RESEARCH

ENGINEERING

RESEARCH

ENGINEERING

RESEARCH

ENGINEERING

RESEARCH

77-29 duplicate

EXECUTIVE SUMMARY

CONSUMPTIVE WATER REQUIREMENTS FOR IOWA POWER PLANTS AS A FACTOR IN ENERGY MANAGEMENT

by

B. L. Butterfield
M. D. Dougal

January 6, 1977

ENGINEERING
RESEARCH
INSTITUTE

IOWA STATE
UNIVERSITY
AMES, IOWA

ENGINEERING

RESEARCH

ENGINEERING

RESEARCH

ENGINEERING
RESEARCH

ENGINEERING
RESEARCH
ENGINEERING
RESEARCH
ENGINEERING
RESEARCH
ENGINEERING
RESEARCH

EXECUTIVE SUMMARY

CONSUMPTIVE WATER REQUIREMENTS FOR IOWA POWER PLANTS AS A FACTOR IN ENERGY MANAGEMENT

by

B. L. Butterfield
M. D. Dougal

January 6, 1977

DEPARTMENT OF FRESHMAN ENGINEERING AND
DEPARTMENT OF CIVIL ENGINEERING
ENGINEERING RESEARCH INSTITUTE
IOWA STATE UNIVERSITY AMES

Iowa State University of Science and Technology Ames, Iowa 50011

December 29, 1976

Department of Freshman Engineering
College of Engineering
112 Marston Hall
Telephone 515-294-8355

Mr. Rodson L. Riggs
Director, Iowa Energy Policy Council
707 E. Locust
Des Moines, IA 50309

Dear Mr. Riggs:

The Executive Summary of this report is transmitted in response to your request of December 21, 1976. The full report will be provided on January 15, 1977, for your review.

The investigation for this report include collection of information from several utilities and agencies from not only the State of Iowa, but other state, regional, and Federal agencies concerning the use of water in the production of electric power. This report recommends a course of action to be taken by the Council and other state agencies concerning these water demands.

Sincerely,

Barry L. Butterfield
Instructor
Department of Freshman Engineering

Merwin D. Dougal
Professor
Department of Civil Engineering

BLB/MDD:isg

I. Description of Study

On December 29, 1975, the Energy Policy Council and the Iowa Commerce Commission contracted with Dr. Merwin D. Dougal and Mr. Barry L. Butterfield, both from Iowa State University, to study the water requirements of Iowa power plants as a factor in energy management. The objectives of this study were threefold: first, to analyze current water use information sources and to outline a method for obtaining more adequate information on total water use at the existing and proposed power plants in Iowa; second, to study and evaluate experienced consumptive water use in Iowa power plants and its relationship to total cooling water use, and to develop statistical relationships to explain such usage; and third, to provide an initial review of the importance of water use as one of the criteria for power plant siting, based on national as well as Iowa experience.

To accomplish these goals, data from eight different power plants, shown in Table 1 and Figure 1, were used. Criteria for selecting these plants were as follows: (1) the rated capacity must be 25 megawatts (MW) or greater; (2) the condenser cooling system must utilize cooling towers; (3) the water use information for the cooling towers must be based on metered data. In addition to these plants, water use information at the Duane Arnold Energy Center (DAEC), near Palo, Iowa, was also obtained. The data from DAEC were used to test those statistical relationships developed in the study of the other eight plants. It was not used to develop such relationships because the total period of record at DAEC was relatively short (18 months) compared to that of the other plants (60 months

TABLE I

POWER STATIONS IN STUDY

PLANT	CAPACITY	OWNER	YEARS OF DATA
Ames	57 MW	Municipal	14
Boone	29.8 MW	IELP	5
Bridgeport	61 MW	ISU	13
Gordon Evans	539.3 MW	KGE	6
Murray Gill	348.3 MW	KGE	6
Sheldon	225 MW	NPPD	6
Sutherland	149.5 MW	IELP	5
Wisdom	38 MW	CBPC	13

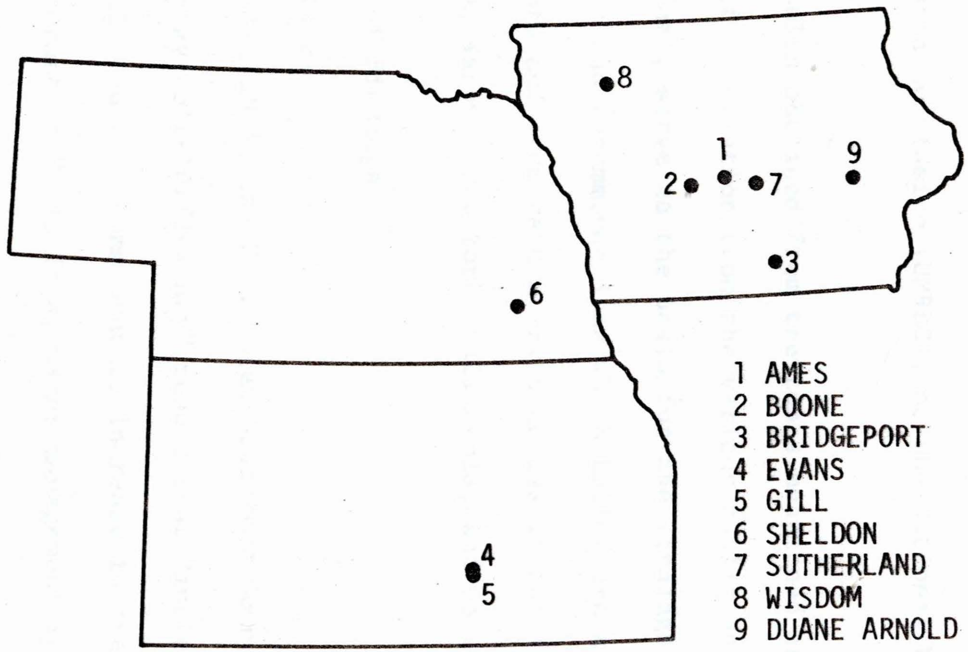

Fig. 1. Locations of power plants used in study

or more). The data collected from these plants include monthly generation, heat rate, capacity factor, and tower makeup.

Upon obtaining the data from these plants, multiple and step-wise regression techniques were used to develop specific mathematical models to explain the consumptive water requirements of the existing systems using mechanical-draft cooling towers. The data were next used to test existing mathematical models, such as those proposed by the Upper Mississippi River Basin Commission (UMRBC), or the National Water Commission (NWC).

The results obtained from the tests mentioned above, as well as solicitation of information from the various public and private utilities who provided data, serve as the basis for the findings of this report. The conclusions and recommendations which follow are also based in part on information obtained from regulatory agencies in the following states: Iowa, Nebraska, Kansas, New York, California, and Nevada.

II. Overview of Findings

1. Data base

In October 1974, the U.S. Water Resources Council stated in its "Water for Energy Self-Sufficiency" report that "increased efficiency in management will require a commensurate increase in the adequacy of management information." In Iowa, water management information is collected primarily by two agencies, the Iowa Department of Environmental Quality (DEQ), and the Iowa Natural Resources Council (INRC). The data collected by the DEQ relates to the quality aspects of the water used, i.e., temperatures of influent and effluent, chemicals added or removed, etc.

The data collected by the INRC concerns the daily amount of water use. Under Iowa law, all water users (using more than 5000 gpd) within the state must obtain a permit to withdraw the water, and must file quarterly reports listing the daily amounts of water withdrawn from the source. Unfortunately, the quarterly reports do not breakdown the water use as to type (consumptive or non-consumptive) or use (condenser cooling, ash control, boiler feed, blowdown, etc.). Water users on the border rivers, the Missouri and Mississippi Rivers, are presently exempt from filing any reports at all.

In establishing a more comprehensive data base, three key questions arise:

1. Why is a better data base needed?
2. Who will use the data -- who has the greatest need for the data?
3. How will the data be used -- is there a real need to analyze, collate, and report summary results?

The growth of the electric power industry has been exponential in the past and is expected to continue as such in the future, although perhaps at a smaller rate of growth. The rapid growth in the past has made the electric power industry one of the largest users of water in the nation. Due to the serious impacts this use has made on water quantity and quality, it is imperative that we know as much as possible about its demands in order to make fair and rational decisions concerning the amount and peak rates of use. The experienced use from data reported by the plants has allowed water resources planners to examine the consumptive requirements of power plants on a monthly basis. As demands increase, conflicts with other users become more probable. For instance, the use of supplemental irrigation, with its large consumptive requirement, is increasing in Iowa. A better data base will allow the planners to make better decisions regarding these competing water uses.

There are many problems associated with establishing a better data collection system. Increased instrumentation at the power plants is one solution, but it creates other problems such as the need for continued calibration of the various instruments, the need for additional personnel to record the data and service the instruments, and the obvious problems of cost of initial installation of these instruments.

Yet another problem would be the increased personnel needed by the receiving agency to process the data, as well as deciding what data should be collected, and how often. It is felt that the large water requirements within a plant, such as condenser cooling, ash control, tower blowdown, etc., should be monitored as much as possible, with the small requirements such as service water, boiler feed, etc. monitored on a "lump sum" basis by monitoring the gross water requirements of the plant.

The method of implementing this system is another problem. Several alternatives are available, including a voluntary effort by all utilities to report these data, requiring all future plants to install the instrumentation needed to obtain the required data, retrofitting existing plants above a given capacity, say 200 MW, to install the needed instrumentation, or selecting certain key plants to install the needed instrumentation. The latter has a real potential and deserves additional attention. Monitoring a few key power plants in a comprehensive program might be sufficient and be more cost effective than attempting to gather a lot of data from all stations with no real attempt made to improve the data accuracy for each.

2. Consumptive Requirements

As mentioned previously, the data obtained from the utilities were used to develop mathematical models to explain and predict the consumptive requirements of cooling towers. In addition to this, the data were also used to test the predictive abilities of existing models. From these tests, it was found that the model used by the UMRBC provided the most accurate results, although the predictions from this model were somewhat higher than the observed data. The UMRBC model and two ISU models developed in this study are shown in Table 2. Shown in Figure 2 are the differences between the UMRBC model, the ISU-A model, and the observed tower makeup at the Ames plant for a typical year.

In addition to these models, the data were also used to develop a single-parameter model which might be utilized for making preliminary water resources planning estimates. This single-parameter model was obtained by first determining the number of gallons required per kilowatt hour of generation, on a monthly basis, and plotting this value against per cent of total production time, as shown in Figure 3. These values were then analyzed as to their frequency and distribution over the given range. The cumulative distribution of these values was plotted against the range, yielding the logistics type "S"-curve shown in Figure 4. As can be seen from this figure, the upper and lower limits of these values were 1.60 gal/kWh, and 0.25 gal/kWh, respectively. It is interesting to note that with 95% of all observations, the consumptive requirement was less than 1.0 gal/kWh, and the average consumptive requirement of all

TABLE 2

MATHEMATICAL MODELS RECOMMENDED FOR USE

1. Upper Mississippi River Basin Commission

$$CR = 0.3258288\ G(.000285HR - 1.2375)$$

2. ISU - A Model

$$CR = 0.4497\ G^{0.887}\ T_{max}^{0.3373}\ C_f^{0.0552}$$

3. ISU - B Model

$$CR = 0.0578\ G^{0.9064}\ T_{max}^{0.3319}\ C_f^{0.0399}\ HR^{0.199}$$

where:

CR = monthly consumptive requirement, in 1000 gal.

G = monthly net generation, in 1000 kWh

T_{max} = monthly average maximum temperature, in °F

C_f = monthly capacity factor, in decimal form

HR = monthly net plant heat rate, in BTU/kWh

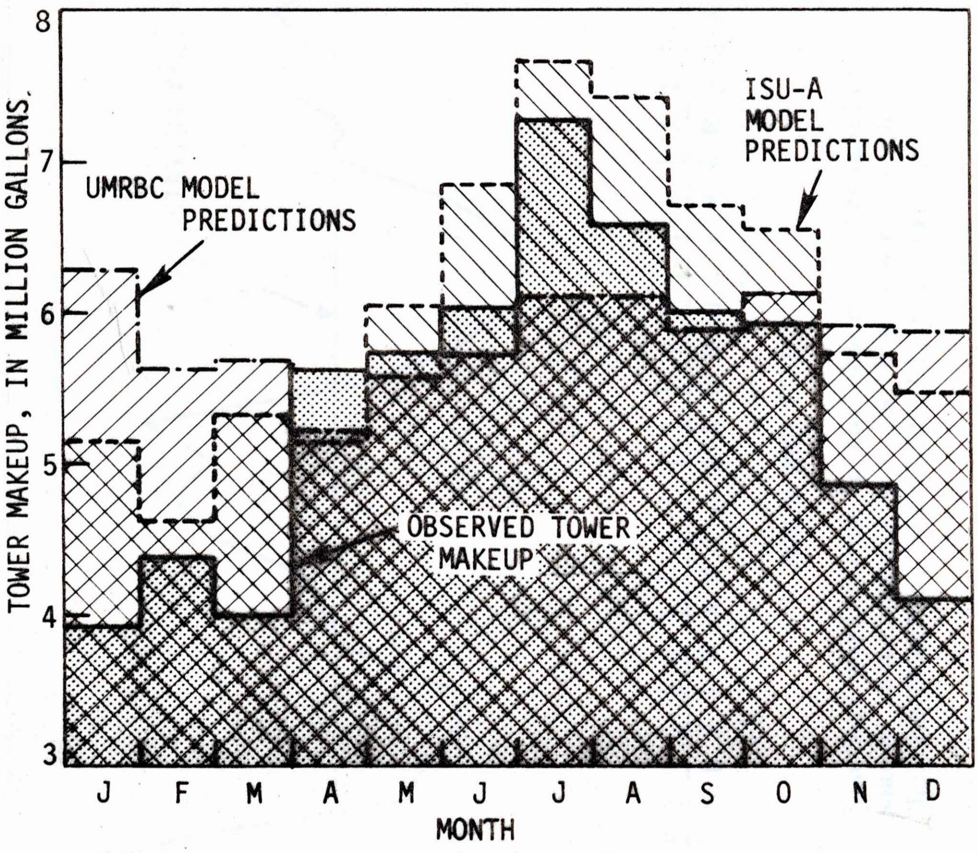

Fig. 2. Variations in predicted tower makeup quantities using UMRBC Model and ISU-A Model at the Ames, Iowa station for the year 1967

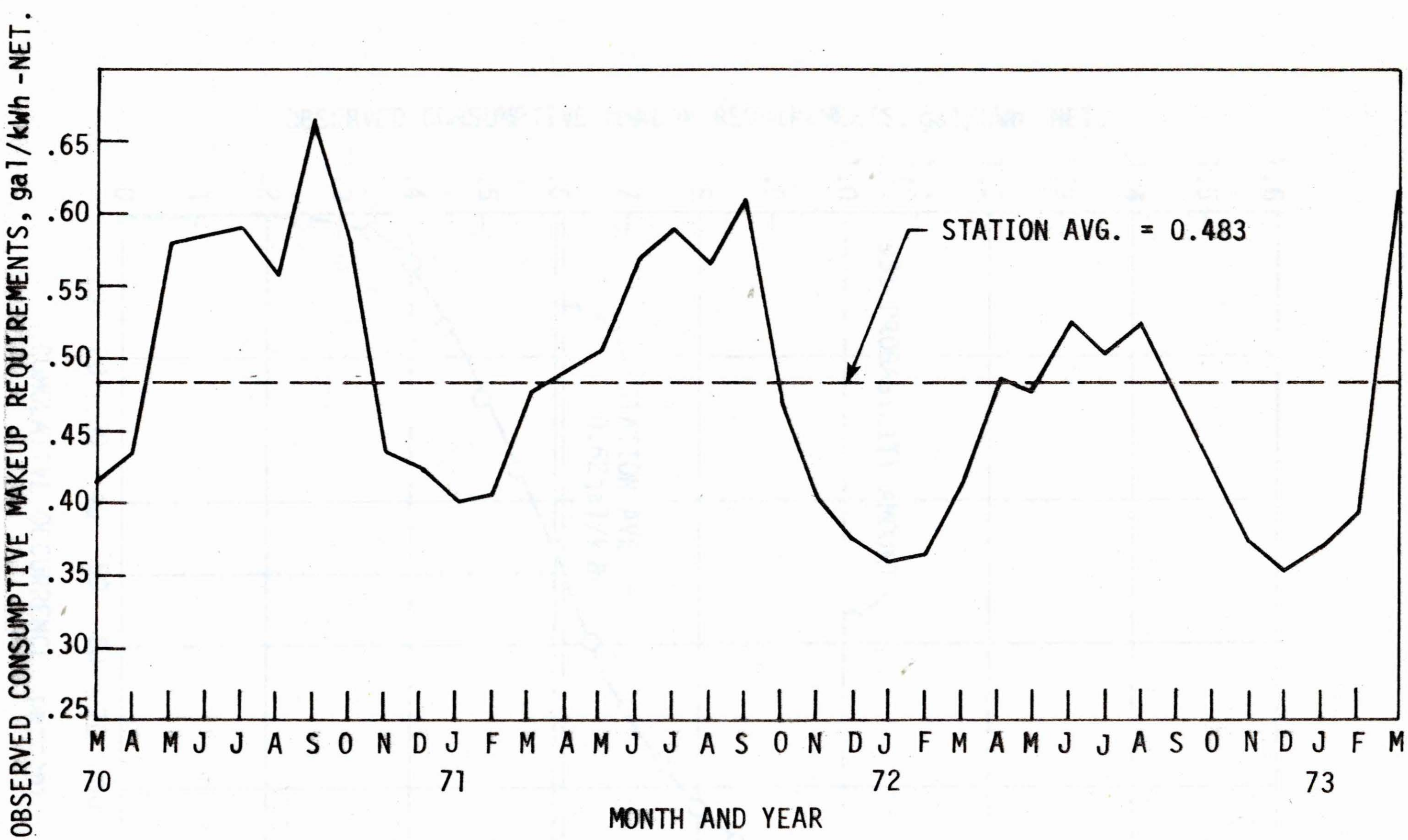

Fig. 3. Seasonal variations in the observed consumptive makeup requirements for cooling towers at the Sheldon Station, near Lincoln, Nebraska

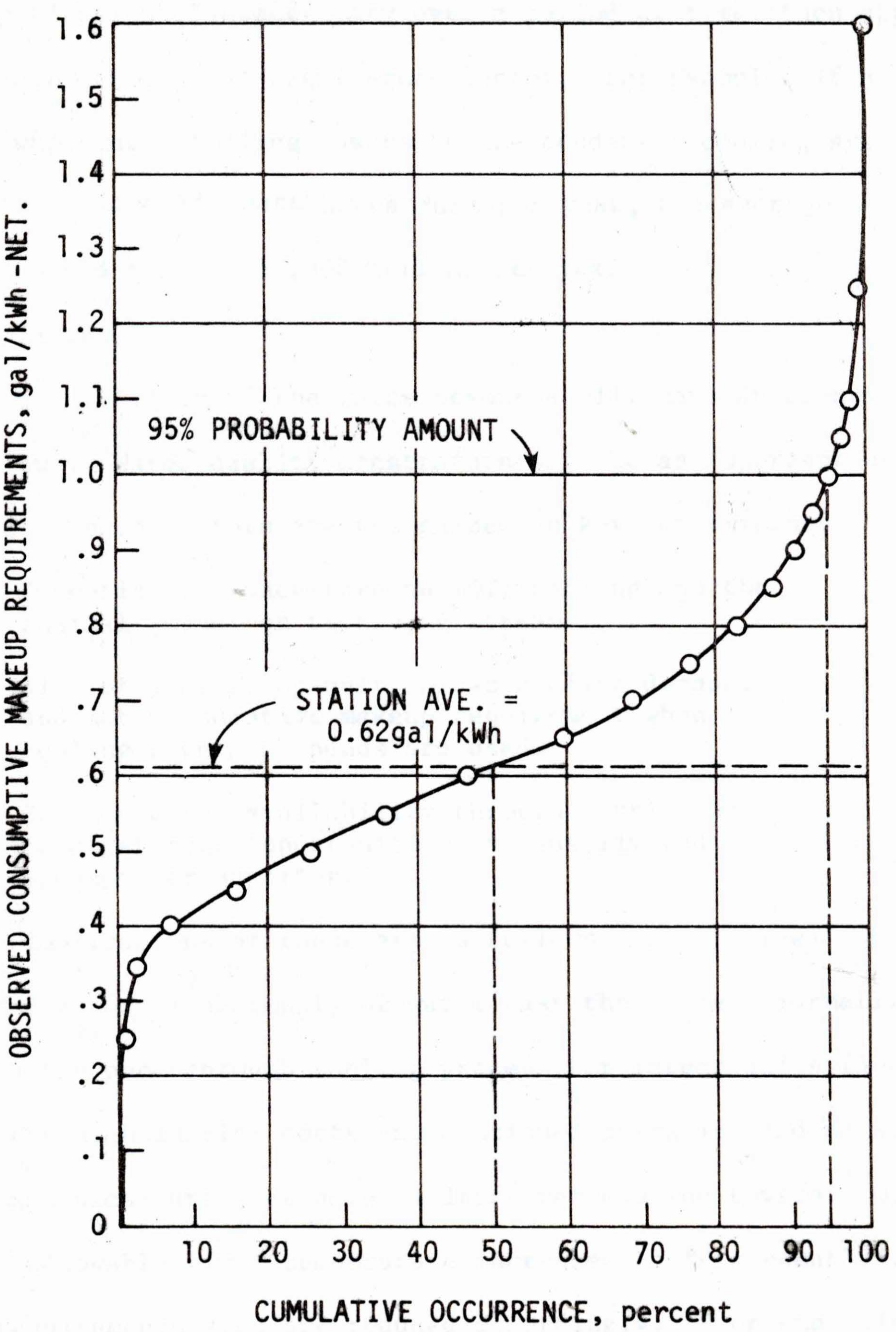

Fig. 4. Observed consumptive use cooling water requirement, gal/kwh-net, vs. percent of time occurrence

plants was 0.62 gal/kWh. Although this analysis is greatly simplified, it will be useful in making rough planning estimates by first estimating the total net production of electricity over a period of time, then applying an appropriate consumptive requirement factor. For example, if a particular plant, which uses cooling towers in the condenser cooling system is to generate one billion kilowatt hours during a year, the average consumptive requirement would be 620,000,000 gallons per year.

3. Siting

The availability of the water resource will have an impact on plant siting in Iowa. Water quality constraints will be as important as quantity limitations. Three factors are recognized as key determinants:

A. Potential for once-through (OT) cooling and the thermal impact on receiving streams.

B. Size of generating unit, gross cooling demand, and net consumptive makeup requirement when cooling towers or ponds are used.

C. Surface water availability through partial or total storage opportunities, versus limited groundwater supplies.

The implications of these are as follows. First, Iowa's border rivers carry a bountiful supply of water past the state. Normally, they can sustain the once-through cooling process for larger units (500-1000 MW), and avoid the high initial costs and continued operation and maintenance costs of mechanical draft or natural draft wet cooling towers. Operating within the allowable river temperature increases (5 °F presently), consumptive requirements also are reduced accordingly. Problems exist, however, during low flow periods -- especially for the larger installations. Special diffuser arrangements for mixing more adequately the heated water discharges with the river flows have been used at the Quad Cities Nuclear Plant, near Cordova, by the Iowa-Illinois Gas and Electric Company and Commonwealth-Edison Company. Expanded use of these diffusers is foreseen if water quality impacts on the aquatic habitat are kept within reason. The border rivers are the only ones which can accommodate the once-through cooling process (requiring 1500 to 2000 cubic feet per second for large plants), and subsequently are the favored sites for large scale units.

Second, the increasing size of most proposed new generating units leads us to conclude that the interior streams can be used as sites only if cooling towers are used and if additional reservoir storage is provided to permit meeting makeup requirements during low-flow periods in these rivers and streams. These rivers would include the larger ones, such as the Cedar and Des Moines Rivers.

Third, water requirements for meeting the energy needs of the state should, as much as possible, be met from the surface water resource. The demands (volumes and rates) are too great for the groundwater resource. The state's groundwater aquifers should, in an energy sense, be used for minor requirements -- i.e., plant service water, boiler feed or blowdown, etc. Perhaps groundwater can serve the makeup demand for plants with 100 MW capacity or less; however, other industrial uses having more stringent water quality requirements should have priority.

III. Conclusions and Recommendations

The report discusses several conclusions, partly drawn on a judgement basis, but also in light of information received from regulatory agencies from those states mentioned previously in this summary and from a thorough analysis of the data received from the participating utilities. Based on these conclusions, recommendations are presented for consideration in establishing a course of action toward meeting Iowa's energy-related water needs. Following are the report's conclusions and recommendations:

Conclusions

1. Current methods of water use data collection utilized by Iowa regulatory agencies do not provide adequate information for efficient water resources management.

   In a steam-electric power plant, water is used for many different purposes, including consumptive and non-consumptive uses. While it is perhaps a universal complaint among utilities that data reporting requires a disproportionately large amount of time and effort, there must be a separation on water use reports between consumptive and non-consumptive uses.

2. Due in part to inadequate and/or questionable data sources, it is difficult to select a single "best" model from those developed to explain the consumptive requirements of cooling towers.

   The data obtained from the various plants show that the consumptive makeup requirements of cooling towers can be placed between upper and lower limits of use, as shown in Figure 4, and an average consumptive requirement is derived (about 0.6 gal/kWh) that is within the range cited in other literature. However inconsistencies within these data will not allow us to greatly emphasize any of the more sophisticated mathematical models other than those three mentioned previously in this report.

3. Water availability will be a constraint in locating <u>specific</u> sites for future energy development in Iowa.

   In making an overall water balance through the state one finds there is a more than ample supply of both surface and groundwater supplies. However, in determining specific sites for power plants or other energy development industries such as coal mining or gasification, the large water demands of these industries may cause conflicts with other users, such as agriculture or recreation.

Recommendations

1. The data collection system should be updated and improved, with more emphasis placed on the quality (accuracy) of data received.

   The large water uses within a plant, such as condenser cooling flow rates, tower makeup, ash control, or other consumptive uses, should be reported, along with the gross water usage, regardless of the cooling system used. A more reasonable time base should be used, such as monthly, with the data reports submitted semi-annually or annually. Accuracy of the data submitted should be assured by requiring annual calibration of all instrumentation.

2. The data format for reporting water use should be made as uniform and useful as possible.

   The data should be submitted to the reporting agency on computer tape, disc, or punched cards if possible to permit more rapid and efficient storage, retrieval, and analysis of all data by computer. The reporting agency should review these data annually and submit a report to each user concerning his use, its relationship to all water use for energy, and, when needed, suggestions for improvement in water use efficiency.

3. Priority in plant siting, from a water resources viewpoint, should be given to the development of multiple-use systems, such as Pleasant Creek Reservoir at the Palo plant site, in meeting energy-related water demands, particulary where other public needs have been identified.

   Although a state-wide evaluation of water availability indicates a general abundance of water, the location of a large power plant at a specific site may cause conflicts in water use with other users in the basin, or fail to recognize complementory uses which would benefit these residents. By stressing multiple-use systems, three objectives are accomplished. First, coordinated planning between the developer and state planning agencies will occur. Second, public participation in the project will be enhanced.

Third, more effective and efficient use of a natural resource will occur.

4. Identification of alternative but suitable sites for energy development within the state's interior should be made.

A recent study by the Iowa Institute of Hydraulic Research at the University of Iowa has identified possible sites for large power plants along the border streams -- the Mississippi and Missouri Rivers. Despite the large quantities of water available in these streams, several Iowa utilities have demonstrated a need for power stations within the State (e.g., DAEC, Iowa Southern's proposed Ottumwa plant, Iowa Power's proposed central Iowa nuclear plant). Transmission losses remain important and, in conjunction with the difficulty of obtaining power line right-of-ways, increase the desirability of locating plants close to the load centers. By identifying potential sites, the state would be more assured of a proper coordinating role in preliminary planning, and the cost to the utility of this planning is reduced. Consequently, the time required to plan and construct generation facilities will be reduced, resulting in quicker on-line commercial operation. Many land acquisition policies might need to be changed, however, in accomplishing this objective.

This recommendation may be implemented in one of several ways. An interagency task force group with utility cooperation and assistance might be appointed, with the sole or primary purpose of this group to be designating, evaluating, and classifying potential sites for electrical energy facilities. These sites might also be determined through advanced water resources Level B planning studies, within the present federal-state water resources program. In these Level B studies, <u>all</u> potential uses of the water resource in a given basin, such as the Des Moines, are identified and placed in proper perspective. The identification of potential sites might also be accomplished by using an interstate regional mode, rather than state-wide. In this mode, concerned agencies could coordinate with the regional river basin commissions as well as the regional energy planning commissions, such as MAPP, to determine potential sites throughout the entire region, rather than the state.