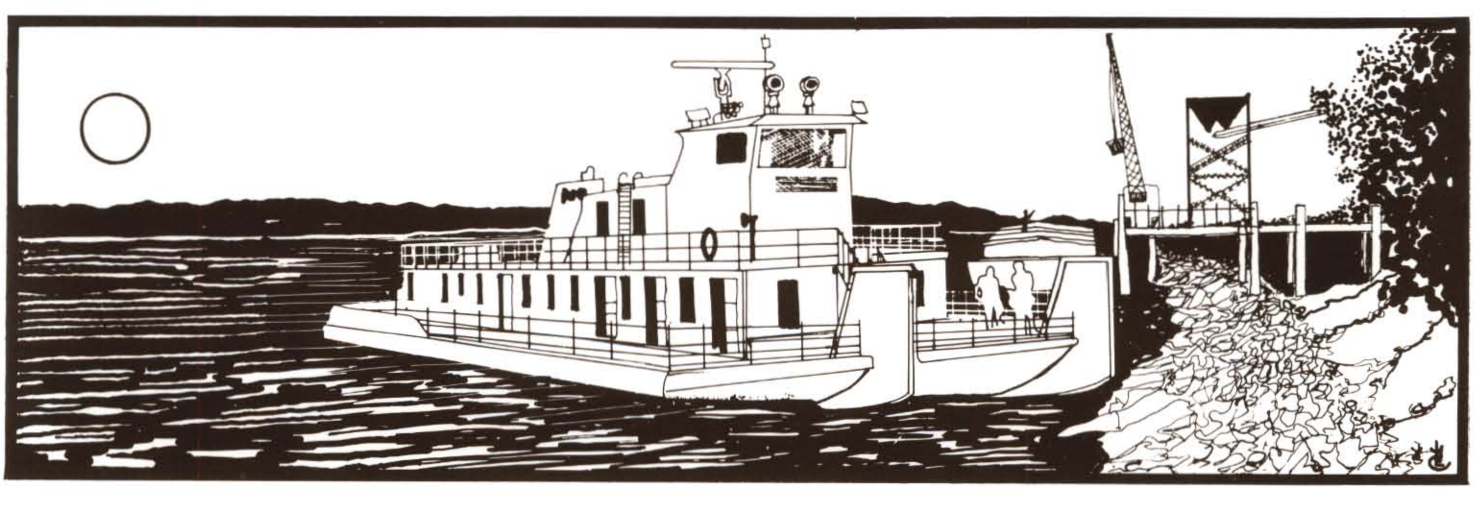
WATER AND ENERGY

State Water Planning and Review Process

Nebraska Natural Resources Commission

JANUARY 1984



POLICY ISSUE STUDY
ON
WATER AND ENERGY

WATER AND ENERGY REPORT

REPORT
OF THE
NATURAL RESOURCES COMMISSION

JANUARY 1984

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PROGRAMS:

SOIL & WATER CONSERVATION
WATERSHED PROTECTION
COMPREHENSIVE PLANNING
FLOOD PLAIN MANAGEMENT
DATA BANK
WATER CONSERVATION FUND
DEVELOPMENT FUND

STATE OF NEBRASKA

NATURAL RESOURCES COMMISSION

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P.O. Box 94876
Lincoln, Nebraska 68509
Phone: (402) 471-2081

The Honorable Robert Kerrey
Governor, State of Nebraska
State Capitol, 2nd Floor
Lincoln, Nebraska 68509

Members of the Nebraska Legislature
Eighty-Eighth Nebraska Legislature, Second Session
State Capitol
Lincoln, Nebraska 68509

Dear Governor Kerrey, Members of the Legislature and Members of the Nebraska Public:

This report entitled "Policy Issue Study on Water and Energy" has been reviewed and approved by the Natural Resources Commission. It is one of a series of studies on water policy issues.

The report examines 12 water policy issues related to energy and related policy alternatives. However, unlike previous policy issue studies it contains no new recommendations by the Commission.

It is the hope of the Natural Resources Commission that the report will be helpful in the examination of water policy issues related to energy. The Natural Resources Commission is prepared to answer any further questions you may have.

Sincerely,

Clinton VonSeggern

Clinton VonSeggern, Chairman
Natural Resources Commission

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FOREWORD

This is one of a series of policy issue studies that are part of the State Water Planning and Review Process. It differs from other policy study reports in that it does not contain any new Commission comments and recommendations on Policy Alternatives. Therefore, with the exception of this foreword this report is substantially the same as the task force report to the Commission.

The Task Force responsible for conducting this study consisted of representatives of state agencies and the University of Nebraska-Lincoln. They were:

Jon Atkinson. . . . . Dept. of Environmental Control
Gerald Chaffin. . . . . .Game and Parks Commission
Susan France. . . . . Dept. of Water Resources
William Lee . . . . .Dept. of Health
Susan Miller. . . . . Water Resources Center, UN-L
Vernon Souders. . . . . . Conservation and Survey Div., UN-L
Gerald Wallin, Leader . . . . . Natural Resources Commission

Dr. Martha Gilliland and Mr. Robert Kuzelka of the University of Nebraska-Lincoln worked on this study under contract with the Natural Resources Commission. Dr. Gilliland and the staff of the Natural Resources Commission were primarily responsible for the preparation of this report.

A special committee of the Commission was assigned to work with the Task Force on this study. The committee members were:

Howard Hardy, Chairman
Richard Hahn
Paul Schroeder

This report was preceded by both the Final Task Force report and a report to the Commission on the preliminary results of the first stage of the study. The first stage report was used as the basis for the decision to revise the study design. The preliminary material contained in that report was refined in the second stage and incorporated into this final report.

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SUMMARY

The Water/Energy Policy Issue Study was the first to originate through the planning and Review Process, not legislative mandate. Several years ago, international and interstate conflicts and demands for energy and water resources created a great deal of uncertainty about future energy development in Nebraska and upstream states. This raised questions about the availability of water and the energy to use it in the future. The Natural Resources Commission and e cooperating state agencies believed these questions were serious enough to warrant study of the problems and issues. This study was authorized for the purpose of formulating and evaluating the effectiveness and impacts of he alternative state policies related to the availability and production of energy for water development and use, and the availability and use of water for energy production. It was to examine potential development in upstream states and their impact on Nebraska water supplies as well as potential development and water availability in this state. This included all forms of energy development and all water uses, although the study eventually focused primarily on electric power generation and water requirements in Nebraska. This study was coordinated with several other policy issue studies that were in progress at the time, and ic material from those studies played an important role in the development of this report.

NEBRASKA ENERGY AND WATER SUPPLY AND DEMAND

Nebraska imported more than 90 percent of the energy it consumed in 1980, and this pattern is not likely to change signficantly in the foreseeable future. Nebraska produces small quantities of natural gas, oil, hydroelectric power, ethanol, and solar energy. It also converts other primary fuels (coal and uranium) to electricity within the state. Of these primary fuel forms, the production of ethanol and solar energy are expected to expand, perhaps rapidly. However, they are unlikely to contribute more than a few percent of Nebraska's total energy consumption.

The three major energy forms (natural gas, oil, and electricity) are likely to maintain about the same share of total primary energy consumption in Nebraska that they now hold. Among fuel types, electric power consumption is expected to grow fastest at 3.1 to 5.1 percent per year through 1990. Oil consumption is expected to remain nearly constant and natural gas consumption is expected to increase slowly.

Total energy consumption in Nebraska is projected to grow at a rate of 1.8 to 2.6 percent per year through 1990. However, it is important to note that, except in the case of one fuel form (electricity) and one sector (agriculture), projected growth rates are inconsistent with trends since 1975, which show declines. Nevertheless, between three and nine new 600 Mw coal-fired power plants will probably be needed in Nebraska by 2009, depending on the growth rate and the completion of the MANDAN transmission line. It is more likely that three plants will be needed than nine.

Available water use data for energy production in the State show that water use by all other energy production technologies is insignificant compared to electric power production. This is true under existing conditions and in the year 2000, regardless of the cooling technology employed by the power plant. If new power plants use once-through cooling, diversions for power generation will be about 1.5 times greater in 2000 than they are today; consumption will be about two times greater. On the other hand, if new power plants use wet cooling towers, diversion in 2000 for power generation will be about the same as today but consumption will be about three times greater.

According to the Second National Water Assessment, irrigation constituted about 94 percent of Nebraska's total non-energy water consumption in 1975. It is projected to remain about the same in the year 2000. Total non-energy water consumption is expected to increase about 91 percent, from about 4.9 million acre-feet per year to about 9.4 million acre-feet per year in 2000. Much of this will be from groundwater, so streamflow will be depleted by only an additional 1.5 million acre-feet per year by 2000.

ENERGY AND WATER DEVELOPMENT IN UPSTREAM STATES

The use of water for energy development in the Missouri River Basin states upstream of Nebraska could affect Nebraska's water supplies in two areas, the Missouri River and the North and South Platte River Basins. Studies generally indicate that annual streamflow depletions by future energy development in the upper Missouri River Basin will increase by a maximum of about one million acre-feet by the year 2000. This is only 4.5 percent of the historic flow of the Missouri River at Sioux City, Iowa. The practical limit of depletions by all types of uses, including projected energy development, in the upper basin states could be as much as 9.9 million acre-feet per year above the 1970 level of depletion.

The North and South Platte Rivers are of more concern because their flows are much smaller. Large-scale water use in Wyoming and Colorado, which is expected only if national policy dictates energy independence, could significantly reduce flows in Nebraska. Even with lower levels of energy development, the depletion to streamflow in these two river basins is projected by the Second National Water Assessment to increase by 37 percent by 2000.

FUTURE WATER AVAILABILITY

The Second National Water Assessment projects that average annual flows available in the year 2000 will be 2,954,100 acre-feet in the Platte-Niobrara area and 1,202,600 acre-feet in the Republican-Blues area. The remaining supply in the North and South Platte Rivers is projected to be 718,000 acre-feet per year. Future depletions to flow in the upper Missouri River Basin should leave average annual flows in the Missouri River at Sioux City of 13,625,400 acre-feet in the year 2000. Even if the unlikely amount of 9.9 million acre-feet of depletions should occur, it is estimated that there would be flows in the Missouri River past Nebraska of at least 6,000 cubic feet per second even in severe droughts. In short, the total water supply will still be substantial on an annual basis, and the minimum flow in the Missouri River should be adequate for power plants.

Water requirements for other energy uses in Nebraska are minor compared to electric power and there probably will be adequate water supplies at enough sites to support the three to nine new power plants that may be needed by 2009. On a statewide basis, water supplies will be adequate for projected energy needs in the foreseeable future. Competition for local supplies may occur in some areas, with locally significant impacts. In the past, conflicts of this nature have raised policy issues, and they will continue to do so in the future.

WATER PROBLEMS AND ISSUES RELATED TO ENERGY

This study showed that it is unlikely that there will be any widespread shortage of water for energy development. However, a number of energy related water problems and issues were identified. Existing problems and issues stemmed from conflicts due to competition for locally inadequate water supplies, related problems such as water quality impacts, and existing policies. Also identified were potential problems and issues that could arise if unexpected development occurs and unplanned demands are made, or projected supplies are not available. The 12 issues that were identified are enumerated in the following sections on water and energy problems.

Loss of Water Supply for Power Generation

At hydroelectric plants and thermoelectric plants with once-through cooling systems, large quantities of water must be available to generate power. Consequently, adequate and reliable streamflow is a prerequisite for these kinds of power plants. This need can cause a conflict between agricultural and power users of water, because agriculture is superior to manufacturing in Nebraska's preference system. Whenever the preferred irrigation demand is upstream of the power plant, the consumptive use of water by irrigators can reduce the amount of water available to the power plant downstream.

Several issues that are related to this problem were identified.

(1) The Ranking of the Energy Industry in the Statutory System of Preference in Water Use.

Manufacturing uses, including energy production, rank below domestic and agricultural uses in Nebraska's preference system. Consequently, an energy industry water right can be pre-empted by agricultural users, if compensation is paid for the water.

(2) Transferability of Water Rights to an Energy Industry From Other Uses. Under newly enacted legislation, water rights may be transferred among users of the same type (for example, among

agricultural users) but not between different types of uses (for example, from an irrigator to an electric utility).

(3) Leasing Water for Generating Hydroelectric Power.
Under existing State laws, only those generating electricity at hydro plants are required to pay the State an annual fee for the amount of water used. No other water users are required to pay anything.

Water and Energy Losses

Many studies have shown that some irrigators pump too much water. This pumping causes extra demand for power during peak load periods. More efficient use of water, more efficient pumps, and scheduling pumping times would reduce the peak power demand and total power consumption. These reductions would reduce the amount of water consumed by power plants and delay or reduce the need for new power plants. This issue has been summarized as follows:

(4) Conservation of Water to Reduce Energy Consumption, Especially Electric Power.
Current policies do not always encourage irrigators to adopt or continue to use techniques such as conservation tillage, irrigation scheduling, and restrictions on the timing and amount of groundwater pumpage.

Effects of Energy Production on Water Quality

In this study, water quality impacts related to water use in energy production were not investigated in detail. One energy production technology that may produce water quality problems is in-situ solution uranium mining. This issue has received a great deal of attention from the legislature and others.

(5) Water Quality Impacts of In-Situ Uranium Mining.
The potential for water pollution, disruption of existing land uses, and competition for local water supplies is substantial but highly uncertain. At this time the impacts are limited because there is only one research and development project.

Consumptive Use of Water by Power Plants

The amount of water required by a thermoelectric power plant depends on the type of cooling used. If once-through cooling is used, large diversions are required but consumptive use is very small. In contrast, if evaporative cooling is used, consumptive use is increased, but diversions are small.

(6) Trade-offs Between Increased Consumptive Use and High Volumes of Withdrawal.
Once-through cooling is the least expensive option, so it reduces the cost of electric power. It makes more water available to downstream users, so it can also enhance instream flow values, but it may reduce the amount available to upstream users. State policies and positions on the use of once-through cooling have not always been consistent.

Interstate and Interbasin Transfers of Water

A proposed energy development in northeastern Wyoming has been the source of considerable controversy. The coal slurry pipeline proposed by Energy Transportation Systems, Inc. (ETSI) has produced disputes and lawsuits among the states of South Dakota, Missouri, Iowa, and Nebraska have several federal agencies. Another lawsuit has increased concerns about groundwater exports. In 1982 the U.S. Supreme Court declared unconstitutional the section of a Nebraska statute that prohibits interstate transfer of groundwater unless the receiving state grants reciprocal rights. That case left unanswered a number of questions concerning the authority of a state to control the export of its groundwater. These problems and conflicts raised several issues.

(7) Water Export for Energy Production.
State policy could be revised to either limit or encourage export of groundwater from Nebraska for energy developments.

(8) Depletion of North Platte River Flows in Wyoming.
Information on proposals or plans for development on the North Platte in Wyoming, or exports from the river or its tributaries, is inadequate to determine possible impacts on Nebraska. Some institutional arrangement or agreement is needed to improve interstate communication and cooperation.

Use of Water to Produce Energy for Export

In 1980, a proposal to construct a power plant in western Nebraska to serve customers in Colorado and Wyoming as well as Nebraska caused considerable opposition among local interests. This controversy eventually led to the passage of the Industrial Groundwater Regulatory Act of 1981. Other statutes that would provide more balanced and comprehensive industrial siting laws have been proposed and considered in the legislature.

Two issues have been identified.

(9) Power Production for Export.
Nebraska could use its water with Wyoming coal to become a major exporter of power. The economic and employment benefits from this type of development could be significant, but it could generate substantial controversy.

(10) A Comprehensive Industrial Siting Law.
An industrial siting act could facilitate the location and construction of industries and minimize impacts on the State's water resources.

Potential Reductions in Water Use by Power Plants

The amount of water used in generating electricity at a given plant is directly related to the amount generated. Reducing power consumption would reduce water use. If it also reduced the peak demand, it might delay the need for new power plants.

(11) Energy Conservation Through Control of Energy Use by Water Consumers. Peak demand for electric power can be reduced through a variety of load management techniques. These techniques can be difficult to implement, but they could have significant effects on water use.

(12) Development of Alternative Energy Sources.
State policy currently encourages the development of some alternative fuels and other energy sources, including geothermal energy. Additional incentives or regulations could reduce the use of electricity and help reduce the water required for generation.

CONCLUSIONS

The 12 issues identified during the course of this study vary widely in importance and the amount of consideration previously given to them in other studies and in the legislature. Three issues do not require further consideration in this study. They are: (No. 3) leasing water for hydropower, (No. 4) conservation of water to reduce energy consumption, and (No. 5) water quality aspects of uranium mining. Five issues (No.'s 1, 2, 6, 7 and 8) have been studied to some extent in the Selected Water Rights Policy Issue Study. The alternatives presented in the reports on that study are applicable to the water/energy aspects of the issues. They are summarized in the following sections as they are presented in Chapter 5 of this report. No specific alternative policies are given in Chapter 5 for the remaining four issues (No.'s 9, 10, 11 and 12). These issues are beyond the scope of this study, and much more information and expertise would be required to formulate responsible alternatives and properly evaluate their impact. Approaches to alternatives that might be examined in future, more detailed investigations are given.

POLICY ISSUES AND ALTERNATIVES

The nine issues addressed in Chapter 5 of this report have been grouped under three headings: "Water Use by Nebraska Electric Power Plants" (Issues 1, 2 and 6), "Nebraska's Role in Energy Development in the Upper Missouri River Basin States" (Issues 7, 8, 9 and 10), and "Changes in Energy Use Patterns as an Approach to Reducing Water Use for Power Generation" (Issues 11 and 12). Policy alternatives that originated in other policy issue studies are included in the first two categories.

Water Use by Nebraska Electric Power Plants

In Nebraska the generation of electric power is the only form of energy production that uses enough water to create substantive policy issues. These issues are: (1) the ranking of the energy industry in the statutory system of preference in the use of water, (2) transferability of water rights to an energy industry from other uses, and (6) trade-offs between increased consumptive use and high volumes of withdrawal. Two applicable alternatives were given in the report on

Preferences in the Use of Water from the Selected Water Rights Policy Issue Study.

> "Make Manufacturing, Commercial, and Industrial Uses Superior to Agricultural Uses" (Alternative 5)

> "Modify the Preference System by Adding Other Consumptive Uses" (Alternative 6)

A third alternative was given in the Transferability of Surface Water Rights report of the Selected Water Rights Policy Issue Study.

> "Provide that surface water rights may be freely severed from the land and transferred to a new use or new location without loss of priority, provided that such transfers are approved in accordance with law" (Alternative 2)

In considering these alternatives during that study, the Commission did not recommend any change in the status of the power industry in relation to agriculture. In the Municipal Water Needs Policy Issue Study, the Commission modified its position to recommend a higher preference for industries supplied by municipal systems. They did not choose to change the status of agriculture and industry in allowing water rights transfers.

Nebraska's Role in Energy Development in the Upper Missouri River Basin States

As one of the Missouri River Basin states, Nebraska has the potential to play an important role in the development and use of the basin's energy and water resources. Energy resources in upstream states are being developed, and they have reduced the inflow of water to Nebraska. Future developments, both upstream and in Nebraska, could have greater effects. Water could be exported from this state for energy development as well as for irrigation. Also, energy companies developing the coal resources in upstream states could locate their coal conversion facilities in Nebraska to take advantage of the abundant water supply.

A full range of alternatives that would define the state's role more clearly are available. Potential policies range from those that promote development of energy industries that would use the state's water supply to Nebraska's best economic advantage to those that restrict the use and export of water as much as possible. They could be implemented by interstate cooperation, or by unilateral action, or both. Alternatives that would accomplish some of these aims were investigated and presented in reports from another policy issue study.

Potential approaches and alternatives are summarized in the following paragraphs.

1. Negotiate additional compacts. Compacts, the most formal and binding means of interstate cooperation, could include neighboring states or all states in the Missouri River Basin. They could include

surface water, groundwater, or both. The Interstate Water Use and Conflicts report of the Selected Water Rights Policy Issue Study gave several alternatives.

> "Authorize and initiate the negotiation and formation of interstate agreements or compacts on interstate streams on which no compacts currently exist" (Alternative 2)

> "Authorize and initiate the negotiation and formation of interstate compacts with states sharing interstate groundwater basins with Nebraska" (Alternative 3)

The Commission generally favored compacts on streams or the groundwater in alluvial aquifers.

2. Form a cooperative organization. For continuity, a formal organization of states could be formed to promote better, more open communication, negotiate differences, and agree on a procedure for conflict resolution outside of the courts.

3. Enact stricter controls on surface water. Alternatives previously considered by the Commission include: (i) claiming more water for Nebraska use by allowing rights or reservations for different kinds of uses, including instream flows, or (ii) declaring some uses to be non-beneficial, so water cannot be exported for those uses. The Interstate Water Use and Conflicts report stated:

> "Declare that natural flow permits may be issued for other beneficial uses including instream uses" (Alternative 4)

> "Provide for the reservation of waters by the Department of Water Resources to fulfill public interest requirements" (Alternative 7)

> "Provide that certain uses of water are not considered beneficial uses" (Alternative 5)

The Commission recommended adoption of only a part of the expansion of rights, and rejected the alternative of defining non-beneficial uses.

4. Enact stricter controls on groundwater. Exports could be limited by restricting the amount of water that could be pumped or the distance it could be transferred. They could also be limited by placing a fee on the water exported which would also produce an economic benefit to the state. The Interstate Water Use and Conflicts report said:

> Strengthen the interstate groundwater transfer statute" (Alternative 6)

The Commission recommended implementation of this alternative without specifying the recommended means of implementation.

5. Encourage and regulate energy development. The economic benefits from energy industries using the state's water resources could outweigh the environmental, social, and water costs, especially if properly sited. Many states have a comprehensive siting law that requires thorough evaluation before industries are built.

Changes in Energy Use Patterns as an Approach to Reducing Water Use for Power Generation

Water use for elecric power generation could be reduced by reducing electric power consumption, because reducing the amount of power generated reduces the amount of water consumed at power plants. There are three approaches to such reductions: load management, conservation, and substitution of alternative energy forms. Since implementation requires new price structures for electricity and energy tax incentives, implementation occurs through energy pricing policy not water policy. Analyses of energy alternatives and energy pricing policies are beyond the expertise of this task force and beyond the scope of this study.

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CHAPTER 1. INTRODUCTION

This study is one of a series of Policy Issue Studies being conducted by the Natural Resources Commission. That series is one of the five activities designed into the State Water Planning and Review Process when it was developed in 1978. The Process, and the Policy Issue Analysis activity in particular, were developed in response to a legislative directive to revise and accelerate state water planning in order to provide information on a number of policy questions set forth in statutes and resolutions. The Commission and cooperating agencies restructured those questions into a group of policy issues and scheduled the series of studies under the Policy Issue Analysis activity. The purpose of the studies was to analyze the issues and formulate alternatives for legislative consideration. Reports and recommendations from five studies have been submitted to the Legislature and the Governor, who have enacted several recommended alternatives into law. This study includes no new policy recommendations.

BACKGROUND

This study was authorized and scheduled by the Natural Resources Commission and cooperating agencies. It was intended to examine water issues related to energy development, and analyses were to include energy development in upstream states in the Missouri River Basin that affects Nebraska as well as energy development within Nebraska. In addition the study was intended to examine issues associated with the availability of energy for other water uses such as irrigation pumping. In many ways, these proved to be inseparable, but as the study progressed, different dimensions of these issues became more clearly focused. For instance, it became apparent that the conservation of water and energy were involved in questions related to the use of water for energy production. Similarly, the conservation of energy was an important component of the issues associated with the production of energy.

REASON FOR THE STUDY

The conflicts in the Middle East and the oil embargo caused this nation to review its energy position and consider changes in national energy policies that would improve its security and economic well-being. The energy policy upheaval came as changes in environmental policies were also causing shifts in energy production. This resulted in a flurry of activities aimed at exploring means of producing energy from the vast resources in the western states: low-sulfur coal, tar sands, oil shale, uranium, and natural gas. It immediately became apparent that such production would require large quantities of water and water was scarce in the west. The scarcity led to proposals to take water from the Missouri River, other streams that flow into Nebraska, and from the Madison Formation, an interstate aquifer. This demand for water has already produced one interstate conflict in which Nebraska was involved. Construction of the Grayrocks Dam and reservoir on the Laramie River in Wyoming, which supplies cooling water for a large power plant, was delayed until a federal court suit on the environmental impact was settled.

These demands and conflicts, and the energy planning that followed the review of national energy and environmental policies, led to a number of water resources planning studies by the Department of Energy, the Water Resources Council, the Missouri River Basin Commission, and other agencies. Nebraska agencies participated in enough of these to realize that proposed development in other states might have significant impacts on this state.

Concurrently, several energy related issues arose in Nebraska. Uranium deposits that could be extracted by dissolving the ore and pumping it out of wells were discovered and explored in western Nebraska. A coal-fired electric power plant that would use groundwater transferred from another river basin for cooling was proposed for the same area. In addition, the most interference ever experienced in the generation of power by a hydroelectric system occurred in eastern Nebraska. A drought and the consequent need for more water for irrigation resulted in the pre-emption of the water supply to the power plants.

Some of the issues associated with these situations have been known for years; others are just becoming prominent. For many of these issues, knowledge of the potential impacts of energy development on Nebraska's water resources was very incomplete, especially where other states were involved. The indications of potential problems and the lack of information on water and energy led to the formulation and scheduling of this study.

ORIGIN OF THE STUDY

The Water/Energy Policy Issue Study was the first to originate through the Planning and Review Process. Other Policy Issue Studies were designed and scheduled during the development of the Process in 1978 in response to a legislative directive. During the annual review of Planning and Review Process activities in 1980, the schedule of policy issue studies was reviewed and the need for additional studies was considered.

The potential for a study of water and energy first surfaced in a meeting of the Interagency Liaison Committee. The Committee identified proposed energy developments in other states and recognized the lack of information on energy and water in Nebraska. Following the normal process, the findings of the Committee were considered by the Interagency Water Coordinating Committee and the Public Advisory Board. The Commission accepted their findings and recommendations and scheduled the study as part of the Planning and Review Process in the 1980 Annual Report and Plan of Work.

STUDY DESIGN

The detailed study design was prepared by the NRC staff with the aid of governmental advisors and the principal contractor retained by the Commission for this study. It was different from designs for previous policy issue studies, because this study was the first on a policy issue that was not defined by the legislature in a legislative bill or resolution. A number of energy issues had been considered by the legislature, but none were specifically directed to the Planning and Review Process.

Since the issue was not precisely defined, the study design was based primarily on the premise that there would be a problem with water supply for energy production, or that energy might not be available to use water for such purposes as irrigation. The study was designed to be completed in two stages, with provisions for review and revisions between stages, if needed. The first stage focused primarily on analyzing energy and water supply and demand in order to test this premise and define the extent of the problems. The secondary focus of this first stage was the identification of other policy issues involving the use of water for energy.

The second stage was designed to investigate in more detail the problems and issues the Commission considered worthy of study and to identify and evaluate alternative legislative and administrative policies and their potential impacts. When the review and assessment at the end of the first stage showed there probably would be no critical energy-related water supply problems in the near future, and that many energy-related issues had been addressed in other policy issue studies, the design of the second stage was modified. The study was shortened, the amount of detailed investigation was reduced, and a different type of report was substituted.

PURPOSE AND SCOPE

Originally, the purpose, objectives, and scope of this study were carefully defined in the Study Design. They were modified after the first stage assessment changed the direction of the study.

Purpose and Objectives

The purpose of this study was to formulate and evaluate the effectiveness, and impacts of, alternative state policies related to the availability and production of energy for water development and use, and the availability and use of water for energy production. This included the evaluation of the effectiveness of conventional technologies to meet demands without policy changes, and the potential for conventional and alternative technologies to meet demands under alternative policies. The objectives that had to be met to fulfill the purpose were listed in the Study Design.

The assessment of the results of the first stage of the study produced a major change of direction, and the purpose and objectives of the study had to be modified in order to guide the second stage. Since it appeared water and energy supply conflicts were unlikely, the purpose was modified to shift the emphasis to energy issues related to water. Several objectives were modified to accomplish this. One was changed to insure that important energy related issues identified in other policy issue studies were defined and integrated with the issues identified in the first stage of this study. Instead of formulating and evaluating alternatives, two objectives were changed so the appropriate level of analysis and explanation for each issue would be determined and alternative strategies or policies that might resolve the issue would be identified.

Scope of the Study

Policy issue studies are intended to provide a broad overview of a complex policy issue, not a detailed plan for a water project. This study was no exception. The work covered all forms of energy produced and used in Nebraska and the upper part of the Missouri basin. It covered current conditions and projections of future conditions as well. In order to address this broad scope in a limited time, with the funds available, the study utilized only available data and methods of projection. Simple methods of estimating missing data for Nebraska were employed to fill the gaps left by some sophisticated modeling programs. Estimates and analyses for Nebraska were more detailed than those for upstream states. Fortunately, the services of a number of people with expertise in the field were available and expert judgment could be used in place of expensive research. Expert advice was also available in assessing data and making conclusions.

First stage work focused on: (1) the assessment of energy and water supply and demand, and potential supply problems, and (2) the identification and assessment of problems and issues indirectly related to water resources. In the first category, available information on current and future water and energy supply and demand was compiled and analyzed. In the second category, research focused on energy problems and issues related to aspects of water resources other than supply identified in this study. These included water quality, economical use of water, environmental impacts, and conservation of energy. Research was also extended to include issues contained in past legislative bills related to both water and energy.

The scope of the study, like the purpose and objectives, was modified after the first stage assessment. In the second stage, some additional research was conducted to better define the probability of the occurrence of certain types of energy development in upstream states. Research on some new aspects of the issues was also conducted, so the issues could be better defined and the means of dealing with the issues employed by other states could be examined and reported. The final report was prepared by Commission staff and contractors, and reviewed by Task Force members, Industry Advisory Committee members, and their associates.

RELATION TO OTHER STUDIES

This study was closely related to several other studies that are currently in progress, or were completed while this one was being conducted. The Water Use Efficiency Policy Issue Study, which is scheduled for completion in June 1984, is examining the potential for increasing the efficiency of water use for power generation as well as other uses. Future changes in efficiency for all uses would have some bearing on the projections made in this study, so an effort was made to take potential efficiency changes into account. Coordination between the two studies was facilitated by the membership of the leader of this Task Force on the Water Use Efficiency Task Force, and vice versa.

During the course of this study, it was found that some of the issues affecting water and energy had already been considered in the Selected Water Rights Policy Issue Study. The reports on *Preferences in the Use of Water*, *Transferability of Surface Water Rights*, and *Interstate Water Uses and Conflicts* contained explanations of issues, alternatives, and recommendations on several subjects affecting energy production. The energy impacts of the alternatives had not been examined in them, so they were considered in this study.

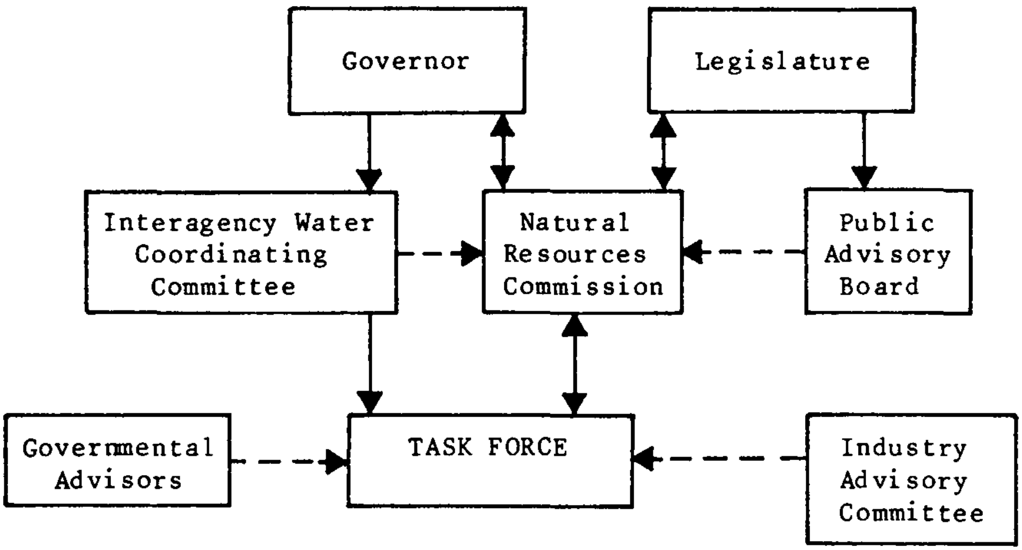
STUDY ORGANIZATION

The Natural Resources Commission was primarily responsible for conducting this study, with guidance from the Governor and the Interagency Water Coordinating Committee. The member agencies of that committee also provided members of the Task Force that conducted the study. The Task Force received input from several advisory groups from government and industry. Figure 1 shows the organization of the entities involved in the study. The members of the Task Force, the Governmental Advisors and Energy Industry Advisory Committee who contributed to this analysis and assessment are also listed.

The work elements and reports were done by the NRC staff and contractors, Dr. Martha Gilliland, Dr. Raymond Supalla, and Mr. Robert Kuzelka from the University of Nebraska. The reports were reviewed by the Task Force and the Energy Industry Advisory Committee. Their comments and contributions were included in the reports and the assessment summaries.

Fig.1

STUDY ORGANIZATION



TASK FORCE

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Jon Atkinson	-	Department of Environmental Control
Gerald Chaffin	-	Game and Parks Commission
Bill Lee	-	Department of Health
Susan France	-	Department of Water Resources
Bob Burns	-	Water Resources Center, UN-L
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CHAPTER 2. CURRENT AND PROJECTED ENERGY AND WATER SUPPLY AND DEMAND IN NEBRASKA

This chapter provides an overview of the supply and demand for energy and water in Nebraska. The first section looks at the energy supply picture, both historically and as projected for the future. This is followed by similar information on energy demand. The last sections focus on water availability (historical and projected) in Nebraska and on water use for agriculture, municipalities, and energy.

NEBRASKA'S ENERGY SUPPLY

This section summarizes information on the amount of various fuel types that are produced, imported to, and exported from the State now and as projected for the future. It includes a description of the energy technologies currently involved in production as well as alternatives to those technologies that may produce energy in Nebraska in the future. All energy data are given as their primary fuel equivalent. Primary fuels refer to fuel prior to conversion to an end use form and prior to transmission to the end use site. For example, the portion of the coal that is lost in the conversion to electricity in an electric power plant is included as a part of the primary fuel.

ENERGY PRODUCTION, IMPORTS, AND EXPORTS

Nebraska imported more than 90 percent of all the energy it consumed in 1981. Imports and exports by fuel type are given in Table 1. All of the petroleum products, coal, and uranium consumed in Nebraska are produced elsewhere. Although Nebraska produces some oil, there are no refineries in the State. Thus, all that is produced is exported as crude oil. In addition to oil, primary energy forms produced in Nebraska include small amounts of natural gas, hydroelectric power, ethanol and solar energy. Nebraska does have some coal resources, but these are not considered economically recoverable, and no significant production is expected.

The amount of electricity generated in Nebraska using each type of primary fuel is given in Table 2 for 1980 and 1981. As indicated, coal was the major fuel for electricity and nuclear was second. In compliance with Federal policy, the use of oil and natural gas to generate electricity is declining, while the use of coal is increasing. A significant part of the power consumed in this state is imported, but generation is more than adequate to meet the balance of the state's needs, so Nebraska is a net exporter of electric power.

Information on the amount of energy production and reserves in Nebraska suggest that Nebraska's status as an energy importer is not likely to change significantly over the next 20 to 30 years. Specifically, oil production in Nebraska peaked in 1962 at 25 million barrels per year. Between 1962 and 1978, production declined to 6 million barrels per year and then began increasing slowly to 6.7 million barrels in 1981. Nebraska oil reserves are estimated at 37 to 46 million barrels. Since annual oil consumption is on the order of 30 million barrels, Nebraska will continue to import most of its oil.

Table 1

PRIMARY ENERGY SUPPLY IN NEBRASKA: 1981

	Imports	In-State Production	Exports
	(trillion British thermal units)		
Oil	205.2	38.9	38.9
Natural Gas	143.7	3.0	0
Coal	97.7	0	0
Uranium	67.4	0	0
Geothermal	0	0	0
Ethanol	u	0.5	u
Hydro	0	12.1	0
Solar/Wind	0	0.04	0
Total	514.1	54.0	38.9

u=Unknown
Source: See Appendix, Table A-1

Table 2

ELECTRIC POWER PRODUCTION IN NEBRASKA BY FUEL TYPE

	Generation			
Fuel	1980	1981a/	1980	1981
	(million kwh)		(percent)	
Oil	126	51	1	-
Natural Gas	947	430	6	3
Hydro	1,335	1,197	8	7
Nuclear	5,783	6,628	35	39
Coal	8,123	8,595	50	51
Total	16,314	16,901	100	100

a/ Preliminary data. The Nebraska Energy Office, which supplied the data to produce the publication used as a source, has since revised and finalized these figures.

The history of natural gas production is similar to that of oil except that some new natural gas development could occur in western Nebraska. Gas production peaked in 1965 at 15.3 billion cubic feet; it has declined since then to 2.5 billion cubic feet in 1981. Nebraska's gas reserves declined from 1960 through 1975, but they have been increasing since 1975, because exploration has increased since that time. For example, in 1960 Nebraska had about 133 billion cubic feet of proven gas reserves. This declined to 49 billion cubic feet in 1974 but has since increased to 85 to 97 billion cubic feet. Since annual natural gas consumption is about 140 billion cubic feet, Nebraska will continue to import most of its natural gas.

Nebraska has both uranium and geothermal resources, but no projections of production are available. Although exploration projects are underway for both, most analysts do not expect future production to change Nebraska's supply picture significantly. However, the uranium deposits in western Nebraska are considered high quality deposits. Consequently, Nebraska could become a net exporter of uranium if the economic climate for nuclear energy improves and a pilot project shows acceptable environmental impacts from in-situ mining.

Production of both ethanol and solar energy is expected to expand in Nebraska. In 1981, there were four ethanol plants capable of producing 3.35 million gallons per year. One new 10 million gallons per year ethanol plant is under construction, and another is awaiting approval of funding. By 1990, more are expected. Each million gallons of ethanol represent about 0.15 trillion British thermal units (Btu's) of energy. For comparison, oil consumption in 1981 in the State was about 200 trillion Btu's. Thus, in order for ethanol to contribute ten percent of total Nebraska oil demand, 13 plants, each producing 10 million gallons per year would be required.

Of the 530 trillion Btu's of energy consumed in Nebraska in 1981, solar energy contributed a negligible amount. Measured as the amount of fossil fuel that would have been consumed without the solar installations, production was about 0.04 trillion Btu's. The Legislative Research Office analyzed the effect of the statewide solar incentives adopted by the 1982 Nebraska Legislature on future growth in solar energy [1]*. Based on the experience of other states which also have incentives, solar energy installations are projected to increase at a rate of 90 percent per year. While this is a very high growth rate, the total solar contribution in 5 years would be only one trillion Btu's -- still a minor contribution to total energy consumption. In short, solar energy, while its use will grow, is unlikely to contribute more than one percent of total Nebraska energy consumption.

ENERGY PRODUCTION TECHNOLOGIES

Technologies for producing energy in Nebraska include: oil drilling and extraction; natural gas drilling, extraction, and processing; electric power generation (including hydroelectric, thermoelectric, and wind power); conversion of grain to ethanol; and conversion of solar energy to heat. In the future, geothermal energy extraction as well as uranium mining may occur in Nebraska. In this section, a brief description of the production

* Numbers in brackets are references listed at the end of the report.

technology and use of water in each industry is given. The descriptions are intended to provide a general overview of energy alternatives, not a detailed description of the technology. Much of the information is from the U.S. Environmental Protection Agency's "Energy from the West" study[2].

Oil Drilling and Extraction

Prior to exploratory drilling, land is cleared, holding ponds for circulating mud and brine are constructed, and access roads are constructed. Water must be provided at the site by completing water wells, installing water lines, or transporting by truck. Exploratory drilling is generally carried out with a rotary drill bit. A fluid circulation system in the well allows removal of the cuttings made by the bit. The circulating fluid, or drilling mud, is a water-based slurry which contains a mixture of clays, chemicals, and oil. If the well is dry, it is "plugged;" if not, the well is cased and made ready for production.

When an oil field is initially developed, natural reservoir pressures cause the oil to move into the well. Sometimes these natural pressures are sufficient to push the oil to the surface, but usually it must be pumped out. Before it is exported to a refinery, the oil from all wells in the field is "gathered" into a central oil-water-gas separation facility. The brine and oil are usually in an emulsion form which must be "broken" and the brine removed. This dehydrating is carried out with heat, a chemical dehydrator, or an electrical dehydrator. The water from the dehydrator must be further treated before being discharged as wastewater or reinjected into the well.

When the natural flow of the crude oil into the well has diminished, additional oil may be obtained by the use of various improved recovery techniques -- either secondary or tertiary recovery. The most common type of secondary recovery is waterflooding. After the natural reservoir pressure has declined (due to removal of the crude), it is replaced by a similar pressure produced by injecting water. Water injected through new or converted production wells flows through the reservoir, pushing the oil out of the pore spaces. Water floods typically recover about 40 percent of the original oil in the reservoir.

Fifty to 65 percent of the original amount of oil may still be in the reservoir so secondary recovery such as waterflooding may be followed by tertiary recovery techniques. Steam injection and carbon dioxide (CO_2) miscible floods are the most commonly employed techniques. To date, steam floods have been used in only a few reservoirs in the U.S., where an additional 10 percent of the original oil was recovered. Carbon dioxide miscible floods are also being tried. In a previously waterflooded reservoir, a CO_2 flood will typically recover about 10 percent of the original oil. When used before waterflooding, a CO_2 flood may be able to remove about 50 percent of the original oil. Thus, as CO_2 flooding is developed, it is likely to be used prior to waterflooding.

The amount of water required for drilling and production is relatively small. Table 3 summarizes national average water use rates for production of oil and natural gas. As indicated, during exploration small quantities of water are consumed as drilling fluid make-up water. Primary recovery of oil and gas requires no water, because water is produced with the oil and

Table 3

WATER USE FOR THE PRODUCTION OF OIL AND GAS

Activity	Water Use	Remarks
Oil and Gas Exploration	200 - 500 barrels of water per day per drilling rig	Primarily for drilling fluid make-up.
Primary Recovery: Oil and Gas	0	Water is normally produced with the oil and gas in excess of the requirements.
Secondary Recovery: Oil Water Flooding	10 barrels water per barrel oil	The amount of water needed for a waterflood is a function of the amount of water produced with the oil. This 10 barrels will be reduced by the amount of water recovered.
Tertiary Recovery: Oil Steam Flooding	1 to 6 barrels water per barrel oil	Water is used for steam generation.
CO_2 Miscible Flooding	7 to 15 barrels water	Water acts as a drive to push the CO_2 through the reservoir.
Natural Gas Processing	0.5 gallons water per cubic foot of gas processed	Water is used to cool the compressed gases and process streams; it is evaporated in cooling towers.

Source: Energy From the West, Energy Resource Development Systems Report, Vol. V; EPA-600/7-79-060 -C, pages 24, 86, 112, 127.

gas extraction. That water is usually in excess of what is needed at the well. However, secondary and tertiary recovery techniques require water. Data from one work element report on the High Plains Ogallala Aquifer Study [11] show about one barrel of water is consumed for each barrel (42 gallons) of oil currently produced in Nebraska. Much of the water consumed is that produced with the oil, not withdrawn from the usual aquifers or surface water supplies.

Natural Gas Drilling, Extraction, and Processing

Exploratory drilling and extraction technologies for natural gas are similar to those for oil. After production and dehydration, raw natural gas is sent to a gas processing plant usually near the well field. There, the gas is processed to meet sales specifications for hydrogen sulfide, air, and CO_2 content and gross heating value. Water requirements for natural gas processing are given in Table 3.

Electric Power Generation

Electric power is currently generated commercially in Nebraska at hydroelectric facilities and thermoelectric plants. The Nebraska Power Association (NPA) expects expanded base-load needs to be met with new coal-fired power plants and expanded peak-load needs to be met with pumped storage facilities and the MANDAN transmission line from Canada[3]. According to the NPA, low-head hydro, wind generated electricity, and the use of biomass as a fuel could also play minor roles.

Hydroelectric Power. Water for generating hydroelectric power may exist as a naturally flowing stream, but greater energy potential is most often obtained by building a dam to create a "head". When run through a power plant, this water drives a turbine which, in turn, drives one or more generators to produce electricity.

Hydroelectric facilities include both on-stream and off-stream plants. At on-stream plants, all or a portion of the natural streamflow flows through the turbines and returns to the river, with essentially no consumptive loss of water. The amount of power generated at on-stream plants is limited by the available streamflow, the amount of head, and the capacity of the turbines to utilize the available flow. For use at off-stream plants, water is diverted from streams and transported via canals to plant sites. Evaporation and seepage losses may occur in canals and reservoirs associated with off-stream plants. In most instances, water diverted for off-stream use is used at more than one hydroelectric plant or is used for other purposes such as irrigation or cooling at thermoelectric plants. An advantage of off-stream plants is the creation of greater heads, which results in greater generating capacity for a given volume of water.

Storage of water for use during peak demand periods is also becoming increasingly significant. One such technique is pumped storage, where electricity from another power source (such as a coal or nuclear plant) is used to pump water from a lower source into an upper storage reservoir during off-peak hours. The water is then run back through the turbines to generate hydroelectric power during peak periods, and stored in a lower reservoir or released to the source.

Water use for hydroelectric power generation in Nebraska in 1980 is summarized in Table 4. For off-stream hydroelectric plants, the amount discharged through the turbines is greater than the amount diverted. This unusual situation occurs because water diverted into the Tri-County Supply Canal generates power at three plants and water in the Loup Power Canal is used at two plants. There is another hydroelectric plant that uses Nebraska water, but the power generated is not considered a part of the state supply. The plant at Gavins Point Dam generated 792.6 million kilowatt-hours (kwh) in 1980, which was about 1.4 times as much as was generated by all hydroelectric plants within the state. To do this, it discharged through its turbines about three times as much water.

Thermoelectric Power Plants. While there are many components and peripheral technologies in a thermoelectric power plant, there are three energy conversions involved in generating electricity and the primary technological components of a power plant are aimed at carrying out these conversions efficiently. Specifically the chemical energy in coal, oil, or gas or the nuclear energy in uranium is first converted to thermal energy as steam. In a fossil fueled plant, this conversion takes place in the boiler; in a nuclear plant, it takes place in the reactor. The steam is then piped to, and expanded through, a turbine where the thermal energy is converted to the mechanical energy needed to drive a turbine and generator. Finally, in the generator, mechanical energy is converted to electricity. The steam from the turbine must be cooled until it condenses, and a separate water system is used to provide the cooling.

The chemical energy in biomass may also be used as the boiler fuel in an electric power plant. The use of municipal waste as a coal supplement has been tried on a limited scale in several other states. The feasibility of using waste as a fuel in Nebraska has not been established. However, the NPA

Table 4

WATER USE RATES FOR HYDROELECTRIC POWER PRODUCTION IN NEBRASKA IN 1980

Type of Plant	Power Generated	Water Diverted	Water Discharged through Turbines	Unit Discharge
	(Million kwh)	(Thousand acre-feet)	(Thousand acre-feet)	(Gallons per kwh)
Off-stream	541.6	3,449.2	5,810.0	3,496
On-stream	11.7	-	871.4	24,273
Total	553.3	3,449.2	6,681.4	3,936

Source: "An Inventory of Public, Industrial, and Power Generating Water Use in Nebraska, 1979 and 1980," Conservation and Survey Division, University of Nebraska, 1983.

projections indicate that the use of biomass waste as a supplemental fuel for coal-fired plants may be economically feasible where large quantities of waste are produced and/or where waste disposal costs are high.[3]

The cooling system in a thermoelectric power plant converts steam to water so it can be pumped back to the boiler or the reactor. The heat in the steam is transferred to the cooling water in a condenser.

Once-through cooling is the simplest of five cooling options. Water is withdrawn from a source, usually a river, circulated through the condenser where it is heated, and then returned to the source. While simple and inexpensive, such systems require relatively large amounts of water; in fact, so large that modern power plants can be located only where large quantities of water are available for circulation. Thus, in Nebraska, once-through cooling is used primarily at power plants along the Missouri River and to a lesser extent along the Platte River.

At many power plant sites in Nebraska, surface water flows are not large enough or not reliable enough to support once-through cooling. At these sites, cooling is carried out in a lake or reservoir or in a wet cooling tower. In the case of a cooling reservoir, warm water from the condenser is returned to the reservoir, where it is cooled by mixing and evaporation, and then recirculated. The reservoir loses water to evaporation, but this water is "made-up" from diversions from a river or groundwater. Cooling reservoirs vary greatly in size and therefore in evaporative water losses. Consumptive use attributed to reservoir cooling systems can vary, because some are constructed solely for the purpose of power plant cooling and some are constructed for other purposes. In those cases, the only additional loss is that caused by the increase in temperature.

Some sites are not favorable geologically or topographically for the construction of a cooling reservoir, so a wet cooling tower is used. Cooling water is withdrawn from a river or from groundwater, circulated through the condenser, and pumped to the cooling tower. As the hot water falls through the tower against a countercurrent flow of rising air, it evaporates. Heat is transferred from the water to the air as the water evaporates. Most of the water that was originally diverted from the river or from groundwater evaporates and is not returned to the source. Six power plants in the Platte River Basin use wet cooling towers.

Where water is simply not available, cooling can be carried out in a dry cooling tower. In a dry cooling tower, water circulates in a closed system, so none is lost to evaporation. As in the radiator of an automobile, cooling is provided by a flow of air across the tubes in the tower. Because large volumes of air are required to take up the heat, dry cooling towers must be larger than wet cooling towers, so they are more expensive. There are no dry cooling towers in Nebraska, but one is operational at a 330 megawatt (Mw) plant, near Gillette, Wyoming.

There is a fifth cooling option, known as wet-dry cooling. This is really a combination of wet and dry cooling which lowers the water requirements of wet cooling alone and the capital cost of dry cooling alone. The system utilizes separate conventional dry and wet cooling towers with the cooling water flowing separately through each. The dry tower is the first in the line and operates during the whole year with its greatest operating efficiency in the winter; the wet tower receives what cannot be handled by the dry tower during warm weather and peak periods. This hybrid, wet-dry cooling system is in operation at a 466 Mw plant near Farmington, New Mexico.

Differences in cost, water diversion requirements, water consumption, and instream flow impacts among cooling options are substantial. Table 5 provides an overview of cost and water use trade-offs among cooling technologies. As indicated, once-through cooling is the least expensive option, followed by cooling lakes or reservoirs. Next are wet cooling towers, which cost about five percent more than once-through cooling. These are the only three types of cooling systems in use in Nebraska.

As indicated in Table 5, the water diversion requirement of the cooling options are the reverse of their cost. Once-through cooling requires the greatest diversion but costs the least. Cooling reservoirs require the diversion of less water but cost about two percent more than once-through cooling. Wet cooling towers require an even smaller diversion but cost about five percent more than once-through cooling. Consumptive water requirements, however, follow a different trend. Once-through cooling consumes the least amount of water. Cooling reservoirs in Nebraska generally consume more than once-through cooling, and less than cooling towers, but in some circumstances they can consume more than cooling towers. Tradeoffs among diversions, consumption, and cost are usually the dominant factors in choosing a cooling option. However, there are also "thermal pollution" and instream flow considerations.

Thermal pollution is most often caused by once-through cooling. This is generally not a problem for power plants on the Missouri River because of the large river flows. It is a problem in other rivers in Nebraska, and it is one of the reasons that cooling reservoirs or wet cooling towers are utilized. On the other hand, instream flow considerations may become a problem with cooling reservoirs and towers. Consumptive water use is high for these options, and consumptive water use reduces instream flows. These reductions, in turn, can increase dissolved solids concentrations and decrease fish and wildlife habitat.

In summary, on large river systems, once-through cooling is nearly always the favored cooling option. It is the cheapest and consumes small quantities of water, keeping instream flow high. Its only disadvantage is the potential for increasing the temperature of the river and altering river ecology. In Nebraska, cooling reservoirs are normally favored when once-through cooling is inappropriate. While consumptive water use and diversion requirements for cooling reservoirs can be significant, the incremental economic cost is low and the reservoir can "double" as an irrigation water storage system. Any new power plants in Nebraska that are not located on the Missouri River will probably require a cooling reservoir or a cooling tower.

Wind Power. The conversion of wind to electricity is technologically feasible and has been demonstrated. However, commercial use of the technology is inhibited by high costs and lack of information on performance and reliability characteristics, a problem which is exacerbated because those characteristics are different in different regions. Conventional rotor-style windmills, which retain the basic configuration used for thousands of years to

Table 5

COMPARISON OF COST AND WATER USE FOR COOLING OPTIONS

Option	Incremental Cost f/	Water Diversions Required	Water Consumption
	(percent)	(gallons/Mwh)	(gallons/Mwh)
Once-through	0	25,000-35,000c/	100-200c/
Lake/Reservoir	2	50-1,500d/	50-1,500d/
Wet Tower	5a/	500-600c/	500-600c/
Wet/Dry Tower	7-9b/	100-170e/	100-170e/
Dry Tower	15-20a/	0	0

a/ EPRI Journal, May, 1983, "Cooling Without Water," p. 21.

b/ Ballard, S. C. et. al., Water and Western Energy, Westview Press, Boulder, Colorado, 1982, p. 119.

c/ Personal Communication, William Thalken, NPPD, 1983.

d/ The high value of 1,500 includes all evaporation from the reservoir and, therefore, assumes that the power plant was built for power generation purposes only; the lower value of 50 is only the increase in evaporation caused by heated water.

e/ Ballard, S. C., op. sit., p. 114.

f/ Expressed as the percent greater than once-through cooling on a cents/kwh basis.

pump water, are technically proven. However, there are also some advanced designs in the laboratory and pilot stages of development. These might prove to be more efficient than the conventional design. Nebraska utilities are actively studying this resource and expect wind power to become a reality in rural parts of the State[3].

Power from the MANDAN Project. The MANDAN project is a proposed 500 kilo-volt high voltage transmission line and substation facilities linking Manitoba, Canada with utilities in North and South Dakota and Nebraska. The line would provide for an exchange of power between the two regions. In Canada and northern North Dakota, peak electric power demands occur in the winter. In Nebraska and most of South Dakota, peak demands occur in summer. The MANDAN line would take advantage of this regional load diversity. Nebraska and South Dakota utilities would sell power to Canada in the winter, while the reverse would occur in summer. Consequently, fewer new electric power plants would be needed in both regions.

Ethanol Production

The production of ethanol involves four basic steps: (1) grinding of grain and mixing with water, (2) cooking to convert starch to sugar by enzymatic action, (3) fermentation of the sugar into alcohol, and (4) distillation to produce anhydrous ethanol. Gasohol is a mixture of 10 percent ethanol and 90 percent unleaded gasoline. The ethanol that is blended in gasohol must be dry (anhydrous) or the blend will separate into two phases.

In Nebraska, numerous small operators currently produce a low grade ethanol (not anhydrous). This low grade source is normally consumed on-farm or sold to one of the four existing facilities in Nebraska that produce anhydrous ethanol. These four facilities are: (1) Lincoln-1.0 million gallons per year, (2) Smithfield-1.5 million gallons per year, (3) Crofton-0.35 million gallons per year, and (4) Wakefield-0.5 million gallons per year[5]. Nebraska also imports ethanol from Illinois and Iowa. One new ethanol plant, capable of producing 10 million gallons per year, is under construction at Hastings. According to the Nebraska Energy Office, demand for gasohol is currently very strong[6]. Sales in 1982 exceeded those in 1981 by almost three times.

Ethanol plants require water for the mixing, fermentation and distillation process as well as for sanitary purposes. In the first year of operation, a commercial size ethanol facility (producing on the order of 10 million gallons of ethanol per year) will consume about 7.2 gallons of water for each gallon of ethanol produced. Because about half of this water can be recycled, water requirements decrease to 3.4 gallons of water per gallon of ethanol in the second year and thereafter[5].

Solar Energy

Solar energy technologies are usually divided into those that are "passive" and those that are "active." Passive solar means heating and cooling without moving parts or mechanical devices such as pumps and fans. Both passive and active solar space heating and active solar water heating are commercially available technologies. In the case of active systems, however, substantial technical challenges in lowering costs and improving durability and reliability still exist. Passive solar cooling designs are also commercially available, but active solar cooling systems do not work efficiently using low-temperature heat from today's flat plate collectors. Much additional technological development is needed.

There are no data available on the number of passive or active solar heated buildings in Nebraska. During the period January 1, 1980 to July 16, 1982, 370 applications for sales tax refunds on solar energy systems were received by the State. Of these, 40 were for passive systems and 330 for active. The Nebraska Energy Office estimates that this may represent about one-third of the actual installations. However, this amount is fundamentally an educated guess.

In-Situ Uranium Production

In-situ solution uranium mining is carried out by leaching the uranium from underground ore deposits. A leaching solution is pumped into the ore through patterns of injection wells. The leaching solution dissolves the uranium and is pumped out of the ground by production wells to precipitation tanks and possibly to a processing mill. The mill is normally an integral part of the in-situ solution mining operation. In-situ mining generally requires that the ore deposit be confined so that fluid losses are restricted and that the deposit not be located in an aquifer used for domestic water supply.

Numerous well patterns are possible, but normally a production well is surrounded by a perimeter of injection wells. The combination of production and injection wells makes up a uranium production cell. Each cell is independent from another; that is, no fluid flow occurs across cell boundaries.

Depending on the characteristics of the ore, the leachate can be acid (relying on a sulfate ion) or alkaline (relying on a bicarbonate ion). The majority of uranium solution mining operations employ an alkaline leaching solution. The solution oxidizes the uranium and then forms a soluble uranium complex that is recovered in the processing plant. Recovery of uranium from the leaching solution requires a sorption process, a precipitation process, and drying process, and packaging of the final uranium oxide (U_3O_8) product.

After the ore formation is mined out, the aquifer that contained the ore must be returned to some agreed upon water quality. Three aquifer restoration techniques are available: (1) total water removal by flushing, (2) water removal, clean-up and recycling, and (3) in-situ restoration. In the first case, contaminated water is pumped from the aquifer and not returned. This water is evaporated or dumped into a deep disposal well. In the second method, contaminated water is pumped from the aquifer, treated and reinjected. In the third method, in-situ restoration, chemicals are injected into the aquifer in order to re-precipitate the chemicals that were mobilized during leaching. This method does not restore water quality completely, so it is less likely to be used.

The entire sequence of in-situ mining, leachate processing, and aquifer restoration is usually carried out simultaneously. When cells of a well field are removed from production, the leaching solution still remaining in the ground can be pumped out and injected into the new area to be mined. At the same time, uncontaminated aquifer water from the new area can be pumped into the mined-out area. After most of the leaching solution has been pumped from the restoration area, the process of "water removal, clean-up, and recycle" begins; and continues until the restoration area has been returned to some agreed upon water quality. This method of operation could make in-situ mining a low consumptive use of water.

The water requirements for an in-situ solution uranium mine producing 500,000 pounds of uranium oxide per year are given in Table 6. Water is required for the drilling operations, for the leaching process, for aquifer restoration, and for sanitary use. The total water requirement of about 183,000 gallons per day, or 205 acre-feet per year, is very small.

Geothermal Energy Technologies

The extraction of geothermal energy is similar to oil and gas in that a well is drilled to sufficient depth, cased, and completed to provide a stable conduit for fluids. Facilities required to control and transport the fluid to its point of utilization are added at the wellhead.

Production begins when the steam or water lines are connected to the wellhead. Natural pressure differentials force the steam and/or water to the surface. For direct use of a geothermal resource, it is often desirable to maintain the water in a liquid form. In that case, the water is pumped out (using downhole pumps) in order to maintain enough pressure to prevent the hot water from "flashing" to steam.

Table 6

WATER REQUIREMENTS FOR AN IN-SITU URANIUM MINE
PRODUCING 500,000 POUNDS OF URANIUM OXIDE PER YEAR

Activity	Water Requirements	
	(gallons/day)	(acre feet/year)
Drilling	9,000	10
Process Water	51,000	57
Aquifer Restoration	121,000	136
Sanitary Water	2,000	2
Total	183,000	205

Source: Energy From the West, Energy Resource Development Systems Report, Vol. IV, EPA-600/7-79-060d. p. 150.

Space heating with a geothermal source is generally applicable only to central, district heating systems or relatively large commercial or governmental buildings. For space heating, heat must be extracted from the geothermal waters at the wellhead and distributed by means of secondary heated water to community buildings. The geothermal water is reinjected into the ground after the heat has been extracted.

As with oil wells, water requirements during geothermal drilling are 200 to 500 barrels per drilling rig per day, primarily for use as drilling fluid. At the average rate of consumption of 375 barrels per rig-day and assuming that sixty days are required to drill each well, the average water requirement is 22,500 barrels per well (less than four acre-feet) in a geothermal field. No water is required to produce the geothermal energy after the wells are drilled.

A feasibility study of geothermal district heating in Scottsbluff, Nebraska has been completed.[7] The study examined the possibility of heating a hospital complex, a junior high and high school complex, and Nebraska Western College. Sites for three production wells and three re-injection wells have been identified. The production well depth would be about 5,200 feet where temperatures of 80-90°C (170-194°F) occur. Well yield rates of at least 150 gallons per minute could be expected. Because of the ease with which the existing heating systems could be retrofitted, geothermal heating of the hospital and college would be more economical than that for the schools. Depending on the assumptions about energy prices in the future, the payback period for the hospital and college could be 7 to 10 years.

SUMMARY OF ENERGY SUPPLY

Nebraska now produces about 10 percent of the primary energy that it consumes. The present trends in consumption and production indicate that this picture is not likely to change significantly in the foreseeable future. Nebraska produces small quantities of natural gas, oil, hydroelectric power, ethanol, and solar energy. It also converts other primary fuels (coal and uranium) to electricity within the state. Of the primary fuel forms, only the production of ethanol and solar energy are expected to expand. Although they could expand rapidly, they are unlikely to contribute more than a few percent of Nebraska's total energy consumption.

ENERGY DEMAND

This section summarizes historical and projected energy consumption in Nebraska. Consumption patterns are discussed by sector (residential, commercial, industrial, agricultural, and transportation) and by fuel type (oil, natural gas, coal, and electricity).

HISTORICAL ENERGY CONSUMPTION

Nebraska consumed 530 trillion Btu's of energy in 1981 (the equivalent of 101 million barrels of oil). For perspective, this is 0.7 percent of total U.S. consumption[8]. On a per capita basis, it represents 337.5 million Btu's per person, which is nearly equal to the national average of 326 million Btu's per person. Total Nebraska energy consumption in 1981 represents a decline of about 18 percent over the peak consumption of 650 trillion Btu's which occurred in 1979. Since 1975, overall energy consumption declined at an average rate of 1.8 percent per year. Nationally, energy consumption declined six percent between 1979 and 1981, and data for 1982 show the same declining trend. Consumption declined 3.7 percent in 1980, 2.6 percent in 1981, and 4.1 percent in 1982.

Figures 2 and 3 provide a graphical summary of these historical trends. Appendix A provides numerical data for 1980 and 1981. The information about fuel types shown in Fig. 2 indicates that most of the decrease in total energy consumption has been brought about by a decline in oil and gas consumption. Specifically, oil consumption in 1981 was 28 percent less than in the peak year, 1979. Since 1975, the rate of consumption has declined an average of 2.8 percent per year. Natural gas use has declined at an average of 4.8 percent per year. It has been declining primarily because of conservation in the residential and commercial sectors, because of sluggish economic activity in the industrial and commercial sectors, and to a lesser extent, because of substitution of electricity. Consumption of electric power is increasing and has been increasing steadily since 1970. Electricity is replacing oil and natural gas for space heating (for example, heat pumps are sometimes used instead of gas furnaces) and for pumping irrigation water. However, although it has declined in relative importance, oil is still the most important fuel source in Nebraska. It accounts for 39 percent of all primary energy consumed. Electricity accounts for 32 percent of all primary energy consumed and has surpassed natural gas (27 percent) in importance to Nebraska.

The information about each sector shown in Figure 3 indicates that energy consumption in the commercial, transportation, and industrial sectors began declining in 1978, 1979, and 1980 respectively. In contrast, residential energy consumption has remained relatively constant since 1970, while agricultural energy consumption is increasing. In 1981, the industrial, residential, and transportation sectors each accounted for about 25 percent of total energy consumption, the commercial sector accounted for about 16 percent, and the agricultural sector for 11 percent.

Figure 4 shows what kind of energy is used within each sector and what it is used for. Nearly all of the energy used in Nebraska industries is consumed in the industrial processes. Only a few percent of the total is needed for heating and lighting. This sector is relying increasingly on electricity as the use of natural gas and petroleum declines.

The commercial sector is similar to the industrial sector in that electricity consumption is increasing while oil and natural gas consumption are declining. In the commercial sector, energy is used for heating, cooling, and lighting commercial buildings (including offices, retail outlets, schools, and hospitals) and some commercial processes (baking, dry cleaning, etc.). Total consumption in the sector peaked in 1977 and has declined at a rate of 6 percent per year since then.

Nearly all of the 754.4 million gallons of fuel consumed in the transportation sector is oil (as gasoline and diesel fuel); currently less than one percent is ethanol. Of the total, about two thirds is consumed by automobiles, 20 percent by trucks, and the remainder by rail and air traffic.

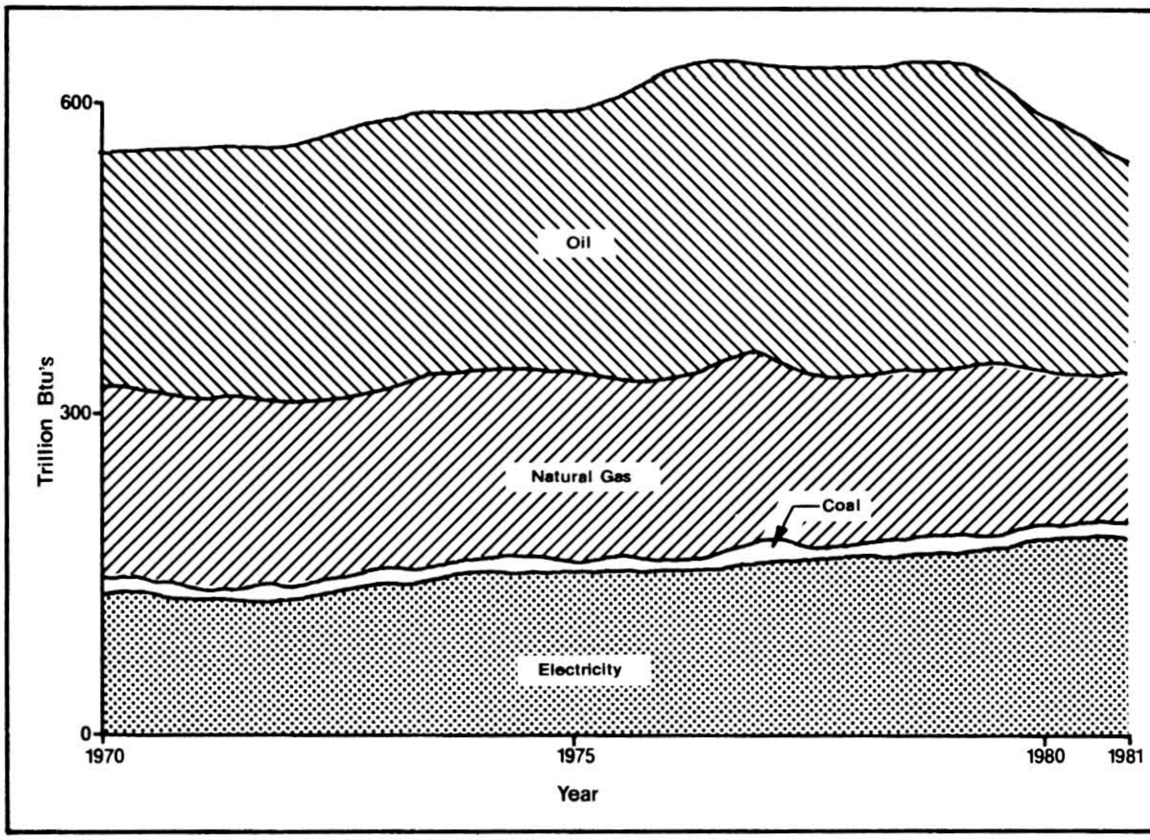


Fig. 2 PRIMARY ENERGY CONSUMPTION IN NEBRASKA BY FUEL TYPE

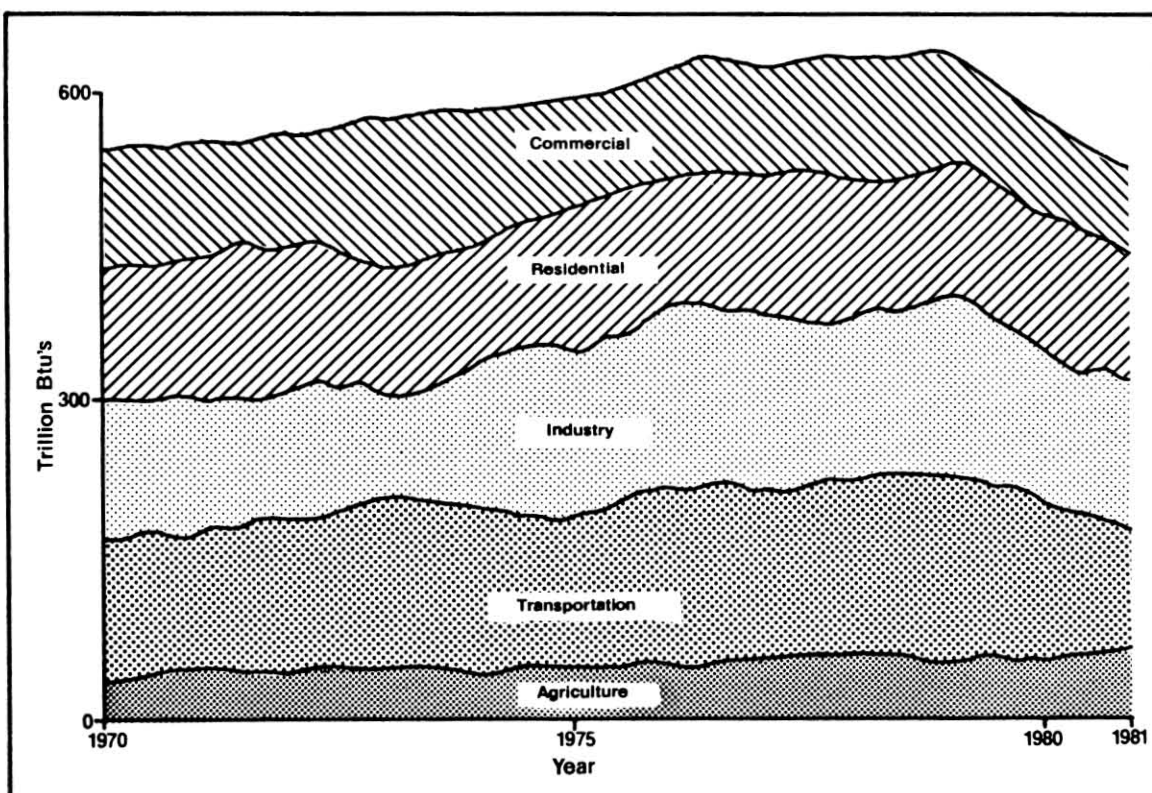


Fig. 3 PRIMARY ENERGY CONSUMPTION IN NEBRASKA BY SECTOR

ENERGY USE PATTERNS BY SECTOR IN 1981

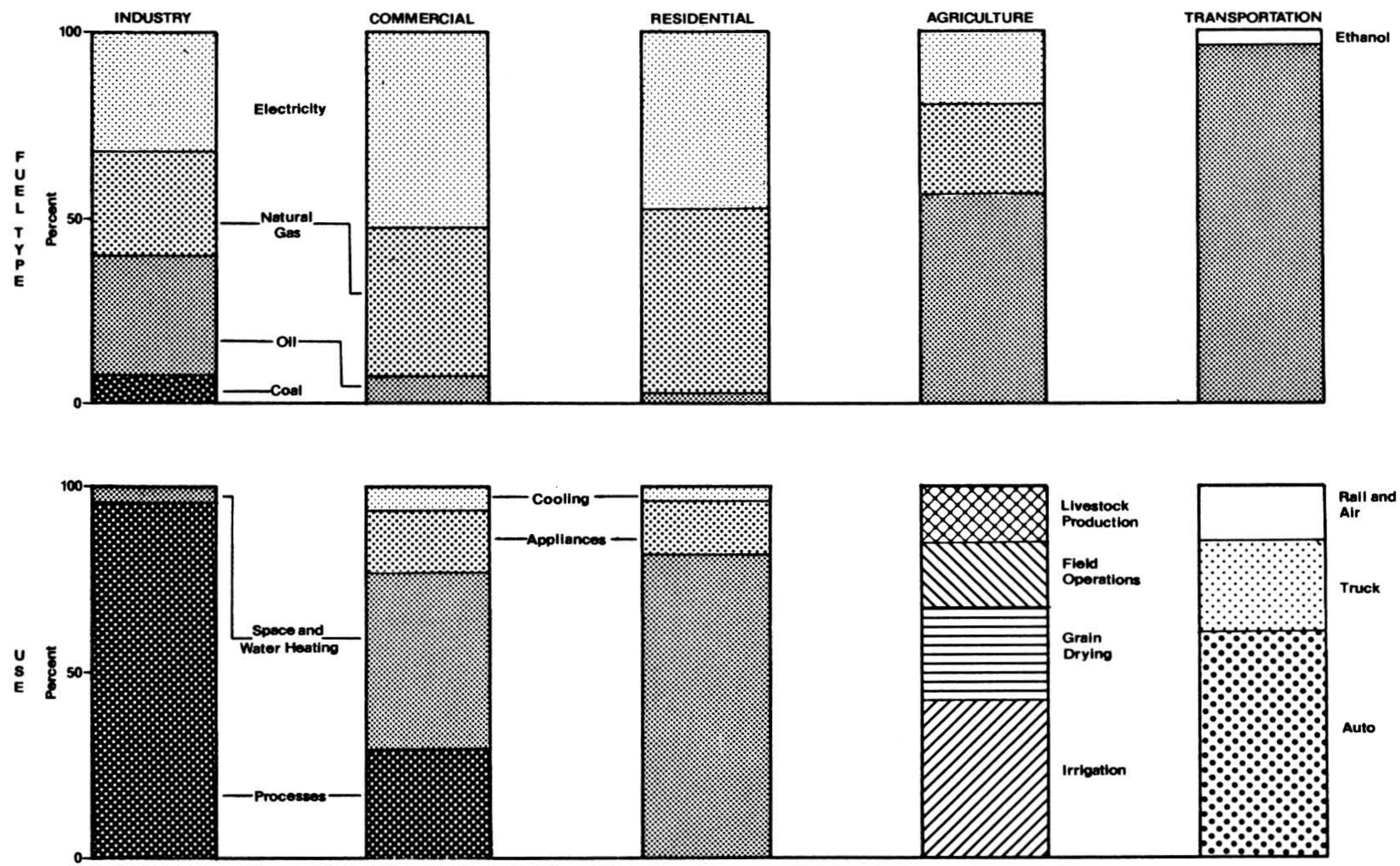


Fig. 4

Rural travel, which is 45 percent of all travel, is any which occurs outside of an urbanized area, including interstate traffic. It has remained relatively constant over the last decade. Urban travel, on the other hand, increased 47 percent between 1970 and 1980. The recent decline in oil consumption has been caused primarily by increased automobile fuel efficiency. Between 1975 and 1980, average fuel efficiency increased nearly seven percent, while total vehicle miles traveled increased only three percent. Rural automobile fuel efficiency now averages 19.5 miles per gallon while urban automobile fuel efficiency averages 11.4 miles per gallon. The State average is 15.9 miles per gallon which is about the same as the national average.

In contrast to the industrial and commercial sectors, fuel use patterns in the residential sector have changed very little over the past ten years. Oil is declining somewhat in importance, while electricity is increasing. Total consumption in the sector is primarily a function of population, the number of occupied housing units, housing unit types, and the extent to which homes are weatherized. Space and water heating account for about 80 percent of all energy consumed in this sector. Total energy consumption in the residential sector declined from 132 trillion Btu's in 1970 to 124 in 1981. This six percent decline in total consumption represents a 22 percent decline in per household energy consumption[1]. Most of this decline represents the effects of conservation in each household, which produces a decline in space heating requirements. In fact, Omaha Public Power District estimates that space heating efficiency increased at the rate of one percent per year from 1975 to 1980. Moreover, about 7,000 homes in their service area now use wood as a primary heat source.

Energy use patterns are changing rapidly in the agricultural sector as oil consumption is declining and natural gas and electricity consumption are increasing. Of the various on-farm energy uses, irrigation represents the largest single energy user (Fig. 4), accounting for about 45 percent of all energy consumed in the sector.

ENERGY CONSUMPTION PROJECTIONS

This overview of energy consumption projections focuses primarily on the 1980 to 2000 time period, comparing projected growth rates with recent historical growth rates. Projections of total energy demand statewide are summarized first; then, the demand by fuel type and by sector is examined. Emphasis is placed on electricity since electricity demand, to a great extent, will determine water needs for energy production.

Information on future energy demand was obtained from three sources. First, the Nebraska Energy Office (NEO) has developed an energy demand model for Nebraska. It projects demand by fuel type, by sector, and by end-use activity as a function of economic, demographic, and technological parameters. For example, residential sector demand is calculated as a function of housing stock, appliance saturation rates, and efficiency of applicances, each of which is forecast. Housing stock, in turn, is a function of population, household size, and the treasury bill rate. This demand model is the only statewide source of data on projections for <u>all</u> fuel types. Thus, the relative significance of each fuel type overall and in each sector can be obtained only from this source. Two other sources, however, analyze electricity demand in the future. The Bureau of Business Research of the University of Nebraska at Lincoln has developed a set of electricity demand forecasts through 1990 disaggregated by sector[9]. The NPA has developed a set of electricity demand forecasts through 2009 for several future scenarios[3].

Total Statewide Consumption

Projections of energy consumption through 1990 are summarized in Figure 5. Detailed information is given in Appendix A in tabular form. All data are expressed as trillion (10^{12}) Btu's. Electricity is given as its primary fuel equivalent (the sum of the electricity and the energy losses associated with generating the electricity). For the 1980 to 1990 time period, projections of energy consumption growth rates available at the time of this study ranged from 1.8 percent per year to 2.6 percent per year. Total consumption in 1990 was projected to be 619 to 707 trillion Btu's compared to 530 trillion Btu's in 1980. The NEO updates its model continuously, and their most recent projections are slightly lower.

The increase in overall energy consumption projected by all sources is in contrast to the decline in energy consumption experienced recently. These trends may indicate that statewide projections overestimate growth rates.

The projected contributions of each fuel type and each sector to total energy demand are given in Figure 6 for 1980, 1985, and 1990. This indicates

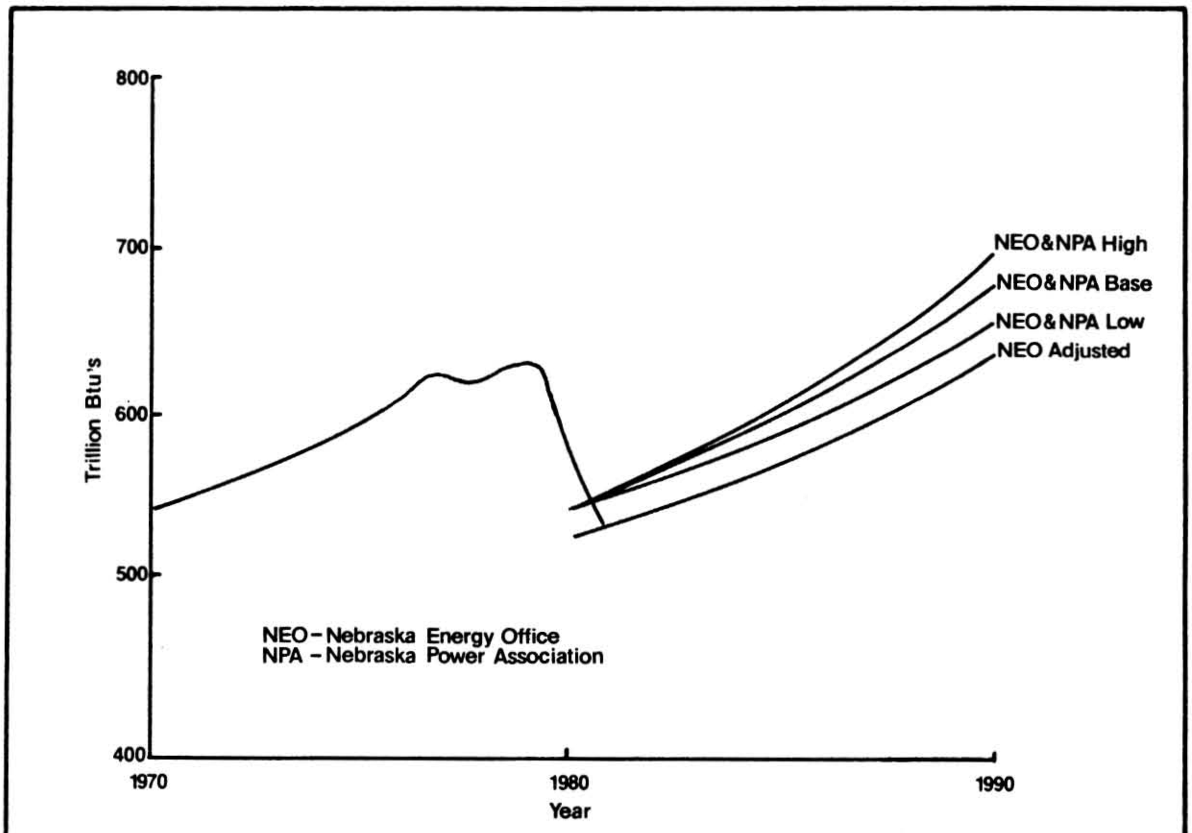
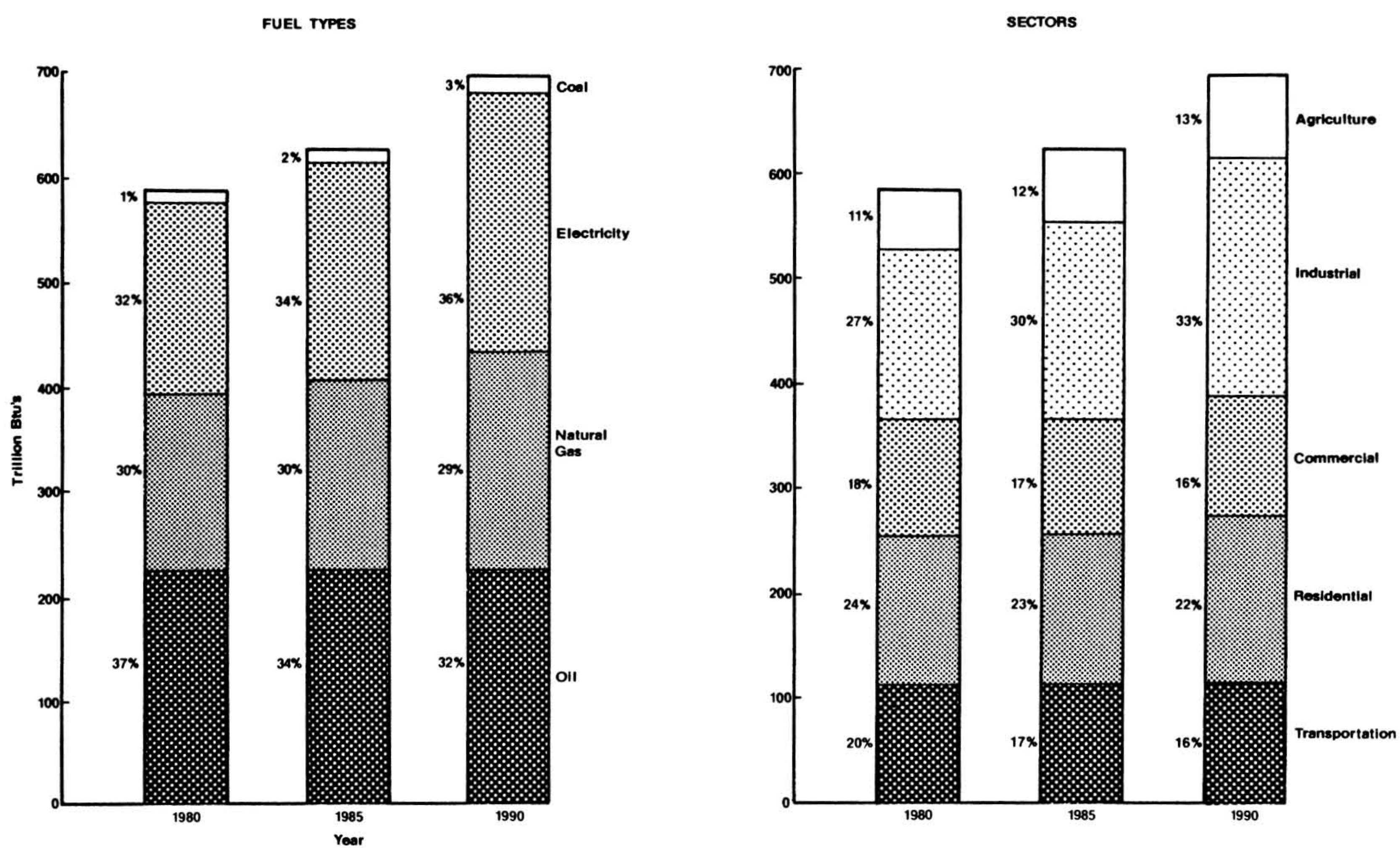


Fig. 5 PROJECTIONS OF ENERGY CONSUMPTION IN NEBRASKA

CURRENT AND PROJECTED ENERGY DEMAND BY FUEL TYPE AND SECTOR



Note: Coal burned for electricity included in electricity

Source: Nebraska Energy Office Demand Model

Fig. 6

that the role of oil and natural gas is expected to decline while the role of electricity is expected to increase. In absolute terms, oil consumption is expected to remain essentially static while natural gas use is projected to increase 1.7 percent per year. However, as was the case with projections of total energy use, the projected trends for oil and gas are inconsistent with the 1975-1981 trends.

All available Nebraska projections show positive, upward trends. Underpinning these projections are the assumptions that: (1) new demand for natural gas caused by new residential construction and renewed economic activity in the industrial and agricultural sectors will more than offset conservation of natural gas and substitution of electricity for natural gas, and (2) new demand for oil caused by an increase in vehicle miles travelled will be about equal to declines in demand caused by increased automobile efficiency.

Energy Consumption Projections by Sector

Overall trends which indicate the importance of each energy consuming sector are included in Figure 6. Both the industrial and agricultural sectors are expected to grow in absolute terms as well as in terms of the percentage of total energy consumption they represent. Some of the reasons for these changing trends in sector contributions are discussed in this section.

Energy use in the residential sector primarily depends on the number of households, the number of dwelling units, the ratio of single family dwellings to multi-family dwellings and the extent to which conservation measures have been employed. Since 1970, household size has been declining but there has been an increasing trend in household energy use. However, a decline in the ratio of single family to multi-family homes and extensive use of conservation measures have resulted in a slight net decline in energy use in this sector. In contrast to recent declines, energy use in the residential sector is projected to grow at one percent per year. In absolute terms, energy consumption for space heating, space cooling, and water heating is projected to remain constant, which implies a decline on a per capita and per household basis.

Energy use in the commercial sector will depend primarily on the vitality of Nebraska's economy as measured by the Gross State Product and real personal income. The Gross State Product in real dollars has been growing but real personal income has been static since about 1975. The net effect has been an overall decline in energy consumption in the commercial sector. As with the residential sector, the forecasted increase of 0.8 percent per year is in contrast to the recent declines. Unlike the residential sector, however, electricity is projected to substitute for natural gas in this sector. As a percentage of total commercial sector energy use, natural gas now represents 48 percent and is projected to decline to 41 percent by 1990; electricity, on the other hand, now represents 48 percent and is expected to increase to 57 percent. Energy use for space heating is projected to decline, reflecting efficiency improvements, improvements, while that for commercial processes will expand in response to expanded economic activity.

Controlling variables in the transportation sector are the total number of miles travelled in Nebraska and the efficiency of the automobiles driven.

Both vehicle miles and vehicle efficiency are expected to increase in the future. The net effect is expected to be a slight decline in oil consumption.

Energy consumption in the industrial sector tends to be affected primarily by economic variables -- gross state product and the interest rate. The interest rate tends to control the rate at which old equipment is replaced with new, more efficient equipment. While sector growth is expected to be healthy at 3.7 percent per year between 1980 and 1990, distribution among the fuel types and between manufacturing and construction is expected to remain constant. Again, this projected 3.7 percent per year growth rate is in contrast to the decline of 2.6 percent per year experienced since 1975.

In the agricultural sector, the role of both natural gas and electricity are expected to increase and that of oil to decline. Among end use activities, energy consumption will increase in absolute terms for all end uses, but it will increase faster for irrigation than for the other end uses. Interestingly, energy consumption for agriculture is projected to increase at 3.3 percent per year during 1980 to 1990, which is slower than it has been increasing since 1975 (5.1 percent per year).

<u>Projected Electric Power Consumption</u>

Three sources of projections of electric power consumption statewide are available. This includes forecasts developed by the UN-L Bureau of Business Research in March, 1982. After consultation with the Bureau and the power industry, these were omitted because they were outdated. The NPA projections are based on econometric and time series forecasting methodologies. In econometric forecasting, energy use is tied to economic variables in a cause-effect relationship and the economic variables are forecast. In time series forecasting, extrapolations are based on historical trends. In contrast, the NEO Demand Model relies on "end-use" data as well as econometric information. For example, the improving efficiency of appliances in the residential sector is accounted for; the improving efficiency of manufacturing processes in the industrial sector is accounted for; and changing trends in the nature of appliances (e.g., increased use of heat pumps for heating) are accounted for.

Projections of total electric power consumption, which are based on NEO and NPA data, are given in Figure 7. Projected growth rates shown in the figure range from a low of 3.1 percent per year (the NEO adjusted value and the NPA's low growth scenario) to a high of 5.1 percent per year (the NPA's high growth scenario). This range produces an electricity demand in 1990 of 21 to 28 billion kwh; for perspective, demand in 1980 was about 16 billion kwh.

The NEO projection and the NPA low scenario are essentially equivalent projections. The NPA low projection was designed to fit "what has been occurring recently" in electric power demand. The coincidence of these two projections by different methods and their proximity to recent trends was taken as evidence of their compatability and reasonableness. It was concluded that the NEO model supported the NPA projections, so they could be used as the basis for projections to the year 2000.

Figure 8 shows the NPA projections of peak electric power demand

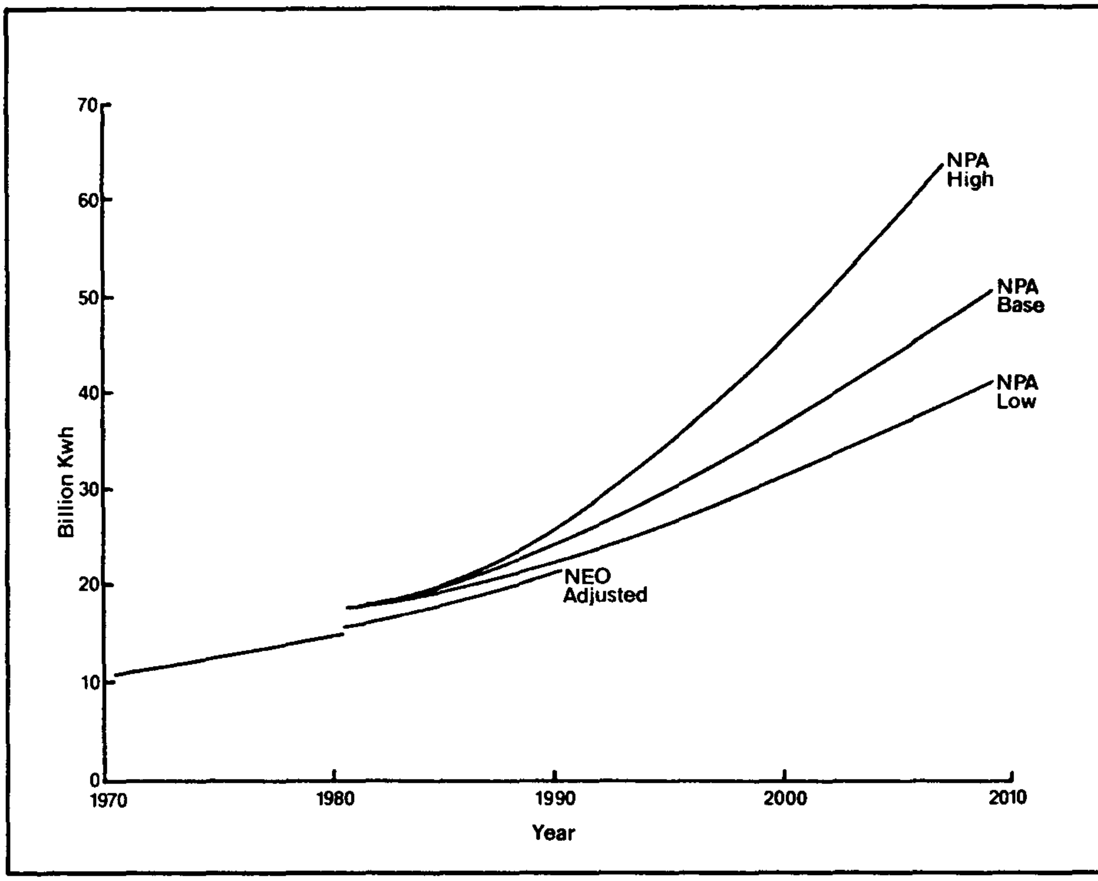


Fig. 7 HISTORICAL AND PROJECTED ELECTRIC POWER CONSUMPTION IN NEBRASKA

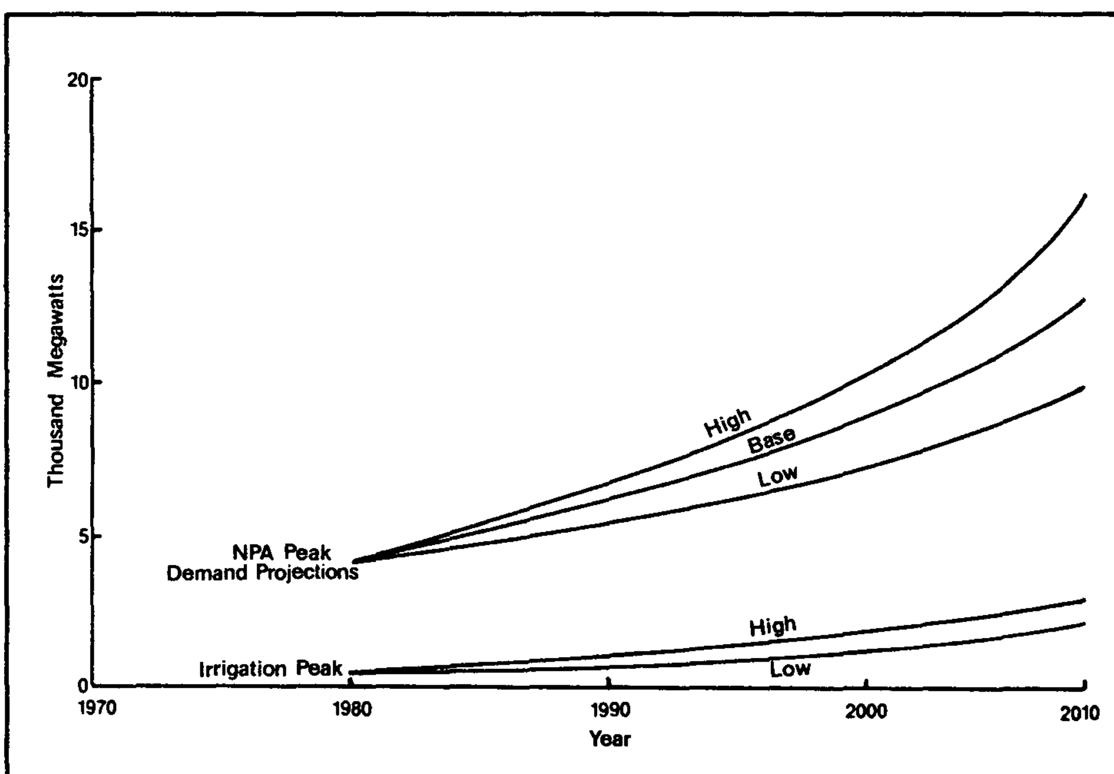


Fig. 8 PROJECTED PEAK DEMAND

The rate of growth indicated by these projections of peak demand is similar to that for total annual electric power consumption. This means that the peak is not projected to grow significantly faster or slower than the total. Additionally, all Nebraska utilities are summer peaking, and the NPA projects that they will continue to be summer peaking. Irrigation is one of the principal contributors to the peak, representing about 20 percent of the peak demand (see Table A-10 in the appendix for derivation of this value).

The rate of growth in peak electric demand determines the need for new power plants in the state. Given growth rates of 3.1 to 4.1 percent per year, between three and nine new 600 Mw coal fired power plants will be needed by 2009 (Table 7). The low value of three power plants reflects the low growth rate and assumes that MANDAN is constructed. Given the low growth rates of the past several years, most observers now believe that the projected need for three power plants is more realistic than the higher projection of nine power plants.

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Table 7

FUTURE NEBRASKA POWER PLANT NEEDS BY 2009 PROJECTED BY THE NPA OPTIMIZATION MODEL

Scenario	Coal[a/]		Combined Cycle Turbine		Pumped Storage	
	Number	Total Capacity (Mw)	Number	Total Capacity (Mw)	Number	Total Capacity (Mw)
4.1%/Yr. Growth Rate						
With MANDAN	7	4200	1	80	4	1382
Without MANDAN	8	4800	5	400	4	1332
Without Pumped Storage	9	5400	3	240	0	0
3.1%/Yr. Growth Rate						
With MANDAN	3	1800	0	0	4	1332
Without MANDAN	4	2400	0	0	4	1332

a/ These include the fossil plant (600Mw) planned for the Loup Basin by NPPD.

Source: Nebraska Power Association, Statewide Generating Planning Study, 1980-2009, March, 1981

UNCERTAINTIES IN PROJECTIONS

Three sources of energy consumption projections were available: the NEO, the NPA, and the Bureau of Business Research. However, only the NEO projections deal with all fuel forms and all sectors. The NPA projections deal only with electricity, but the two compared favorably. The Bureau of Business Research projections were not usable.

The projections of electric power consumption developed by the NPA included forecasts of power use (in kilowatt hours), power demand (in kilowatts), and the number of new power plants needed. These projections were considerably more detailed than the projections for any other forms of energy.

The NEO projections include oil, natural gas, coal, and electricity for each of the five consumer sectors. However, data for the industrial sector are incomplete in that construction activities and mining are excluded. These were estimated for this study and the NEO projection was "adjusted" to account for them. Estimates were based on actual 1980 data and growth rate projections for manufacturing.

All projections utilized 1980 as the starting point. However, this starting point--the total amount of energy consumed in Nebraska in 1980--is inconsistent among sources. There are two reasons for this inconsistency. First, the NEO Demand Model calculates 1980 energy demand using the relationships in the model whereas the NPA analysis uses actual 1980 energy consumption data. Secondly, the manner in which electricity is evaluated varies among data sources. Sometimes electricity consumption in 1980 is given as the number of kilowatt hours consumed at the point of use (an approach that excludes transmission and distribution losses); sometimes it is given as the amount of electricity leaving the power plants in Nebraska (an approach which ignores electricity that is imported and exported); and sometimes it is given as the amount of primary fuel required to generate the electricity. Since it is difficult to convert among these conventions, some inconsistency is introduced.

Finally, projected growth rates for all fuel forms and nearly all sectors are higher than recent trends. These projections are based on the assumption that certain economic variables, to which energy demand is tied, will show improvements over the recent recession years. For instance, some energy forecasts are tied to forecasts of Gross State Product and to personal income. To the extent that these forecasts of economic variables are in error, the energy forecasts will also be in error, so the projections may overestimate energy consumption in the future. If so, the problems and issues created will be reduced.

SUMMARY OF ENERGY DEMAND

1. Total energy consumption in Nebraska is projected to grow at a rate of 1.8 to 2.6 percent per year through 1990.

2. Among fuel types, electric power consumption is expected to grow fastest at 3.1 to 5.1 percent per year through 1990. Oil consumption is expected to remain constant and natural gas consumption is expected to increase slowly.

3. The three major energy forms (natural gas, oil, and electricity) are exected to maintain their relative positions in total primary energy consumption.

4. Among sectors, energy consumption by industry and agriculture is expected to grow fastest--3.5 to 4.1 percent per year through 1990.

5. Except in the case of one fuel form (electricity) and one sector (agriculture), projected growth rates are inconsistent with trends since 1975.

6. Growth rates in the peak demand for electricity will not be substantially different from growth rates in total annual consumption of electricity. Depending on the growth rate and the completion of the MANDAN transmission line, between three and nine new 600 Mw coal-fired power plants will be needed in Nebraska by 2009. Most analysts believe that three plants are more likely to be needed than nine plants.

HISTORIC WATER SUPPLY

Nebraska's water supply includes large quantities of both surface and groundwater, but it is not well distributed. Surface water is more abundant in the eastern one-fourth and groundwater is more abundant in the western three-fourths of the State. About 1.9 billion acre-feet of recoverable, good quality groundwater underlies the State. The average annual streamflow into the State, excluding the Missouri River on the eastern border, is about one million acre-feet and the average annual outflow is about seven million acre-feet. Historically the flow in the Missouri River has averaged more than three times this outflow. The potential for the use of this supply for energy development is summarized in the following sections.

SURFACE WATER

Since most of the total supply of surface water originates from rainfall runoff, the quantity of streamflow can vary considerably from year to year in all basins except those dominated by the Sandhills groundwater basin. Although baseflow of all Nebraska streams is supported by groundwater, streams in the Sandhills derive almost their entire flow from groundwater.

Information on the historical water supply in Nebraska streams is contained in the records of stream gaging stations located at strategic points. The number of stations with suitable length of record is not always sufficient for analysis of supply for specific developments, such as energy industries. There are very few sources of accurate and complete data on historic water uses and availabe water supplies in Nebraska. If information is needed that is compatible with the information from other states in the Missouri River Basin, there is only one source, the Second National Water Assessment[10]. The average annual flows estimated to be available in the four major river basins of the state under 1975, 1985, and 2000 level of water uses and depletions are summarized in Table 8 Additionally, the historic annual average, maximum, and minimum streamflows recorded at selected U.S. Geological Survey (USGS) gaging stations are summarized in Table B-1 of Appendix B.

In addition to the streams, there are hundreds of natural lakes and many reservoirs in the State. The natural lakes are mainly shallow Sandhills lakes that would not provide an adequate water supply for energy development. Major reservoirs constructed for purposes other than energy production have been used in the past to provide water for energy development. In the future, reservoirs might have to be constructed specifically for the purpose of providing supplies for energy production.

GROUNDWATER

Nebraska's groundwater supply is much greater than that of its neighboring states. Although it occupies only one-seventh of the Missouri River Basin, more than one-half of the basin's total groundwater is stored in the State. Most of this groundwater is stored in a principal groundwater reservoir composed of Pleistocene deposits and the Pliocene Ogallala Formation. It has been estimated that nearly 1.9 billion acre-feet of water are stored in the sand, sand and gravel, sandstone, and silty sandstone layers of these deposits. The saturated thickness of this groundwater reservoir ranges from zero to 1600 feet, but not all of this water is physically available for development because of the drawdown limitations and economic infeasibility of pumping from excessive depths.

Table 8

SURFACE WATER SUPPLIES IN NEBRASKA

River Basin	Location	Available Depleted Flows		
		1975	1985	2000
			(AF/YR)	
North and South Platte	North Platte, NE	1,143,600	844,7000	718,800
Platte-Niobrara	At the Missouri	4,390,600	3,579,000	2,954,100
Eastern Dakotas	Missouri River at Sioux City, IA	18,458,400	16,418,800	13,625,400
Kansas River[a/]	At the State line	1,283,300	1,242,100	1,202,600

a/ The flows for the Nebraska portion of the Kansas River Basin which includes the Big Blue, the Little Blue and the Republic River Basins, were recomputed with water uses and depletions prorated from the entire basin.

Source: Missouri River Basin Commission, Water and Related Resources in the Missouri River Basin--Present and Future Uses and Associated Problems and Issues--Technical Memorandum No.2 for the Second National Water Assessment, August 1976.

Most of the state has aquifers capable of yielding enough water to wells for irrigation and industrial use, including energy industries. However, there are areas near most of the boundaries of the state where it is difficult to get even a good domestic well. In addition there are some areas in the state where historic uses have caused water tables to decline, and continued growth of pumpage will seriously deplete the available supply.

More than 60 percent of the groundwater stored in the principal reservoir is in the Niobrara and Loup River Basins. This water would be available for energy development in this state, or for export. Extensive pumpage for these purposes, combined with use for irrigation, might deplete the flow of the streams, which are mostly dependent on groundwater contributions. This could have an impact on water supplies for energy developments on those streams.

HISTORIC WATER USES AND DEPLETIONS

Any plan for future water use requires knowlege of current and historic water use patterns. Ideally, information is needed on the location, purpose, and quantity of water use, time and space variability of return flow, and quantity of water in storage at the beginning and the depleted flow at the end of the period. The Second National Water Assessment[10] provides information about existing (1975) and projected water uses for the years 1985 and 2000 in seven major functional categories:

- o Municipal and Industrial (Central Systems)
- o Rural Domestic
- o Manufacturing (Self-Supplied)
- o Mining
- o Irrigation
- o Livestock
- o Steam Electric

The existing (1975 condition) water uses, both withdrawal and consumptive use, for the state of Nebraska as reported in the Second National Water Assessment, are shown graphically in Figures 9 and 10, and summarized in the following sections.

NON-ENERGY USES

Quantitatively, irrigation is by far the largest use of both surface and groundwater in Nebraska. The rate of irrigation development has not been consistent in the past, but technological advances such as center pivot irrigation systems led to great increases in irrigation development in the recent past. Groundwater irrigated acreage has increased dramatically. In 1975, total water withdrawal from both surface and groundwater for irrigation was about five times the withdrawal for the second largest category, power

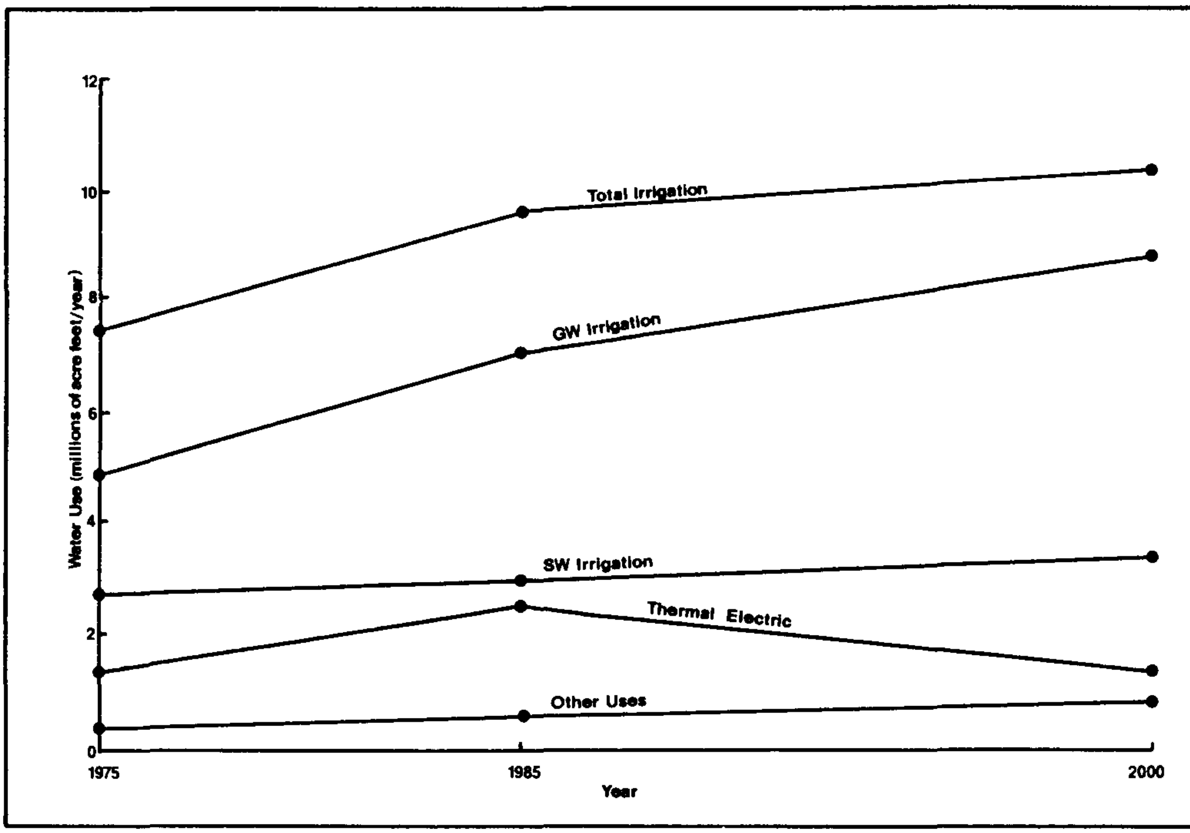


Fig. 9 EXISTING AND PROJECTED WATER USES (WITHDRAWALS) FOR THE STATE OF NEBRASKA

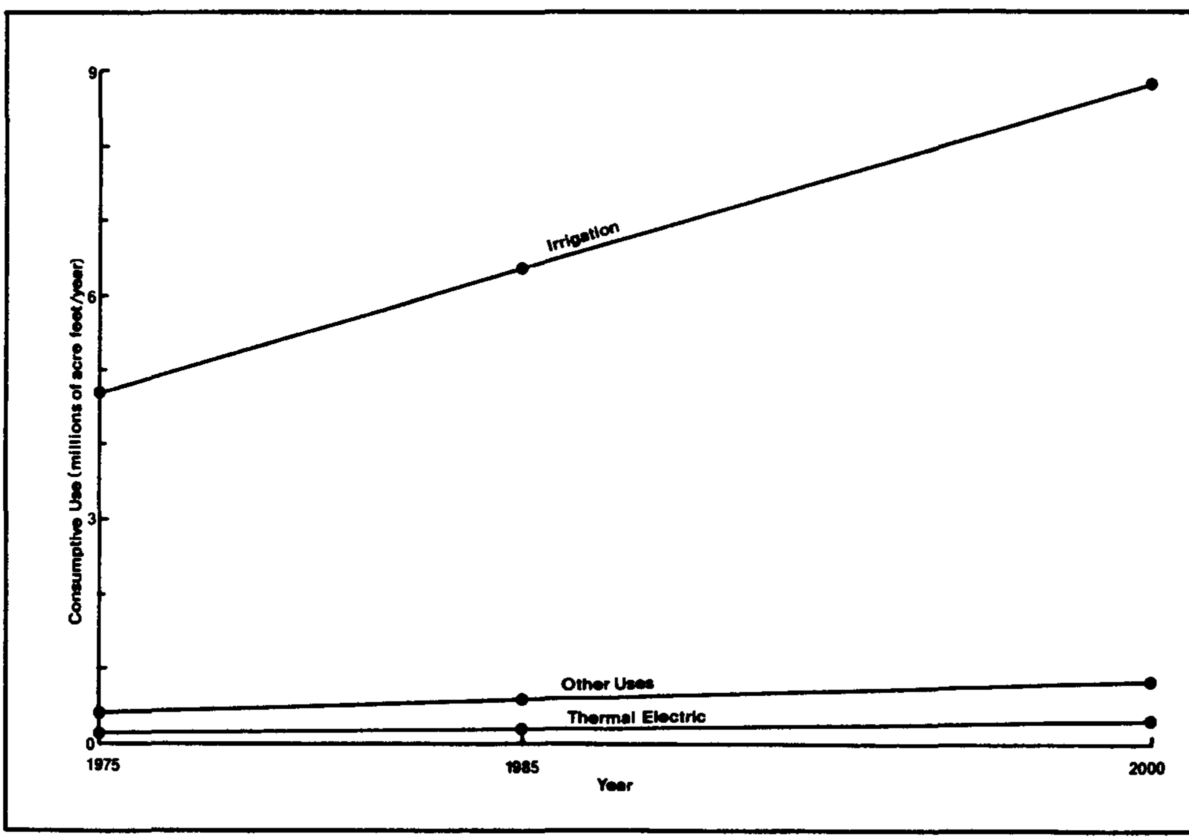


Fig. 10 EXISTING AND PROJECTED WATER USES (CONSUMPTIVE USE) FOR THE STATE OF NEBRASKA

plant cooling, and about 40 times as large as the amount withdrawn for municipal and other public uses. Surface water diversions for electric power production constitute a major component of diversions. In fact, if hydroelectric power is added, more water is diverted from surface water for power generation than for irrigation. In contrast, water consumption for electric power production is negligible compared with water consumption for irrigation regardless of the cooling technology employed.

WATER USE FOR ENERGY PRODUCTION

A more detailed analysis of water use for energy than that summarized in Figures 9 and 10 was done for this study. All energy producing technologies in Nebraska that consumed water (oil, natural gas, electricity, and ethanol) were included. Nebraska's geothermal and uranium resources have not been developed, but water will be required for their production.

Using the typical water consumption rates described in the section on technologies, total water use for energy production in Nebraska in 1980 was calculated. The results are summarized in Table 9. While about 6,400,000 acre-feet of water were needed to produce power, nearly all of this was non-consumptive use. Only 15,730 acre-feet were consumed and most of this consumption occurred in cooling reservoirs and in wet cooling towers.

FUTURE WATER USES AND DEPLETIONS

The estimated future water requirements for Nebraska, both withdrawal and consumption, under baseline conditions as projected by the Second National Water Assessment are given in Table 10 and presented graphically in Figures 9 and 10. The trend toward increased water use in the State for the years 1985 and 2000 is primarily based on projected socio-economic characteristics and land use patterns. The projected water uses of major water users are discussed in the sections on energy and non-energy uses.

NON-ENERGY USES

Major uses in the non-energy category include irrigation, livestock water, and municipal, rural domestic, and industrial uses.

Irrigation

Irrigation development, especially irrigation with groundwater, is expected to continue to increase in the State. Projected increases in profitability provide the basis for projections of continued expansion of irrigation. This means irrigation should continue to be the major water use, especially in the Platte and Kansas River Basins.

The growth of groundwater pumpage for irrigation will continue, even with improvements in irrigation efficiency and stringent allocations of groundwater. This will eventually produce significant impacts on the water supply in some areas. Water table levels will continue to decline in these areas until pumping is too costly or the supply is nearly exhausted.

Table 9

TOTAL WATER USE FOR ENERGY PRODUCTION
IN NEBRASKA IN 1980

Type of Production	Water "Withdrawn"	Water Consumed
	(Thousand acre-feet)	
Oil and Gas Production a/	0.9	0.9
Electric Power Generation		
Hydroelectric b/	3,500	0
Thermoelectric		
Once-Through	2,860.8 c/	12.8 f/
Wet Cooling Towers	9.5	2.0 d/
Alcohol Production e/	0.03	0.03
Total	6,371.23	15.73

a/ From Ballard, ibid.
b/ See Table 4.
c/ From "An inventory of Public Industrial and Power Generating Water Use in Nebraska, 1979 and 1980," Conservation and Survey Division, ibid.
d/ Based on 600 gallons per 10^3 kwh and 1,094.1 x 10^6 kwh generated in 1980 at plants with wet cooling towers.
e/ Based on 3.4 gallons water per gallon alcohol and 3.35 x 10^6 gallons alcohol produced in the State in 1981.
f/ 13,890,119 Mwh generated at once-through cooling power plants where 300 gal/Mwh consumed (some with cooling reservoirs).

Table 10

EXISTING AND PROJECTED NON-ENERGY WATER USES

Water Use	1975			1985			2000		
	Withdrawal		Consump-tion	Withdrawal		Consump-tion	Withdrawal		Consump-tion
	SW	GW		SW	GW		SW	GW	
	(THOUSAND ACRE-FEET PER YEAR)								
Irrigation	2,438.1	5,175.9	4,610.8	2,512.0	7,139.1	6,188.3	2,774.0	8,794.6	8,780.4
Livestock	22.0	77.0	99.0	32.1	127.9	160.0	38.0	161.0	199.0
Municipal & Industrial	32.0	150.0	95.0	51.0	349.0	184.0	69.0	388.0	224.2
Rural Domestic	0.0	29.6	18.8	0.0	40.8	25.5	0.0	37.6	23.6
Self-supplied Industrial	5.0	84.0	85.0	5.0	102.0	103.0	5.0	128.0	129.0

Source: Missouri River Basin Commission--"Water and Related Land Resources in the Missouri River Basin--Present and Future Uses and Associated Problems and Issues"--Technical Memorandum No.2 for the Second National Water Assessment, August 1976.

The projected demand for surface water should not increase appreciably. A slight increase in surface water use for irrigation is expected by the year 2000, on completion of the North Loup Division and O'Neill Unit.

Livestock Water

Projected increases in livestock water requirements are based on anticipated growth of the livestock industry. Livestock production is expected expected to double the 1970 level by the year 2000. The total water requirements for the livestock in the State are estimated to increase from about 99,000 acre-feet per year in 1975 to 160,000 acre-feet per year in 1985, and 199,000 acre-feet per year by the year 2000.

Municipal Water Supplies

Historically there have been adequate quantities of water available for municipal use and water sources are judged to be adequate for the projected growth. Progressive development of almost all of the municipal systems is projected to occur. Municipal water requirements are projected to increase to 400,000 acre-feet per year in 1985 and 457,000 acre-feet per year by the year 2000.

Rural Domestic Water

Rural domestic water users include all persons not served by municipal systems. Currently, approximately 20 percent of the State's population obtain their domestic water supply from private systems or from a rural water distribution system. Rural domestic use is predominantly from groundwater.

Future rural domestic water requirements are projected to increase to 40,800 acre-feet per year in 1985, a significant increase (about 38 percent) from 1975. However, total use is expected to drop slightly by 2000 because of loss of farm population.

Self-Supplied Industrial Water

Estimated future industrial water requirements from private sources were based on present use and the anticipated use necessary to accommodate growing industrialization. The biggest industrial water users, particularly large meat packers, sugar processors, and fertilizer manufacturers, are expected to continue the present trend toward the development of their own water supplies. The manufacture of fertilizer will likely show the greatest increase in water use with new plants tending to locate near areas of greatest fertilizer demand. Water requirements of industries with private water supply systems are estimated to increase to 107,000 acre-feet per year in 1985, and 133,000 acre-feet per year by 2000.

ENERGY USES

Water use for steam-electric generation was the only energy use projected for the Second National Water Assessment. All other energy uses were included in the "Other Uses" category in Figures 9 and 10. More detailed analyses of projected water use in the State by all energy producing technologies were performed as a part of this study.

Oil and Natural Gas

It is assumed that future oil production from Nebraska's limited oil reserves will range from none to the current level of production of about seven million barrels per year and that production will be entirely under the water flooding technique. Based on a water use rate of ten barrels of water per barrel of oil produced, it is estimated that future oil production in the State will continue to use a maximum of 9,000 acre-feet of water annually. The quantity of water required for natural gas production is minimal, and although natural gas development could occur in western Nebraska, the amount of water required will be relatively insignificant.

Ethanol Production

As production of ethanol in Nebraska is projected to expand substantially, water use in ethanol production will increase accordingly. It is assumed that four to 15 ethanol plants, each producing 10 million gallons annually, will be in operation by the year 2000. With a water use rate of 3.4 gallons for each gallon of ethanol produced, an estimated maximum of 1,600 acre-feet of water will be needed annually by the year 2000 for production of ethanol.

Uranium Mining

No reliable projection of uranium production in the State is available. It is assumed that zero to two uranium mining/milling plants, each producing 500,000 pounds of uranium oxide per year will be in operation by the year 2000. At a water use rate of 183,000 gallons per day per plant, 410 acre-feet of water will be required annually by the year 2000.

Geothermal Energy

Although geothermal resources occur in western Nebraska, as with uranium mining, no projection of production is available. Even if geothermal energy sources are developed, water use will not be significant, and is not expected to be derived from the principal groundwater aquifers.

Electric Power

Thermal-electric power generation is the only energy related water use for which the Second National Water Assessment provides data. The estimates for thermal-electric water use were based on projections of future electric power requirements made by the Federal Power Commission. For the foreseeable future they expected that most of the electric power would be generated by nuclear and fossil-fueled power plants. Hydroelectric plants in the State (including the Gavin's Point plant on the Missouri River) which now provide about eight percent of the State's total electric power generation, were expected to provide even smaller percentages in the future. The noticeable drop in the quantity of cooling water starting in 1985 in the Second National Water Assessment projections shown in Figure 9 was mainly due to the assumption that numerous old and inefficient plants using once-through cooling would be phased out and new plants would utilize cooling towers.

More recent and detailed projections were used to calculate energy uses in this study. As in the Assessment, it has been found that electric power is the only form of energy production in Nebraska that is likely to experience significant increases in water requirements in the future. However, the quantity of water required for future electric power generation will be dictated primarily by the cooling technology to be used in the plants. As no new off-stream hydroelectric plants are planned for the foreseeable future, the present level of water diversion of about 3.5 million acre-feet annually for hydroelectric plants will not undergo any increase.

It is assumed that all new electric power plants in the State will be fossil-fueled or nuclear thermoelectric plants. Depending on the type of cooling technologies considered, a range of water requirements has been projected. If new power plants use once-through cooling, the water diversion requirement for power generation in the State in the year 2000 will be about 4.2 to 4.8 million acre-feet annually, which will be about 1.5 times greater than in 1980. However, consumption will be approximately 28,000 to 34,000 acre-feet annually, which will be about two times greater than in 1980. If, on the other hand, new power plants use wet cooling towers, diversion requirements in the year 2000 for power generation will be about 2.9 million acre-feet annually, but consumption will be in the range of 41,000 to 53,000 acre-feet annually.

The projected water use in the year 2000 by each form of energy production is summarized in Table 11. As evident from the table, water use by other energy production technologies is dwarfed by that for electric power production. This is true under existing conditions as well as in 2000, regardless of the cooling technology employed by the power plants.

FUTURE WATER AVAILABILITY

Potential conflicts and water/energy issues will be dependent to a large extent on the availability of adequate water supplies in the future. Under the existing system of water rights, water will be available for energy development only after domestic, municipal, and agricultural needs have been satisfied. In assessing future water availability, therefore, projected needs for these uses were accounted for, allowances were made for uses in upstream states, and then the availability of water for energy development in this state was analyzed.

According to the Second National Water Assessment, irrigation constituted about 94 percent of total non-energy water consumption in 1975. It is projected to remain the same in the year 2000. Total non-energy consumption is expected to increase about 91 percent, from about 4.9 million acre-feet per year to about 9.4 million acre-feet per year. Much of this will be from groundwater, so streamflow will be depleted by only an additional 1.5 million acre-feet per year by 2000.

The Second National Water Assessment also projected water use for thermoelectric power generation. It indicated that the 1975 consumptive use of 13,100 acre-feet per year for this purpose will increase to 116,300 acre-feet per year in 2000. The consumptive use for this purpose calculated for this study was 14,800 acre-feet per year in 1980 and 53,100 acre-feet per year in 2000. Thus, the projection in the Second National Water Assessment is considered conservative, and it is considered unlikely that energy uses in Nebraska will have a major effect on the estimate of available water. Even

Table 11

WATER USE FOR ENERGY PRODUCTION IN NEBRASKA

	Water Use in 1980		Projected Water Use in 2000	
	Diverted	Consumed	Diverted	Consumed
	(1000 acre-feet per year)			
Oil and Gas Production[a/]	0.9	0.9	0-9.0	0-9.0
Electric Power Generation				
Hydroelectric[b/]	3500	0	35000	
Thermoelectric[c/]	2870.3	14.8		
If new plants use once-through			4178.0-4784.8	27.9-33.9
If new plants use wet cooling			2896.4-2908.6	41.0-53.1
If new plants use wet/dry cooling			2878.1-2881.8	22.6-26.3
Uranium Mining/Milling[d/]	0	0	0.0-0.4	0.0-0.4
Alcohol[e/]	0.03	0.03	0.4-1.6	0.4-1.6
Geothermal	0	0	0.0	0.0
Solar Heating/Cooling	0	0	0.0	0.0
Wind	0	0	0.0	0.0

a/ Data for 1980 are from Ballard, J.L., "Nebraska A-2 Element of the High Plains Ogallala Aquifer Study," 1980, University of Nebraska.

b/ Data for 1980 from Table 9.

c/ Using NPA projections, electric power consumption in Nebraska in 2000 will total 31,094 to 37,683 gigawatt hours. Of this total, 16,885 GWH were generated in 1981, so 14,209 to 20,798 GWH represents new generation.

d/ One mine/mill requires 205 acre-feet/year (Energy From the West, Energy Resource Development Systems Report, Vol. IV, EPA-600/7-79-060d. p. 150).

e/ Assumes 3.4 gallons water/gallon ethanol (Nebraska Gasohol Committee, personal communication).

with this conservative estimate of projected consumption for power generation, the Second National Water Assessment shows that average annual flows available in 2000 in the Platte-Niobrara area will be 2,954,100 acre-feet and in the Republican-Blues area it will be 1,202,600 acre-feet. The Second National Water Assessment also looked at future depletions to flow in the rest of the upper Missouri River Basin, and estimated that average annual flow in the Missouri River at Sioux City will be 13,625,400 acre-feet in the year 2000. The remaining supply in the North and South Platte Rivers is projected to be 718,000 acre-feet per year. In short, the total water supply will still be substantial on an annual basis.

Most energy developments require such small amounts of water that adequate supplies should be available in most areas of the state. Only electric power plants require large supplies at all times of the year, so that water availability might be a problem, even though average annual flows might be adequate.

A detailed power plant siting study conducted by Kaiser Engineers, Inc. for the Nebraska Public Power District in 1974 analyzed water availability for power plants on a statewide basis. This study, the results of which are still reasonably valid, found seven potentially suitable sites in the State for nuclear or fossil fueled power plants utilizing surface water for cooling. It found four sites for power plants that might accommodate as many as four 600 Mw coal-fired generating plants.

Two of these are near the Missouri River where there would be sufficient water available for any type of cooling process. The other two are located farther west. One is on the Middle Loup River below the confluence of the Dismal River, and the other is near the Platte River below the confluence with the Loup River. The analysis of water availability for this study indicates that streamflow in the Middle Loup River will be depleted very little in the future. With projected water uses the average annual streamflow of the Middle Loup River at the site of the proposed power plant will be decreased by only five cfs in 1985 from the present average flow of 720 cfs. At the Rogers site on the Platte River below the confluence with the Loup, the analysis indicates that under 1985 conditions of projected water uses in the North Platte, South Platte, and Loup River Basins, the average annual flow of the Platte River at North Bend will be reduced by 378,500 acre-feet per year. This amounts to a 13 percent reduction of the existing average annual flows, but future depleted flows would still average more than two million acre-feet per year. Therefore, at both of these sites, there would be sufficient water for several 600 MW power plants using wet cooling towers. However, because water availability during low flow periods at these sites is less than power plant requirements during peak demand periods, once-through cooling for power plants at these sites does not appear feasible.

In addition, it appears there will be sufficient flow in the Missouri River in the future to support a number of plants with once-through cooling, and as many as eight plants if cooling towers are used. Therefore, it appears that water supplies statewide will be adequate for production of the electric power that will be needed in the State in the foreseeable future.

From a water availability perspective, there are enough sites to support the 3 to 9 power plants that may be needed in the State by 2000. There have always been and will continue to be local shortages of water due to time and space variability of flows depending on meteorologic and other conditions. Competition for local water supplies may occur in some areas, with locally significant impacts. However, if facilities requiring large amounts of water are not located in such problem areas, water supplies statewide appear to be adequate to meet the projected needs for all energy uses in the foreseeable future.

UNCERTAINTY IN WATER USE PROJECTIONS

An accurate assessment of the water supply situation for this study was limited by the lack of detailed, documented sources of information for water use and availability in the State. Early in this study it appeared that the Missouri River Basin (MRB) Hydrology Study by the Missouri Basin States Association could be used, but its Water Accounting System was not completed before the analysis phase of this study. The only other source of information on present and projected water use and depletion that is compatible with the information on other upstream states in the basin is the Second National Water Assessment conducted by the U.S. Water Resources Council. The technical validity of some of the methods on which the estimates of this assessment were based are questioned by some state agencies, but in the majority of the areas in the basin, the quantities estimated by these methods are a small part of the total depletion and supply, so the overall accuracy was considered acceptable for national and regional planning purposes.

SUMMARY OF WATER USE AND AVAILABILITY PROJECTIONS

1. Irrigation is by far the largest consumptive use of both surface and groundwater in Nebraska, and it will continue to dominate in the foreseeable future.

2. The diversions from surface water for electric power generation, primarily for hydroelectric and once-through cooling plants, is greater than diversions for irrigation, and will continue to be if the favored cooling option can be used.

3. Diversion requirements and consumptive use for other energy uses will be insignificant compared to electric power and irrigation, respectively.

4. In the future, average annual water supplies in Nebraska will be adequate for energy development, even after all other consumptive uses in upstream states and Nebraska are satisfied.

5. There will be sites with adequate water supplies even in low flow periods for once-through cooling at future electric power plants, or at least for cooling towers, at some sites.

6. Although there will be no serious, widespread shortage of water for energy, shortages and conflicts have occured in some localities in the past, and will continue to occur in the future.

CHAPTER 3. CURRENT AND PROJECTED ENERGY AND WATER RESOURCES DEVELOPMENT IN UPSTREAM STATES

Current and projected energy and water resource development in upstream states could affect Nebraska's water supplies. Upstream states have abundant supplies of energy resources but inadequate supplies of water resources in most areas. The development and utilization of these energy resources could reduce water supplies entering Nebraska or could utilize Nebraska water for development. This chapter provides an overview of energy and water resources in the upstream states, and then examines the water needs for projected energy development upstream.

ENERGY RESOURCES

Energy resources in the western states have great potential to contribute to increased domestic energy production. The region has abundant reserves of coal, oil shale, uranium ore and some reserves of oil and natural gas. The energy reserves, production technologies and projected development of these resources are summarized in the following sections.

COAL

Interest in western coal reserves to meet projected energy demands has increased in the past 10 years. The production and transportation technologies, including the water requirements, necessary to develop these resources are discussed in this section.

Reserves

Abundant reserves of good quality bituminous and subbituminous coal lie in the neighboring western states (Table 12). The Northern Great Plains and the Rocky Mountain Coal Reserve Provinces contain an estimated 2,040 billion tons, approximately 63 percent of the nation's identified and undiscovered deposits of coal. The Green River Regional Coal Reserve of southern Wyoming contains one of the highest quality subbituminous coal deposits with heating values ranging from 5,000 to 14,000 Btu/lb.

Water Requirements

There are two basic types of mining used to extract coal: surface mining and underground mining. The water requirements for both extraction techniques are generally quite low. Water requirements consist of water for dust control in the crushing plant and along haulage roads in surface mining. In underground mining operations water for dust control is available from reclaimed mine drainage so no additional water is required.

Coal is generally transported from the western states by conventional surface methods, primarily by railroads. A different method, transporting coal in the form of a slurry through a pipeline, has been proposed for eastern Wyoming. In a coal slurry pipeline, the coal is pulverized, mixed with water, and pumped through a pipeline. Approximately equal parts of coal and water (by

Table 12

WESTERN COAL RESERVES BY STATE

	Potential Mining Method		
	Underground	Surface	Total
	(Million Tons)		
Arizona	0	350	350
Colorado	14,000	870	14,870
Montana	65,165	42,562	107,727
New Mexico	2,136	2,258	4,394
North Dakota		16,003	16,003
South Dakota	0	428	428
Utah	3,780	262	4,042
Wyoming	27,554	23,674	51,228
TOTAL WESTERN STATES	114,082	86,915	200,997a/
TOTAL U.S.	297,235	136,713	433,948

a/ Includes measured and indicated categories as defined by the U.S. Bureau of Mines and U.S. Geological Survey and represents 100 percent of the coal in place.

Source: Dupree, Walter G., Jr. and John S. Corsentino. United States Energy Through the Year 2000, Revised. Washington: Bureau of Mines, 1975, p. 5.

weight) are required. A standard sized coal slurry pipeline will have a carrying capacity of 25 million tons of coal per year. The water consumption for a standard size slurry pipeline ranges from 13,500 to 18,400 acre-feet per year.

Production Projections

Coal is expected to play an important role in supplying national energy needs. Given a national energy policy which emphasizes decreased dependence on external sources, coal production is expected to continue to increase. Some forecasts now suggest that the 1975 level of western coal production may double by 1985[2].

According to nominal and low demand scenarios outlined in the Energy from the West study the production of coal in the eight western states (ND, SD, MT, WY, CO, UT, NM, AZ) is projected to range from 302 million tons in 1980 to 1,800 million tons in 2000[2].

URANIUM

The technology for mining the uranium reserves recently discovered in Nebraska is explained in Chapter 2. Uranium reserves of the western United States known prior to the discovery in Nebraska are concentrated in New Mexico and Wyoming. These two states contained 86 percent of the 1978 proven reserves of the region. The Colorado plateau (which covers parts of Utah, Colorado, Arizona and New Mexico) contains the major portion of both proven reserves and potential reserves of ore that can be mined by conventional techniques.

Estimates of recoverable uranium resources have a high degree of uncertainty. Resource estimates vary from year to year and according to the organization doing the assessment. Yearly organizational estimates can vary by as much as 20 to 30 percent.

According to projected national nuclear fuel requirements by the Stanford Research Institute, 1977 fuel needs of 17,400 tons will increase to 34,900 tons by 1984[2]. However, depressed prices, uneconomical recovery techniques, and the uncertain future for nuclear power plants make future demand for uranium resources difficult to predict. For the eight western states the Energy from the West study projects that uranium will contribute 4,770 trillion Btu's in 1980, increasing to 23,750 trillion Btu's in 2000[2].

SYNTHETIC FUEL

Synthetic fuel development currently relies upon coal gasification or coal liquefaction processes. Water is used both for cooling and as a source of hydrogen for these processes.

A standard size coal gasification plant has a production capacity of 250 million cubic feet per day while a coal liquefaction plant has a production capacity of 100,000 barrels per day[12]. The standard size coal gasification plant consumes 4,890 to 8,670 acre-feet of water per year, while the coal liquefaction plant consumes 9,230 to 11,750 acre-feet of water per year.

Synthetic fuel development by coal liquefaction processes are currently at a much earlier stage of development than gasification, and it is not anticipated that coal liquefaction will be commercially available before 1995-2000. Coal gasification by the "Lurgi Process" is now a commercially available technology, and some projections indicate that high Btu coal gasification processes could be commercially available by 1985 to 1990. However, low demand projections include five coal gasification plants and one coal liquefaction plant in Wyoming after the year 2000[12].

OIL AND NATURAL GAS

Proven reserves of crude oil in eight western states account for approximately seven percent of the total U.S. reserves. The ultimate recoverable production is estimated to be 21 percent of the total U.S. supply (Table 13).

Total proven natural gas reserves for the western region have been estimated to be approximately 20 trillion cubic feet (tcf) in 1975. The western region has a potential of 56 tcf of recoverable but yet-to-be discovered reserves of natural gas. From Table 14 it can be seen that natural gas reserves in the western states account for about 10 percent of total U.S. reserves.

Water requirements vary for oil exploration and production. The total amounts required are generally insignificant. Drilling and producing these resources usually have minimal impact on water supply due both to low volume and utilization of deeper, less potable water.

According to nominal and low demand scenarios in one study, production of crude oil in the eight western states is projected to range from 300 million barrels in 1980 to 155 million barrels in 2000. The production of natural gas is projected by the same study to range from 2 tcf in 1980 to 1.19 tcf in 2000[2].

OIL SHALE

About 90 percent of the identified oil shale resources of the United States are located in a single geological formation in western Colorado, Utah, and Wyoming known as the Green River Formation. This formation underlies 25,000 square miles of land, some 17,000 square miles of which are believed to contain oil shale deposits with commercial development potential. About 80 percent of these commercially developable deposits lie in Colorado and most of these lands are federally owned.

Potential oil shale development technologies in the western states include underground oil shale mining, surface oil shale retorting, and in-situ oil shale retorting. Water is used for dust control during mining and crushing of raw shale and is also required for the disposal of pulverized spent shale.

A standard size oil shale facility, using either surface retorting or in-situ retorting, can produce 100,000 barrels per day. The surface retorting facility consumes approximately twice as much water as the in-situ technique. A standard size surface retorting facility consumes 12,000 to 18,600 acre-feet per year, while an in-situ facility consumes 7,600 acre-feet per year.

Oil shale deposits in the western states that contain more than 2 trillion barrels of oil, of which 418 billion barrels are estimated to be economically recoverable, have been identified. Projections of oil shale production in the eight western states range from 0.17 million barrels in 1980 to a maximum of 818 million barrels in 2000[2].

Table 13

WESTERN OIL RESERVE ESTIMATES

State	API Proved Reserves[a/]	USGS Identified But Not Proved Reserves	FEA Reserve Estimates[b/]	API Culmination Production[a/]	USGS Ultimate Production[a/]
		(Millions of Barrels)			
Colorado	289	328	305	1,006	1,660
Montana	207	390	196	790	1,422
New Mexico	625	769	868	2,866	4,217
North Dakota	173	193	187	395	754
Utah	251	443	350	439	1,127
Wyoming	903	815	1,102	505	5,385
Total Western	2,448	2,938	3,008	6,001	34,565
Total U.S.	34,250	33,335	38,440	96,330	163,706
Ratio=Western / U.S.	0.07	0.09	0.08	0.06	0.21

a/ Based on API (American Petroleum Institute) reports as of December 31, 1974.
b/ As quoted in Oil and Gas Journal, 1975 (July 7), from FEA (Federal Energy Administration).

Source: U.S. Environmental Protection Agency, Energy from the West, Vol. V, 1979, p.11.

Table 14

WESTERN NATURAL GAS RESERVE ESTIMATES

State	AGA Proved Reserves[b]	USGS Identified But Not Proved Reserves	AGA Culumination Production[a]	USGS Ultimate Production[b]
		(Billions of Cubic Feet)		
Colorado	1,893	1,344	2,233	5,232
Montana	930	577	1,371	3,012
New Mexico	11,759	6,364	23,134	41,833
North Dakota	417	368	658	1,467
Utah	917	876	979	2,877
Wyoming	3,703	3,412	6,296	13,797
Total Western	19,619	12,941	34,677	68,218
Total U.S.	228,200	202,548	436,896	904,576
Ratio=Western / U.S.	0.09	0.09	0.08	0.08

a/ Based on AGA (American Gas Association) reports as of December 31, 1972.
b/ Based on AGA reports as of December 31, 1975.

Source: U.S. Geological Survey, Geological Estimates of Undiscovered Recoverable Oil and Gas Resources in the United States, Circular 725, Washington, D.C.: 1975.

ELECTRIC POWER

In the Missouri River Basin there was an installed capacity of approximately 31,000 megawatts in 1979. This figure represents an increase of 31 percent in electric generation capacity since 1975. During this same period the total number of plants in service increased by only one. Several plants were taken out of service, others were modified to increase their capacity, and some new plants were brought on line. Of this 31,000 megawatts, Colorado accounts for 5,500; Montana 2,900; North Dakota 2,765; South Dakota 2,436; and Wyoming 2,765 megawatts.

Electric power production technologies in the western states are not different from the technologies presently utilized in Nebraska. In assessing water requirements for electric power production it is assumed that a coal fired power plant using once-through cooling would require diversion of 30,000 gallons per Mwh, of which 300 gallons per Mwh would be used consumptively. A coal fired power plant using a wet cooling tower will consume 600 gallons per Mwh.

Projections of upstream development in the Missouri River Basin give different levels of increased electric generation capacity by 2000[13]. Table 15 summarizes these electric power projections from three sources.

The projections in Water and Western Energy: Impacts, Issues and Choices[12] do not agree with the Missouri River Basin Commission (MRBC) and Second National Water Assessment projections for several western states because the former assumed development to be proportional to the proven coal reserves in each state. In addition, the MRBC and Second National Water Assessment projections are also difficult to compare because of the different time periods used. However, the two sources appear to be in reasonably close agreement.

CURRENT AND PROJECTED WATER SUPPLY, USE AND DEPLETIONS

The water supply available after energy and non-energy demands are met in the upstream Missouri River Basin states is represented by the flow of the Missouri River at Sioux City, Iowa, and the combined flows of the North Platte and South Platte Rivers at North Platte, Nebraska. The current and projected water supply and use in the upper Missouri River Basin and the North Platte-South Platte River Basins, and the resulting future water available to Nebraska are discussed in the following section.

HISTORIC WATER SUPPLY, USE AND DEPLETIONS

The historic average annual discharge of the Missouri River at Sioux City, Iowa, based on an 83-year period of record, is 23.2 million acre-feet. This historic average figure, however, may not represent the actual amount of water available in the river. Water use and depletions in the upper Missouri River Basin have been progressively increasing. The average annual depletion in the Missouri River Basin above Sioux City was approximately 2.7 million acre-feet in 1910. Most of this was caused by irrigation. By 1949, depletion had increased to 3.7 million acre-feet and by 1970 to about 6.5 million acre-feet. The latest depletions include evaporation from the main stem reservoirs, which

Table 15

PROJECTED GENERATING CAPACITY

	MRBC		Ballard						2nd National Assessment		
			1980		1990		2000				
	1980	1990	Low	Nominal	Low	Nominal	Low	Nominal	1975	1985	2000
	(Megawatts)										
Montana	2,890	4,446	3,000	6,000	9,000	15,000	15,000	18,000	1,400	6,100	8,200
Wyoming	3,671	6,751	3,000	3,000	9,000	6,000	6,000	9,000	1,680	4,240	12,330
Colorado	5,478	12,723	3,000	3,000	3,000	6,000	3,000	6,000	2,540	6,160	18,700
North Dakota	2,765	4,605	6,000	6,000	12,000	18,000	18,000	27,000	2,900	6,083	21,360
South Dakota	2,437	2,465	---	---	---	---	---	---	1,180	1,080	1,120

Sources: Missouri River Basin Commission, 1980. Status of Electric Power in the Missouri River Basin, Omaha, Nebraska.

Ballard, Steven C., et. al. 1981. Water and Western Energy: Impacts, Issues, and Choices, Westview Press.

Missouri River Basin Commission, 1976. Water and Related Land Resources in the Missouri River Basin -- Present and Future Uses and Associated Problems and Issues, Technical Memorandum No.2, for the Second National Water Assessment.

were completed during this period. According to the Second National Water Assessment, under 1975 water use conditions, the estimated outflow from Montana and Wyoming in the Missouri River and Tributaries Area was about 7.8 million acre-feet annually. With the added contributions of North Dakota, South Dakota, and northern Nebraska, the outflow from Gavins Point Dam on the Missouri River above Sioux City was 18.5 million acre-feet, which is considerably less than the historic average annual flow recorded at that location.

The historic average outflow of the North and South Platte Rivers from the drainage areas in Wyoming, Colorado, and Nebraska recorded at North Platte, Nebraska is 1,655,300 acre-feet annually. It includes a transbasin diversion from the Colorado River which currently amounts to about 327,000 acre-feet annually. The historic average flow also includes some non-regulated flows of the North Platte River before construction of Lake McConaughy in Nebraska and other reservoirs in Wyoming, so it does not represent the current water supply available in Nebraska. The average supply available on an annual basis is more closely approximated by the depleted flows estimated for the Second National Water Assessment. Total consumptive water use in these two basins, excluding evaporation from reservoirs, was approximately 2.7 million acre-feet annually in 1975. When the total water use and depletion by the 1975 level of development were taken into account, the 1975 level outflow from these basins at North Platte, Nebraska, was about 1,143,000 acre-feet annually.

PROJECTED WATER USE AND DEPLETIONS

Several studies have estimated the amount of water required for energy and non-energy uses in the upstream states. The Second National Water Assessment projections of energy uses include water uses only for thermal electric power and mining activities. However, some later studies looked in detail at projected water uses for development of the following energy resources: coal, including synthetic fuel conversions and coal slurry pipelines; uranium; and oil shale. In this section the total water use and depletions in upstream states presented in the Second National Water Assessment are discussed first, and then water uses in energy development projected by other studies are given in more detail.

Total Water Use and Depletions

In the upper Missouri River Basin the total consumptive water use, exclusive of evaporation from large reservoirs, from surface and groundwater sources has been projected to increase from 7.7 million acre-feet per year in 1975 to 11.5 million acre-feet per year in 2000. These projected upstream uses and evaporation from the main stem reservoirs will deplete the streamflow of the Missouri River at Sioux City, Iowa by an additional 4.8 million acre-feet in 2000.

The total estimated water consumption in the North and South Platte River Basins, exclusive of evaporation from reservoirs, is projected to increase to 3.5 million acre-feet per year in 2000 from the 1975 level of 2.7 million acre-feet. The total annual streamflow depletion including reservoir evaporation is projected to increase from 2.16 million acre-feet in 1975 to 2.58 million acre-feet in 2000. Transbasin diversion from the Colorado River to the South Platte is projected to increase by about 63 percent in 2000 from the 1975 level of diversion. However, most of this increase will be consumed in Colorado and there will be no net effect on the river in Nebraska.

Water Use in Energy Development

The amount of water required for future energy development in the upstream states is subject to considerable uncertainty, particularly regarding the total magnitude and types of energy development that will occur. Table 16 shows the water requirements of projected energy development in Montana, Wyoming, and North Dakota from one source. Projected water use in development of the following energy forms in the upstream states that might have impacts on Nebraska water supplies are discussed more specifically in the following paragraphs.

Oil Shale. The extraction of oil shale in western Colorado could pose a water supply problem, because the streams in the Colorado River Basin are already fully used and flowing water is valued for environmental purposes such as protecting instream uses[12]. If intensive and large-scale development of this resource should come about, possible major transbasin diversion of water in the Northern Plains-Rocky Mountain Region may be necessary. The total estimated requirements for this industry for the low demand scenario range from 47,000 to 59,000 acre-feet of water a year by 2000. This could be supplied from the upper Colorado River Basin. Estimates for a nominal demand scenario do not predict amounts of Missouri River Basin water that may be needed. However, the demands for water in such a scenario could necessitate interbasin transfer from the upper Missouri River Basin[2].

Oil and Natural Gas. Drilling and producing these resources will use small quantities of water. The water utilized will be extracted from deeper, less potable supplies so this activity will have an insignificant impact on overall water supplies.

Uranium. A low demand scenario projects that total water requirement for uranium mining and milling activities in the upper Missouri River Basin could be 6,600 acre-feet per year in 2000[12]. This small amount of consumptive use is unlikely to affect Nebraska's water supplies significantly.

Coal. The projected major water use in coal production would be for coal slurry in pipelines. The low demand scenario projects that as much as 250,000 acre-feet of water could be consumed annually by the coal slurry pipelines in the upper Missouri River Basin in 2000[12]. The same scenario projects an additional water consumption of 150,000 to 230,000 acre-feet per year by the coal gasification and liquifaction processes in the upper Missouri River Basin. Specific data on the projected water use for development of coal resources in the North Platte River Basin portion of Wyoming are not available.

Electric Power. Electric power will continue to be the major water use for energy development in the upstream states. The low demand scenario projects total consumptive water requirements for the coal fired power plants in the Missouri River Basin will range from 335,000 to 374,000 acre-feet per year by 2000[12]. The Second National Water Assessment, however, projects that the corresponding annual consumptive water requirement for thermoelectric power generation in the Upper Missouri River Basin and in the North Platte-South Platte Basins will be 129,000 and 160,300 acre-feet respectively.

Table 16

PROJECTED ENERGY RESOURCE PRODUCTION IN MONTANA, NORTH DAKOTA, AND WYOMING

	Production		Number of Standard Sized Facilities		Water Consumption	
	1990	2000	1990	2000	1990	2000
	(Trillion Btu's)				(acre-feet/year)	
Montana						
Electric Power Plants	188	314	3	5	81,000	135,000
Gasification	0	734	0	9	0	63,000
Liquefaction	0	184	0	1	0	11,000
North Dakota						
Electric Power Plants	251	377	4	6	96,000	144,000
Gasification	164	1,067	2	13	12,000	78,000
Wyoming						
Electric Power Plants	188	188	3	3	88,200	88,200
Gasification	0	410	0	5	0	40,000
Liquefaction	1	184	0	1	0	17,500
Uranium			12	22	12,000	22,000
Coal Slurry Pipeline (3 States)	2,000	5,200	5	13	92,000	239,200
Total	2,792	8,663	29	78	381,200	837,900

Source: Ballard, S.C. et.al. Water and Western Energy. Impacts, Issues and Choices, Westview Press, Boulder, Colo., 1982, p. 19, 21, 36, 42.

Projected Total Water Use For Energy Development in the Upstream States

The estimates of projected total water use for energy development in the upstream states differ substantially. According to the Second National Water Assessment the total energy related annual water consumption in 2000, which includes thermoelectric power and mining only, will be 212,700 acre-feet in the upper Missouri River Basin. The total water requirements for energy in the upper Missouri River Basin, including thermoelectric plants, coal gasification, liquifaction, mines and slurry pipelines, oil shale and uranium development in the low demand scenario in Water and Western Energy: Impacts, Issues and Choices, could range from 861,000 to 981,000 acre-feet per year[12]. According to the regional scenario in Energy From the West, this demand could vary from 470,000 to 1,217,000 acre-feet per year[2]. The upper limit of this regional scenario was, however, constructed prior to the decline in energy demand in the U.S. that has occured since 1979. Consequently, the projections overestimate the rate at which development will occur.

Nevertheless, it is useful to examine the effects of such development on water. The projected level and distribution of development is still likely to occur, but later than the year 2000. Hence, for the purpose of this study it is considered that the upper limit of total consumptive water use for energy development in 2000 in the upper Missouri River Basin will be of the order of one million acre-feet per year. In the absence of detailed estimates of projected energy related water uses in the North Platte-South Platte Basins from sources other than the Second National Water Assessment, it is assumed that 180,000 acre-feet per year will be the upper limit of total water use for energy development in this basin.

FUTURE WATER AVAILABILITY

The Second National Water Assessment estimated that, with the projected uses and depletions, the future available flow in the Missouri River at Sioux City, Iowa in 2000 will be 13.6 million acre-feet per year. The contribution from energy related water uses to the streamflow depletion included in the estimate is only 212,000 acre-feet per year, which is smaller than those projected by other, more detailed estimates. However, if one million acre-feet is considered to be the maximum depletion attributable to energy uses, the additional depletion of 788,000 acre-feet will be only six percent of the available flows. Under these conditions the impact of this energy development on the availability of flow in the Missouri River is not considered significant for energy development in Nebraska. The decreased availability probably would not impact on water that would be available for municipal, industrial or power plant needs along the river[2]. However, several studies have analyzed the probable impact of upstream depletions on navigation in the Missouri River. An increase of depletions by 1.5 million acre-feet per year in 2000 would reduce the navigation season by one week in a normal year[14].

The Northern Great Plains Resources Program Water Work Group Report[16] examined the depletions caused by projected energy developments in combination with other projected uses in the Upper Missouri River Basin, especially irrigation, and concluded:

"A practical limit of additional future depletions in the upper basin has been tentatively determined to be 9.9 million acre-feet per year above 1970 level. This 9.9 million acre-feet will more than supply all the projected depletions that have been made in any study undertaken to date. Even with the entire 9.9 million acre-feet consumed, there could still be partial service to navigation, a viable hydropower generation facility, and minimum flows throughout a decade long drought period, as experienced in 1930-1941, of 6,000 cubic feet per second between and from all main-stream reservoirs."

Strictly from the viewpoint of water availability for energy development in Nebraska, it appears that even in the event of such unlikely future streamflow depletions in the upper Missouri River Basin, there should be adequate flows in the Missouri River to cool all the needed power plants in Nebraska by the year 2000. Analysis of the adequacy of those flows for fish, wildlife, navigation or other uses is beyond the scope of this study.

The projected depleted outflow from the North Platte and South Platte Rivers at North Platte, Nebraska has been estimated to be 718,800 acre-feet per year in 2000[10]. The energy developments in Wyoming probably will not result in reduced flows of the North Platte River into Nebraska unless large scale coal gasification occurs. Additional water uses for municipal, agricultural and environmental needs in Colorado in excess of those projected in the Second National Water Assessment may reduce South Platte flows into Nebraska. Energy related water uses in Colorado are not expected to cause any significant reduction of flow in the South Platte River.

CHAPTER 4. SUMMARY, CONCLUSIONS, AND ISSUES

In order to better define the policy issues, the first stage of this study concentrated on determining the extent of possible water and energy supply problems that might make current issues more critical or raise new issues. This chapter presents a summary of the technical analysis of demands and supplies and an explanation of the problems and issues that were identified.

SUMMARY OF THE ANALYSIS OF SUPPLY AND DEMAND

The compilation and analysis of the technical data on energy and water described in Chapter 2 provided the information base to assess the problems and issues related to water and energy in the State. The results of the analysis are summarized in this section.

ENERGY CONSUMPTION

Energy consumption patterns have been changing in the past ten years. It is essential to review current consumption and trends in order to assess projections of future consumption.

Current Consumption and Trends

In Nebraska the consumption of all forms of energy in 1981 totaled 530.2 trillion Btu's--the equivalent of 101 million barrels of oil. On a per capita basis the average Nebraskan consumed 337.5 million Btu's, which is nearly equal to the national average per capita consumption of 326 million Btu's.

Statewide, total energy consumption peaked in 1979 and has declined about 18 percent since then. Most of the decrease in total consumption has been brought about by a decline in oil consumption. In contrast, consumption of electricity has been increasing steadily at a rate of 2.7 percent per year. Currently, oil represents about 25 percent of total energy consumption, electricity 32 percent and gas 27 percent. Ethanol consumption totaled 0.4 trillion Btu's--the equivalent of 3 million gallons.

About equal amounts of energy were consumed in Nebraska's industrial, residential and transportation sectors in 1981. Energy consumption has declined in all sectors except agriculture since 1975. Agriculture (including irrigation, field operations, grain drying and livestock) accounted for only 11 percent of total energy consumption in 1980, but consumption in this sector has grown at an average rate of 5.1 percent per year since 1975.

Projected Consumption

Projections of future energy consumption in Nebraska were obtained from the Nebraska Energy Office, the UN-L Bureau of Business Research, and the Nebraska Power Association. Supplementary data and critiques of statewide projections were provided by the electric and natural gas utilities in the State. Only the Nebraska Energy Office provided statewide projections for all forms of energy. Although it was difficult to compare assumptions and data bases, projections were generally consistent, particularly the electric power projections by the Nebraska Energy Office and the Nebraska Power Association.

Available projections generally indicate that total statewide primary energy consumption will grow at a rate of 1.8 to 2.6 percent per year. Of the three major fuel forms, only electric power consumption is expected to increase appreciably; natural gas consumption may increase slowly while oil consumption is likely to remain about the same. There are no statewide projections for alternative fuels such as ethanol.

Consumption of electricity is expected to increase at a rate between 3.1 and 3.9 percent per year. Peak demand for electricity will increase 3.1 to 4.1 percent per year. Electric power consumption is likely to expand in all sectors, but the expansion in the agricultural sector will be about double the rate in other sectors. This is because of projected expansion in irrigated agriculture. In 1980, irrigation represented six percent of electricity consumption but 20 percent of peak demand for electricity. Agriculture is likely to represent a larger and larger share of total power consumption, but not necessarily a larger share of peak demand.

ENERGY PRODUCTION, IMPORT AND EXPORT

When measured as primary energy or its equivalent, energy production in Nebraska represents about ten percent of the State's total energy consumption. All of the petroleum products, coal, and uranium consumed in the State are produced elsewhere. Nebraska produces some oil, natural gas, electric power and small quantities of ethanol and solar energy. Nebraska could also produce uranium and energy from wind, biomass, and geothermal resources.

Nebraska is currently a net exporter of electricity. Electricity production in the State has a strong coal and nuclear base. While hydroelectric power generation has remained constant, use of oil to generate power has been decreasing and there has been an increasing reliance on coal and nuclear sources. The shift from petroleum and natural gas to more plentiful and less expensive fuels for generation continued through 1981. Nebraska electric utilities used more than five million tons of coal in 1981 compared to two million tons in 1976. During the same period their use of petroleum products decreased almost tenfold. An ample supply of open-mined coal from nearby states should provide a stable source of fuel for generation of electricity now and in the future.

Several alternative forms of energy might be substituted for coal and nuclear generated electricity in the future. The indigenous, alternative energy forms (wind, solar, waste, geothermal, ethanol) that have large resource bases are generally more expensive to produce than the conventional energy forms at the present time.

In summary, Nebraska is an importer of energy, but some of the primary fuels that are imported are used to produce enough electricity to be a net exporter of electric power. All indications are that this picture is not likely to change; that is, the state will continue to import the vast majority of its energy. However, Nebraska utilities will continue to generate enough electricity to meet future increases in demand.

At the projected rate of increase in consumption of electricity, between three and nine new 600 megawatt power plants will be needed in Nebraska between now and the year 2009. This includes NPPD's "fossil III" unit planned for sometime in the early 1990's. Like the projections of electricity consumption, the need for new power plants is likely to be toward the low end of the range. It is more likely that three or four new plants will meet the future need than eight or nine.

WATER USE AND SUPPLY FOR ENERGY

Water use in Nebraska for primary energy production, such as oil and natural gas, is relatively small. Only the generation of electric power based on the conversion of primary energy forms (coal and uranium) will require significant amounts of water in the future. However, Nebraska's water supplies could be affected by water use for energy production in upstream states.

The amount of water diverted for electric power production is a major portion of total diversion, including irrigation, municipal, and industrial uses. In fact, if hydroelectric generation is included, more water is diverted from surface waters for power generation than for irrigation. In contrast, water consumption for electric power production is negligible compared with water consumption for irrigation, regardless of the cooling technology employed.

The quantity of water consumed for electric power production varies, depending on the cooling technology employed by a thermoelectric plant. Available water use data for energy production in the State show that water use by all other energy production technologies is insignificant compared to electric power production. This is true under existing conditions and in the year 2000, regardless of the cooling technology employed by the power plant. If new power plants use once-through cooling, diversions for power generation will be about 1.5 times greater in 2000 than they are today; consumption will be about two times greater. If, on the other hand, new power plants use wet cooling towers, diversions in 2000 for power generation will be about the same as today but consumption will be about three times greater.

AVAILABILITY OF WATER FROM UPSTREAM STATES

The Missouri River Basin states upstream of Nebraska (Colorado, Wyoming, Montana, North Dakota, and South Dakota) have experienced some impacts on their water supply from increased production of energy. They have the potential for even greater energy development in the future. Their use of the water required for this development could have an effect on Nebraska's water supplies in two areas, the Missouri River and the North and South Platte River Basins.

The amount of water likely to be required by potential energy facilities is a small percentage of the total water supply of the Missouri River. Studies generally indicate that annual streamflow depletions by future energy development in the upper Missouri River Basin will increase by a maximum of about one million acre-feet by the year 2000. This is only 4.3 percent of the historic flow of the Missouri River at Sioux City, Iowa. It has been estimated that the practical limit of depletions by all types of uses, including projected energy development,e in the upper basin states could be as much as 9.9 million acre-feet per year abov the 1970 level of depletion. Even if this unlikely amount of future development should occur, it is estimated that there should be flows in the Missouri River in Nebraska of at least 6,000 cubic feet per second even in severe droughts.

The North and South Platte Rivers are of more concern because the water supplies are much smaller. Large-scale water use in Wyoming and Colorado could significantly reduce flows into Nebraska. The North Platte Basin is an area of potential concern due to extensive coal reserves and limited water resources. Water uses related to municipal, agricultural and environmental needs may reduce South Platte flows into Nebraska. According to the Second National Water Assessment, the depletion to streamflow in these two river basins is projected to increase by 37 percent by 2000.

WATER AVAILABILITY FOR FUTURE POWER PRODUCTION

Future water availability for power production in this state will be dependent to a certain extent on the demand for water for other preferred uses, including domestic, municipal and agriculture. However, available projections of water requirements for these needs and the analysis of electric power needs made for this study show that water supplies should remain adequate for future power generation.

A power plant siting study conducted for NPPD by Kaiser Engineers, Inc., in 1974 analyzed the suitability of sites for future power plants on a statewide basis. It shows there are several sites along the Missouri River that are probably suitable for power plants using once-through cooling. There are also two other sites in eastern and central Nebraska (Dunning and Rogers) that are probably suitable. This study indicates there will be sufficient water at both of these sites for several 600 Mw power plants using cooling towers. However, because water availability during low flow periods at these sites is less than power plant requirements during peak demand periods, once-through cooling does not appear feasible.

In summary, projected water uses and the consequent depletions of available water supplies, in Nebraska and upstream states, will not be an obstacle to the production of adequate amounts of electric power in the foreseeable future. There probably will be adequate water supplies at enough sites to support the three to nine power plants that may be needed by 2009. Water requirements for other energy uses are minor compared to electric power, so total annual water supplies for the state should be adequate for projected energy needs in the foreseeable future. Competition for local supplies may occur in some areas, with locally significant impacts. In the past, conflicts of this nature have raised policy issues, and they will continue to do so in the future.

WATER PROBLEMS AND ISSUES RELATED TO ENERGY

The first stage of this study concentrated on the analysis of future water needs and supplies to determine the nature and extent of possible problems and issues that might be caused by general water shortages. This analysis showed that it is unlikely that there will be any widespread shortage of water for energy development and no critical water supply issues.

In the process of making this determination, a number of problems and issues were identified. Existing problems and issues stemmed from conflicts due to competition for locally inadequate water supplies, related problems such as water quality impacts, and existing policies. Also identifed were potential problems and issues that could arise if unexpected development occurs and unplanned demands are made, or projected supplies are not available.

When making assessments and judgments based on projections, it is necessary to keep in mind the uncertainties involved. Planning projections are generally based on past performances with modifications to account for recent trends. Catastrophic events or unpredictable scientific breakthroughs cannot be forecast in ordinary water resources planning.

The 1973 war in the Middle East and the subsequent oil embargo are good examples of the type of events that can make ordinary planning projections miss the mark by a wide margin. They were not predicted, they caught this nation unprepared, they disrupted the entire economy of the nation, and they led to national energy plans and policies that completely changed water resources plans in the Missouri River Basin. Recently the policies of the federal government have shifted and plans for energy development in the western states have returned closer to the level that existed prior to 1973. This makes it seem that these events were abnormalities in the course of history and more conventional economic forces will prevail in the future.

Another disruptive event of this nature is not impossible. The situation in the Middle East has not changed substantially, but it is still not possible in ordinary water resources planning to predict the occurrence of another such event, or one that might be even more destructive. We can only keep in mind the past disruptive events and the plans for water use that they produced and examine potential actions and policies for coping with such contingencies.

Twelve issues were identified. They are numbered and explained in the following sections, which discuss the problems that produced them.

LOSS OF WATER SUPPLY FOR POWER GENERATION

At hydroelectric plants, the quantity of power generated is essentially proportional to the quantity of water discharged through the turbines. In thermoelectric plants, the efficiency of the cooling system is one of the factors that determines the amount of power that can be generated, and total loss of cooling can shut down a plant completely. Once-through cooling systems are as dependent on streamflow as hydroelectric plants. In either case, the quantity of water available is critical to the generation of power. Consequently, adequate and reliable streamflow is a prerequisite for these kinds of power plants.

This need for adequate and reliable streamflow has been the cause of a long-standing conflict between agricultural and power users in the Loup River Basin. During the irrigation season in 1980, for example, the Loup Public Power District was unable to generate power at their Monroe and Columbus plants because of reduced flows in the Loup River Power Canal. These low flows were caused by high irrigation demands upstream in the North Loup, Middle Loup, and Sargent Irrigation Districts and by irrigators pumping directly out of the power canal. The only remedy available to the power district was to collect compensation for its loss, because agriculture is superior to manufacturing in Nebraska's preference system. It simply had to stop generating power.

The conflict between irrigation demand for water and the water needs of a power plant, thermal or hydroelectric, can occur whenever the preferred irrigation demand is upstream of the power plant. In such a case, the consumptive use of water by irrigators upstream can reduce the amount of water available to the power plant downstream. The conflict does not arise when the dominant irrigation demand is downstream of a hydroelectric plant, because they consume very little water, and the discharge through the plant is available for irrigation downstream.

As already indicated, there is the potential for conflict in the Loup system. That potential could even make the Rogers site unsuitable for power development. The site is just downstream of the confluence of the Loup and Platte Rivers. Although any power develoment at Rogers would be thermoelectric, not hydroelectric, the plant would still need cooling water. During dry years and during the irrigation season, water for power at that site might be inadequate.

Several issues that are related to this problem were identified. Two of them were examined in another policy issue study, the third was raised by this study. These issues are summarized in the following paragraphs.

(1) The Ranking of the Energy Industry in the Statutory System of Preference in Water Use. Manufacturing uses, including energy production, rank below domestic and agricultural uses in Nebraska's preference system for the use of surface water. Consequently, an energy industry water right can be pre-empted by agricultural users, if compensation is paid for the water. This issue was analyzed in the Selected Water Rights Policy Issue Study. Alternatives were presented in the Preferences in the Use of Water report, and they have been considered by the legislature.

(2) Transferability of Water Rights to an Energy Industry From Other Uses. Under newly enacted legislation, water rights may be tranferred among users of the same type (for example, among agricultural users) but not between different types of uses (for example, from an irrigator to an electric utility). This issue was also examined in the Selected Water Rights Policy Issue Study. Alternatives were presented in the Transferability of Surface Water Rights report and they were considered by the legislature.

(3) Leasing Water for Generating Hydroelectric Power. Under existing State laws, only those generating electricity at hydro plants are required to pay the State an annual fee for the amount of water used. No other water users, including municipal, agricultural or industrial, are required to pay anything. While the fee is small, the requirement is sometimes considered inequitable.

WATER AND ENERGY LOSSES

Many studies, including the Six-State High Plains Ogallala Aquifer Regional Resources Study in which the Natural Resources Commission took part, have shown that many irrigators pump too much water. This pumping consumes excessive amounts of energy as well as water. Many of these pumps are powered by electric motors, and the excess demand for power occurs during peak load periods, which are critical periods. More efficient use of water and more efficient pumps would reduce the peak demand and total consumption, which would reduce the amount of water consumed by power plants. The following issue was identified as being association with these problems.

(4) Conservation of Water to Reduce Energy Consumption, Especially Electric Power. The projected rate of growth in electric power consumption and in peak demand can be reduced through a variety of techniques in the agricultural sector. Current policies do not always encourage irrigators to adopt or continue to use techniques such as conservation tillage, irrigation scheduling, and restrictions on the timing and amount of groundwater pumpage. This issue has been examined in the Groundwater Reservoir Management Policy Issue Study and some aspects will also be considered in the Water Use Efficiency study.

EFFECTS OF ENERGY PRODUCTION ON WATER QUALITY

In this study, energy production technologies were examined only in the context of quantitative water use and water availability. Water quality impacts related to water use in energy production were not investigated in detail. One possible impact, thermal pollution from power plant cooling systems, was covered in Chapter 2. Several other energy production technologies may produce water quality problems. For example, in-situ solution uranium mining is carried out by leaching the uranium from underground ore deposits. A leaching solution is pumped into the ore through patterns of injection wells. The leaching solution dissolves the uranium and is pumped out of the groundwater production wells into a processing mill. After the ore formation is mined out, the aquifer must be returned to some agreed upon water quality. While there are a number of aquifer restoration techniques available, the uranium mining industry has little experience with in-situ uranium mining so that complete restoration is uncertain.

(5) Water Quality Impacts of In-Situ Uranium Mining. This issue has received a great deal of attention from the legislature and others. The potential for water pollution, disruption of existing land uses, and competition for local water supplies has been examined and discussed extensively. At this time the potential impacts are limited because the amount of mining currently planned, one research and development project, is minimal.

CONSUMPTIVE USE OF WATER BY POWER PLANTS

The variation in diversion requirements and consumptive use for different types of power plant cooling systems causes different kinds of problems for other water users, depending on whether they are located upstream or downstream of the power plant. Once-through cooling requires large diversions and consumes very little water, so upstream users must allow large quantities of water to pass by. Since little water is consumed, downstream users receive the full benefit of that large quantity. On the other hand, with cooling towers and reservoirs, more water could be used upstream because diversion requirements for them are much smaller. However, consumptive use is high for these options, and this reduces flows downstream. In addition to reducing available supplies for off-stream uses, these reductions can increase dissolved solids concentrations and decrease fish and wildlife habitat.

From the downstream point of view, once-through cooling is the favored alternative. In fact, based on water availability and instream flow considerations, the State of Nebraska favored once-through cooling for the Laramie River power plant at Wheatland, Wyoming. The plant, which burns coal from the Powder River Basin, was located in the North Platte River Basin to take advantage of the available water supply. Grayrocks Dam was built on the Laramie River to make the water supply for the cooling towers dependable. Nebraska opposed the consumptive use by this form of evaporative cooling because of the potential reduction in flows entering this state. A suit was filed in federal court to prevent depletion of flows that would cause environmental impacts on the North Platte River and damage to critical habitat along the Platte River. In this case, an out-of-court settlement allowed the proposed cooling towers, but it limited the amount of water that the power plant could consume, guaranteed releases from the reservoir on the Laramie River, and established a trust fund for protection of the whooping crane habitat on the Platte River in Nebraska. The importance of maintaining instream flows, by choosing a cooling option with low consumptive water use, is indicated by this case.

This led to the formulation of the following policy issue:

(6) <u>Trade-offs Between Increased Consumptive Use And High Volumes of Withdrawal</u>. Cooling towers and other forms of evaporative cooling at power plants consume more than once-through cooling, but they withdraw only about 2 percent of the withdrawal by once-through cooling systems. Requiring power plants to use once-through cooling, as some advocated in the Laramie River Power Station case, would make more water available to downstream users. The effects of this kind of requirement would vary depending on the location of the plant and the number of opportunities to use the water downstream. The possible economic and social impacts of this type of policy would require careful analysis, because the Missouri River sites are the only ones that can support once-through cooling without storage reservoirs and the costs of power to consumers could vary considerably.

INTERSTATE AND INTERBASIN TRANSFERS OF WATER

Another energy development in northeastern Wyoming has also been the source of considerable controversy. The shipment of coal from the Powder River Basin by a coal slurry pipeline has been debated in the Nebraska legislature, the Congress, many federal agencies, and finally litigated in the federal courts. The original source of water Energy Transportation Systems, Inc. (ETSI) proposed to use was a deep, interstate aquifer. South Dakota protested its use, because it would interfere with the supplies of several municipalities in that state. As an alternative, South Dakota proposed to sell Missouri River water to ETSI in place of groundwater. Missouri, Iowa, and Nebraska protested this depletion of the Missouri River for export out of the basin, and filed suit in federal court to stop the sale, claiming the proper procedures were not used in approving it. The three states claim that the precedent in this case is the most important aspect of the issue.

Most of the published plans for energy independence leave little doubt that this precedent would be followed if national policy dictated such extensive domestic energy development. These plans indicate that the flow of the Missouri River could be depleted by as much as one million acre-feet per year. By itself, this is not a very significant figure, because the Missouri River at Sioux City averages about 25 million acre-feet per year. When added to other potential water uses, however, the impacts on the Missouri River could be substantial.

Nebraska has greater supplies of water than any of the states with energy resources. However, the inflows from those states in interstate streams are vital to some developments in Nebraska. Upstream depletions would cause direct impacts in this state. Depletion of the interstate aquifer would have limited impact on Nebraska's groundwater, but recent court actions indicate that Nebraska groundwater could be withdrawn and exported for energy and other uses.

In 1982 the U.S. Supreme Court declared unconstitutional the section of a Nebraska statute that prohibits interstate transfer of groundwater unless the receiving state grants reciprocal rights. In that case, generally known as the Sporhase case, an irrigator was pumping water from a well on his land in Nebraska to irrigate his land in Colorado, where he could not get a well permit. When the state sought to stop this transfer because Colorado does not reciprocate, the court ruled this requirement was a restraint on interstate commerce, so it was unconstitutional. However, it let the other provisions of the statute stand, and implied that transfers could be controlled on the basis of the other provisions. The opinion also stated that any requirements must apply equally to users from Nebraska and other states.

Policy Framework

The legal framework within the other states and the interstate compacts which control some Nebraska streams vary considerably. All the western states acknowledge and employ the prior appropriation doctrine to some extent in regulating the use of their surface waters. Colorado, Montana, North Dakota, and Wyoming have specifically repudiated the riparian doctrine. Kansas and South Dakota, like Nebraska, acknowledge it to varying degrees.

Water rights in these states may be transferred to different owners and different locations. Colorado, Wyoming, and Montana, unlike Nebraska, allow transfers between types of uses, with varying degrees of restrictions. All require that other appropriators not be injured. Colorado allows only the transfer of the amount beneficially used. Montana provides for the reservation of flows for maintenance of minimum flows or other beneficial uses.

In the states north and west of Nebraska, groundwater is subject to appropriation just like surface water. With the exception of domestic wells in some states, permits are required for appropriation of groundwater. In Colorado, rights to groundwater that is tributary to a stream are integrated with the priority system for the stream. The same is true in Montana, in certain cases.

Nebraska has entered into compacts with Colorado on the South Platte River; Wyoming on the Upper Niobrara River; Colorado and Kansas on the Republican River; and Kansas on the Big and Little Blue Rivers. In addition there is a Supreme Court decree apportioning the waters of the North Platte River between Colorado, Wyoming, and Nebraska. All these decrees and compacts apportion the surface water flows of the streams by some means. The Big Blue compact also includes control of groundwater for the benefit of streamflow to a limited extent.

Related Issues

These problems and conflicts raised several issues directly related to the court cases. Several others that are more directly linked with other problems are also indirectly related to these cases.

(7) Water Export for Energy Production. Several aspects of this issue are of interest to Nebraskans. The first is the potential for export of groundwater from Nebraska for energy developments. State policy could be revised to either limit or encourage such export. Means of limiting it will require considerable deliberation and careful preparation. Encouraging export would also require extensive study, because the potential economic benefits to the State could be substantial.

The second facet of the export issue would probably not be of any benefit to Nebraska. If water is exported from upstream states, the amount of water reaching Nebraska would be diminished. Alternative methods of resolving conflicts with other states could be explored through existing institutions, or new compacts and agreements.

In either case, the fundamental issue is whether the State now has the requisite institutional arrangements and controls needed to manage water exports.

(8) Depletion of North Platte River Flows in Wyoming. Flows in the North Platte River could be affected by energy development in Wyoming. Information on proposals or plans for development on the North Platte in Wyoming, or exports from the river or its tributaries, is inadequate to determine possible impacts on Nebraska. Some institutional arrangement or agreement is needed to improve interstate communication and cooperation.

USE OF WATER TO PRODUCE ENERGY FOR EXPORT

In 1980, a proposal to construct a power plant in western Nebraska created considerable controversy. Tri-State Generation and Transmission Association, Inc. proposed to construct a power plant near Hemingford to serve customers in Colorado and Wyoming as well as Nebraska. Like the Laramie River station, this plant would have been built where it could use an available water supply to generate power with Wyoming coal shipped by rail. In this case, though, the water would have been pumped from a well field 30 miles from the plant.

This unconventional demand on the local water supply caused considerable opposition among agricultural interests, especially water users. This controversy eventually led to the passage of the Industrial Groundwater Regulatory Act of 1981. This statute will have an effect on the siting and design of future power plants, but the magnitude of the effect on the power industry and other industries, and its potential costs, are completely unknown at this time. Other statutes that would provide more comprehensive coverage of industrial siting, and more thorough review of the impacts have been proposed and considered in the legislature.

Two issues related to this controversy have been identified. They are summarized in the following paragraphs.

(9) Power Production for Export. Nebraska is an energy importer, except in the case of electric power. If demand for electricity should increase in population centers in other states, Nebraska could use its water and uranium, or Wyoming coal, to become a major exporter of power. The economic and employment benefits from this type of development could be substantial. However, major water use for non-agricultural purposes in Nebraska could generate substantial controversy.

(10) A Comprehensive Industrial Siting Law. The legislature has considered several industrial siting bills in the past. An Industrial Siting Act proposed in 1982 would have required any energy production facility costing over 50 million dollars to obtain a certificate of public impact from a new council. As in other states, a one-stop siting process could facilitate the location and construction of industries and minimize impacts on the State's water resources.

POTENTIAL REDUCTIONS IN WATER USE BY POWER PLANTS

The amount of water used in generating electricity at a given plant is directly related to the amount generated. Reducing power consumption would reduce water use. If it also reduced the peak demand, it might delay the need for new power plants and their water rights.

Load Management

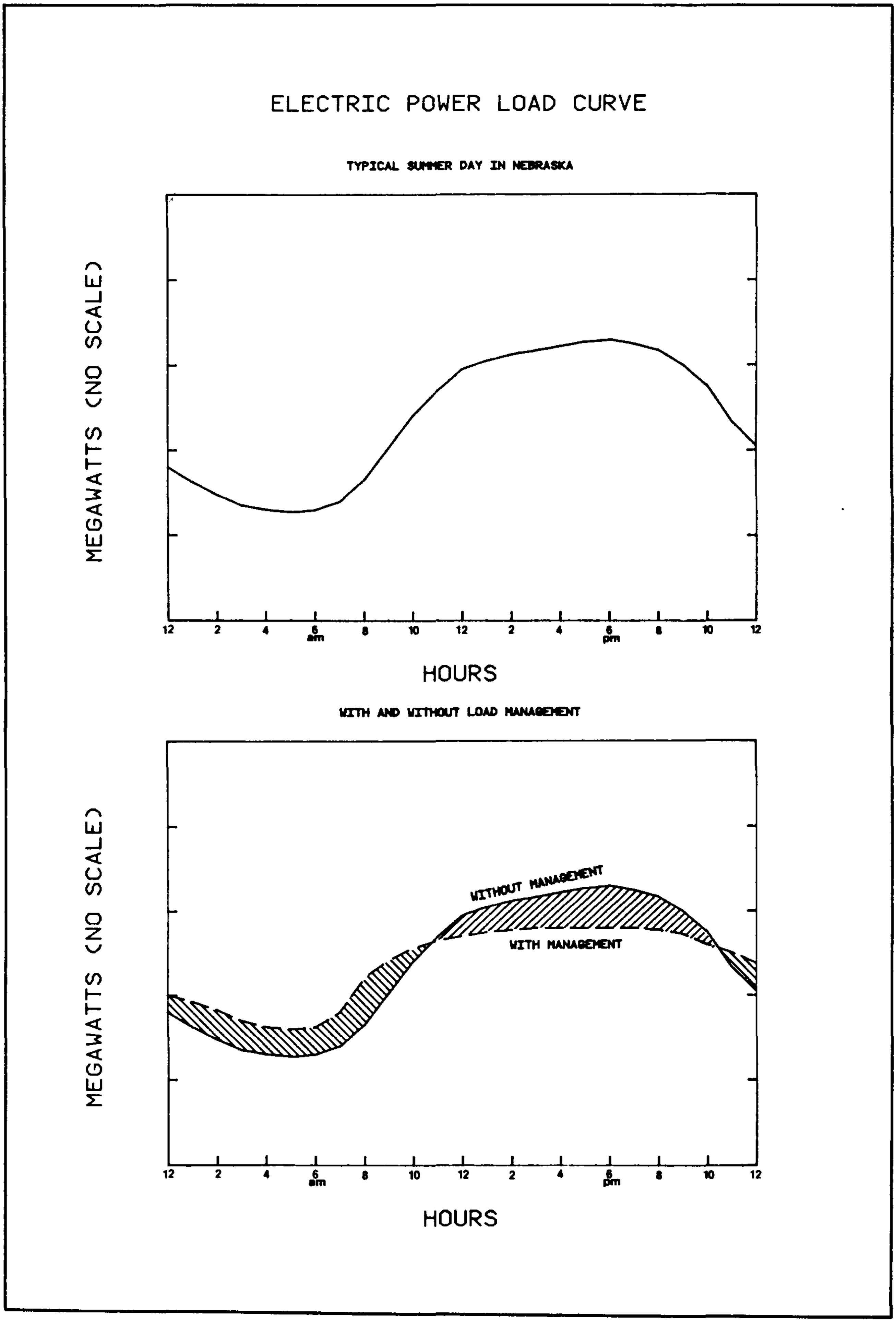
Demand for electric power can vary widely on a daily, weekly, and seasonal basis. Daily variations occur because consumers turn on appliances and lights during the day and evening, and turn them off at night. Weekly variations occur because of differences in consumption patterns on the weekends compared with the work week. In Nebraska, seasonal variations occur because irrigation pumps and air conditioners operate only during the summer. Consequently, in all power districts in Nebraska, the greatest demand for electricity occurs in the summer, and they are known as "summer peaking" utilities. A typical daily load curve for a summer day in Nebraska is shown in Figure 11. Demand is lowest at 5:00 a.m. and highest at 6:00 p.m.

A utility must have sufficient generating capacity to meet this peak demand plus some reserve capacity to handle this peak when units are forced out of service. The total capacity of a utility may be used infrequently (only on hot, dry days for example) but the capacity must be there when it is needed.

Load management is the shifting of the demand for electricity during peak periods to non-peak periods. As indicated in Figure 11, through load management, the total amount of electricity consumed during a 24-hour period can remain constant while the amount of power plant capacity needed to generate that electricity is reduced substantially. To the extent that this shifting can occur the need to construct a new power plant is deferred, and the need to have water available at that new site is deferred. Although this load shifting costs money, it is usually cheaper than building a new power plant.

The principal causes of summer peaks in Nebraska are irrigation pumps in the agricultural sector and air conditioners in the residential sector. Consequently in order to reduce the peak demand, irrigation pumps and air conditioners must be scheduled so that they are not all working at the same time. This scheduling, in

Fig. 11


ELECTRIC POWER LOAD CURVE
TYPICAL SUMMER DAY IN NEBRASKA
MEGAWATTS (NO SCALE)
12
2
4
6
am
8
10
12
2
4
6
pm
8
10
12
HOURS
WITH AND WITHOUT LOAD MANAGEMENT
MEGAWATTS (NO SCALE)
WITHOUT MANAGEMENT
WITH MANAGEMENT
12
2
4
6
am
8
10
12
2
4
6
pm
8
10
12
HOURS

turn, spreads the electricity demand throughout the day, making the curve in Figure 11 flatter. Interestingly, where irrigation scheduling has been implemented already, the total amount of water applied to the field has also been reduced. Because of improved management on the farm, the water conservation benefits occur in two places--in the power industry and on the farm. The water conservation benefit in the power industry is manifest as a delay in the need for a power plant and, therefore, for water at that site.

Water is also conserved when the amount of electricity consumed overall (regardless of the time of day) is reduced. Depending on the cooling option, 300 to 600 gallons of water are not consumed and up to 30,000 gallons are not diverted for each megawatt-hour of electricity conserved. For perspectives if consumers had used 10 percent less electricity in 1980 than they actually did, about 1,500 acre-feet of water would not have been consumed at power plants.

Reductions in electricity consumption are brought about because consumers simply use less power from power plants. The growth rate in electricity consumption in Nebraska and the U.S. as a whole has declined over the past decade, indicating that people are conserving. Most of this conservation seems to be in response to higher electricity prices.

Related Issues

Two issues were identified as being related to this problem. They are summarized in the following paragraphs.

(11) Energy Conservation Through Control of Energy Use by Water Consumers. Peak demand for electric power can be reduced through a variety of load management techniques. Examples include devices that shut off electric motors, graduated rate structures that increase the cost of excessive use, and limiting the number of hook-ups. A reduction in power demand will, of course, reduce water consumption for power generation. This issue is only one part of a larger issue, i.e., the regulation of the electric power districts in the State.

(12) Development of Alternative Energy Sources. State policy currently encourages the development of some alternative fuels and other energy sources, including geothermal energy. Incentives provided by the legislature for energy conservation and development of alternative sources include tax credits and tax exemptions. The legislature has also considered many other bills that would have encouraged energy conservation measures. To the extent they reduce the use of electricity, they help reduce the water required for generation.

SUMMARY AND CONCLUSIONS

The 12 issues identified during the course of this study vary widely in importance and in the extent to which they have been considered previously. Some are important to a large segment of the population, in other states as well as Nebraska. Others are only of interest locally, or to a limited constituency. Some have been included in other policy issue studies, and alternatives related to several have been considered by the Commission and sent to the legislature.

The issues have been summarized as follows:

(1) The ranking of the energy industry in the statutory system of preference in water use,

(2) Transferability of water rights to an energy industry from other uses,

(3) Leasing water for generating hydroelectric power,

(4) Conservation of water to reduce energy consumption, especially electric power,

(5) Water quality impacts of in-situ uranium mining,

(6) Trade-offs between increased consumptive use and volumes of withdrawal,

(7) Water export for energy production,

(8) Depletion of North Platte River flows in Wyoming,

(9) Power production for export,

(10) A comprehensive industrial siting law,

(11) Energy conservation through control of energy use by water consumers, and

(12) Development of alternative energy sources.

Three issues do not require further consideration in this study. They are (3) leasing water for hydropower, (4) conservation of water to reduce energy consumption, and (5) water quality aspects of uranium mining. Five issues have been considered to some extent in a previous policy issue study, and the alternatives given in the reports from that study are listed in Chapter 5. Alternatives are not given in Chapter 5 for the remaining four issues, but potential approaches to their resolution are presented.

ISSUES ELIMINATED FROM FURTHER CONSIDERATION

The issue (No. 3) related to leasing of water for generation of hydropower appears to be relatively minor. It affects only a few public power districts. None of the affected parties have indicated that the issue is troublesome to them, so it will not be examined further.

Issue number 4, related to water conservation, is one of the subjects of the Water Use Efficiency Policy Issue Study. It is specifically considering means of reducing water use while maintaining crop production. Although the alternatives developed in that study will not be aimed at reducing energy use, they will have that effect. Since the focus of that study is on water use and efficiency, alternatives should be presented in that report, not this one.

The water quality impacts of in-situ uranium mining (Issue No. 5) have been addressed by the Nebraska Legislature through recent enactment of L.B. 356. The provisions of this act give the Department of Environmental Control the authority to establish rules and standards regulating construction, operation and abandonment of mineral production and injection wells. This should provide adequate safeguards for water quality and mitigation of adverse environmental impacts resulting from in-situ uranium mining. Therefore, this issue will not be discussed further.

ISSUES WITH ALTERNATIVES FROM OTHER STUDIES

Five issues have been studied to some extent in the Selected Water Rights Policy Issue Study. They were not examined specifically for their relation to water and energy as in this study, but the alternatives presented in the reports on that study are applicable to the water/energy aspects of the issues. The alternatives from that study are given in Chapter 5.

Two of the issues (No.'s 1 and 2) are specifically discussed in that chapter in the section on "Water Use by Nebraska Electric Power Plants." Another (No. 6) is indirectly included as part of both of those issues. The other two (7 and 8) are discussed in the section entitled "Nebraska's Role in Energy Development in the Upper Missouri River Basin States." The alternatives applicable to these issues are listed in Chapter 5 as they were given in previous reports and considered by the Commission.

ISSUES BEYOND THE SCOPE OF THIS STUDY

Specific alternatives are not presented in Chapter 5 for the remaining four issues. Approaches to potential policies that might be examined in other, more detailed investigations are given.

The issues on export of power (9) and siting laws (10) are discussed in the section in Chapter 5 titled, "Nebraska's Role in Energy Development in the Upper Missouri River Basin States." Development and evaluation of specific policy alternatives for these issues are beyond the scope of this study. Policies on expanding the development of the energy industry and control of facility siting would affect the economy, social well-being, and environment of the state much more than its water resources. Adequate analysis of these issues, possible alternatives, and their impacts would require much more time and money than this study was alloted, and additional expertise.

The energy conservation (11) and alternative sources (12) issues are in the section on "Changes in Energy Use Pattern as an Approach to Reducing Water Use for Power Generation." Development of specific alternatives on energy conservation, by such means as electric power load management, would require more and different expertise than is represented on this Task Force. This issue is only part of a larger issue. That issue is the regulation of the electric power districts. It has been the subject of many studies and debates by the legislature in the past. This Task Force does not have the expertise in utility operation, economics, energy technology, or social impacts to examine the larger issue.

CHAPTER 5. POLICY ISSUES AND ALTERNATIVES

The water/energy issues described in Chapter 4 that were found to be important enough to warrant further consideration and possible action are combined into three categories in this chapter. They are grouped according to their relation to (1) electric power plant water use, (2) interstate energy production and water use, or (3) energy conservation.

Policy alternatives presented in this chapter are limited to those that originated in other policy issue studies. They are presented just as the Commission considered them in previous reports. Specific alternatives for other issues are not given; instead the issues are explained and approaches that could be taken in developing and evaluating policy alternatives are described. As explained in Chapter 4, these issues are beyond the scope of this study, and different information and expertise would be required to formulate responsible alternatives and properly evaluate their impact.

WATER USE BY NEBRASKA ELECTRIC POWER PLANTS

The only energy production technology that uses significant quantities of water, and thereby creates substantive policy issues, is the generation of electric power. Thermoelectric power plants that use once-through cooling and hydroelectric power plants need adequate and reliable streamflows. The drought of 1980 produced a classic example in the Loup River Basin of the type of conflict that can develop between agricultural and hydroelectric power users of water. In that case, the Loup Public Power District was unable to generate power at their Monroe and Columbus plants because upstream irrigators reduced flows to zero in the Loup River Power Canal. Since agriculture is superior to manufacturing in Nebraska's preference system, the Power District had to stop generating power. There is potential for the same type of conflict at future thermoelectric plants.

The second type of issue arises because the preference system may affect the choice of a cooling option at future thermoelectric power plants. In turn, the cooling option chosen affects cost and water consumption.

Once-through cooling, while it requires a large water diversion, consumes negligible amounts of water and is the cheapest of the options. Thus, power companies usually favor this option. In Nebraska, at locations where once-through cooling is not feasible, cooling reservoirs are normally used. Consumptive water use in cooling reservoirs can be significant and they cost more than once-through cooling. However, the reservoir can also provide irrigation water storage. Any new power plants in Nebraska that are not located on the Missouri River will probably require a cooling reservoir or cooling tower. In general, cooling towers are more expensive than reservoirs.

Nebraska's preference system, because it favors agricultural water use over manufacturing (power) use, acts as a disincentive to once-through cooling. Since an irrigator may "take" appropriated water from a power plant during times of water shortage, water supplies to power plants can be viewed as unreliable. The result is that the current preference system makes it more likely that the more expensive cooling options will have to be used; it favors the cooling reservoir or tower options that consume more water and reduce downstream flows.

POLICY ALTERNATIVES

The present preference system which favors agriculture was the subject of a report of the Selected Water Rights Policy Issue Study. It contained several applicable alternatives.

Make Manufacturing, Commercial, and Industrial Uses Superior to Agricultural Uses (Alternative 5, Preferences in the Use of Water)

A superior preference for industry would clearly increase the reliability of water for power. Therefore, it would also favor once-through cooling -- the lowest cost option. However, an alternative which merely reverses the existing priorities includes all manufacturing and commercial uses in the superior preference. The consequences of such a major and all-inclusive change are difficult to predict.

In general, there are some economic arguments for making industrial water use superior to agriculture. Because a unit of water generally has a higher value to industry than to agriculture and because industrial users are more likely to be able to compensate agricultural users than the reverse, a superior preference for industry is more consistent with economic reality than the present inferior preference. Thus, this alternative would likely enhance economic efficiency and create the potential for redistribution of wealth from agricultural users to industrial users in Nebraska.

This alternative was not favored by the Commission when they considered the report on preferences, because they preferred to maintain agriculture's superiority and because a reassessment of the full list of water users would be required prior to making any changes. When considering the report of the Municipal Water Needs Policy Issue Study, the Commission amended its position to favor a higher preference for manufacturing, commercial and industrial uses supplied by a municipality.

Modify the Preference System by Adding Other Consumptive Uses (Alternative 6, Preferences in the Use of Water)

Under this alternative a specific change could be made to add only the electric power industry. It would elevate only one kind of industry--power--to a superior position in the preference system. Like the previous alternative, it is more consistent with economic reality because water has a higher value for power and power companies are likely to be able to compensate agricultural users. Basically, it would provide more favorable conditions for power development in Nebraska. It would also tend to favor the once-through cooling option with its lower costs and water consumption. In theory, this might tend to keep power rates to agricultural users lower. In practice, however, the preference system seems to have had little historical effect on the choice of a cooling option. Moreover, actual instances of agricultural interference with power generation are limited.

The Preferences in the Use of Water report recommended that water use for power plant cooling and other types of energy development be added as a separate category to the preference list, but the recommendation was for a lower preference, not a higher preference. This would maintain the current status of the power industry, and continue to make supplies for once-through cooling at plants downstream of future irrigators unreliable. The effect of this would be to encourage the higher water consumptive and more expensive wet cooling option. This is the opposite of the effect of the position Nebraska took on the Laramie River Station and Grayrocks Dam in Wyoming. There, Nebraska was concerned about downstream flows and sought to discourage consumptive water use.

A third alternative was investigated in the Selected Water Rights Policy Issue Study. It was:

> Provide that surface water rights may be freely severed from the land and transferred to a new use or new location without loss of priority, provided that such transfers are approved in accordance with law. (Alternative 2, Tranferability of Surface Water Rights)

This alternative would provide the means for the power industry to purchase older rights with a reliable supply for power plants. However, the Commission recommended that only limited kinds of tranfers be allowed, and the law enacted in 1983 provided different limitations.

Current law in Nebraska allows surface water rights to be transferred among users within the same preference category (an agricultural user to an agricultural user) but not among users in a different preference category (an agricultural user to an industrial user). Thus, a power company cannot buy water rights from agriculture. This inability to transfer rights limits the surface water available for energy development in general, and power generation in particular. However, it probably does not affect the choice of a cooling option. Once-through cooling in a typical 600 Mw power plant would require several hundred thousand acre-feet per year, a quantity so large it is unlikely to be purchased anyway. Moreover, changes in the location of use of such a large amount of water would probably disrupt flow patterns.

In short, the inability to transfer water rights among user categories may inhibit energy development in general, but it probably does not affect the choice of a cooling system for a power plant.

SUMMARY

Thermoelectric power plants that use once-through cooling and hydroelectric power plants consume the least water and cost the least to operate. However, these types of plants must have reliable streamflows to generate power. Nebraska's system of preferences in the use of surface water is one of the factors that reduce the reliability of flow at downstream power plants during the irrigation season, because industry has a lower preference than agriculture. This makes it necessary to locate a thermoelectric power plant at a less favorable site or use a more expensive cooling option. In such situations, the preference system acts as a disincentive to once-through cooling and hydropower.

Alternatives that would address the cost and reliability issues include changes in the preference system and the ability to transfer water rights. These alternatives were investigated and presented in another policy issue study. The impact analysis in that study indicated that there are economic benefits associated with water use for energy development. Nevertheless, the Commission did not choose to alter the legal status of the power industry. It did not recommend changing an industry's preference unless it was served by a municipality or allowing the transfer of water rights to the power industry from agriculture.

NEBRASKA'S ROLE IN ENERGY DEVELOPMENT IN THE UPPER MISSOURI RIVER BASIN STATES

The existence of large reserves of some forms of energy, especially coal, in the western states has been known for many years. The war in the Middle East and the oil embargo in 1973 led this nation to prepare policies and plans for developing these energy sources. The planned development would have required large quantities of water.

One energy development that has already caused a conflict over water, the Laramie River power plant and Grayrocks Reservoir, was built in the North Platte River Basin to take advantage of the available water. Another development in northeastern Wyoming that served as a source of controversy was a coal slurry pipeline proposed by Energy Transportation Systems, Inc. (ETSI).

These cases, the decision on the export of groundwater from Nebraska by the Supreme Court, and the proposal to build a power plant in Nebraska to export power to other states all raised issues concerning this state's water laws, and federal laws, that are tied to Nebraska's relations with other states. These issues are summarized as follows:

- Water export, for energy production, as well as for irrigation (7),
- Greater consumptive use and less flow downstream in Nebraska versus large diversions and less consumption (6), especially in the North Platte River (8),
- Energy development, such as power plants, using Nebraska water to produce energy for export (9), and
- Siting of energy facilities (10).

ALTERNATIVE APPROACHES

Resolution of potential interstate problems could be approached many ways within the existing federal and interstate structure. Several methods could be employed, and a full range of objectives could be pursued within each method.

The first method is interstate cooperation. In cooperating, different degrees of formality are possible. Additional interstate compacts would be the most formal means, because they require ratification by each legislature and Congress. Less formal, complicated, and binding means of cooperation could be based on membership in organizations of states and federal agencies that would provide a forum for notification and discussion of proposals, and negotiation or mediation of differences by the group.

The second method would be based on unilateral action by this state. There are a number of steps the state could take to strengthen its position in future disputes. These actions could be combined with those in the first method in a number of ways, also.

A full range of objectives could be accommodated within these methods. If it were decided that the policy of this state should be to protect its resources to the maximum extent for its citizens for as long as possible, this could be done by either method, or combinations of both methods. On the other hand, if state policy were to maximize the use of its resources for the economic benefit of its citizens, it too could be implemented in several ways. Actions could be taken to encourage the sale of the resource for export and use in other states, or to develop Nebraska industry to make use of the water and export the product.

ALTERNATIVES FOR INTERSTATE COOPERATION

The existing legal and institutional framework provides several means the state could utilize to seek agreements to define what resources it is entitled to and place restraints on potential uses and exports. Provision is made in the U.S. Constitution for compacts between states if approved by Congress. Compacts between two states, among all states in the Missouri River Basin, and among all 17 western states are possible. These compacts could cover surface water or groundwater, or both. At this time, Nebraska is not a party to a compact pertaining only to groundwater, but it is involved in compacts that cover only surface water, and two that consider both surface and groundwater. In fact, the White River and Hat Creek, the lower Niobrara River and Ponca Creek, and the Missouri River are about the only major streams entering or leaving Nebraska that are not covered by compacts.

Interstate compacts were investigated in the Selected Water Rights Policy Issue Study, and several alterntives were given.

> Authorize and initiate the negotiation and formation of interstate agreements or compacts on interstate streams on which no compacts currently exist. (Alternative 2, Interstate Water Use and Conflicts)

The Natural Resources Commission recommended that the Legislature adopt a modified version of this alternative. If further explanation of this alternative and action is desired, the Interstate Water Use and Conflicts report provides that information.

Another alternative in that report concerning compacts referred to groundwater, but it did not pertain to all the groundwater that might be affected by energy development. The alternative was stated as follows:

> Authorize and initiate the negotiation and formation of interstate compacts with states sharing interstate groundwater basins with Nebraska. (Alternative 3, Interstate Water Use and Conflicts)

The description of the alternative refers to the two existing compacts that contain provisions dealing with the relationship of groundwater to streamflow. The scope of both of these compacts is very limited, however. They are concerned only with the effect of groundwater use on interstate streamflow, and only one regulates the alluvial aquifer associated with the river. If future compacts were limited to interstate aquifers, a number of potential conflict situations would not be covered. For instance, the construction of well fields in the Sandhills for the export of water for energy production or transportation, as proposed for the Hemingford power plant, would not be covered. Technically, it should be possible, at least, to negotiate compacts with other states to limit the amount of water that will be withdrawn for export, especially in groundwater control areas. If mutually acceptable limits could be set, well permits could be refused after the limit has been reached.

Agreements as formal as compacts may not be necessary to secure interstate cooperation. Informal agreements between governors' offices can secure interstate cooperation. Many controversies and conflicts could be averted with a simple interchange of plans for water resources development and management at the draft stage. Open discussion in the preliminary stage of projects can often produce modifications that alleviate objectionable features and reduce or eliminate controversy.

This kind of notification and discussion could take place within the purview of a number of existing organizations. The Missouri Basin States Association was formed to provide a medium for the exchange of information on the water resources of all states in the basin. It could serve the specific purpose of reducing possible controversies if the member states agreed to do it, and made a point of using it for that purpose. There are several other organizations that could also be modified to serve the same purpose. The Western Governors Policy Office, for instance, is an organization that includes most of the western states. It has shown interest in water policy previously.

An organization of this kind could be given additional powers and responsibilities by mutual agreement of the states. They could agree to use the organization as a mediating body or a source of a ruling on a dispute, short of going to court. At the current time there is no organization with such authority. The Missouri Basin States Association comes closest, but it would have to have its charter modified to be able to serve in that capacity.

ALTERNATIVES FOR UNILATERAL ACTION

There are a number of possible actions the state could take on its own to strengthen its position with respect to energy development and water export or use. Some of these actions would also help the state in negotiations on interstate agreements.

Alternatives Related to Surface Water

The use of surface water for energy developments in this state is regulated by current permit procedures. The state's position in claiming surface water supplies that might be appropriated for energy uses in upstream states could be improved by several means. The Interstate Water Use and Conflicts report states:

> "It has been suggested that Nebraska recognize and appropriate water for instream uses in order to improve its overall position in any future

interstate arguments over water. Courts, in general, will consider the amount of water appropriated for legal uses in considering the best allocation scheme. The effectiveness of such an alternative, however, should not be overestimated. Appropriations for instream uses could in fact "use" all the water remaining in the streams and courts will not necessarily allocate enough water to meet all of the state's claims."

To accomplish this, two alternatives were given that would give the status of a water right to flows remaining in a stream.

> Declare that natural flow permits may be issued for other beneficial uses including instream uses. (Alternative 4, Interstate Water Use and Conflicts)

> Provide for the reservation of waters by the Department of Water Resources to fulfill public interest requirements. (Alternative 7, Interstate Water Use and Conflicts)

The Natural Resources Commission recommended adoption of a modified version of Alternative 4, consistent with its recommendations on instream flows, and rejection of Alternative 7.

These alternatives would not only limit upstream development for energy, they would limit development in this state. Alternative 4 says other uses could be permitted, but consideration of it is limited almost exclusively to instream flow. Another alternative given in the report would not restrict development in this way. This alternative would prohibit the use of water for any purpose that is not considered beneficial in Nebraska.

> Provide that certain uses of water are not considered beneficial uses. (Alternative 5, Interstate Water Use and Conflicts)

Mining and refining shale oil, which is not found in Nebraska, could be declared "non-beneficial" uses, so no permit could be granted for its export to other states with extensive oil shale deposits. The Interstate Water Use and Conflicts report states:

> "Water in Nebraska can be appropriated only for beneficial uses. The term "beneficial use" is not currently defined in any Nebraska statutes except those pertaining to interbasin transfers. In some cases, narrow definitions of lawful beneficial use have been used to restrict diversions of water. The State of Montana, for example, has enacted a law prohibiting the use of water for the slurry transport of coal. Similar restrictions as to other uses of water likely to be large interstate uses might also be possible. Care should be used in selecting these prohibited uses so as not to similarly restrict desired in-state uses of water."

Alternatives Related to Groundwater

In 1982 the U.S. Supreme Court declared unconstitutional a section of a Nebraska statute that prohibits interstate transfer of groundwater unless the receiving state grants reciprocal rights. It left intact the provisions of the statute that provide for regulation and control of the amount and conditions of a transfer. The Court also stressed that one other factor would have to be included in the future; the residents of other states would have to be given equal treatment. Any restrictions on exporters would have to apply to Nebraskans as well.

<u>Strengthen the interstate groundwater transfer statute.</u>
(Alternative 6, <u>Interstate Water Use and Conflict)</u>

The report says, "This alternative could be implemented by an amendment to the statutes. By placing restrictions on transfers not to exceed a certain distance or quantity, the large scale interstate demands for water, such as energy development, would be prevented."

The Natural Resources Commission recommended adoption of this alternative. The recommended version apparently would restrict exports and development as much as possible. In its section on socio-economic impacts, the report states:

> "An absolute ban on the interstate transfer of groundwater would be economically inefficient. Economic criteria support the use of water where it will earn the highest return irrespective of the existence of state boundaries. The problem is that an individual state may be disadvantaged by a transfer of water beyond its jurisdiction, even though the transfer itself enhances economic efficiency. This raises significant equity issues. The problem is raised because a state may receive no compensation from the transfer. If the state was able to profit from the transfer, many of its equity concerns would be alleviated."

Groundwater is a resource that could be used to encourage economic development or produce economic benefit to the state. This could be accomplished by varying the means used to implement the alternative.

If the policy of the state were to achieve maximum economic benefit from its groundwater with minimal costs, the statute could be changed to permit exports and secure compensation for it in some form. The State of South Dakota has used this strategy in its sale of water for the ETSI coal slurry pipeline. Several methods could be used to secure payment for the water pumped. A user fee could be levied on all withdrawals, and a sliding fee scale could be applied, so small users would pay little or nothing, and large users, such as energy producers, would pay larger fees. It has also been suggested that a permit fee could be charged for interstate transfer wells. This fee could also be graduated so that large users would contribute significant revenues to the state.

Exporting water to derive greater economic benefits for the state would not achieve the full range of potential benefits from the development of the resource. Even greater gross benefits, if not greater net economic benefits, could be gained by developing the industries that use the water to produce energy in this state.

The proposed Hemingford power plant was a project of this type. That plant would have been located close to a railroad in the panhandle of Nebraska so it could use coal from Wyoming with Nebraska water. This plant would have been built close to the railroad to save hauling costs and the water would have been piped about 30 miles from a well field in the Sandhills.

The combination of railroads serving the coal regions traversing areas in Nebraska with extensive supplies of groundwater occurs in several places. If the policy of the state were to promote maximum economic development, it might be possible to capitalize on these two resources. Electric power plants and coal gasification plants both have these requirements.

The effects of this kind of development would be many and varied. Exporting electric power, as in the case mentioned previously, would increase state revenues. In addition, a number of jobs would be created. Large power plants employ several hundred people, and the benefits of this much employment spread throughout the region. Employing a labor force this large also has costs. The employees and their families require health and safety services, such as fire and police protection, schools, and many other services funded through local taxes. Coal-fired power plants also have some environmental impacts. The smoke reduces the quality of the air, ashes and other solid waste must be disposed of, and removal of groundwater could affect the area in many ways.

At the present time the prospects are not very bright for development of electric power plants for exporting power. The demand for electricity has declined in other states, including Colorado, so the proposed plant is not needed now. The growth of demand in the eastern states has also ceased, so it would be difficult to develop markets there for some years. If it turned out that development of this type were feasible in the future and the state were going to promote it, efficient means of licensing and regulating it should also be provided. Large industries have extensive impacts of many types and they are affected by many kinds of regulations at the local, state and federal level. Obtaining the necessary permits and approvals from all the government agencies with jurisdiction over the affected land, water and air can take several years. This adds to the cost of the plant and the cost to those governments for the necessary investigations and actions.

In recent years, other states have made substantial changes in their administrative structures and in the scope of their analysis concerning the suitability of new energy facilities. Many states have expanded their regulatory activities by requiring specific site suitability certificates. In other states, more attention has been given to traditional reviews of the implications for water and other natural resources of a site.

States use several criteria in the certification process. Need for power is the most common requirement, but other factors considered include conformance to state and local laws, environmental impacts, socioeconomic mitigation measures, financial qualifications of project sponsors, plant size and location, and cost-benefit factors.

Some states now inventory suitable sites for energy facilities before a need has been established. Maryland has a statutorily required site acquisition (banking) program under way. All states review sites and inventories that have been developed by utilities, and early site reviews are gaining attention.

Prompt state reviews are fostered by setting statutory or administrative limitations on the time that can be taken in processing an application. Procedures have been developed to allow for extensions when the review is very complex or new information is needed. In some states the number of permits required has been reduced, or the licensing procedures have been coordinated to eliminate duplication, which has reduced the time required.

Formal environmental assessments are conducted by many states. In some cases the reviews are conducted by the certifying agency; in others, the energy office or environmental control agency is assigned the responsibility [15].

SUMMARY

As one of the Missouri River Basin states, Nebraska has the potential to play an important role in the development and use of the basin's energy and water resources. Energy resources in upstream states have already been developed, and they have reduced the inflow of water to Nebraska. Even though there are compacts on many streams, future developments, both upstream and in Nebraska, could have even greater effects. Water could be exported from this state for energy development as well as irrigation. Also, energy companies developing the coal resources in upstream states could locate their facilities in this state to take advantage of the abundant water supply.

A full range of alternatives that would define the state's role more clearly are available. Potential policies range from promoting the development of energy industries that would use the state's water supply to the best economic advantage to restricting the use and export of water as much as possible. They could be implemented by interstate cooperation, or by unilateral action, or both. Alternatives that would accomplish some of these aims were investigated and presented in reports on another policy issue study.

Potential approaches and alternatives are summarized in five categories.

1. Negotiate additional compacts. Compacts, the most formal and binding means of interstate cooperation, could include neighboring states or all states in the basin; surface water, groundwater, or both. The Commission generally favored compacts on streams or the groundwater in alluvial aquifers.

2. Form a cooperative organization. For continuity, a formal organization of states could be formed to promote better, more open communication, negotiate differences, and agree on a procedure for conflict resolution outside of the courts.

3. Enact stricter controls on surface water. Alternatives previously considered by the Commission include claiming more water for Nebraska use by allowing rights or reservations for different kinds of uses, including instream flows, or declaring some uses to be non-benificial, so water cannot be exported for those uses. The Commission recommended adoption of only a part of the expansion of rights, and rejected the alternative of defining non-beneficial uses.

4. Enact stricter controls on groundwater. Exports could be limited by putting a restriction on the amount of water, or the distance it could be transferred. They could also be limited by placing a fee on the water exported, which would produce an economic benefit to the state. The Commission recommended this alternative without specifying the recommended means of implementation.

5. Encourage and regulate energy development. The economic benefits from energy industries using the state's water resources could outweigh the environmental, social, and water costs, especially if properly sited. Many states have a comprehensive siting law that requires thorough evaluation before industries are built.

CHANGES IN ENERGY USE PATTERNS AS AN APPROACH TO REDUCING WATER USE FOR POWER GENERATION

Water use for electric power generation could be reduced by reducing electric power consumption, because reducing the amount of power generated reduces the amount of water consumed at power plants. There are three approaches to such reductions: load management, conservation, and substitution of alternative energy forms.

LOAD MANAGEMENT

Load management is the shifting of the demand for electricity during peak periods to non-peak periods. Utilities must build enough power plants to insure adequate capacity to meet the peak, even though full capacity may be used only a small percentage of the time, and some plants may stand idle at low demand periods. To the extent that the peak load can be reduced by shifting, the need to construct a new power plant is deferred, and the need to have water available at that new site is deferred. Although this load shifting costs money, it is usually cheaper than building a new power plant. Nebraska Public Power District estimates that load management can reduce its summer peak by about 12 percent. About half of this load shifting has already been achieved[17].

Irrigation pumps and air conditioners are the principal causes of summer peaks in Nebraska. In order to reduce the peak demand, they must be managed so that they are not all working at the same time. This type of managment has already reduced peaks in some areas. It has also produced another type of benefit. Load management has generally been accompanied by irrigation scheduling. Where irrigation scheduling has been implemented the total amount of water applied to the field has also been reduced. Because of improved management on the farm, the water conservation benefits occur in two places -- in the power industry and on the farm.

CONSERVATION

Water is also conserved when the total amount of electricity consumed, regardless of the time of day, is reduced. Depending on the cooling option, 300 to 600 gallons of water are not consumed and up to 30,000 gallons are not diverted for each megawatt-hour of electricity that is conserved. For perspectives if consumers had used 10 percent less electricity in 1980 than they actually did, about 1,500 acre-feet of water would not have been consumed at power plants.

Reductions in electricity consumption are brought about because consumers simply use less. Examples of consumer strategies for conserving are: increased use of more efficient appliances, especially air conditioners; increasing the thermostat setting on an air conditioner; reduced lighting use; setting back the thermostat on an electric water heater; increasing water heater insulation; increased building weatherization and insulation; and increased use of landscaping and shading. The growth rate in electricity consumption in Nebraska and the U.S. as a whole has declined over the past decade, indicating that people are conserving. Most of this conservation seems to be in response to higher electricity prices.

SUBSTITUTION OF ALTERNATIVE ENERGY FORMS

To the extent that some other form of energy (rather than electricity from central station power plants) is used to meet energy demand, power generation needs are reduced. As with the conservation option, this reduction means that 300 to 600 gallons of water are not consumed and up to 30,000 gallons are not diverted for each megawatt-hour of electricity not needed. Examples of energy forms that can substitute for central station power are: photovoltaic cells and windmills, both of which generate electricity without the use of water; active solar cooling systems on buildings; and passive solar building designs. The electricity from photovoltaic cells or windmills can be used to operate irrigation pumps, run air conditioners, or operate any other electrical appliance. However, these technologies are still in the very early stages of development and, while available, are expensive. The same is true with active solar air conditioning. Passive solar designs, on the other hand, are available and are quite economical. However, they have limited applicability since they generally require new construction.

IMPLEMENTATION

To some extent all three of these approaches have already been implemented. High electricity prices have caused reductions in electric power consumption. Moreover, there are tax incentives available at the federal and state levels for conservation and alternative energy forms. These have caused a decline in per capita electricity consumption and a concomitant decline in water use at power plants.

Implementation of a load management program is more difficult. Basically, it is based on a price structure that penalizes users of electricity during peak periods. Presently, electric power rates, as measured in cents per kilowatt-hour, decrease with increased use. Such a rate structure provides no incentive for load shifting. Under peak load pricing, electricity rates are higher during peak periods to discourage use during certain periods of the day. For example, the Loup Public Power District has just implemented a new rate structure for its large users of electricity. A business which now operates during on-peak hours and shifts some of its load to off-peak hours would be charged $2.35 per kilowatt instead of the current $6.70 per kilowatt.

In order to implement peak load pricing, a utility must be able to measure consumption continuously at the point where consumption occurs and, more importantly, to control that consumption. Reliable control must be provided or power shortages (brown-outs) can develop. Thus, utilities need time-of-day meters on irrigation pumps and air conditioners and automatic timing devices or remotely controlled on-off switches in order to distribute the load among power consumers. For example, air conditioners and irrigation pumps are cycled on and off in such a manner that the load at the power plant remains relatively constant.

Load management programs are frequently difficult to implement since consumers rarely understand the concept of power plant load; customers may resist the idea of utility controls; and equitable pricing structures are complex and difficult to develop.

SUMMARY

Water use by the power industry can be reduced by changing energy use patterns -- that is, by managing the power load, encouraging consumers to conserve electricity, or encouraging customers to adopt alternative energy forms. Such changes require energy policy changes, not water policy alternatives. Moreover, since these changes could be effected only through new price structures for electricity and through tax incentives, implementation would occur through energy pricing policy not water pricing policy. Analyses of energy alternatives and energy pricing policies are beyond the expertise of this task force and beyond the scope of this study.

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APPENDIX A

Energy Consumption in Nebraska:

Now and in the Future

Table A-1

ENERGY SUPPLY IN NEBRASKA: 1981

(IMPORTS, IN-STATE PRODUCTION, AND EXPORTS)

	Imports	In-State Production	Exports	Net Supply[a] (Use) in NE y/
Primary Fuels[b/] (10^{12} Btu's-th)				
Oil	205.2	38.9d/	38.9	205.7
Natural Gas	143.7	3.0d/	0	146.3
Coal	97.7	0d/	0	97.7
Uranium	67.4	0d/	0	67.4
Geothermal	0	0	0	0
Ethanol[e/]	u	0.5	0.1 (net)	0.4
Hydro	0	12.1	0	12.1
Solar/Wind[f/]	0	0.04	0	0.04
Total[c/]	514.1	54.0	39.0	529.6
Electricity[b/]				
(10^{12} Btu's-th)	0 (net)	180.2g/	7.9 (net)h/	172.3
(10^{12} Btu's-e)	0	57.7	2.8	54.9
(10^{9} kwh)	0 (net)	16.9	0.8	16.1

u=Unknown

a/ Net Supply represents the sum of imports and in-state production minus exports; thus, it represents the quantity of each fuel that is consumed in Nebraska: Except for ethanol and solar, these data are from Nebraska Energy Characteristics, An Historical Overview, Legislative Research Office, July 1982.

b/ Primary fuels refer to fuels prior to consumption or prior to conversion to an end use form. Thus the portion of the coal, oil and gas fuel that are lost in the conversion to electricity in Nebraska is included as a primary fuel and expressed as Btu's-thermal (Btu's-th). Fuels, such as uranium and hydro that are used only for electric power generation, are converted to their primary fuel equivalent using a heat rate of 10,665 Btu's/kwh. In the electricity rows, electric power is expressed as Btu's-thermal, in order to indicate what portion of total primary energy becomes electricity, as Btu's of electricity, and as kilowatt-hours (3,414 Btu's/kwh).

c/ Total is the sum of all primary fuels plus any electricity not accounted for in its primary fuel form.

d/ Data are from "Nebraska's Fossil Fuel Resources" by Don Macke, Legislative Research Office, July, 1982, pp. 8 and 14.

e/ The Nebraska Energy Office (Gary Lay, personal communication) indicates that 31.18×10^6 gallons of gasohol were sold in Nebraska in 1981. At 10% ethanol, this 3.1×10^6 gallons represents 0.45×10^{12} Btu's. The Nebraska Energy Office indicates that most of the ethanol consumed in Nebraska is produced out of state. (The Archer, Daniel, Midland Co., in Illinois and Midwest Solvents in Iowa). However, there are also four commercial ethanol plants in Nebraska with a combined capacity of 3.35×10^6 gallons per year (0.49×10^{12} Btu's). The exact amount imported to Nebraska is not known.

f/ The Nebraska Energy Office (Pete Davis, personal communication) indicates that there were 370 applications for a sales tax refund on solar energy devices during the period of January 1, 1980-July 16, 1982; that these applications represent about 1/3 of the total solar installations in Nebraska; that 10% of the applications are for passive homes, 36% are for active solar domestic hot water heating, and 54% are for active solar heating. Solar energy use in Nebraska was estimated using these percentages, assuming that non-solar homes use an average of 27.6×10^6 Btu's/home for water heating and 82.2×10^6 Btu's/home for space heating, and assuming that passive solar reduces space heating demand by 50% and active solar reduces water heating demand by 90% and space heating demand by 60%.

g/ Nebraska Energy Characteristics, A Historical Overview, by Don Macke, Legislative Research Office, July 1982; page A6 gives $16,901 \times 10^6$ kwh as electricity production for 1981; conversion to Btu's thermal at a heat rate of 10,665 Btu's/kwh yields 180.2×10^{12} Btu's.

h/ Because electricity production in Nebraska exceeded in-state consumption by 7.9 billion kwh, this represents net exports. The State actually exported more than 7.9 billion kwh but also imported some.

Table A-2

Energy Demand in Nebraska: 1980 and 1981 a/

Trillion Btu's

	Transportation e/			Residential			Commercial			Industrial			Agriculture			Total		
	NEO	LRO		NEO	LRO		NEO	LRO		NEO	LRO		NEO	LRO		NEO	LRO	
	1980	1980	1981	1980	1980	1981	1980	1980	1981	1980	1980	1981	1980	1980	1981	1980	1980	1981
Oil b/	108.4	126.6	117.9	6.9	7.5	5.6	3.6	8.6	7.1	7.3f/	43.9	39.2	36.0	36.4	35.4	162.2f/	223.0	205.2
Natural Gas	0	0	0	59.6	59.6	55.4	44.9	36.4	32.6	29.0f/	45.6	44.2	9.1	9.1	9.9	142.6f/	150.7	142.1
Coal	0	0	0	0	0	0	0	0	0	7.4f/	9.4	10.3	0	0	0	7.4f/	9.4	10.3
Geothermal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0
Alcohol	u/	u/	0.4	0	0	0	0	0	0	0	0	0	u/	u/	u/		u/	0.4
Solar/Wind	0	0	0	u/	u/	0.04	0	0	0	0	0	0	0	0	0		u/	0.04
Electricity c/ (Btu's-th)	0	0	0	61.9	66.2	62.7	45.3	48.0	46.6	25.9f/	47.9	47.9	13.4	15.1	15.0	146.5f/	177.2	172.2
Total c/ (Btu's-th)	108.4	126.6	118.3	128.4	133.3	123.7	93.8	93.0	86.3	69.6f/	146.8	141.6	58.5	60.6	60.3	458.7f/	560.3	530.2
Electricity d/ (Btu's-e)	0	0	0	19.8	18.9	17.9	14.5	13.9	13.6	8.3f/	14.0	14.0	4.3	4.3	4.3	46.9f/	51.1	49.8
Total	108.4	126.6	118.3	86.3	86.0	78.9	63.0	58.9	53.3	52.0f/	112.9	107.7	49.4	49.8	49.6	359.1	434.2	407.8

u/ = A small but unknown quantity.

a/ The data on energy consumption in 1980 and 1981 that are from the Energy Demand Model of the Nebraska Energy Office (NEO) and from a series of reports prepared by the Nebraska Legislative Office (LRO). Most of the data in those reports, however, came from the NEO. Data labeled "LRO" represent actual energy consumption in 1980 and 1981. In contrast, the data labeled "NEO" are "backward" projections using NEO's Energy Demand Model; these data are generated by the functional relationships in the Model. The extent to which the projection for 1980 agrees with consumption in 1980 is relevant because projections of future energy demand will rely on the demand model. Note that the Demand Model excludes construction and mining energy consumption in the industrial sector. Only manufacturing is included in the industrial sector of the Demand Model. Additionally, the "projected" 1980 energy consumption in the residential, transportation, and agricultural sectors is slightly less than actual consumption. Thus, the model may tend to underestimate energy consumption in these sectors.

b/ Includes propane, LP Gas, distillate oil, heating oil, gasoline and diesel fuel.

c/ Electricity expressed as its thermal equivalent using a heat rate of 10,700 Btu's/kwh.

d/ Electricity (excluding losses associated with generation) at 3,413 Btu's/kwh.

e/ Excludes aviation fuel.

f/ Excludes construction and mining.

Table A-3

PROJECTIONS OF ENERGY CONSUMPTION IN NEBRASKA: 1980-1990a/

(Trillion - 10^{12} - Btu's)

	Transportation b/			Residential			Commercial			Industrial			Agriculture			Total		
	1980	1985	1990	1980	1985	1990	1980	1985	1990	1980	1985	1990	1980	1985	1990	1980	1985	1990
Primary Energy																		
Oil	108.3	99.0	102.6	6.9	6.8	6.9	3.6	3.2	2.7	7.4 (43.9)	8.5 (52.0)	10.4 (62.1)	36.0	34.9	34.9	162.2 (198.8)	152.4 (195.9)	157.5 (202.2)
Natural Gas	0	0	0	59.6	63.5	67.0	44.9	41.3	41.5	29.0 (45.6)	33.5 (53.3)	41.5 (65.1)	9.1	12.2	14.9	142.6 (159.2)	150.5 (170.3)	164.9 (188.5)
Coal	0	0	0	0	0	0	0	0	0	7.4 (9.4)	8.3 (10.6)	10.0 (12.7)	0	0	0	7.4 (9.4)	8.3 (10.6)	10.0 (12.7)
Electricity	0	0	0	62.0	65.1	69.8	45.6	50.5	57.7	26.1 (47.9)	31.1 (57.9)	38.5 (71.1)	13.5	21.8	31.4	147.2 (169.2)	168.5 (195.3)	197.4 (230.0)
Ethanol	u/	u/	u/	0	0	0	u/	u/	u/	0	0	0	u/	u/	u/	u/	u/	u/
Solar	0	0	0	u/	u/	u/	0	0	0	0	0	0	0	0	0	u/	u/	u/
Total	108.3	99.0	102.61	28.5	135.4	143.6	94.1	95.0	101.9	69.9 (146.8)	81.4 (173.8)	100.4 (200.0)	58.6	68.9	81.2	459.4 (536.6	479.7 (572.1)	529.7 (640.3)
Electricity																		
Btu's-e	0	0	0	19.7	20.7	22.2	14.5	16.1	18.4	8.3 (15.2)	9.9 (18.5)	12.3 (22.2)	4.5	6.9	10.0	46.8 (54.0)	53.6 (62.3)	62.9 (73.4)
kwh(billion)	0	0	0	5.8	6.1	6.5	4.2	4.7	5.4	2.4 (4.5)	2.9 (5.4)	3.6 (6.6)	1.3	2.0	2.9	13.7 (15.8)	18.4 (21.5)	18.4 (21.5)

Source: Energy Demand Model — Nebraska Energy office.

u/ = unknown
a/ The NEO Demand Model includes manufacturing only in the industrial sector (excluding construction and mining); in order to obtain a total for the State as well as the industrial sector (given in parentheses), construction and mining energy use was estimated using the fuel specific growth rates for manufacturing.
b/ Excludes Aviation Fuel.

TABLE A-4

PROJECTIONS OF ENERGY CONSUMPTION IN NEBRASKA'S RESIDENTIAL SECTOR

(Trillion - 10^{12} - Btu's)

	Natural Gas			Electricity			Oil			Total		
	1980	1985	1990	1980	1985	1990	1980	1985	1990	1980	1985	1990
Space Heating	42.1	41.7	40.5	7.4	8.8	10.1	6.9	6.8	6.9	56.4	57.3	57.5
Water Heating	13.5	13.8	14.2	7.1	7.9	8.7	0	0	0	20.6	21.7	22.9
Space Cooling	2.9	2.0	1.6	12.3	11.1	11.0	0	0	0	15.2	13.1	12.6
Other Appliances	1.1	6.0	10.7	35.2	37.3	40.0	0	0	0	36.3	43.3	50.7
Total	59.6	63.5	67.0	62.0	65.1	69.8	6.9	6.8	6.9	128.5	135.4	143.6

Source: Energy Demand Model — Nebraska Energy Office

TABLE A-5

PROJECTIONS OF ENERGY CONSUMPTION IN NEBRASKA'S COMMERCIAL SECTOR

(Trillion - 10^{12} - Btu's)

	Natural Gas			Electricity			Oil			Total		
	1980	1985	1990	1980	1985	1990	1980	1985	1990	1980	1985	1990
Space Heating	30.5	28.1	28.2	5.9	6.6	7.5	2.2	1.9	1.6	38.6	36.6	37.3
Water Heating	1.3	1.2	1.2	1.4	1.5	1.7	0.7	0.6	0.5	3.4	3.3	3.4
Space Cooling	3.6	3.3	3.3	11.4	12.6	14.4	0	0	0	15.0	15.9	17.7
All Other	9.4	8.7	8.7	26.9	29.8	34.0	0.7	0.7	0.6	37.0	39.2	43.3
Total	44.9	41.3	41.5	45.6	50.5	57.7	3.6	3.2	2.7	94.1	95.0	101.9

Source: Energy Demand Model — Nebraska Energy Office

TABLE A-6

PROJECTION OF VEHICLE MILES TRAVELED (VMT)
AND AVERAGE MILES PER GALLON (MPG)

	1980	1985	1990
VMT (million)			
Autos	9,669	11,220	12,431
Motocycle	240	291	352
Gasoline Trucks	110	127	141
Diesel Trucks	1,203	1,398	1,553
MPG			
Autos	14.8	19.2	23.4
Motorcycle	50.0	50.0	50.0
Gasoline Trucks	7.0	8.4	6.7
Diesel Trucks	7.0	8.4	6.7

Source: Nebraska Energy Office

TABLE A-7

PROJECTIONS OF ENERGY CONSUMPTION IN NEBRASKA'S AGRICULTURAL SECTOR

(Trillion - 10^{12} - Btu's)

	Natural Gas			Electricity			Oil			Total		
	1980	1985	1990	1980	1985	1990	1980	1985	1990	1980	1985	1990
Field Operations	0	0	0	0	0	0	10.5	10.6	11.5	10.5	10.6	11.5
Grain Drying	4.6	7.1	8.7	2.8	5.3	7.7	2.9	4.1	4.7	10.3	16.5	21.1
Irrigation	4.5	5.1	6.1	9.1	14.1	20.5	17.3	15.0	13.7	30.9	34.2	40.3
Livestock	0	0	0	1.6	2.4	3.1	5.3	5.2	5.0	6.9	7.6	8.1
Total	9.1	12.2	14.8	13.5	21.8	31.4	36.0	34.9	34.9	58.6	68.9	81.2

Source: Energy Demand Model — Nebraska Energy Office

TABLE A-8

ENERGY CONSUMPTION GROWTH RATES IN NEBRASKA

Percentages Per Year

	Actual	Projected		
	1975-1981	1980-1985	1985-1990	1980-1990
Total Primary Energy Consumption	-1.8	+0.9	+2.0	+1.4
Fuel Types				
Electricity	+2.7	+2.7	+3.2	+3.0
Natural Gas	-4.8	+1.1	+1.8	+1.5
Oil	-2.8	-1.2	+0.7	-0.3
Coal	+5.7	+2.3	+3.8	+3.1
Sectors				
Residential	-0.9	+1.0	+1.2	+1.1
Commercial	-2.7	+0.2	+1.4	+0.8
Industrial	-2.6	+3.1	+4.3	+3.7
Transportation	-3.7	-1.8	+0.7	-0.5
Agriculture	+5.1	+3.3	+3.3	+3.3

Source: Energy Demand Model — Nebraska Energy Office

TABLE A-9

ENERGY CONSUMPTION GROWTH RATES BY FUEL TYPE IN EACH SECTOR

Percentages Per Year

	Actual	Projected		
	1975-1981	1980-1985	1985-1990	1980-1990
Residential				
Natural Gas	+0.1	+1.1	+1.1	+1.1
Electricity	+2.1	+1.0	+1.4	+1.2
Oil	-17.4	-0.3	+0.3	0
Total	-0.9	+1.0	+1.2	+1.1
Commercial				
Natural Gas	-4.9	-1.7	0.0	-0.8
Electricity	+1.3	+2.1	+2.7	+2.4
Oil	-10.4	-2.3	-3.3	-2.8
Total	-2.7	+0.2	+1.4	+0.8
Industrial				
Natural Gas	-8.5	+2.9	+4.3	+3.6
Electricity	+4.0	+3.6	+4.4	+4.0
Oil	-2.6	+2.8	+4.1	+3.5
Coal	+6.4	+2.3	+3.8	+3.1
Total	-2.6	+3.1	+4.3	+3.7
Agriculture				
Natural Gas	+7.1	+6.1	+3.9	+5.0
Electricity	+6.0	+10.0	+7.6	+8.8
Oil	+4.2	-0.6	0.0	-0.3
Total	+5.1	+3.3	+3.3	+3.3

Source: Energy Demand Model -- Nebraska Energy Office

TABLE A-10

Peak Electric Power Demand in Nebraska

Statewide Total and That for Irrigation

	1977	1980	1985	1990	2000	
						2009
Statewide Peak Demand[a/]						
Base Forecast (MW)		4,208	5,272	6,481	9,475	13,379
Range (MW)		NA	5,006-5,507	5,804-7,027	7,763-11,384	10,124-17,643
						2020
Agriculture						
Hookups[b/] (10^3Hp)	1,072	1,200[d/]	1,391-1,742	1,721-2,389	2,418-3,684	3,731- 5,754
Hookups (MW)[f/]	799	895	1,037-1,299	1,283-1,781	1,803-2,751	2,781- 4,291
Peak Demand[c/] (80% of Hookups)	639	716	830-	1,026-1,425	1,442-2,201	2,225- 3,433
Power Plant Demand[e/] Peak x 1.15	735	823	954-1,195	1,180-1,639	1,658-2,531	2,559- 3,948
Ag Peak/State Base Peak (%)		19.5	18 - 23	18 - 25	18 - 27	

a/ Nebraska Power Association, Statewide Generation Planning Study 1980-2009, March 1981, Table V-7

b/ Supalla R.J. -- Memo to NRC on Energy Use Projection in Agriculture Sector, January 3, 1983

c/ Supalla R.J. personal communication based on NPPD service area.

d/ Approximated by interpolation from Supalla's data.

e/ Accounts for 15% transmission and distribution losses.

f/ 0.7457 kw/Hp

APPENDIX B

Historic Annual Average, Minimum and Maximum Discharges at Selected Streamflow Gaging Stations

Table B-1

ANNUAL AVERAGE, MINIMUM AND MAXIMUM DISCHARGES AT SELECTED STREAMFLOW GAGING STATIONS

River Basin Station Name	Station Number	Approx. Drainage Area (Sq. Mi.)	Annual Discharge for Period of Record (1000 AF)		
			Average	Minimum	Maximum
WHITE RIVER - HAT CREEK					
White River at Crawford	4440	313	14.8	11.9	22.8
NIOBRARA					
Niobrara River at Wyo.-Nebr. State Line	4540	450	2.8	1.7	4.2
Niobrara River above Box Butte Reservoir	4545	1,400	21.7	16.2	30.8
Niobrara River Near Spencer	4650	12,100	1007.0	793.3	1539.4
MISSOURI TRIBUTARIES					
Bazile Creek Near Niobrara	4665	440	56.6	27.8	142.7
Omaha Creek at Homer	6010	170	23.4	4.0	46.7
New York Creek at Herman	6090	254	4.8	0.6	13.8
NORTH PLATTE					
North Platte River at Wyo.-Nebr. St. Line	6745	26,177	547.0	261.9	1659.0
North Platte River at Lewellen	6875	32,600	1020.6	576.0	2305.4
North Platte River at North Platte	6930	34,900	582.3	232.1	1647.0

Table B-1

ANNUAL AVERAGE, MINIMUM AND MAXIMUM
DISCHARGES AT SELECTED GAGING STATIONS (Continued)

River Basin Station Name	Station Number	Approx. Drainage Area (Sq. Mi.)	Annual Discharge for Period of Record (1000 AF)		
			Average	Minimum	Maximum
SOUTH PLATTE					
South Platte River at Noth Platte	7655	24,300	253.5	55.0	1106.6
MIDDLE PLATTE					
Platte River Near Duncan	7740	64,900	1059.1	104.7	3356.4
Platte R. Near Overton	7680	61,700	995.2	148.6	3282.6
LOUP					
Middle Loup River at Dunning	7755	1,760	289.9	264.0	304.7
Dismal River at Dunning	7765	1,780	235.3	220.1	246.4
Middle Loup River at St. Paul	7850	7,720	821.7	602.0	1112.6
North Loup River at Taylor	7860	2,210	331.5	256.3	411.6
Calamus River Near Burwell	7875	1,260	218.9	176.6	274.4
North Loup River Near St. Paul	7905	4,460	663.1	477.3	1335.0
Cedar River Near Spalding	7915	805	111.5	88.5	150.2
Cedar River Near Fullerton	7920	1,220	173.8	123.1	266.0
Loup River Power Canal Near Genoa	7925	--	1133.5	206.7	1435.8
Beaver Creek at Genoa	7940	627	87.7	51.9	183.7

Table B-1

ANNUAL AVERAGE, MINIMUM AND MAXIMUM
DISCHARGES AT SELECTED GAGING STATIONS (Continued)

River Basin Station Name	Station Number	Approx. Drainage Area (Sq. Mi.)	Annual Discharge for Period of Record (1000 AF)		
			Average	Minimum	Maximum
Loup River at Columbus	7945	15,200	689.9	213.6	2309.3
ELKHORN					
Elkhorn River at Ewing	7975	1,400	117.6	38.9	424.2
Elkhorn River at Waterloo	8005	6,900	784.1	276.3	2092.4
LOWER PLATTE					
Platte River Near Ashland	8010	83,800	3662.7	1969.8	6245.1
Salt Creek at Lincoln	8035	710	147.8	61.2	353.8
Salt Creek Near Ashland	8050	1,640	345.2	122.0	663.7
Platte River at Louisville	8055	88,800	4147.0	2133.5	7689.7
REPUBLICAN					
Arikaree River at Haigler	8215	1,460	17.0	3.4	90.9
N. Fork Republican R. at Colo.-Nebr. Lake	8230	--	34.1	22.6	48.9
Frenchman Creek at Culbertson	8355	3,080	74.3	32.9	129.5
Republican River Near Hardy	8535	22,400	439.7	76.8	1274.5

Table B-1

ANNUAL AVERAGE, MINIMUM AND MAXIMUM
DISCHARGES AT SELECTED GAGING STATIONS (Continued)

River Basin Station Name	Station Number	Approx. Drainage Area (Sq. Mi.)	Annual Discharge for Period of Record (1000 AF)		
			Average	Minimum	Maximum
LITTLE BLUE					
Little Blue River Near Deweese	8830	979	100.5	45.0	245.8
Litte Blue River Near Fairbury	8840	2,350	265.0	77.4	762.4
BIG BLUE					
Lincoln Creek Near Seward	8800	426	31.1	6.5	76.7
Big Blue River at Seward	8820	1,099	80.3	9.4	197.4
Big Blue River Near Crete	8810	2,716	253.4	78.9	492.2
Big Blue River at Barneston	8820	4,444	565.3	83.2	1600.0
NEMAHA					
Weeping Water Creek at Union	8065	238	63.8	14.3	160.1
Little Nemaha River at Auburn	8115	801	203.6	48.9	625.0
Big Nemaha River at Falls City	8150	1,340	421.1	60.4	1455.0