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REPORT BY THE

# Comptroller General

OF THE UNITED STATES

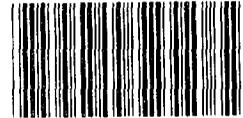


## Increased Productivity Can Lead To Lower Costs At Federal Hydroelectric Plants

On the basis of cost per unit of electricity produced, a selected group of private hydroelectric power plants are more efficient than a comparable group operated by the Federal Government. Had these Federal plants been run as efficiently, they could have saved at least \$11.7 million in annual operation and maintenance costs.

Using automation and remote control at Federal hydroelectric plants, where feasible, would yield substantial savings and increase productivity. In addition, use of maintenance management information systems would further enhance plant productivity by assessing the performance of plant maintenance programs.

This is one of a series of reports comparing the per unit cost of Government services with the cost of similar private sector services.



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COMPTROLLER GENERAL OF THE UNITED STATES

WASHINGTON, D.C. 20548

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The Honorable Russell B. Long  
Chairman, Committee on Finance  
United States Senate

The Honorable Robert Packwood  
Committee on Finance  
United States Senate

In your letter of April 5, 1977, you asked us to make several studies of the per unit or per capita cost of several services performed by the Federal Government as compared with the cost of comparable services provided by private companies. This report compares the Federal and private sector operations of selected hydroelectric power plants and suggests how the operation and maintenance of selected Federal hydroelectric power plants can be improved.

During our work on this report we became aware of significant savings in fossil fuel achievable by the productive development of hydroelectric power resources. Based on our preliminary analysis, it appears that the potential savings in fossil fuel from hydropower development may be in the billions of dollars.

Our Energy and Minerals Division is currently studying hydropower potential, constraints on its development, effects it could have in displacing fossil fuels, and actions needed to obtain optimum development. We anticipate that the study will be completed and a report issued by early summer 1979.

This report contains recommendations to the Secretary of the Army and to the Secretary of the Interior to have the Corps of Engineers and the Bureau of Reclamation improve the operations and maintenance of Federal hydroelectric power plants.

As arranged with your offices, unless you publicly announce its contents earlier, we do not plan any further distribution of this report until 30 days from the date of the report. At that time we will send copies to interested parties and make copies available to others upon request.

Copies of this report will be sent to the Senate and House Committees on Appropriations, the Senate Committee on Governmental Affairs, and the House Committee on Government Operations.

A handwritten signature in black ink, appearing to read "James B. Stewart". The signature is written in a cursive, slightly slanted style.

Comptroller General  
of the United States

- Evaluate the feasibility and cost-benefit of automating and/or remote controlling the remaining plants and, where both feasible and cost effective, develop budget justifications for automated and/or remote controlled projects.
- Establish uniform maintenance management information systems for use by all organizational levels in operating and maintaining hydroelectric plants.
- Evaluate the operation and maintenance costs of hydroelectric power plants within their jurisdictions, considering the staffing disparity between the public and private sectors. Further, consideration should be given to reassigning or retraining personnel and eliminating personnel through attrition in plants that are automated or remote controlled. Also, the validity of cost allocations for the current joint activity (for example, flood control and recreation) needs to be assessed.

AGENCY COMMENTS

Both agencies essentially concurred with the report's findings, conclusions, and recommendations. We have incorporated their comments where appropriate.

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This is one of several GAO studies comparing the per unit cost of Government services with the cost of private sector services. The studies were made at the request of Senator Russell Long, Chairman of the Senate Finance Committee, and Senator Robert Packwood.

D I G E S T

If selected Federal hydroelectric plants were as efficient as comparable plants in the private sector, annual operating costs of the Federal plants would be about \$11.7 million less in 1977.

GAO reached this conclusion after comparing the operations of Federal and private sector hydroelectric power plants. [As the basis of comparison, GAO selected 6 Federal systems, consisting of 95 plants, and 5 comparable private systems, consisting of 47 plants. The large Federal plants were not included because there were no comparable private plants.]

GAO based its comparisons on Federal Energy Regulatory Commission production cost data for 1973-1975, and the update of this data to 1977, the latest data available. *Its* review focused on plants operated by the Army Corps of Engineers and the Interior Department's Bureau of Reclamation.]

*Find* Although operation and maintenance costs for individual plants vary considerably, production costs of the private plants in GAO's review generally are less than those of Federal systems--\$2.72 per kilowatt-hour versus \$3.29 per kilowatt-hour, based on plant capacity. (See p. 4.)

Based on 1973-1975 data, the Federal hydroelectric systems had about 48 percent more employees per plant than private systems.

Assuming that Federal plants could have operated with comparable staffing levels, the Government plants would have needed 447 fewer employees. At an average 1977 annual Federal employee cost of \$20,000, the additional staffing of Federal systems costs about \$8.9 million annually.)  
(See p. 6.)

Automation and/or remote control of hydroelectric plants usually increases the cost effectiveness of operations. The Corps of Engineers and the Bureau of Reclamation have made progress in installing these improvements, thus reducing production costs.

However, (delays in the design or installation of automation and/or remote control in 17 Corps and Bureau projects have prevented the Government from potentially saving about \$1.5 million.) The delays ranged from 2 to 7 years. Corps and Bureau officials cited the lack of staff and funding as well as organizational problems as primary reasons for the delays. Completing the conversions at plants where economically feasible will require 5 to 8 more years. (See ch. 3.)

(Close control of maintenance costs can also yield savings at hydroelectric plants. Neither the Corps nor the Bureau has a uniform maintenance management information system that allows managers to evaluate maintenance performance effectively.)

At the recommendation of Department of the Interior auditors, the Bureau is developing such a system. The Corps is not convinced that it needs a uniform system, although several district offices have expressed dissatisfaction with their current methods and have established or are seeking more useful maintenance management systems. (See ch. 4.)

#### RECOMMENDATIONS

The Secretaries of the Army and the Interior should direct the Corps of Engineers and the Bureau of Reclamation to:

- Complete the automation and/or conversion to remote control of those hydroelectric plants where such changes have been evaluated and are both feasible and cost effective.

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ABBREVIATIONS

FERC	Federal Energy Regulatory Commission
GAO	General Accounting Office
DOE	Department of Energy

## CHAPTER 1

### INTRODUCTION

On April 5, 1977, Senator Russell Long, Chairman of the Senate Finance Committee, and Senator Robert Packwood asked us to make several studies of the per unit or per capita cost of several services performed by the Federal Government as compared with the cost of private sector services. This report compares selected comparable Federal and private sector operation and maintenance of hydroelectric power plants and suggests how the productivity of Federal operations can be increased.

### BACKGROUND

The three major sources of energy for generating electricity in the United States are petroleum, coal, and moving water. Power plants which produce and distribute electricity using moving water are called hydroelectric plants. Most other power plants burn fossil fuels, such as coal or oil, to create electricity. This study is limited to hydroelectric power plants.

Hydropower is a relatively clean and renewable resource which has historically provided a significant portion of the Nation's electrical generating capacity. Federal agencies produce a substantial portion of hydroelectric output.

In 1975 the national production of electricity was 1,917.6 billion kilowatt-hours. As shown in the table on the following page, the Nation's 1,156 hydroelectric plants generated 300 billion kilowatt-hours, or 15.6 percent of the total electricity production.

Three agencies are responsible for most Federal hydropower production--the Corps of Engineers, the Bureau of Reclamation, and the Tennessee Valley Authority.

The Corps is a civil agency within the Department of the Army. It is responsible for the Army's civil works program, which includes construction and operation of dams, reservoirs, and other water-related structures. These projects, besides generating hydroelectric power, provide flood control, navigation development, supply water for municipal and industrial use, recreational opportunities, and other benefits.

The Bureau is an agency of the Department of the Interior. The Bureau is authorized to locate, construct, operate, and maintain works for storing, diverting, and developing waters for the reclamation of arid and semiarid lands in the West. Reclamation projects serve multiple purposes. Besides generating hydropower, they provide municipal and industrial water supplies, irrigation service, flood control, recreation improvement, and other services.

The Tennessee Valley Authority is a Government-owned corporation that conducts a unified program of resource development for advancement of economic growth in the Tennessee Valley region. The Authority's activities include flood control, navigation development, electric power production, fertilizer development, recreation improvement, and forestry and wildlife development. While its power program is required to be self-supporting, its other programs are financed primarily from congressional appropriations.

National Production of Hydropower in 1975

	<u>Operating plants</u>		<u>Installed capacity</u>		<u>Net generation</u>	
	<u>Number</u>	<u>Percent</u>	<u>mW</u>	<u>Percent</u>	<u>kWh</u>	<u>Percent</u>
					(billions)	
Major Federal plants:						
Bureau of Reclamation	50	4	8,512	13	39.1	13
Corps of Engineers	62	5	15,641	24	85.4	28
Tennessee Valley Authority	<u>29</u>	<u>3</u>	<u>3,212</u>	<u>5</u>	<u>17.2</u>	<u>6</u>
Total major Federal	141	12	27,365	42	141.7	47
All other plants:						
Private	734	63	23,162	35	80.3	27
Public (note a)	273	24	15,348	23	77.9	26
Other Federal plants (note b)	<u>8</u>	<u>1</u>	<u>49</u>	<u>-</u>	<u>.1</u>	<u>-</u>
Total all other	<u>1,015</u>	<u>88</u>	<u>38,559</u>	<u>58</u>	<u>158.3</u>	<u>53</u>
Total	<u>1,156</u>	<u>100</u>	<u>65,924</u>	<u>100</u>	<u>300.0</u>	<u>100</u>

a/Municipal, State, and district, plus various cooperatives.

b/International Boundary and Water Commission, National Park Service, and Bureau of Indian Affairs.

## SCOPE OF REVIEW

We compared the per unit costs of hydropower produced by the Federal Government with private companies' costs. Our comparison included selected power plants operated by the Bureau of Reclamation, the Corps of Engineers, the Tennessee Valley Authority, and private companies. We made extensive use of hydropower production cost data prepared by the Federal Energy Regulatory Commission (FERC). The large Federal plants were not included because there were no comparable private plants.

Our comparisons were based on average costs for 1973-1975 and the update of this data to 1977. 1/ In Chapter 3, however, we used 1977 data in discussing the progress made toward automation by the Bureau and the Corps; current private sector data was not available.

In addition, we attempted to determine whether the productivity of Federal operations could be increased significantly.

We talked with Bureau of Reclamation and Corps of Engineers officials about reducing operator staffing through automation and remote control. We made brief visits to two private utility companies to discuss their automation and remote control practices and to determine whether they had made productivity studies of their hydroelectric power plants.

Because of their importance to productivity improvement, we made a limited survey of maintenance management information systems. We discussed them with agency headquarters officials and reviewed selected records, reports, and written descriptions of procedures.

We visited the Bureau of Reclamation headquarters and its Engineering and Research Center, the Office of the Chief of Engineers of the Corps of Engineers, and selected field offices. We also visited FERC headquarters.

1/ "Hydroelectric Plant Construction Cost and Annual Production Expenses 1977," published Dec. 1978 by the Department of Energy.

## CHAPTER 2

### PUBLIC/PRIVATE SECTOR COMPARISONS

#### OF PRODUCTION AND UNIT COSTS

The agencies which operate Federal hydroelectric plants do not currently conduct productivity analyses of their plants. However, for reports to FERC, they do record and maintain some cost and production information, including the cost per kilowatt-hour of installed capacity. This data is also used by Federal agencies for evaluation purposes when considering development of new hydroelectric plants.

The private companies we contacted also do not collect data specifically for productivity comparisons. However, they too collect information for FERC, and that information is similar to data kept by Federal plants. Hence, for the purposes of this report, we used both sectors' data in comparing productivity.

The data which Federal agencies and private companies record, maintain, and report to FERC includes cost per kilowatt-hour of installed capacity, production expenses per kilowatt-hour, and investment cost per kilowatt-hour of installed capacity.

We compared unit costs per kilowatt-hour of capacity for 6 Federal systems, comprising 95 plants with an average capacity of 120,000 kilowatt-hours, with costs of 5 private systems, comprising 47 1/ plants with an average capacity of 89,000 kilowatt-hours. The Federal plants had been in operation an average of 23.7 years, and the private plants had been in operation an average of 39.3 years. The selected Federal plants represented about 42 percent of total Federal capacity, and the private plants represented about 18 percent of total private capacity.

#### PRODUCTION UNIT COST COMPARISONS-- PRIVATE SECTOR MORE EFFICIENT

For fiscal 1973-1975, the selected Federal systems' cost to produce electricity was an average of \$3.29 per kilowatt-hour of installed capacity; average cost of the comparable private systems was \$2.72. According to FERC production cost criteria, larger systems should cost less

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1/Costs for a few of the smaller plants in the private systems were not included in the FERC annual reports on hydroelectric plant construction and annual production costs.

per kilowatt-hour of capacity to operate and maintain than smaller systems. Had the Federal systems averaged the same unit cost per kilowatt-hour as the comparably sized private ones, annual operation and maintenance costs would have been about \$6.5 million less. Based on a recent DOE report, the operation and maintenance costs have increased approximately 80 percent in 1977 from the 1973-75 average. Therefore, the savings of \$6.5 million increased to \$11.7 million in 1977.

COMPARISON OF PUBLIC/PRIVATE  
PRODUCTION COSTS WITH FERC-  
ESTIMATED COST CRITERIA

We also compared 1973-1975 average production costs for the plants in the selected Federal and private systems with production cost criteria compiled by FERC for use in project evaluations required under its licensing and related responsibilities.

FERC estimates of annual operation and maintenance expenses are based on actual expenses reported to it for both privately owned and publicly owned plants, as well as on estimates and projections made by FERC's staff. FERC production cost estimates were last published in 1968, but a yearly cost record is maintained for about 300 hydroelectric plants. We updated the FERC estimates through 1975. A Corps official said that labor was a substantial percentage of onsite power operation and maintenance expenses; he said it varied from 60 percent to over 80 percent. Also, offsite labor expenses are charged to a plant's production costs.

FERC supplemental instructions on annual production costs caution against drawing conclusions based on 1 year's experience. For any given year, maintenance costs might be unusually high. Thus, we based comparisons and analyses on average costs for 1973-1975 and an update of this data to 1977.

Because annual production expenses reported to FERC do not include depreciation, taxes, interest, dividend or amortization costs of the investment, or allocated administrative and general expenses, reported public and private costs should be generally comparable. Since most Federal hydroelectric plants are multipurpose projects and other activities, such as flood control, share in the cost of operating and maintaining common-use facilities (such as the dam), unit cost measurement may give Federal projects a more beneficial cost allocation. On the other hand, Federal plant costs of operating switchyards are charged to power production, whereas similar costs in the private sector are charged to power transmission.

Primarily, FERC's criteria consider plant size and type of operation--manual or automatic. From available data, we could not determine whether a plant should be considered manual, automatic, or semiautomatic; all three types were reported. Therefore, we compared 1973-1975 average actual costs with FERC production cost criteria, and based on the type of operation reported to FERC, we assumed that all plants were (1) automatic, (2) manual, or (3) a combination of automatic and manual, based on the type of operation reported to FERC.

We discussed with an FERC official our method of comparing Federal and private production costs and our selection of systems for analysis. He believed that our methodology was appropriate and should produce reasonable results.

Our comparisons showed that, on a selected basis, the private systems were more efficient than the Federal systems in all three categories, as reported. Federal automatic system costs exceeded FERC production cost criteria by 97 percent, compared with private systems costs, which were 54 percent higher than the criteria. Federal manual systems costs were 16 percent higher, while private systems were 15 percent lower; Federal mixed systems were 28 percent higher, and private systems were 5 percent lower. For further details on our comparisons, see appendix I.

#### AVERAGE PLANT STAFFING--48 PERCENT MORE EMPLOYEES AT FEDERAL PLANTS

Our comparison of 1973-1975 average plant staffing, as reported to FERC, showed that the Federal systems <sup>1/</sup> employed about 48 percent more employees per plant than private systems --14.4 for Federal and 9.7 for private. Although the Federal systems are somewhat larger on the average than the private systems, the average number of generating units per plant is about the same. In addition, the percentage of plants that are automated is the same.

Our review did not disclose any reasons for the additional staffing at the Federal plants.

Since most Federal hydroelectric plant operations have purposes besides providing power, such as recreation improvement and flood control, the actual number of Federal employees per plant could be even larger. For two Corps systems, for

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<sup>1/</sup>Staffing information for one of the six Federal systems was not reported. Average staffing for the other five systems was used in the cost comparisons.

example, we determined that allocated costs for these joint activities, including personnel costs, represented about 34 percent of total costs charged to power. The validity of costs allocated for joint activities at Federal hydroelectric plants needs to be assessed.

Assuming that Federal plants could have operated with staffing levels comparable to those of private plants, the Government plants would have needed 447 fewer employees. At an average annual Federal employee cost of \$20,000, based on fiscal 1977 Federal salary data plus fringe benefits, the additional staffing of Federal systems cost about \$8.9 million annually.

The additional staffing at Federal power plants also shows up when comparing staffing on a per-generator-unit basis. Federal plants had 4.1 employees per unit compared with 2.8 per unit at private plants. Had the Federal plants been staffed at the same level as private plants on a per unit basis, the estimated annual production cost of Federal plants would have been about \$8.6 million less. Both estimates approximate the additional costs computed using FERC production cost criteria.

## CHAPTER 3

### IMPROVING PRODUCTIVITY THROUGH AUTOMATION

Historically, the production of power at hydroelectric plants has required many operation and maintenance personnel. During the last 20 years, however, significant technological advances have been made. Automation through use of electronic controls and computers has minimized the number of operators required. Besides reducing operating costs, automation increases reliability, accuracy, and operational control.

There are potentially two phases to automation.

The first phase is to centrally locate and automate all necessary control equipment. A plant with up to eight generators can be operated by one person per shift. The operator can start, load, operate, monitor, and stop the generators from the central control room.

A second phase, remote control, is feasible in some locations. In this phase, an operator at a different plant can control the plant with additional equipment. Controlling one power plant from another location usually allows removal of all or most of the permanently assigned operators at the remote plant. A major benefit of automation, therefore, is reduced labor costs. However, in any labor saving effort, consideration should be given to reassigning or retraining personnel or eliminating personnel through attrition. This consideration must be given if resistance to automation and remote controlling is to be overcome.

#### FEDERAL PROGRESS IN AUTOMATION

During the past 20 years, the Corps of Engineers and the Bureau of Reclamation have had programs to automate their hydroelectric plants.

The Corps has used advanced technology to reduce staffing at some of its hydroelectric power plants. In 1955 the Corps began to design new plants with centralized or remote control. As of April 1978, almost all Corps-operated hydroelectric power plants that were economically feasible to automate had achieved a sufficient degree of automation to allow operation with the one operator per shift. 1/

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1/Large capacity plants with multiple units require only one operator per shift for every eight units. Five Missouri River plants have been only partially automated and, therefore, require more than one operator per shift.

FERC data covering power plants in operation in 1965 shows that by 1977 the Corps had reduced its plant staffing levels. The data indicates that in 1965 there were 873 operation and maintenance employees at 37 plants, or 5.1 employees per generating unit. As of August 1977 there were 1,187 personnel at 66 power plants with 295 generating units--or 4 per unit. This represents a 21.6-percent reduction in the staff-unit ratio in 12 years.

Corps officials indicated that some of the reduction had been caused, in part, by staff and budgetary restrictions. However, technology apparently was the primary means of reducing staffing. By August 1977, 46 of the 66 Corps plants had already been automated, and 35 of the 46 had also been connected to remote control systems--22 as controlled, 13 as controlling. The 11 remaining automated plants were under contract for possible remote controlling.

Corps officials estimate that completion of conversions at all plants where this is economically feasible will require 5 to 8 more years, and this will be possible only if funding is made available.

The Bureau of Reclamation has also used technological advances to reduce staffing at its power plants. This effort began in the early 1960s when new plants were designed with labor-saving controls. In 1965 additional emphasis was given to modernizing plants built before 1960 by converting to centralized control or remote control. By 1977 a substantial number of the Bureau's hydroelectric power plants were automated to allow operation by one operator per shift.

Although total staffing data (operational and maintenance) on a per unit basis was not available for the Bureau as it was for the Corps, we obtained statistics showing the number of Bureau operators on a unit basis in 1964 and 1977. This data shows that in 1964 the Bureau had 288 operators, excluding maintenance workers, at 40 power plants with 118 generating units, or an average of 2.4 operators per unit. In 1977 the Bureau had 211 operators at 44 plants with 140 generating units, or an average of 1.5 operators per unit. Therefore, from 1964 to 1977 the Bureau reduced its operator/unit ratio by about 37.5 percent by increasing automated and other centralized control devices at plants, as well as by installing remote control systems in some plants. According to Bureau officials, the establishment of automation and remote control plant projects may have been due partly to staffing ceilings. Since personnel would not be available for plant operation, the need for automation projects intensified. By 1977, 26 of the Bureau's 44 plants were in remote controlled operations while 18 were manually operated.

Bureau officials estimate that the present plans for completing automation and remote control of its plants will require about 5 more years, assuming that adequate funding is available.

SAVINGS LOST THROUGH DELAYS  
IN IMPLEMENTING AUTOMATION  
OR REMOTE CONTROLS

Although progress has been made by the Corps and the Bureau in automating and remote controlling their power plants, substantial delays have occurred. As of the end of 1977, the Corps and the Bureau had lost about \$1.5 million in savings since 1965 (approximate time that modernizing began) through delays at 17 power plants.

The lost savings for the Corps totaled \$1.2 million due to delays which ranged from 2 to 7 years. The reasons given by Corps officials for the delays were insufficient funding and an inadequate technical staff. However, we believe the reason for delay was and continues to be the Corps' management decisionmaking process.

The Corps has a policy of delegating power plant operation decisions to the Corps' district and division levels. Because automation leads to reassigning and laying off personnel, resistance to such moves by those directly involved is not uncommon. Thus, decentralized decisionmaking could cause other programs to be emphasized at the expense of automation and result in delays in submitting requests for funds for hydroelectric plant automation.

Corps officials said they were aware of plants where staffing could be significantly reduced by automation. Automation plans, however, have met with resistance at the regional level. In light of such resistance, reluctant subordinate divisions have not been required to initiate and promptly complete labor-saving improvements. These officials believed that if they forced a division to install remote controls, the program would be unsuccessful because plant staff would not support it. Although they recognized this as an organizational problem at present, they believed the plants in question would ultimately be remote controlled.

The Omaha district serves as an example of resistance to automation conversion. Since 1965 the Office of the Chief of Engineers, the Corps' Missouri division, and the Missouri division's Omaha district have engaged in a running debate as to the merits of remote controlling. The issues involved are:

- Which agency should control remote-controlled Corps power plants?
- Can remote-controlled plants respond quickly to energy needs?
- Are remote-controlled plants secure?
- Are remote-controlled plants at remote locations capable of effective response in an emergency when their communication systems fail?
- How many operators are needed for a remote-controlled system?

The primary issue appears to be the number of operators needed. The division claims that a substantial number of operators would be required despite remote controlling. The Office of the Chief of Engineers is firm, however, in its belief that staffing remote-controlled plants would not be cost effective. Since other Corps districts have successfully operated remoted-controlled plants without onsite operators, the Office of the Chief of Engineers appears to be correct.

The Bureau of Reclamation lost the opportunity to save about \$326,000 at eight power plants due to delays of 2-1/2 to 5 years in installing automation and remote controls. The delays were caused by a backlog of design work and funding constraints. Bureau officials said they were not in a position to comment upon the specifics of these problems because the situations had developed under the supervision of the regional directors. They said they had little management control over the operation and maintenance functions of the regions.

Appendix II contains details on the Corps' and the Bureau's delays in implementing automation and remote control programs. Potential savings will continue to go unrealized as long as the conversion programs are delayed.

## CHAPTER 4

### IMPROVING PRODUCTIVITY THROUGH NEW

#### MANAGEMENT TECHNIQUES

Computer technology now enables managers to develop maintenance management information systems. At hydroelectric power plants, maintenance costs are a significant portion of overall operating costs. A uniform maintenance management information system would permit evaluations of the cost effectiveness of plant maintenance programs against standards. Without a uniform system, we believe that assessing the reasonableness of such costs on a plant-to-plant or on an agencywide basis is difficult.

Operation and maintenance costs of a hydroelectric plant consist mostly of labor costs. As in plant automation, a purpose of a maintenance management information system is to reduce staffing by improving the productivity of each employee. The intended effect is fewer employees per unit of output.

#### MAINTENANCE MANAGEMENT INFORMATION SYSTEMS REDUCE COSTS

An article in an engineering publication <sup>1/</sup> reported that a change in the basic maintenance management concepts of a county flood control district was expected to produce savings of \$400,000 the first year of implementation and to increase the annual savings to between \$2 million and \$3 million within 5 years. The article contained two basic insights:

- Control of maintenance organizations through dollars is far less effective than control through preapproved, clearly defined work.
- Worksite control of routine work is a far less effective strategy than a good postaudit, which identifies trends in the work development and approval process that need correcting.

The article indicated that savings could be achieved by preplanning, preestimating, and preapproving most operations and maintenance functions. A maintenance management system must establish:

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<sup>1/</sup>"Reorganizing the Maintenance Department To Save Money," Industrial Engineering, vol. 9, no. 10, Oct. 1977.

- Maintenance standards.
- Acceptable maintenance conditions.
- Routines, or specific applications of resources to accomplish needed maintenance work.

The Corps of Engineers' North Pacific division has established a maintenance information system. The division now maintains records which include:

- Actual staff-hours spent on a job, work done, and materials used.
- Inventory of project equipment.
- Equipment to be inspected and the frequency of inspections.
- Checklist of detailed procedures for performing maintenance inspections, minor services, and adjustments, plus a tickler card for routine overhauls.
- History of maintenance inspections and equipment modifications, additions, and replacements.

An analysis report covering North Pacific division operations using the above system revealed very positive results. The maintenance costs for four major multipurpose hydroelectric projects were reduced by a total of 113,000 staff-hours during a 4-year period. Within this same period, generator unit availability increased from 89.2 percent to 95.4 percent.

MAINTENANCE MANAGEMENT INFORMATION  
SYSTEMS ARE NOT IN GENERAL USE

Comments by officials at three other Corps districts disclosed a wide variation in the use of any formal management information system, as follows:

- One district was developing a computer-based system, but as of December 1978, the system had not yet been useful for developing work standards.
- Another district neither had nor wanted a system because it believed such a system would be too time consuming to operate and would siphon off scarce resources needed to reduce its maintenance backlog.

--A third district had a manual system at the project level that was used only for scheduling maintenance operations from work orders. Forced outage rates are about the only indicator the district uses to evaluate project maintenance operations.

Corps officials said that they met with officials of private utility companies and hydroelectric power associations to exchange maintenance experience and information. This data is usually issued to the districts. The Corps officials were not convinced that the Corps needed a uniform system even though one division had an information system of some value and two other districts had attempted to develop new systems because they were dissatisfied with their current ones.

The situation at the Bureau of Reclamation is somewhat different. A Department of the Interior internal audit report dated September 1969 stated that the Bureau's reporting system showed maintenance costs only by groups of facilities and provided no information as to the number of staff-hours actually expended or work units scheduled for maintenance. The report recommended that an interagency committee be established to develop a departmental information system that would identify maintenance costs, staff-hours, work units, and other relevant statistics as a means of establishing a more uniform approach to cost control.

Thus, although the Bureau does not have a maintenance management information system, it is developing one. Bureau officials are convinced they can develop an effective system and plan to test it by October 1979.

The Bureau expressed some reservations, however, that the system might not be as effective as it could be due to the Bureau's organizational structure. An official of the Bureau's Engineering and Research Center said that the new system required a strong central management system to evaluate maintenance performance of all power plants on a Bureau-wide basis. However, the Bureau has a decentralized organization, and the Bureau's regions are rather autonomous. In addition, when the Department of Energy was established, the Bureau's power division, which performed the plant operation and maintenance evaluation function, was virtually eliminated, and only two people were left.

Although the Bureau has a decentralized organization, we believe that a uniform system can give the regions the data necessary to evaluate the cost effectiveness of their plant maintenance programs. The Bureau may also want to establish a means of comparing its regions' maintenance programs using such a uniform system.

DATA USED BY GAO IN COMPARING PRODUCTION COSTS OF  
FEDERAL AND PRIVATE HYDROELECTRIC PLANTS

System identifica- tion code	Number of plants in system			Capacity in MW		Number of generators		Average age as of 1977
	Total plants	Number automatic	Percent	System	Average plant	System	Average plant	
Federal:								
F-1	21	7	33	1,920	91	61	2.9	15.9
F-2	18	2	11	2,090	116	66	3.7	17.3
F-3	6	0	0	2,048	341	36	6.0	21.2
F-4	9	5	56	1,556	173	a/ 21	a/ 3.0	18.1
F-5	12	1	9	594.4	55	38	3.2	24.2
F-6	<u>29</u>	<u>10</u>	33	<u>3,200</u>	110	<u>109</u>	3.8	35.2
	<u>95</u>	<u>25</u>	26	<u>11,408.4</u>	120	<u>331</u>	3.5	23.7
Private:								
P-1	13	4	31	1,342.3	103	34	2.6	27.3
P-2	8	2	25	534.5	67	38	4.8	44.9
P-3	10	1	10	456.8	46	42	4.2	52.6
P-4	9	4	44	1,228.4	136	24	2.7	26.3
P-5	<u>7</u>	<u>1</u>	14	<u>618.2</u>	88	<u>26</u>	3.7	52.6
	<u>47</u>	<u>12</u>	26	<u>4,180.2</u>	89	<u>164</u>	3.5	39.3

a/Excluded units and staffing for two plants--one which was operated and maintained by the State of California and the other which was a pumping plant. Figures shown are 1977 statistics. The 1973-75 data was not reported to FERC.

DATA USED BY GAO IN COMPARING PRODUCTION COSTS OF  
FEDERAL AND PRIVATE HYDROELECTRIC PLANTS (cont.)

System identifica- tion code	1973-75			1973-75 average costs				
	Average System	staffing Plant	1973-75 Unit	Total actual	Actual per kWh	FERC production (automatic)	Actual over/(under) Amount	FERC Percent
Federal:								
F-1	243	11.6	4.0	\$ 5,831,499	\$3.04	\$ 3,362,312	\$ 2,469,187	73
F-2	278	15.4	4.2	7,465,001	3.57	3,555,898	3,909,103	110
F-3	168	28.0	4.7	6,641,999	3.24	2,978,000	3,663,999	123
F-4	a/ 110	a/ 15.7	a/ 5.2	3,041,639	1.95	2,444,968	596,671	24
F-5	161	13.4	2.7	3,063,678	5.15	1,314,173	1,749,505	133
F-6	<u>412</u>	14.2	3.8	<u>11,498,511</u>	3.59	<u>5,398,512</u>	<u>6,099,999</u>	113
	<u>1,372</u>	14.4	4.1	<u>\$37,542,327</u>	3.29	<u>\$19,053,863</u>	<u>\$18,488,464</u>	97
Private:								
P-1	175	13.5	5.1	\$ 3,724,001	2.77	2,322,138	\$ 1,401,863	60
P-2	106	13.3	2.8	2,690,668	5.03	1,013,887	1,676,781	165
P-3	53	5.3	1.3	1,727,333	3.78	959,970	767,363	80
P-4	66	7.3	2.8	1,942,333	1.58	1,974,346	(32,013)	(2)
P-5	<u>54</u>	7.7	2.1	<u>1,266,999</u>	2.05	<u>1,119,098</u>	<u>147,901</u>	13
	<u>454</u>	9.7	2.8	<u>\$11,351,334</u>	2.72	<u>\$ 7,389,439</u>	<u>\$ 3,961,895</u>	54

a/Excludes units and staffing for two plants--one which was operated and maintained by the State of California and the other which was a pumping plant. Figures shown are for 1977 staffing. The 1973-75 data was not reported to FERC.

## CHAPTER 5

### CONCLUSIONS AND RECOMMENDATIONS

#### CONCLUSIONS

Our review showed that production costs of selected private hydropower systems were generally less than the comparable Federal systems. On the basis of plant capacity, the six selected Federal systems operated at a cost of \$3.29 per kilowatt-hour compared with only \$2.72 per kilowatt-hour for the five selected private systems for the period 1973-75.

In addition, our comparisons of 1973-75 average hydroelectric plant staffing, as reported to FERC, showed that the Federal systems employed about 48 percent more employees per plant than private systems--14.4 for Federal versus 9.7 for private. Delays in implementing automation and remote control programs have contributed to this disparity.

Although the Corps and the Bureau have made considerable progress in reducing production costs through automating and remote controlling power plants, additional economies and efficiencies are possible. In a number of projects, substantial delays in conversion have occurred. These delays, which range from 2 to 7 years, have already prevented the Corps and the Bureau from potentially saving about \$1.5 million. Since these systems are not estimated to be completed for another 5 to 8 years, the total of lost potential savings will be substantial. District or regional power officials attributed the delays primarily to insufficient funding, lack of technical staff, and organizational problems. We did not evaluate the validity of these reasons.

Both the private and public sectors generally agree that automating and remote controlling hydroelectric power plants is desirable where cost effective. Although we identified 17 Federal projects where the economic feasibility studies showed that automation and/or remote control were cost effective, we did not review all Corps and Bureau projects. Consequently, there may be other projects where either a feasibility study has not been made, or, if made, improvements may not have been implemented.

#### RECOMMENDATIONS

We recommend that the Secretaries of the Army and the Interior direct the Corps of Engineers and the Bureau of Reclamation to:

- Complete the automation and/or conversion to remote control of those hydroelectric plants where such changes have been evaluated and are both feasible and cost effective.
- Evaluate the feasibility and cost-benefit of automating and/or remote controlling the remaining plants and, where feasible and cost effective, develop budget justifications for automated and/or remote controlled projects.
- Establish uniform maintenance management information systems for use by all organizational levels in operating and maintaining hydroelectric power plants.
- Evaluate the operation and maintenance costs of hydroelectric power plants within their jurisdictions, considering the staffing disparity between the public and private sectors. Further, consideration should be given to reassigning or retraining personnel and eliminating personnel through attrition in plants that are automated or remote controlled. Also, the validity of costs allocated for current joint activity (for example, flood control and recreation) needs to be assessed.

#### AGENCY COMMENTS

Both agencies essentially concurred with the report's findings, conclusions, and recommendations. We have incorporated their comments where appropriate.

DATA USED BY GAO IN COMPARING PRODUCTION COSTS OF  
FEDERAL AND PRIVATE HYDROELECTRIC PLANTS (cont.)

System identifica- tion code	1973-75 Average costs					
	FERC production (manual)	Actual over/(under) Amount	FERC Percent	FERC production (mixed)	Actual over/(under) Amount	FERC Percent
Federal:						
F-1	\$ 6,125,508	\$ (294,009)	(5)	\$ 5,199,968	\$ 631,531	12
F-2	6,012,306	1,452,695	24	5,773,746	1,691,225	29
F-3	4,266,630	2,375,369	56	4,266,630	2,375,369	56
F-4	3,848,584	(806,945)	(20)	3,199,160	(157,521)	(5)
F-5	2,739,366	324,312	12	2,625,813	437,865	17
F-6	<u>9,326,903</u>	<u>2,171,608</u>	23	<u>8,250,893</u>	<u>3,247,618</u>	39
	<u>\$32,319,297</u>	<u>\$ 5,223,030</u>	16	<u>\$29,316,210</u>	<u>\$8,226,087</u>	28
Private:						
P-1	4,095,499	(371,498)	(9)	3,572,536	151,465	4
P-2	1,960,840	729,828	37	1,800,225	890,443	49
P-3	2,117,926	(390,593)	(18)	1,993,126	(265,793)	(13)
P-4	3,263,852	(1,321,519)	(40)	2,763,479	(821,146)	(30)
P-5	<u>1,914,296</u>	<u>(647,297)</u>	(34)	<u>1,835,296</u>	<u>(568,297)</u>	(31)
	<u>\$13,352,413</u>	<u>\$(2,001,079)</u>	(15)	<u>\$11,964,662</u>	<u>\$ (613,328)</u>	(5)

ANALYSIS OF FEDERAL PROJECT LOSSES DUE TO DELAYS IN AUTOMATING

Agency project	Date of feasibility study	Type of improvement	Estimated annual savings	Initiation of substantial design work	Date design or installation completed	Date work could have been completed	Estimated delay (years)	Unrealized savings	Reasons for delay
<b>Corps of Engineers:</b>									
Omaha District (Gavins Point, Fort Randall, Garrison, Oahe, Big Bend, and Fort Peck)	1965	Automation	\$/5129,600	Not available	1977-78 (est.)	1970 (est.)	7	\$/ 907,200	Higher priority was given to other work, which diverted the technical staff's capability to commence design. Also, a lengthy conflict ensued between the district, divisions, and the Office of the Chief of Engineers (OCE) over the advisability to operate plants at reduced operator levels. OCE failed to initiate strong management action to direct the district/division to expedite the work.
Bull Shoals	July 1974	Automation	50,000	Oct. 1976	Apr. 1978	Apr. 1976	2	100,000	A delay of about 2 years occurred from the date of the design memorandum to initiation of design. The district official did not know the reason for the delay. OCE said that local expertise was not available to design an automation system.
Greers Ferry	July 1974	Remote control	22,500	Aug. 1977	1981 (est.)	1976	3	67,500	A delay of about 3 years occurred from the date of the design memorandum to initiation of design work. The reason was the same as for Bull Shoals.
Hartwell	Oct. 1974	Remote control	46,300	Jan. 1974	Apr. 1978	July 1975	2.5	115,700	A delay of about 2.5 years occurred caused by inadequate funding which, in turn, stretched out the time required to design the remote control system. OCE said the delay was also attributable to the need to make the system compatible with a planned area control system.
<b>Total Corps</b>									
<b>Bureau of Reclamation:</b>									
Central Valley project (7 plants)	Not available	Automation/remote	90,000	Not available	Dec. 1972	June 1970	2.5	225,000	The 2-1/2 year delay from the time the control system design was substantially completed to award of the contract in June 1975 was attributable to funding constraints. The automation and remote control program is estimated to be operational by July 1978.
Anderson Ranch	Sept. 1970	Remote	\$/ 20,147	Not available	June 1979 (est.)	June 1974	5	\$/ 100,870	The Bureau did not assign this project sufficient priority. This caused the project to be unfunded for about 3 years in the early 1970s. A backlog of other design work at the Bureau's Engineering and Research Center kept this project from being designed for about 2 years.
<b>Total Bureau</b>									
									\$ 325,870
<b>TOTAL</b>									\$1,516,270
a/Adjusted to 1975 dollars based on Bureau of Labor Statistics data.									

## NOTE:

Economic feasibility studies are prepared to help an agency decide whether to automate and install remote control facilities. These studies consider the interest and amortization cost of the control equipment and communication system necessary to operate a system of connected power plants. The savings realized through the reduction in staff, less the interest and amortization costs of the new control equipment, is considered the net annual cost savings. To proceed with a new project, the net annual cost savings must be a significant positive number.

Consider, for example, the first line of the preceding table. The net annual savings in the Corps' Omaha district, based on a staff reduction of 19, was \$129,600 per year (1975 adjusted sum from 1965 figure of \$89,135). The lost time was 7 years, and, therefore, the total loss was over \$900,000.

We used the criteria established by the Office of the Chief of Engineers to evaluate how the Corps determines the cost benefit of automation and remoting. These criteria state that generally only one operator per shift per eight generating units is needed at plants with modern centralized automated equipment (five operators are required for a one-operator-per-shift, three-shift day, 7-day-week operation). In a remote control operation, the controlled plant(s) usually do not require any operators located at the plant, unless some special situation exists (for example, large switchyards).

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