REPORT TO THE CONGRESS

Opportunities For Improvement In The Development And Evaluation Of Design Alternatives For Federal Water Resources Projects

B-125045

Corps of Engineers (Civil Functions)
Department of the Army

Bureau of Reclamation
Department of the Interior

BY THE COMPTROLLER GENERAL OF THE UNITED STATES

APRIL 6, 1971

COMPTROLLER GENERAL OF THE UNITED STATES
WASHINGTON, D.C. 20548

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To the President of the Senate and the
Speaker of the House of Representatives

This is our report on opportunities for improvement in the development and evaluation of design alternatives for Federal water resources projects by the Corps of Engineers, Department of the Army and the Bureau of Reclamation, Department of the Interior.

Our review was made pursuant to the Budget and Accounting Act, 1921 (31 U.S.C. 53), and the Accounting and Auditing Act of 1950 (31 U.S.C. 67).

Copies of this report are being sent to the Director, Office of Management and Budget; and to the Secretaries of the Interior, Defense, and the Army.

Comptroller General
of the United States

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D I G E S T

WHY THE REVIEW WAS MADE

Both the Bureau of Reclamation, Department of the Interior, and the Corps of Engineers, Department of the Army, plan, construct, and operate similar water resources projects. The General Accounting Office (GAO) wanted to know whether certain design practices of the Bureau and the Corps for such projects--as well as any differences in their approaches to design--were appropriate and whether there was adequate coordination, dissemination, and documentation of design information and techniques.

FINDINGS AND CONCLUSIONS

Differences existed in the design procedures and practices of the two agencies.

GAO concluded that substantial savings could be achieved by improved coordination and dissemination of design information and techniques provided (1) differences in design procedures and practices are identified and evaluated and (2) both agencies adopt, where practicable, those procedures and practices which will meet most economically their requirements.

The following matters examined and discussed in this report demonstrate the need for improved coordination and communication between the Bureau and the Corps.

The Bureau has made significant progress in the design and construction of arch dams which, under certain conditions, have significant advantages over other types of dams. The Corps built two small arch dams in California about 30 years ago but no others.

GAO believes that the Corps has not kept abreast of the technological advancements in arch dam design to the same degree as the Bureau. The Corps has no published criteria to assist its engineers in the design and analysis of arch dams. The Corps may have constructed

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larger dams of other types at certain locations where an arch dam might have been more suitable and might have cost less. (See pp. 6 to 7.)

The Corps is constructing a rock-fill dam, rather than an arch dam, at the site of the New Melones project in California. Had the Corps made a more complete evaluation of the design alternatives, using the Bureau's expertise in arch dam design, it might have recognized a possible cost advantage in favor of the arch dam, which GAO estimates to be about $9 million. (See pp. 7 to 16.)

The Bureau generally requires the use of water-reducing admixtures on projects involving 2,000 or more cubic yards of concrete, whereas the Corps of Engineers restricts their use to unusual circumstances. Water-reducing admixtures are organic chemicals which can be added to concrete mixtures to improve their characteristics.

The Bureau estimates savings of $665,000 on three projects, because the use of admixtures resulted in a reduction of the requirements for cement. Since the Bureau's use of these admixtures has resulted in significant savings, the Corps should make greater use of water-reducing admixtures to achieve similar savings on its projects. (See pp. 17 to 19.)

Another area where improved coordination could result in savings in construction costs is outlet works for embankment dams--structures which permit controlled releases of water stored behind dams and include, among other features, the gate structures and conduits which convey the water through the dam.

The two agencies generally construct outlet works of significantly different design. Under the Bureau's preferred design, the gate structure is located in the dam itself. This method provides for the use of a buried gate chamber. The Corps prefers to locate the gate structure in a separate tower upstream of the dam.

The Corps' engineering manual did not mention the buried chamber method which the Bureau has found to be generally more economical than the tower method. In view of the Bureau's experience, the Corps should develop procedures for considering the buried gate chamber in the design of embankment dams. (See pp. 20 to 22.)

In addition, GAO found that significant differences existed in the design of conduits for embankment dams. The conduits designed by the Bureau were usually one of two shapes--circular and horseshoe. The Corps has developed an oblong design which has been used for conduits under embankment dams. Savings of $100,000 or more have been estimated in every case where the oblong conduits have been used. GAO found that the Bureau was unaware that the oblong design was being used by the Corps. GAO believes that the Bureau should consider oblong conduits in their designs for embankment dams. (See pp. 23 to 24.)

In still another area, guidance was needed for evaluating design alternatives. The Bureau chose an unreinforced-concrete lining for the San Luis Canal in California rather than a compacted-earth lining. If the Bureau had given what GAO believes to be proper consideration to certain cost factors in evaluating the design alternatives, the analysis would have shown a cost advantage of about $12 million in favor of the earth lining rather than the concrete lining chosen by the Bureau. (See pp. 25 to 38.)

GAO believes also that the matters discussed in this report, both with respect to the type of dam for the New Melones project and the type of lining for the San Luis Canal, indicate a need to develop guidelines setting forth those factors, including those for making cost comparisons, that are to be considered in evaluating design alternatives.

RECOMMENDATIONS OR SUGGESTIONS

GAO is recommending that the Secretary of the Army and the Secretary of the Interior:

--Review the coordination and exchange of information on water resources engineering to ensure that both agencies (1) evaluate and adopt, where practicable, those procedures and practices which most economically meet their requirements and (2) make the most efficient use of their joint capabilities.

--Require the development of guidelines identifying the techniques to be used and the items of cost to be considered to ensure objective evaluations of design alternatives.

GAO is also recommending that the Secretary of the Army require the Chief of Engineers to develop written guidelines and procedures for the purpose of improving the Corps' capability in the design and analysis of arch dams.

AGENCY ACTIONS AND UNRESOLVED ISSUES

The Department of the Army agreed with GAO on the desirability of further efforts relating to interdepartmental coordination and communications on matters pertaining to design and construction of water resources projects, including guidelines for cost evaluation of design alternatives.

Tear Sheet

A meeting was held between the Corps and the Bureau on July 27, 1970, to establish the framework for expanded procedures in accordance with GAO's recommendation. (See p. 60.)

On November 2, 1970, the Bureau and the Corps entered into a written agreement to facilitate the systematic exchange of information on design and construction practices employed by each other. In addition, the Corps and the Bureau have issued instructions on the administration of the agreement to their various offices.

This agreement, if properly implemented, could result in significant future savings through improved interdepartmental coordination and communication in the design and construction of water resources projects.

The Department of the Interior agreed that a formalized exchanged of design information would be beneficial to both agencies but advised that written procedures for evaluating design alternatives were not generally considered necessary or appropriate. (See p.61 .) The Department stated that feasibility, judgment, economic experience, new developments and intangibles are, in its opinion, part of the background considered in rendering an engineering decision. Recognizing that many considerations enter into comparisons of design alternatives, GAO sees no reason why these factors, along with the appropriate economic considerations and procedures, should not be formalized to ensure their uniform application and evaluation by appropriate officials.

The Department of the Army advised GAO that it is proceeding with the construction of a rock-fill dam because of (1) relatively small differences in the cost of the two designs--rock-fill and arch--in relation to the total cost, (2) the uncertainties involved which could increase the cost of an arch dam, and (3) the possible delay in project completion resulting from shifting to an alternate design at this time. (See p. 58.)

The Corps agreed that water-reducing admixtures may be helpful in some of its projects and to encourage their consideration the Corps will revise its concrete specifications. (See p. 54.) The Corps also issued instructions requiring, under certain conditions, the consideration of buried gate chambers in the planning and design studies of outlet works for embankment dams. (See p. 55.)

The Bureau agreed to consider oblong conduits in its next study for an embankment dam. (See p. 23.)

MATTERS FOR CONSIDERATION BY THE CONGRESS

This report is being submitted to the Congress to advise it of the savings that could be achieved through improved cooperation in water resources engineering by the Corps and the Bureau and of the actions taken by the two agencies in implementing GAO recommendations.

Contents

ABBREVIATIONS

c.f.s.	cubic feet per second
GAO	General Accounting Office
O&M	operation and maintenance

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CHAPTER 1

INTRODUCTION

The General Accounting Office has reviewed selected policies and procedures of the Bureau of Reclamation, Department of the Interior, and the Corps of Engineers (Civil Functions), Department of the Army, for the design and construction of water resources projects. The scope of our review is discussed in chapter 6.

The Bureau is authorized, pursuant to the Reclamation Act of 1902 (43 U.S.C. 391 et seq.), to plan, construct, and operate and maintain works for the storage, diversion, and development of waters for the reclamation of arid and semiarid lands in 17 Western States. In carrying out its work, the Bureau designs and constructs storage and diversion dams, water distribution systems, pumping plants, hydroelectric-generating plants and other related structures on its water development projects.

The Corps' responsibilities include both civil and military functions within the Department of the Army. A primary civil function of the Corps is the administration and discharge of those responsibilities of the Department of the Army pertaining to navigation and flood control activities of the United States. The Corps' civil works program includes administration of matters pertaining to construction, regulation, and maintenance of navigation, flood control and multiple-purpose projects.

The Corps' appropriation for construction for fiscal years 1969 and 1970 averaged about $800 million and the Bureau's appropriation for the same period averaged about $160 million. The combined construction appropriation for both agencies for fiscal year 1971 is approximately $1 billion.

The principal officials responsible for administration of activities discussed in this report are listed in appendix IV.

CHAPTER 2

IMPROVED COORDINATION NEEDED IN DEVELOPMENT AND APPLICATION OF DESIGN PROCEDURES AND PRACTICES

The Corps and the Bureau have made outstanding technical contributions toward the development of water resources projects. Although the two agencies construct and operate similar projects, we found that substantial differences existed in their design procedures and practices. In certain instances, the reasons for the differences were attributable to technological improvements by one agency, which were (1) unknown to the other agency or (2) known, but not implemented by the other agency.

We believe that savings in the costs of constructing water resources projects could be realized through better coordination and dissemination of design information and techniques between the Corps and the Bureau to ensure that (1) differences in design procedures and practices are properly identified and the merits of each carefully evaluated and (2) both agencies adopt, where practicable, those procedures and practices which will meet most economically their requirements.

Some of the design procedures and practices examined into during our review are discussed in the following sections of this chapter and relate to the (1) design and construction of concrete arch dams, (2) use of concrete admixtures, and (3) design of outlet works for embankment dams.

USE OF CONCRETE ARCH DAMS

The Bureau has made significant progress in the design and construction of arch dams and has constructed arch dams on several of its projects. Under certain conditions, the construction of an arch dam is less expensive and provides a greater margin of safety against structural failure than any other type of dam. Descriptions of the three most common types of dams, embankment (rock-fill or earth fill), concrete gravity, and concrete arch, are included as appendix III.

We found that the Corps has not constructed arch dams (except for two small dams built in California about 30 years ago) and that the Corps has no published criteria to assist its engineers in the design and analysis of arch dams. A typical arch dam is shown in the photograph on the following page.

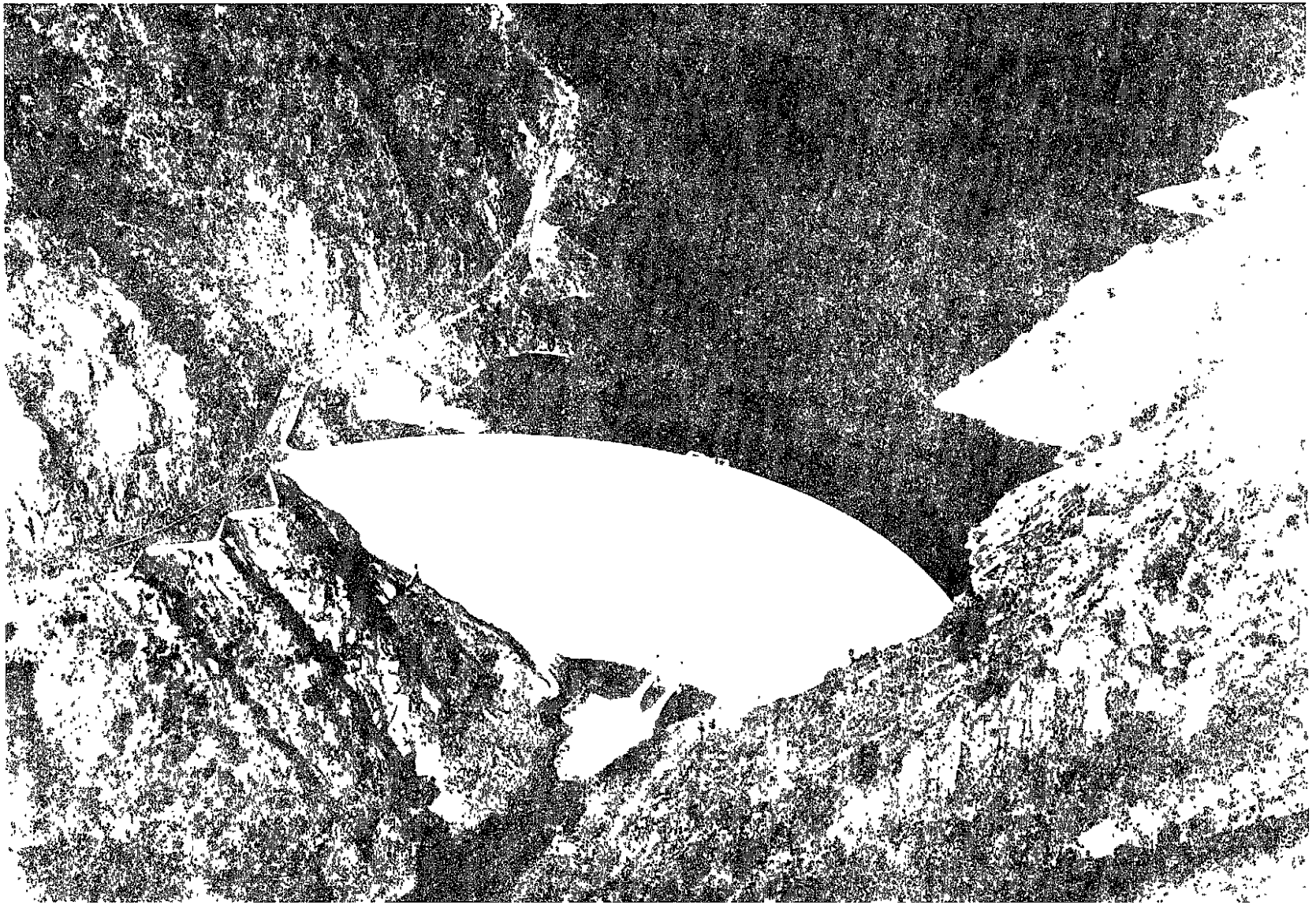
The Corps has not kept abreast of the technological advancements in arch dam design to the same degree as the Bureau, and, on the basis of our review, we believe that the Corps may have constructed larger embankment or concrete-gravity-type dams at certain locations where an arch dam might have been more suitable and might have been constructed at less cost. The following case illustrates the savings that may have been realized if an arch dam rather than a rock-fill dam would have been constructed by the Corps at the New Melones project in California.

New Melones project

In 1966 the Corps selected a rock-fill embankment dam for the New Melones project. We believe, however, that this decision was made without adequately considering all pertinent factors, including the Bureau's expertise in arch dam design. On the basis of current information, we believe also that the construction of an arch dam for the New Melones project would cost about $8.7 million less than the presently planned rock-fill structure.

The New Melones Reservoir was authorized by the Flood Control Act of 1944 (58 Stat. 887) and modified by the Flood Control Act of 1962 (76 Stat. 1191). The project provides for the construction of a rock-fill dam about 600-feet high on the Stanislaus River. The dam will create a reservoir with a gross storage capacity of 2,400,000 acre-feet of water for flood control, irrigation, hydroelectric power, recreation, and fish and wildlife enhancement purposes.

On the basis of examinations of the site conditions and the Corps' Sacramento district design studies, the Corps' consultants concluded that a safe dam could be constructed with any one of three different designs--rock-fill, gravity, or arch. At a meeting between the Corps and their consultants on August 30, 1966, a rock-fill dam was unanimously selected for the New Melones project.



CREDIT U.S. BUREAU OF RECLAMATION

The Monticello Dam - A concrete arch dam constructed by the Bureau of Reclamation in California.

A cost comparison used during the consultant's meeting showed the following costs.

	Rock-fill dam	Concrete arch dam	Concrete gravity dam
	(000 omitted)		
Dams	$54,500	$58,020	$63,180
Power plant	1,190	1,035	1,840
Access roads	850	545	600
Engineering and design	3,110	3,290	3,620
Supervision and administration	4,150	4,410	4,860
Total (note a)	$63,800	$67,300	$74,100

[a]These estimates were based on costs of project items which would vary among the three types and did not cover common items. The consultants did not review common costs because they would not affect the decision on the type of dam to be built.

Although the cost study showed that the rock-fill dam had a cost advantage of about $3.5 million over an arch dam, Corps officials pointed out during the meeting that certain estimated costs of the rock-fill dam were expected to increase, whereas certain estimated costs of the arch dam were expected to decrease. The consultants concluded, however, that the rock-fill dam would be the most economical. This decision was based primarily on their assumption that:

> "*** it is more likely for the arch dam to experience a significant increase in cost *** due to unforeseen foundation conditions."

The Office of the Chief of Engineers approved the type of dam determination but made the following comment regarding the failure to recognize the expected changes in costs:

> "The recommended rockfill type of dam is satisfactory. However, the design memorandum does not recognize the expected significant decrease in

arch dam thickness and cost and the increase in steel tunnel lining in the rockfill dam, which were pointed out at the August 1966 meeting."

The Corps' Sacramento district replied that information presented at the meeting with the consultants indicated that the estimated volume of concrete in the arch dam might have been reduced as much as 5 percent if a different or more complete method of analysis had been used for evaluating the arch dam but that the more complete method of analysis had not been used because of the excessive amount of design time required.

The Sacramento District Office noted that, in addition to the $3.5 million cost advantage of the rock-fill dam, there were other possible costs unfavorable to the arch dam, such as:

"(1) more extensive provisions to control uplift and seepage through the abutments by pre-stressing the foundation, constructing a fool-proof drainage system, and providing more extensive grouting of the foundation; and

"(2) possible significant change orders due to unforeseen foundation conditions."

It was the district's opinion that these possible additional costs of constructing the arch dam when added to the estimated $3.5 million advantage of the rock-fill dam would be equal to or greater than the possible cost considerations favoring the arch dam, which had not been evaluated in detail by the consultants--the increased cost of the tunnel lining for the rock-fill dam and the reduced cost of concrete for the arch dam.

Our examination of project records showed that in July 1968 the estimated cost of the steel tunnel lining and other modifications to the outlet works and the estimated cost of the foundation for the rock-fill dam had increased by $7.6 million, about $4.1 million more than the estimated cost advantage of the rock-fill dam as had been presented in the dam selection studies. The estimated cost of the

proposed rock-fill dam had increased to $72.4 million or about $18 million more than the estimate in the 1966 studies.

In contrast to the rising estimated cost of the rock-fill dam, the estimated cost of an arch dam was substantially less than that estimated in the 1966 studies. Using the Bureau's November 1966 Engineering Monograph No. 36 "Guide for Preliminary Design of Arch Dams," we computed the quantity of concrete for an arch dam for New Melones at about 1,443,000 cubic yards, or 552,000 cubic yards less than the amount estimated by the Corps.

On the basis of unit prices contained in the 1966 studies, such a reduction represented a $9 million decrease in costs or about a 28-percent decrease in the volume of concrete which was far greater than the 5-percent decrease mentioned at the consultants' meeting. Further, the Bureau informed us that the use of the method presented in their monograph generally yields conservative values and that computer analysis generally provides an even lower quantity estimate.

We brought this matter to the attention of the Corps by letter dated July 18, 1969, and we suggested that a reassessment be made of the possible construction of an arch dam for the New Melones project. We suggested also that to expedite this assessment the Corps arrange to use the Bureau's computer facility in Denver, Colorado. We also advised the Corps that we did not believe that comparative design and cost determinations should be unduly influenced by unforeseen conditions which had not been evaluated as had been the case during the 1966 studies.

In response to our suggestions the Corps' Sacramento district prepared new comparative cost estimates for both types of dams. The estimates at that time showed "*** a potential cost advantage of the arch dam over the rockfill dam in the order of $11,600,000." In view of this significant cost advantage of the arch dam over the rock-fill dam, the Sacramento district proposed a two-phase program to restudy the type of dam that should be constructed.

The first phase provided for the utilization of the Bureau's computer facilities, as suggested in our letter of July 18, 1969, in developing a comparative cost estimate for the concrete arch dam essentially without further field investigation. The second phase provided for the exploration and testing necessary to develop the foundation conditions. The restudy was initiated in September 1969 and was to continue as long as it appeared that the construction of an arch dam had an indicated cost advantage.

The Chief of Engineers, by letter dated March 2, 1970, advised us that the first phase of the restudy had been completed and he provided us with the revised estimated construction cost of both types of dams excluding all common items. The estimated costs were $90,720,000 for the rockfill dam and $85,050,000 for the arch dam--a savings of $5,670,000 in favor of the arch dam.

With regard to further studies, the Chief of Engineers advised:

> "If these type-of-dam studies were continued into a more detailed phase, it would involve additional field investigations of the foundation for the arch, and refinement of the arch dam analyses. *** However, after reviewing the results of the studies completed to date and a careful consideration of all involved factors, I have decided to terminate further studies of the type of dam and to proceed with the design and construction of a rockfill dam at the New Melones site. The bases for this decision are as follow:"
>
> * * * * *
>
> "b. By proceeding now with the rockfill dam we will avoid a 2-year delay in award of the next major construction contract and at least a 1-year delay in completion of the project. ***
>
> "c. We will also provide flood protection and other benefits one year earlier. *** A one-year delay in project completion would cause a total loss of about $10,000,000 in benefits,

including flood control, irrigation, power and recreation."

* * * * *

"In summary, the comparative cost estimates indicate that the relatively small difference in cost between the two types of dam is well within the order of accuracy of the estimates. Furthermore, the possible savings in cost which might result from more detailed studies of the arch dam are not nearly large enough to justify the delay in project completion with the resulting delay in project benefits."

Subsequent to providing us with its views on this matter, the Corps, in June 1970, awarded a contract for about $26 million for construction of the diversion and outlet works for a rock-fill dam.

We believe that the Corps did not give adequate consideration to all appropriate factors in developing the revised estimated construction costs, and, as a result, the cost advantage of constructing the arch dam over the rock-fill dam was understated significantly. The basis for our conclusion is contained in the following sections.

GAO's comparison of costs between alternative designs

The Corps' studies acknowledged a comparative cost advantage of the arch dam over the rock-fill dam of about $5.7 million. The Corps' comparative cost estimates, however, did not include certain costs which had the effect of minimizing the cost advantage of constructing an arch dam. For example, the Corps limited its comparison to construction costs and did not consider the cost of interest during construction which, in our opinion, should be considered in evaluating the feasibility of alternative designs. Had interest during construction been considered, the comparative cost estimates would have shown that the arch dam would have been about $8.7 million less rather than $5.7 million less than the estimated cost of a rock-fill dam.

The following schedule shows our adjustment to the Corps' estimated construction costs in arriving at the cost advantage of $8.7 million that would result from the construction of an arch dam. In computing the interest during construction, we used an interest rate of 4-7/8 percent--the rate established by the Water Resources Council for fiscal year 1970.

	Rock-fill	Arch
	(000 omitted)	
Corps' estimated construction costs excluding all common items	$ 90,720	$85,050
GAO's adjustment for interest during construction based on a 6-year period for the arch dam and a 7-year period for the rock-fill dam	15,479	12,439
Total	$106,199	$97,489
Arch dam advantage		$ 8,710

The Corps' estimate of the cost of the arch dam includes design costs of about $4 million that were incurred previously for the development of the design for the rock-fill dam. We believe that the inclusion of these costs, although being justified, further demonstrates the obvious cost advantage of the arch dam.

A factor which we believe should have been considered in evaluating design alternatives was anticipated operation and maintenance (O&M) costs. The annual estimated O&M costs for a rock-fill dam are $150,500, whereas the annual estimated O&M costs of an arch dam are $116,900. Since O&M costs will be incurred over the project life, we believe that they are significant and should have been considered by the Corps in making its decision on the type of dam to be constructed.

Another factor which had a significant impact on the relative cost of the design alternatives was the contingency allowance for possible unforeseen conditions. In developing the cost estimates for the 1966 studies, the Corps added 20 percent to the cost of both dams as a contingency allowance. The Corps' cost comparison resulting from its restudy

contained a 20-percent contingency allowance for many of the arch dam's features but only a 10-percent contingency allowance for the rock-fill dam. This added contingency allowance results in about a $4 million penalty being assessed against the arch dam. The reason given for using a higher contingency for the arch dam was because "*** no further work has been done to refine the design, since the type of dam decision was made in October 1966."

When we compared the Corps' recent cost estimates for the arch dam with those made in October 1966, we found that significant "increases" had been made to the estimates for certain major items of the arch dam, but no corresponding decreases had been made in the contingency allowance for these items. Although we are not in a position to recommend an alternative contingency allowance, we believe that the use of a 20-percent contingency allowance for certain arch dam items, in view of the design changes that have taken place, was not justified.

The Corps advised us that by proceeding now with the rock-fill dam it would avoid a 2-year delay in the award of the next major construction contract and at least a 1-year delay in the completion of the project. On the basis of an evaluation of construction periods for comparable arch dams, we believe that the Corps' estimate of the construction period for the arch dam at New Melones is conservative, and that a construction period of about 3 or 4 years rather than 6 years would be more representative for a project of this size.

For example, the larger arch dam recently completed at New Bullards Bar by the State of California was constructed in about 3-1/2 years. Although we recognize that a change to an arch dam would result in a delay in the start of construction, we believe that an arch dam would provide flood control and other benefits no later than the currently proposed rock-fill dam.

We recognize that the foundation conditions, which the Corps contends were an unknown factor, would play a major part in determining the final cost of constructing an arch dam. In December 1969, however, a consulting Geologist advised the Corps on the extent of the exploration and testing

that would be necessary to determine the foundation conditions. We believe that the potential savings involved, had it been recognized by the Corps at an earlier date, justified further exploration of the foundation conditions before the final decision had been made as to the type of dam to be constructed.

USE OF WATER-REDUCING ADMIXTURES

Water-reducing admixtures are organic chemicals which can be added to concrete mixtures to improve their characteristics. For example, they can improve the workability of the mixture and permit production of very high-strength concrete which is generally desirable in constructing large structures. Water-reducing admixtures also permit required strength to be obtained although using less cement in the concrete.

The Bureau has used water-reducing admixtures in its various projects, whereas the Corps has made limited use of such admixtures. Since the Bureau's use of these admixtures has resulted in significant savings, we believe that the Corps should make greater use of these admixtures to achieve similar savings on its projects.

Bureau's practices

The Bureau's first large scale use of water-reducing admixtures was during the construction of the Glen Canyon Dam (1957-64). Admixtures were not included in the Bureau's specifications, but the contractor requested, and was granted, permission to use them. After using admixtures successfully on this and other projects, the Bureau revised its concrete specifications and generally required their use on projects involving 2,000 or more cubic yards of concrete.

The Bureau furnished us with estimates of the savings resulting from the use of admixtures on three projects, as shown below.

Project	Savings per cubic yard	Total savings (000 omitted)
Glen Canyon Dam	$0.06	$240
Morrow Point Dam	.48	173
San Luis Canal	.19	252
		$665

The savings obtained varied because the specific effects of admixtures can vary with the type, quantity, and properties of the cement used. Other variables, such as temperature, may also necessitate an adjustment in the proportions of the admixture used.

Corps' practices

In contrast to the Bureau's policy, the Corps' manual on concrete practices states that the use of water-reducing admixtures will (1) be approached with caution and (2) be restricted to unusual circumstances requiring the approval of the Chief of Engineers.

The Corps' procedures provide that the use of an admixture may be approved when requested by a contractor if an evaluation shows it to be economically beneficial. The procedures provide also that the requesting contractor must bear the cost of evaluating the admixture and that if the evaluation shows a savings the contractor is given a portion of the net savings (usually half).

Although the Corps has had some limited experience in the use of water-reducing admixtures (on one project the Corps' estimated savings in cementitious materials of about $132,000), it appears that, in many cases, the potential savings may be too low to provide an incentive to the contractor to make the evaluation study. We noted that such studies are required even though the same admixture had been similarly studied and qualified on past projects.

When questioned about their reluctance to use water-reducing admixtures, the Corps' Washington Office advised us that for the type of concrete customarily used for navigation locks and low-height dams the cement content was already so low that further cost reductions from the use of admixtures were insufficient to cover the cost of the admixtures. The Corps advised us also that small jobs may not justify the expense of testing. We agree that for certain types of concrete the Corps may have reduced the cement requirement to a point where admixtures would not have been warranted. We believe, however, that, in some cases, Corps' projects include enough concrete with a cement content to justify the specification of admixtures.

Officials within the Corps' North Pacific Division advised us that savings would probably be available through the use of admixtures whenever a comparatively rich structural concrete was being placed.

We reviewed three Corps' projects in the North Pacific Division, and, in each case, we found that the quantity and quality of concrete as shown below would have, in our opinion, justified the use of water-reducing admixtures.

Project	Estimated structural concrete used (cubic yards)
Lower Monumental	285,500
John Day Lock and Dam	967,500
Little Goose	360,000
Total	1,613,000

We believe that substantial savings could have been achieved if water-reducing admixtures had been specified in the contract for these projects. We also noted another project, Lower Granite, where the use of about 360,000 cubic yards of structural concrete had been planned. Because we believed that substantial savings could have resulted from the use of admixtures in this case, we discussed the matter with Division officials. Subsequently, we noted that the bid document for this project specified admixtures as a separate bid item.

It appears to us that the use of water-reducing admixtures would be equally applicable to Corps' projects as well as to Bureau projects. In commenting on our draft report, the Corps agreed that water-reducing admixtures may be helpful in some of their structural concrete, and stated that to encourage their consideration a paragraph on water-reducing admixtures will be included in its forth coming revision of the Standard Guide Specifications for Concrete.

DESIGN OF OUTLET WORKS FOR EMBANKMENT DAMS

We believe that savings in construction costs could be achieved through improved coordination between the Corps and Bureau in the design of outlet works for future embankment dams. A typical embankment dam is shown in the photograph on the following page. At present the two agencies generally construct outlet works of significantly different design.

Outlet works are the structures which permit controlled releases of water stored behind dams and include, among other features, control gates for normal operation, emergency gates, access ways to the gates, and conduits which convey the water through the dam.

Under the Bureau's preferred design, the gate structure is located in the dam itself (see diagram A, p. 22). This method provides for the use of a buried gate chamber. The Corps, on the other hand, prefers to locate the gate structure in a separate tower upstream of the dam (see diagram B, p. 22).

The upstream tower method requires construction of a separate structure and a service bridge connecting the structure to the dam or an abutment. This separate structure must be constructed to withstand ice pressures if the dam is located in a cold climate.

We found that the Corps' engineering manual "Structural Design of Spillways and Outlet Works," did not mention the buried chamber method which the Bureau has found to be generally more economical than the tower method. The Corps, however, has used the buried chamber method occasionally, justifying it on the basis of either lower cost or added safety.

We discussed this matter with the Corps and suggested that, in view of the Bureau's experience, the Corps should develop procedures for considering the buried gate chamber in the design of future embankment dams. In response to our suggestion, the Corps issued an Engineering Technical Letter (ETL 1110-2-84) which requires, under certain conditions, such as potential earthquake activity, the consideration of buried, hemispherical gate control structures in the planning and design studies of outlet works for embankment dams.

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The Trinity Dam - An embankment dam constructed by the Bureau of Reclamation in California.

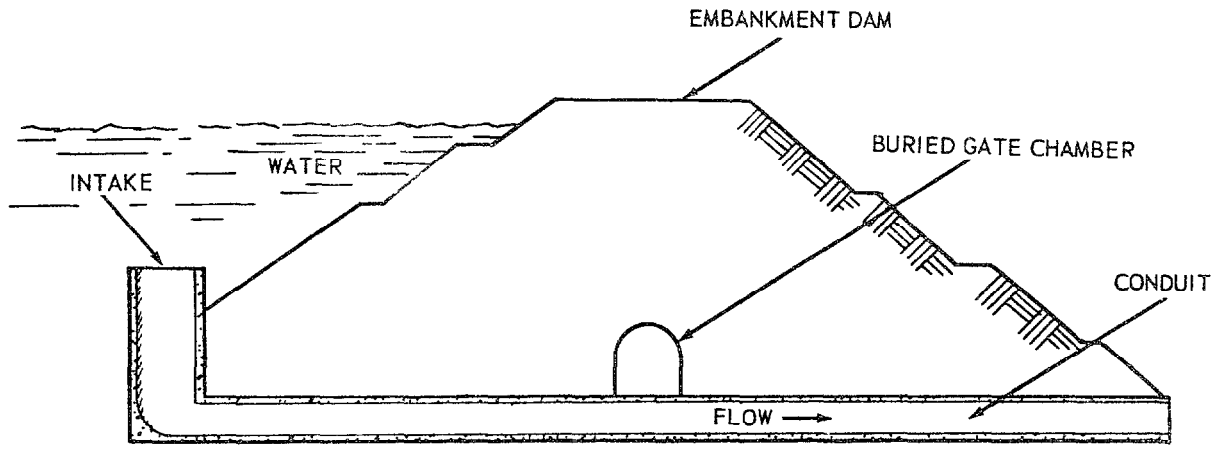


DIAGRAM A - An embankment dam with a buried gate chamber. Access to the gate chamber can be provided by a vertical shaft or through the downstream opening of the conduit.

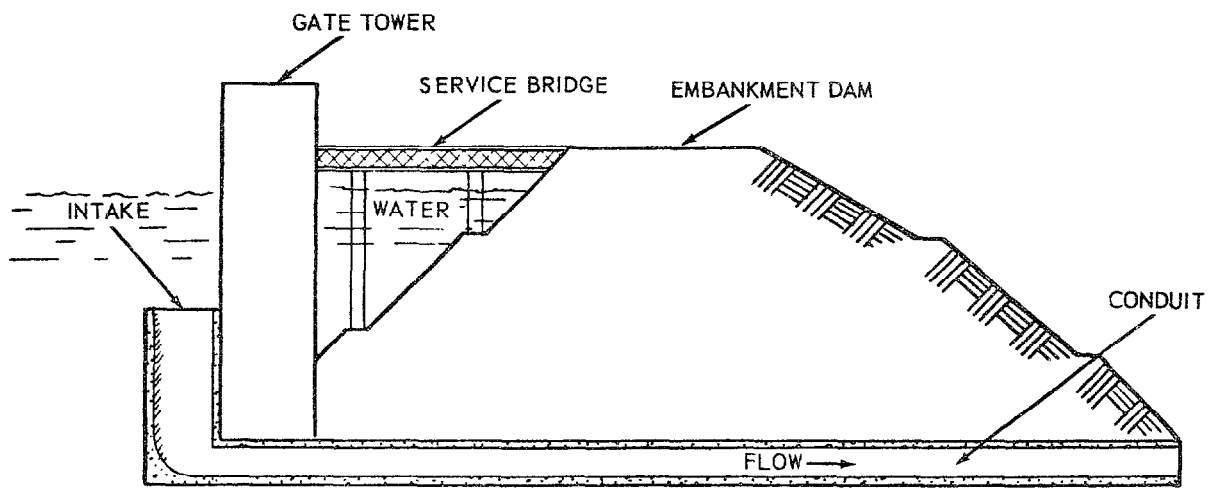
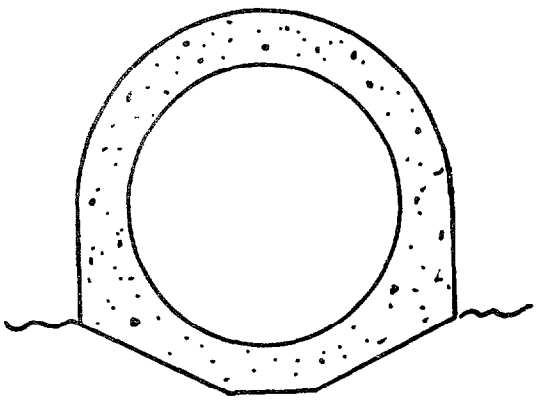


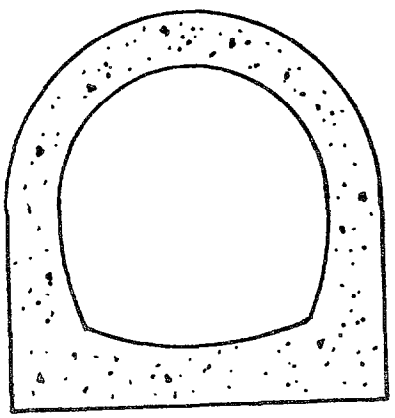
DIAGRAM B - An embankment dam with a gate tower. Access to the gate tower is provided by the service bridge.

In addition to the differences in the overall design of outlet works, we noted significant differences existed in the design of conduits for embankment dams. The conduits designed by the Bureau were usually one of two shapes--circular or horseshoe (see p. 24). The Corps has developed an oblong design (see p. 24) which has been used for conduits under embankment dams ranging from 100 to 160 feet in height. Savings of $100,000 or more have been estimated in every case where the oblong conduits have been used. In commenting on our draft report, the Corps advised us that the use of oblong conduits is also intended, and will provide greater economy, in dams higher than 160 feet.

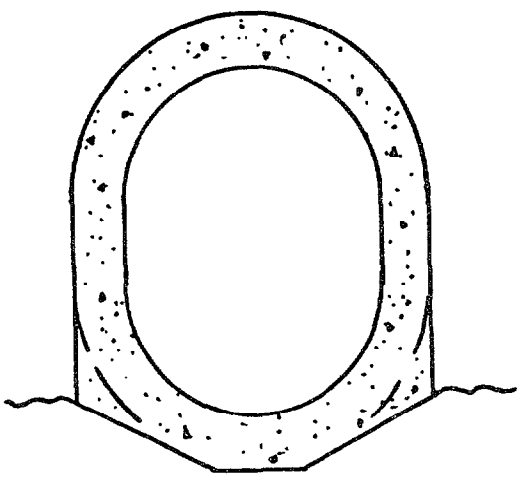
We found that the Bureau was unaware that the oblong design was being used by the Corps. After bringing this matter to the Bureau's attention and providing information available from the Corps, the Bureau advised us that its next feasibility study for an embankment dam would take into consideration the oblong design for conduits.



CIRCULAR SECTION



HORSESHOE SECTION



OBLONG SECTION

CONDUIT SECTIONS

CHAPTER 3

GUIDANCE NEEDED FOR EVALUATING DESIGN ALTERNATIVES

DESIGN OF SAN LUIS CANAL

We believe that the Bureau exercised questionable judgment in its analysis for comparing the costs of a compacted-earth lining with the costs of a 4-1/2-inch-thick unreinforced-concrete lining for the San Luis Canal. If the Bureau had given what we believe to be proper consideration to certain cost factors in evaluating the design alternatives, the analysis would have shown that the earth lining would cost about $12 million less than the concrete lining chosen by the Bureau. We believe that the Bureau's analysis could have been prepared in a more appropriate manner if the Bureau had clearer instructions on making cost comparisons when construction alternatives were being considered.

The San Luis Canal is the major conveyance facility of the San Luis Unit of the Central Valley project of California. The San Luis Unit was authorized for construction in June 1960 (74 Stat. 156) as a separate Federal project or a joint Federal-State project. In December 1961 the United States, through the Bureau of Reclamation, and the State of California agreed to the construction of joint-use facilities. The principal purposes of the San Luis Unit include furnishing irrigation water to about 579,000 acres of land in California and providing a link in the State's conveyance system to furnish water from northern California to areas of need in southern California.

The December 1961 agreement provided that the Bureau design and construct the joint-use facilities and that the State pay 55 percent of the total cost of construction. The agreement provided also that at the completion of construction the State assume the operation and maintenance of the joint-use facilities and that the Bureau and the State each pay an equitable share of the cost.

The San Luis Canal is one of several joint-use facilities in the San Luis Unit. The canal is about 100 miles

long and consists of five reaches or sections. During the design of the San Luis Canal, the Bureau gave serious consideration to three different types of lining: (1) buried membrane, (2) compacted earth, and (3) unreinforced concrete. The buried membrane lining appeared to be the least suitable and was dismissed quite early from further consideration. Detailed studies and comparative economic estimates were concentrated on earth-lined and concrete-lined canal sections.

In reaching the decision to line the canal with concrete rather than earth, the Bureau prepared three studies for comparing the incremental or additional costs of constructing one alternative with the other. The first study in June 1961 showed a cost advantage of about $8.7 million in favor of using earth. The second, prepared later the same year, showed a cost advantage of about $12.3 million or $15.6 million in favor of using earth (depending on whether or not seepage losses were included). The third study, prepared in August 1962, showed a cost advantage of about $2.5 million in favor of using concrete.

The third study was based primarily on the earlier studies, but differed in that it included some additional O&M costs for an earth-lined canal as compared to a concrete-lined canal, and it contained the results of additional engineering studies. Also the third study covered only the last four reaches (about 82 miles) of the canal's five reaches (about 100 miles), because in October 1961 the Bureau and the State had tentatively agreed to line the first reach with concrete. The third study also applied to O&M costs an inflation and cost-trend factor which was not included in the earlier Bureau studies.

Our evaluation of the report prepared by the Bureau showed:

1. Interest during construction was not considered.

2. Questionable judgments in the analysis and projection of O&M costs.

3. Invalid values assigned to water lost through seepage and evaporation.

Each of these items was an influencing factor in the decision to construct a canal with a concrete lining rather than an earth lining. In addition, the Bureau added an inflation factor to the O&M costs. To our knowledge such a factor is not normally considered in Bureau comparative cost estimates. We have included it, however, in our analysis in connection with those O&M costs that we consider valid.

The following schedule compares the Bureau's final study costs with the costs as adjusted by us.

August 1962 study by type of lining	Schedule of incremental costs			
	Bureau of Reclamation		As adjusted by General Accounting Office	
	Earth	Concrete	Earth	Concrete
	(000 omitted)			
Cost items:				
Construction costs, including bridges	$ -	$17,230	$ -	$17,230
Interest during construction	-	-	-	963
Right-of-way	840	-	840	-
O&M costs (before inflation factor)	5,154	-	2,753	-
Loss of indirect agricultural benefits	880	-	880	-
Evaporation	2,460	-	-	-
Seepage	6,740	-	-	-
Total (before inflation)	16,074	17,230	4,473	18,193
Inflation factor for O&M costs	3,624	-	1,852	-
Total (after inflation)	$19,698	$17,230	$ 6,325	$18,193
Incremental advantage		$ 2,468	$11,868	

As indicated, if the Bureau had given what we believe to be proper recognition to the above factors, the study would have shown that the earth lining was the more economical of the two methods. Our analysis of the differences in each of the cost items shown in the schedule is contained in the following sections.

Interest during construction not considered

In comparing the cost of the earth and concrete lining alternatives, the Bureau failed to consider the interest costs on Federal funds used during the construction period. This factor is usually considered in making cost comparisons but, according to the Bureau, it inadvertently was overlooked on this project.

The interest during construction amounting to $963,000 was computed on the basis of $16.39 million which represents the difference between the incremental construction costs of the $17.2 million for concrete lining and the incremental right-of-way cost of $840,000 for earth lining. Interest was computed on the basis of a composite Federal-State rate of 3.33 percent for the period of construction. Interest during construction should have been an incremental cost attributable to the concrete lining and its omission contributed to making the concrete alternative appear more economical.

Questionable judgments in analysis and projection of O&M costs

The Bureau estimated incremental O&M costs of $5,154,000 attributable to an earth lining. This cost estimate included the following items and their incremental costs.

Item	Incremental costs
Lining repair	$ 173,000
Canal cleaning:	
Weeds	987,000
Clams	700,000
Embankment maintenance	1,594,000
Weed control:	
Emergent weeds	615,000
Bank top weeds	102,000
Structural maintenance	205,000
Pumps and meter maintenance	717,000
Turnouts--construction	61,000
Total	$5,154,000

We found several instances in which the Bureau exercised questionable judgment in the estimation and calculation of costs as they related to (1) lining repair, (2) canal cleaning for weeds and clams, and (3) emergent weed control.

Lining repair

The Bureau's study assigned incremental lining repair costs of $173,000 to the earth-lined canal. We believe this to be an incorrect assumption, because the limited historical cost data available at the Bureau's Region 2 in Sacramento, California, shows that the cost of concrete-lining repairs for another Bureau-constructed canal--the Delta-Mendota--is, per mile, almost twice the cost of earth-lining repairs. The Delta-Mendota Canal, completed in 1951, provides a particularly valid basis for comparison because (1) it is located immediately adjacent to the San Luis Canal and (2) it has both concrete- and earth-lined sections. Limited cost data for the Delta-Mendota Canal for a 3-year period showed the cost for earth-lining and concrete-lining repairs to be $12.67 and $23.63 a mile, respectively.

The Bureau representative, who prepared the estimate used in the cost study, told us that costs of lining repairs probably should have been considered as an incremental cost of concrete lining rather than earth lining.

Canal cleaning--aquatic weeds

Incremental costs of $987,000 for cleaning aquatic weeds were assigned to the earth-lined canal on the basis of the Bureau's experience for the Friant-Kern Canal which--like the Delta-Mendota Canal--has both concrete- and earth-lined sections. The Delta-Mendota Canal had not been used in this case because it had never experienced an aquatic weed problem, although it had been in operation for about the same period of time as the Friant-Kern Canal, which the Bureau completed in 1951 and is located about 60 miles south and east of the San Luis Canal.

We believe that the Bureau's assignment to the earth-lined canal of the incremental costs for aquatic weed cleaning was questionable, because it did not assign any incremental costs to the concrete-lined canal for controlling

algae growth, a problem that existed in the concrete-lined reaches of the Friant-Kern Canal used as the basis for estimating the cost of cleaning. In fact, the algae problem was more serious than the weed problem in the Friant-Kern Canal because the algae growth diminished the capacity of the canal.

In August 1962 the Bureau found that a copper sulphate treatment it had been using, "in desperation," to prevent algae from developing had controlled the weed problem as well. Subsequent to the introduction of this treatment, the control of algae and aquatic weeds can be obtained by biweekly applications in only two locations on the 153-mile canal. Inasmuch as this treatment solved both problems, we do not believe that the incremental costs should have been assigned to the cost of earth lining.

Canal cleaning--clams

The study assigned incremental canal cleaning costs of $700,000 to the cost of the earth-lined canal for the removal of clams, on the basis of information pertaining to the removal of clam deposits in a concrete section of the Delta-Mendota Canal. Data on clam deposits in the earth-lined sections was not available.

We believe that the incremental cost for the removal of clam deposits should not have been assigned to the earth lining, because the Bureau had no proof that clams were a greater problem in one type of lining than another. An indication of the questionable premise on which the projection was made is shown in the following remarks contained in the Bureau's workpapers.

> "We do not know what controls the rate of deposit--water temperature, water silt load, environment (hard vs earth lining)--but suppose there is a unit area relationship in hard linings, and double this rate in earth ***."

Using this rationale, the Bureau then determined, on the basis of the Delta-Mendota Canal experience, that clams develop on a concrete lining at the rate of 8.7 cubic yards a mile each year. This rate was then "rounded to 10 yards *** in a hard lining or double 20 in an earth lining."

Although the Bureau admitted that it did not know what controls clam deposits, it arbitrarily assumed that clams would be twice the problem in an earth-lined canal. On the basis of this questionable assumption, the Bureau estimated the cost of the required canal cleaning equipment to arrive at the incremental cost of $700,000.

The Bureau's estimate was based partly on a university professor's opinion that clams would favor an earth lining. His opinion was based on his knowledge of marine biology and observations made during a visit to the Delta-Mendota Canal at which time about 30 miles of the canal--which is entirely concrete lined--had been dewatered to allow for cleaning of silt, clams, and other biological material. Since his observations did not cover any portion of the earth lining, he qualified his opinion by indicating that there could be no real proof except through scientific research.

Emergent weed control

We found that the Bureau's assignment of incremental costs of $615,000 for control of emergent weeds in an earth-lined canal was erroneous because (1) an arithmetic mistake had been made in computing the area to be affected by the weeds and (2) there had been no valid basis for the costs used.

The Bureau's study stated:

> "There would be a 5-foot strip along each side of an earth-lined canal at the water line that would require emergent weed control. This would amount to about 2 acres per mile.
>
> "Estimate = 2 at $150 = $300 per mile per year"

The study applied the $300 a mile to the 82 miles of canal to arrive at the annual cost of $24,600. An area 5 feet by 1 mile, however, amounts to about 1.2 acres rather than 2 acres. This correction alone would have reduced the annual cost from $24,600 to $14,760.

When we attempted to ascertain the basis for estimating weed control costs at $300 a mile, we were told that it was based on the best information available at the time and that no further documentation was available. To determine the reasonableness of the estimate, we reviewed the Bureau's cost data for the Delta-Mendota and Friant-Kern Canals. We found that emergent weeds were not a problem for the Delta-Mendota Canal and that the total annual expense for emergent weed control at the Friant-Kern Canal for the 5-year period 1957-61 averaged $910. The application of this cost to the earth-lined section of the canal resulted in costs of about $36.07 a mile each year. On the basis of this cost, we estimate that the cost of controlling emergent weeds for the 82 miles of the San Luis Canal would be $2,958 a year rather than $24,600 a year as estimated by the Bureau. This results in a decrease in the cost of controlling emergent weeds of about $541,000 (an 88-percent reduction).

Inflation factor for O&M costs

In computing the O&M costs attributable to an earth-lined canal, the Bureau included an estimated annual net increase in incremental O&M costs of 4 percent, representing the net effect of (1) inflation and (2) decreased costs resulting from improved O&M methods and equipment. The net rate of increase was based on both historical costs of a group of selected stable irrigation projects and on the judgment of the estimators.

The Bureau estimated the present worth of incremental O&M costs attributable to the earth lining alternative over the 50-year estimated project life at $8,778,000. Of this amount, $3,624,000 represented the present worth of the projected net 4-percent annual increase in O&M costs over the 50-year period. It should be noted that the 4-percent annual increase was applied to O&M costs which were overstated, as pointed out on page 29. A reduction in these costs also would reduce the amount attributed to inflation, and we have adjusted the amount accordingly in our schedule of incremental costs.

Invalid values assigned to water lost through seepage and evaporation

An earth-lined canal, because its sides have flatter slopes, occupies a greater area than a concrete-lined canal of equal capacity, and as a result, the water losses due to evaporation and seepage will be greater in an earth-lined canal. The Bureau considered such losses in its comparison but did not evaluate them correctly.

The Bureau assigned an incremental cost of $9.2 million to the earth-lined canal as a result of water losses due to evaporation and seepage. The amount of the water loss was estimated, for the most part, on the basis of the average cost of providing water through a future State water project. The estimated water loss for an earth-lined canal amounted to 116 cubic feet per second (c.f.s.) and for a concrete-lined canal it amounted to 86 c.f.s.--an incremental loss of 30 c.f.s.

Since the comparison between the two construction alternatives was made to compare incremental costs, we believe that the analysis should have considered the additional construction costs of enlarging the capacity of the earth-lined canal to compensate for the incremental losses. In this case, it would have been the incremental cost of providing another 30 c.f.s. capacity. The maximum design capacity of the canal was 13,100 c.f.s. and an increase to 13,130 c.f.s.--about two tenths of 1 percent--would have resulted in such a small increase in construction costs as to be almost unmeasurable.

In requesting a reduction in the value assigned to water losses, the Acting Regional Director of Region 2 advised the Bureau's Office of the Chief Engineer of this fact in a letter dated July 3, 1962, which stated:

* * * * *

"Since the total seepage loss equals about 100 c.f.s., the actual savings attributable to a completely watertight lining would be the difference in construction cost of a 13,000-c.f.s. canal as opposed to a 13,100-c.f.s. canal. The saving cannot manifest itself in any way other than by the elimination of this last increment of cost.

"This reduction in construction cost is a real saving but one so small as to be indeterminate as a practical matter. ***"

We found no indication that this was considered by the Office of the Chief Engineer in its calculation of comparative costs of canal linings for the San Luis Canal. Instead, by stating that incremental water losses of $9.2 million were attributable to an earth-lined canal, the Bureau presented another factor which incorrectly favored the use of concrete lining.

Questionable decision to construct a concrete-lined canal

In addition to those problems previously discussed, which relate to the cost of alternatives, we noted other

factors which we believe raised serious questions about the reasonableness of the decision to proceed with the construction of a concrete-lined canal.

A 1963 Bureau publication "Linings for Irrigation Canals," which is intended as a guide for engineers, supervisors of irrigation districts, and others concerned with the planning, design, construction, and maintenance of irrigation canals, states in part:

> "Where suitable materials for the construction of a thick compacted-earth lining are available at the jobsite ***, this is likely the lowest cost permanent type of lining with respect to both first and ultimate costs for use on large canals. A thick compacted-earth lining has an advantage not possessed by any other type of lining in general use. Because of its weight and plastic characteristics, it can withstand considerable hydrostatic pressure without loss of effectiveness, and it can be used in many instances without drains under the lining in areas where the canal prism intersects the ground water table. For similar reasons, a thick compacted-earth lining can be used to advantage over expansive clays which disrupt more rigid type linings. Another distinct advantage of thick compacted-earth linings is the ease of constructing partially lined sections or reaches, as required to cut off permeable strata or areas. The earth lining blends in with the unlined earth sections."
>
> * * * * *
>
> "The most important factors influencing the unit cost of thick compacted-earth linings are size of the job, source of materials, weather conditions, mixing requirements, subgrade preparation, and cover materials. ***
>
> "A job involving the placement of large quantities of lining in large canals permits the effective use of heavy equipment. Hence, the unit cost of

material handling is reduced and the in-place cost per square yard of lining is relatively low.

"The source of materials may be a controlling factor influencing unit cost because of the cost of excavation or haul. The least expensive linings will be those for which materials removed in the required canal excavation can be used in the lining. ***"

The application of these general criteria to conditions known to exist on the San Luis Canal route present, in our opinion, a strong case for the use of an earth lining for the canal.

1. The San Luis is one of the largest canals constructed by the Bureau, and, according to several geological studies, there was an adequate supply of suitable materials from canal excavation for earth-lining purposes.

2. Expansive clays were expected to be a problem at several locations in the area of the San Luis Canal. One Bureau geology study stated that:

> "There were a number of instances where expansive clays were encountered within the first 25 feet of depth. Such clays could be detrimental to the canal from stability and uplift standpoints."

3. Another Bureau geology report states that:

> "*** there are several reaches where shallow subsidence or expansive clays will require excessive subgrade preparation to warrant the use of a rigid lining such as concrete. There may be some areas where any amount of treatment would not produce a subsoil suitable for a rigid lining."

Another factor which would appear to enhance the desirability of constructing an earth-lined canal is that almost

the entire canal line crosses an area known to be subject to subsidence. In fact the area is affected by two types of subsidence--deep subsidence caused by groundwater withdrawals and shallow subsidence caused by soils that consolidate when wet.

Although the Bureau planned to take steps to reduce the problems caused by subsidence, the Chief, Geology Branch, Region 2, in a letter dated September 28, 1961, to the Regional Engineer, stated that shallow subsidence would continue with some possible cracking of embankment foundation material and probable cracking of the proposed concrete lining. He stated also that deep subsidence in some areas might continue well beyond the time the groundwater table was stabilized. In view of the expected subsidence, we believe that an earth lining with its plastic, flexible qualities would have been superior to a rigid concrete lining.

The comments of the California Department of Water Resources on this matter tend to further question the validity of the Bureau's cost study. The State, in conveying its official position to the Bureau on the type of lining to use for the San Luis Canal, indicated that its studies showed that the use of a 4-1/2-inch-thick unreinforced concrete lining could not have been economically justified over the use of a heavy-compacted-earth lining. The State pointed out that in the region subject to shallow subsidence concrete lining may not be the best selection. In conclusion, however, the State said that:

> "Although we have some reservations, as expressed above, we are willing to accept your judgment in this matter and concur in the construction of a concrete lining 4-1/2 inches thick in reaches of the San Luis Canal where wetting of the underlying soils would not be expected to result in structural failure."

At the completion of our field review on this project, we became aware of preliminary planning by the Bureau to raise the level of the canal due to subsidence problems. As of February 1970, contract costs for the work--in reaches 2, 3, and 5--were estimated at about $12 million. Additionally, the Bureau will incur noncontract costs of about

$4 million, or total costs of about $16 million to correct subsidence problems. The work is planned to be done in stages over the next 4 years. Although it would be necessary to raise the level of the canal for either type of lining, Bureau studies indicate that an earth-lined canal could be accomplished easier and at less cost.

CHAPTER 4

AGENCY COMMENTS AND OUR EVALUATION THEREOF

In a draft of this report, we proposed that the Secretary of the Army and the Secretary of the Interior take appropriate action to jointly develop and implement procedures which (1) ensure improved coordination and communication in the design and construction of water resources projects and (2) provide a free exchange of ideas and technological advances.

We proposed also that the agencies act jointly to establish guidelines identifying the techniques used and the items of costs considered to ensure objective evaluations of design alternatives. With respect to the selection of the dam at New Melones, we proposed that the Secretary of the Army direct the Chief of Engineers to consider further exploration of the foundation conditions to determine the effect such conditions might have upon the cost of an arch dam.

In commenting on our draft report, the Department of the Army, in a letter dated September 8, 1970, accepted our recommendations on the desirability of further efforts relating to interdepartmental coordination and communications on matters pertaining to design and construction of water resources projects, including guidelines for cost evaluation of design alternatives (see app. I). The Department advised us that systematic exchange of design criteria, guide specifications, and cost guidelines, with opportunities for discussion between appropriate agency representatives, was explored by representatives of the Corps and the Bureau in Denver on July 27, 1970. Conclusions reached at the meeting were:

> "1. Design standards and criteria, guide specifications, and cost estimating guidelines (including drafts of such material issued for field review) will be exchanged automatically at the time of issuance. For this purpose, distribution lists for various types of publications will be exchanged between the Corps and the Bureau.

"2. Where applicable, questions raised by exchange of material concerning agency practices should be resolved immediately by correspondence. Meetings will be arranged to facilitate discussions between appropriate agency representatives when deemed advisable.

"3. Information on engineering computer programs will be interchanged automatically when issued. The Corps will furnish the Bureau copies of the current Abstract List of Computer Programs available at Corps offices. When the proposed computer library at the Waterways Experiment Station becomes operational, the Bureau will be supplied information on available engineering computer programs on a regular periodic basis. Bureau lists of available program plus other information generated from the Bureau of Reclamation Engineering Computer Systems (BRECS) will be furnished to the Corps.

"4. Exchange of information on schedules of intra-agency technical conferences will be made, including invitations for the other agency to attend when appropriate. In any event, the publications or minutes generated from such conferences will be exchanged."

In commenting on the July 1970 meeting with the Corps, the Department of the Interior also agreed that a formalized exchange of design information would be beneficial to both agencies. (See app. II.) With regard to our proposal for the establishment of guidelines identifying the techniques to be used and the items of cost to be considered in evaluating design alternatives, however, the Department stated that alternative studies, using established engineering economic principles, are a basic professional requirement and written procedures are not generally considered necessary or appropriate.

The Department stated also that feasibility, judgment, economics experience, new developments, and intangibles are, in its opinion, part of the background considered in

rendering an engineering decision. Although we recognize that many professional considerations enter into comparisons of design alternatives, we see no reason why these factors, along with the appropriate economic considerations and procedures, should not be formalized to ensure their uniform application and evaluation by appropriate officials.

Although the Department of the Interior did not comment specifically on our views regarding the San Luis Canal, they advised us that, if we desired it, certain material relating to the Bureau's rationale was available for our examination. The information referred to by the Department was reviewed and was given appropriate consideration by us.

The Department of the Army advised us that it was not adopting our suggestion regarding the need to consider further the economic advantages of constructing an arch dam for the New Melones project and that it had awarded a contract in the amount of $26 million for construction of diversion and outlet works for a rock-fill dam.

The Department stated that, although there were differences in cost estimates which, on the surface, favored the arch dam, these differences were relatively small in relation to the total estimated cost of either form of structure and that the nature of the uncertainties involved created a substantially greater risk that undefined problems could increase the cost of the arch dam construction. The Department stated also that, in its opinion, these factors, coupled with the delay that could be encountered in shifting to an alternate design, provided a sound and reasonable basis for proceeding with the rock-fill dam.

In commenting on this matter, the Corps advised us that although its analysis could be refined, the refinements were not considered to be of sufficient magnitude to alter the views and conclusions presented in the Chief of Engineers' letter to us dated March 2, 1970 (see p. 12).

With regard to our views on the contingency factors used, the Corps stated that the contingency factors are related to the degree of refinement of the design and that, at the time of the latest cost analysis, the design for the rock-fill structure was essentially complete although the

design for the arch dam was very preliminary without completion of the necessary foundation investigations. Therefore contingency factors of 20 percent for many of the arch dam's features were deemed appropriate, whereas a contingency factor of 10 percent was considered appropriate for the rock-fill dam.

We believe that inherent in this concept is an automatic weighted factor in favor of any given design alternative toward which, for whatever reasons, the greatest amount of effort or consideration has been directed. In any event, we noted that the Corps' use of a 10-percent contingency in its cost analysis for the rock-fill dam is inconsistent with the contingency allowance used in other recent cost estimates for the New Melones project.

The Project Cost Estimate for New Melones dated August 1, 1970, which serves as a basis for requesting congressional funding contains an average contingency allowance of 17 percent for many of the rock-fill dam features. The use of a 17-percent contingency allowance for the rock-fill dam in lieu of the 10-percent contingency allowance would further increase the cost advantage of the arch dam.

With regard to our views on the consideration that should have been given to interest during construction, the Corps stated also that, from a practical point of view, funding rates would likely govern construction periods thereby resulting in a significantly smaller advantage for the arch dam than our analysis indicated. The Corps stated further that this smaller cost advantage was not considered to be of significant magnitude to offset the economic losses and probable price-level increases which would result from delays that would be incurred in construction of an arch dam.

We recognize that the construction period for either type of dam will be governed by the rate at which the Congress appropriates funds, thereby affecting the interest during construction, but we see no basis for the Corps' assumption that this factor will have a greater impact on the arch dam.

The Corps commented that our evaluation of the cost of interest during construction was based on an interest rate of 4-7/8 percent, whereas the Corps' estimation for the cost of interest during construction was based on a rate of 3-1/8 percent, which is the rate used in justification of the initial appropriation of construction funds. The Corps may have used a 3-1/8-percent rate in estimating interest during construction for justification of the project, but the revised estimates of cost used in evaluating the two design alternatives, as contained in the Chief of Engineer's letter of March 2, 1970, did not give consideration to interest during construction at either rate.

We believe that the use of an interest rate of 4-7/8 percent is more appropriate, because it is the rate prescribed by the Water Resources Council for use in fiscal year 1970 in plan formulation and evaluation of water resources developments.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

We believe that the matters discussed in this report indicate that substantial savings could be achieved in the cost of designing and constructing water resources projects by improvements in the coordination, communication, and interchange of ideas between the Corps and the Bureau.

We found that the use of different design practices and procedures by the two agencies results in substantial differences in cost for accomplishing essentially the same objectives. We believe that there is a need for better coordination to ensure that (1) differences in design procedures and practices are identified and evaluated and (2) both agencies use the most economical practices consistent with the design requirements.

Subsequent to commenting on our draft report, the Bureau and the Corps, on November 2, 1970, entered into a written agreement to facilitate the systematic exchange of information on design and construction practices employed by each other. In addition, the Corps and the Bureau issued instructions on the administration of the agreement to their various offices.

We believe that this agreement, if properly implemented, could result in significant future savings through improved interdepartmental coordination and communication in the design and construction of water resources projects.

The Corps has advised us that it is proceeding with the construction of a rock-fill dam because of (1) relatively small differences in the cost of the two designs--rock-fill and arch--in relation to the total cost, (2) the uncertainties involved which could increase the cost of an arch dam, and (3) the possible delay in project completion resulting from shifting to an alternate design at this time.

We believe, however, that, if the Corps had made a more appropriate evaluation of the two design alternatives at an

earlier date, it would have recognized a significant cost advantage in favor of constructing an arch dam in the amount of about $9 million. Had the Corps recognized the significance of the cost advantage, it could have evaluated more thoroughly the uncertainties attributed to the arch dam and thereby avoided the possible delay in shifting to an alternate design at this late date.

In this regard, the Bureau, which has developed considerable expertise in the design and analysis of arch dams, could have provided invaluable assistance to the Corps.

The problems discussed in this report, both with respect to the type of dam for the New Melones project and the type of lining for the San Luis Canal, indicate, in our opinion, a need to develop guidelines setting forth those factors that are to be considered in evaluating design alternatives. Such guidelines are necessary to ensure a complete and objective analysis which will result in the most efficient, effective, and economical use of Federal funds.

RECOMMENDATIONS TO THE SECRETARY OF THE ARMY AND THE SECRETARY OF THE INTERIOR

We recommend that the Secretary of the Army and the Secretary of the Interior:

- --Review the coordination and exchange of information on water resources engineering to ensure that both agencies (1) evaluate and adopt, where practicable, those procedures and practices which most economically meet their requirements and (2) make the most efficient use of their joint capabilities.

- --Require the development of guidelines identifying the techniques to be used and the items of cost to be considered to ensure objective evaluations of design alternatives.

We recommend also that the Secretary of the Army require the Chief of Engineers to develop written guidelines and procedures for the purpose of improving the Corps' capability in the design and analysis of arch dams.

CHAPTER 6

SCOPE OF REVIEW

Our review dealt primarily with evaluating differences in design practices between the Bureau of Reclamation and the Corps of Engineers. We evaluated also the design practices of the Bureau for the San Luis Canal. We reviewed design and construction manuals, applicable laws and regulations, we examined selected records, and we interviewed officials of the Bureau and Corps.

Our review was made at the following locations:

Location	Office
Washington, D.C.	Corps of Engineers, Office of the Chief of Engineers
Portland, Oregon	Corps of Engineers, North Pacific Division
Walla Walla, Washington	Corps of Engineers, Walla Walla District
Sacramento, California	Corps of Engineers, Sacramento District and Bureau of Reclamation, Region 2
Denver, Colorado	Bureau of Reclamation, Office of the Chief Engineer

APPENDIXES

DEPARTMENT OF THE ARMY
WASHINGTON, D.C. 20310

08 SEP 1970

Mr. C. M. Bailey
Director, Defense Division
United States General Accounting Office
Washington, D. C. 20598

Dear Mr. Bailey:

This is in reply to your letter of 17 June 1970, which submitted for review and comment the draft of your proposed report to the Congress on "Opportunity for Improvements in the Development and Evaluation of Design Alternatives for Federal Water Resources Projects." (OSD Case # 3129).

The Chief of Engineers has prepared a detailed statement of comments, which is enclosed. I concur in his comments. Specifically, we accept the recommendations on the desirability of further efforts relating to interdepartmental coordination and communications on matters pertaining to design and construction of water resources projects, including guidelines for cost evaluation of design alternatives. The enclosure cites examples of present coordination practices which your staff may not have been aware of at the time the draft report was prepared. In addition, the enclosure reports on a recent meeting with the Bureau of Reclamation designed to lay the ground for expanded coordination procedures in accordance with your suggestion.

I would like to address specifically the issue relating to the type of dam for the New Melones project. We have concluded that construction should proceed with a rockfill dam, and a contract in the amount of $26 million for construction of the diversion and outlet works was awarded in June 1970. I appreciate that there is room for legitimate difference in engineering opinion on the type of dam to be used in a particular location. It seems to me that, where the selection of the type of dam by a responsible agency is a result of a careful and deliberate evaluation of costs, hazards and uncertainties, and is fully supported by much of the most expert engineering talent available,

Mr. C. M. Bailey --

including eminent consultants drawn from outside the agency itself, the General Accounting Office would be reluctant to suggest that the judgment of its staff be substituted for that of the responsible officials. I have carefully reviewed the history of the engineering decisions made in connection with New Melones. That history indicates that both the District and Division offices were clearly aware of the considerations favoring competing forms of structures. No effort was made to submerge this issue; on the other hand, the field offices solicited the assistance of experts in the Office of the Chief of Engineers, and ultimately a board of experts on the construction of large dams was impaneled to address the question. In October 1969, at your suggestion, the Corps reassessed the possible use of an arch dam using the Bureau of Reclamation computer methods and again developed comparative cost estimates based on existing field investigations. Based on this reassessment and the aforementioned area of expert advice, the Chief of Engineers made the final decision. Although there were differences in cost estimates which on the surface favored the arch dam, these differences were relatively small in relation to the total estimated cost of either form of structure, and the nature of the uncertainties involved created a substantially greater risk that undefined problems could greatly increase the cost of the arch type construction. These factors, coupled with the delay which could be encountered in shifting to an alternate design, provide, we believe, a sound and reasonable basis for proceeding with the rockfill dam.

While we have, therefore, not adopted the recommendation with respect to the type of dam, I would like to make it clear that I fully understand why your staff raised this issue in the draft report. This is an area in which no one can properly assert infinite or ultimate wisdom, in view of the substantial uncertainties and judgment factors involved. We will continue with respect to the Corps of Engineers Civil Works Program our practice of carefully considering various alternative basic types of dams in every case, in order to assure that the pros and cons of each are fully developed and adequately satisfied prior to embarking on any particular type of construction.

We appreciate your courtesy in providing us the opportunity to comment on your draft report. The improved coordination procedures

Mr. C. M. Bailey --

between the Corps of Engineers and the Bureau of Reclamation should be helpful to both agencies, and will contribute to the objective of conducting both programs on the most economical possible basis.

Sincerely,

Robert E. Jordan, III
Special Assistant to the Secretary of the Army
(Civil Functions)

Enclosure
COE Statement

Comments of the Corps of Engineers on
Proposed Report of the Comptroller General of the United States
to the Congress of the United States Entitled:

OPPORTUNITY FOR IMPROVEMENTS
IN THE DEVELOPMENT AND EVALUATION
OF DESIGN ALTERNATIVES FOR
FEDERAL WATER RESOURCES PROJECTS

Bureau of Reclamation
Department of the Interior

Corps of Engineers (Civil Functions)
Department of the Army

The draft report recommends (1) further foundation explorations for the purpose of refining the estimate of cost for an arch dam at the New Melones Project, and (2) inter-departmental action to improve coordination and communication on matters pertinent to the design and construction of water resources projects, including guidelines for the cost evaluation of design alternatives.

The Corps' position with respect to the contents of the draft report relating to Corps programs follows in order presented in the draft.

Use of Concrete Arch Dams

Although the Corps has not constructed a concrete arch dam since the 155-foot high North Fork Dam in California, completed in 1939, and the 260-foot high Englebright Dam, also in California and completed in 1941, consideration of this type of structure has been made in all cases where appropriate. It is of course essential that topography and foundation conditions be favorable before an extensive study of an arch structure would be justified. It is the practice of the Corps of Engineers to make at least a preliminary comparison of all suitable dam types for every project.

Regarding the statement on the greater safety of an arch dam "at certain dam sites", it could also be said that "at certain dam sites" an arch dam will provide a smaller margin of safety relative to a fill dam. This could be particularly true for areas of strong seismic activity. The opinions of consulting engineers as to which type of dam will perform better under strong seismic shocks vary. Their opinions are necessarily based upon judgement as the engineering technology of behavior of dams and their foundations under seismic shock is not sufficiently advanced to allow a rigorous valid analysis.

New Melones Project

For the reasons outlined in the letter dated 2 March 1970, from the Chief of Engineers to Mr. Allen R. Voss, Associate Director, U. S. General Accounting Office, we are proceeding with the construction of a rockfill structure at the New Melones site. A contract in the amount of approximately $26,000,000 was awarded in June 1970 for construction of the diversion and outlet works. The June contract award meets the present schedule and avoids an otherwise resulting delay in funding and later construction.

The recommendation in the draft report for considering further a concrete arch dam is based on a comparative cost analysis that differs from the Corps analysis in several respects. The differences having the greatest effect on the comparative analysis are related to the contingency factors used and consideration of interest during construction. Although it is recognized that the Corps analysis could be refined the refinements are not considered to be of sufficient magnitude to alter the views and conclusions presented in the Chief of Engineers' letter of 2 March 1970. Therefore, those views and conclusions are considered equally valid and applicable at this time. However, in the interest of further clarification of this position the following comments are offered on the differences in the comparative analyses.

Contingency factors are related to the degree of refinement of the design. At the time of the latest cost analysis, the design for the rockfill structure was essentially complete while that for the arch was very preliminary without completion of the necessary foundation investigations for an arch dam. Contingency factors of 20% for the main dam and Spillway and 15% for the Outlet Works and Power Intakes were, therefore, deemed appropriate for the arch dam plan, whereas a 10% contingency factor was considered appropriate for the rockfill plan. The Chief of Engineers does not consider that it would be appropriate to use the same contingency factor for both plans.

Shortly before the 1966 Board of Consultants Meeting, an extensive clay-gouged fault zone was found in the upper left abutment which would require expensive remedial treatment for the arch dam. While an allowance for this remedial treatment was included in the comparative estimates, the Corps of Engineers and its consultants were concerned that additional similar conditions might be found in subsequent explorations as experience has shown that such defects in similar metavolcanic rock formations usually are not isolated instances. This possibility further supports use of the higher contingency factor for the arch dam.

With regard to interest during construction, it should be recognized that, from a practical point of view, funding rates will likely govern construction periods thereby resulting in a significantly smaller advantage for the arch dam than your analysis indicates. The smaller advantage in first and investment costs in combination with the possible small advantage for operation and maintenance costs is not considered to be of sufficient magnitude to offset the economic losses and probable price level increases which would result from delays associated with the arch dam.

The GAO evaluation is based on an interest rate of 4-7/8% which is the rate prescribed by the Water Resources Council for use in FY 1970 in the plan formulation and evaluation of water resources developments. The Corps' estimates for cost of interest during construction are based on a rate of 3-1/8%, which is the rate used in justification of the initial appropriation of construction funds, in accordance with implementation of the Water Resources Regulations prescribing the interest rate to use in plan formulation and evaluation of Federal water resources projects (Title 18 of the Code of Federal Regulations, Part 704.39, Discount Rate).

[See GAO note, p. 57.]

Use of Water Reducing Admixtures

A research program undertaken at our Waterways Experiment Station established that in most lean mass concrete the use of water reducing admixtures would not be economically justified. We agree that such admixtures may be helpful in some of our structural concrete. To encourage consideration of this we will include a paragraph on water-reducing admixtures in the forthcoming revision of the Standard Guide Specifications for Concrete.

Consideration is currently being given by the American Society for Testing and Materials and Federal Agencies to permitting water reducing agents as functional additions to be included in the cement. Such a cement should effectively eliminate the principal technical problem in the use of these materials which is the incompatibility of cement and admixture. There will also be major economic benefits since a contractor will not be required to handle a separate material in the mixing plant and the cost of testing admixture will be eliminated. Performance of the addition will be checked as part of cement testing.

Design of Outlet Works for Embankment Dams

[See GAO note, p. 57.]

The buried dome gate structure has operational disadvantages and usually is not economical for projects where multi-level intakes are necessary for water quality releases. Access to gates in dome structures is more awkward and inspection and maintenance of the portion of the conduit upstream of the gates are more difficult and generally impracticable at the higher pool levels. Most of the Bureau of Reclamation irrigation projects require a smaller outlet than Corps projects since the latter usually provide for flood control releases through the outlet works. The smaller outlet requirement on the Bureau Projects permits the installation of a pipe or pipes in the conduit or tunnel (originally sized for diversion) and thereby permits an economical access to the gates in the buried dome through the same conduit or tunnel. In cases where a large conduit is required for flood control releases and a separate access must be provided to the dome structure, economy generally favors an arrangement with the gates in an upstream tower with only a single conduit for water releases through the dam. This has been verified by recent studies on two projects with embankments 205 feet and 160 feet in height.

It is agreed that in certain circumstances, such as the absence of adequate rock structure at economical depth for the foundation of a high intake tower or where a project will have a relatively small outlet, a buried dome gate structure may prove to be more feasible. ETL 1110-2-84 was issued, therefore, in response to the GAO suggestion, in order to insure that its use will be considered where design conditions warrant.

[See GAO note, p. 57.]

With respect to the last paragraph on page 21 of the draft report, the use of the oblong conduit is not restricted to dams from 100 to 160 feet in height. This is the range of applications to date; however, its use also is intended, and will provide greater economy, in dam heights greater than 160 feet.

Report Conclusions and Recommendations

We have always favored close coordination with the Bureau of Reclamation and other public and private agencies in the water resource field. There are a great many ways in which this coordination is carried out and it may be well to discuss some of the current procedures.

The Corps and the Bureau participate in formal biennial research conferences. These meetings provide for the interchange of information on research activities and include discussions of associated design and construction problems. Technical sessions are usually held on Hydraulics, Soils, Concrete and Structural, Rock Mechanics, and Electric Power. Post conference tours are a feature of these meetings and provide an opportunity for the exchange of visits to projects of the participating agencies.

Both the Corps and Bureau are well represented on the United States Committee on Large Dams, an organization whose purpose is to encourage improvements in the design, construction, maintenance and operation of large dams, and in other technical societies such as the American Society of Civil Engineers, the American Society for Testing and Materials, American Concrete Institute, U. S. Committee on Soils Mechanics and Foundation Engineering, International Commission on Irrigation and Drainage, the Reinforced Concrete Research Council, and the World Energy Conference. Corps of Engineer and Bureau representatives are very active in these societies, serving as officers of the organizations and as members of many of the technical committees. This participation provides beneficial liaison between Corps and Bureau engineers and other designers as well. The technical journals of these societies provide an excellent means of reporting criteria improvements. An example is the recent publication in the Journal of the Power Division, ASCE, of the Bureau's new design criteria for power penstocks on which the Corps prepared a discussion for publication in a subsequent journal.

Meetings of Corps and Bureau engineers are often arranged on an ad hoc basis. Examples are the visits of Corps personnel to Denver to coordinate specifications for embankment compaction with tamping rollers and to review design flood criteria. Ad hoc inter-agency meetings also are held concerning federal specifications, such as the one held by the Corps during the week of 13 July 1970, on Federal Specifications for Cement and Pozzolans.

Design help has been sought and supplied on an "as-needed" basis. An example of this type of cooperation is the loan to the Bureau of a Corps specialist on cofferdam design for the Grand Coulee new powerplant construction.

Corps of Engineers' libraries maintain an inventory of the Bureau's technical literature such as the Engineering Monographs and Design Standards for use by engineering personnel. Corps of Engineers guide specifications are furnished automatically to the Bureau upon issuance.

"Selected Water Resources Abstracts", a semimonthly publication of the Water Resources Scientific Information Center, Office of Water Resources Research, U. S. Department of the Interior, includes abstracts of current articles, reports and other publications pertinent to water resources development. It is distributed to Government Agencies and others interested in water resources projects and is an excellent aid in keeping abreast of current literature in this field, including information on design and construction of engineering works.

While these procedures have been very beneficial and productive, we agree that an expanded program to include the systematic exchange of design criteria, guide specifications, and cost guidelines, with opportunities for discussion between appropriate agency representatives, would be desirable. This matter was explored with representatives of the Bureau during a meeting which was held in Denver on 27 July 1970. Conclusions of the meeting follow:

1. Design standards and criteria, guide specifications, and cost estimating guidelines (including drafts of such material issued for field review) will be exchanged automatically at the time of issuance. For this purpose, distribution lists for various types of publications will be exchanged between the Corps and the Bureau.

2. Where practicable, questions raised by exchange of material concerning agency practices should be resolved immediately by correspondence. Meetings will be arranged to facilitate discussions between appropriate agency representatives when deemed advisable.

3. Information on engineering computer programs will be interchanged automatically when issued. The Corps will furnish the Bureau copies of the current Abstract List of Computer Programs available at Corps offices. When the proposed computer library at the Waterways Experiment Station becomes operational, the Bureau will be supplied information on available engineering computer programs on a regular periodic basis. Bureau lists of available programs plus other information generated from the Bureau of Reclamation Engineering Computer Systems (BRECS) will be furnished to the Corps.

4. Exchange of information on schedules of Intra-agency technical conferences will be made, including invitations for the other agency to attend when appropriate. In any event, the publications or minutes generated from such conferences will be exchanged.

The Chief of Engineers does not concur in the recommendation to consider further an arch dam for the New Melones site. Based upon the results of the restudy of dam type suggested by the GAO, the decision was made in March 1970 to proceed with a rockfill dam. It appeared at that time that costs to design and construct either type of dam would not be significantly different, and this assessment is still considered valid for reasons previously discussed herein under the heading of the New Melones Project. In addition, the disadvantages associated with the arch plan, which are outlined in the Corps' letter of 2 March 1970 to Mr. Allen R. Voss, Associate Director, U. S. General Accounting Office, will be avoided.

GAO note: The deleted comments relate to matters which were discussed in the draft report but omitted from this final report.

United States Department of the Interior

OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

SEP 18 1970

Mr. Allen R. Voss
Associate Director, Civil Division
General Accounting Office
Washington, D. C. 20548

Dear Mr. Voss:

The Department of the Interior has reviewed with interest the GAO Draft Report "Opportunity for Improvements in the Development and Evaluation of Design Alternatives for Federal Water Resources Projects, Corps of Engineers (Civil Functions), Department of the Army, and the Bureau of Reclamation, Department of the Interior." Our comments are directed to that portion concerned with the Bureau of Reclamation. While we are interested in the auditors' observations on the type of dam selected for the New Melones Project, we cannot comment on the procedures or judgment of the Corps of Engineers' experts on the basis of the information in the report.

We have examined the Bureau's comments concerning the portions of this report dealing with the choice of lining used on the San Luis Canal and conclude the Bureau's documented rational for their decision has not been totally included in the GAO material. This material is available for your examination if you desire.

The auditors' conclusions and recommendations state the need for improved coordination and communication between the Bureau of Reclamation and the Corps of Engineers regarding design of water resources projects. At present there is a meaningful exchange of information by way of specifications, laboratory reports, and other printed documents. There is also an exchange of information through professional society meetings. Both the Bureau and the Corps participate actively in technical societies such as American Society of Civil Engineers, American Society for Testing and Materials, American Concrete Institute, U.S. National Committee on Soil Mechanics and Foundation Engineering, International Commission on Irrigation and Drainage, World Energy Conference, and the U.S. Committee on Large Dams. More specifically,

design practices of the Bureau and the Corps, as well as those of major engineering consulting organizations, are being continually reported and compared within the technical committee structure of the American Society of Civil Engineers. For example, top level design representation of the Corps and the Bureau has for many years existed on the Committee on Embankment Dams and Slopes of the Soil Mechanics and Foundations Division. Similar representation has existed on technical committees in the Hydraulics Division, Power Division, and Structural Division of the Society. Through committee meetings, committee reports, and presentation of papers on design of projects, Corps and Bureau practices for major structures are disseminated to each other as well as to the engineering profession at large.

Since 1960 biennial conferences on coordination of research activities have been held among the Bureau of Reclamation, Corps of Engineers, Tennessee Valley Authority, and Bonneville Power Administration. These 3-day conferences include a detailed review of research programs to avoid duplication of effort in such activities as structures, hydraulics, and materials. Design and operating philosophies and practices of the Corps of Engineers and the Bureau of Reclamation are discussed in connection with these research coordination meetings. Typical design matters included are slope stability and dam design; earthquake engineering; hydraulic energy dissipators; gates, valves, and control devices; vibration of structures and equipment; hydraulics of intakes; riprap studies; air-entrainment studies; waterways; water measurement; pipeline and tunnel hydraulics; structural analysis and design; rock mechanics; electric power systems; and transmission line structures and hardware.

Cooperation on specific problems has been effected by consultation and individual assignments such as visits by the Corps personnel to study arch dams analysis, to utilize our facilities, and consultation in analysis of a specific structure, and to assist us in design of a large cellular cofferdam in an area where they had constructed similar facilities. On a number of occasions the Bureau has met with the Corps to discuss or coordinate construction specifications. As an example, in October 1969, a meeting was held between the Bureau and the Corps to discuss modification of specifications for sheepsfoot rollers. This resulted in an agreement on a specification that would permit manufacturers of sheepsfoot rollers to meet the requirements of both the Corps and the Bureau.

The two agencies have been fully cooperative in the field of flood hydrology, reservoir flood storage, spillway capacity design, and flood releases from reservoirs. Through such cooperation the spillway of the Auburn Dam on the American River was designed to permit a great deal of flexibility in controlling flood releases and allocations of flood storage capacities in Auburn Reservoir and the downstream Folsom Reservoir.

In a joint meeting between the Corps and the Bureau in July 1970 it was concluded that a formalized exchange of design information would be beneficial to both agencies. This will be accomplished by the following procedures:

1. Design standards and criteria, guide specifications, and cost estimating guidelines (including drafts of such material issued for field review) will be exchanged automatically at the time of issuance. For this purpose, distribution lists for various types of publications will be exchanged between the Corps and the Bureau.

2. Where applicable, questions raised by exchange of material concerning agency practices should be resolved immediately by correspondence. Meetings will be arranged to facilitate discussions between appropriate agency representatives when deemed advisable.

3. Information on engineering computer programs will be interchanged automatically when issued. The Corps will furnish the Bureau copies of the current Abstract List of Computer Programs available at Corps offices. When the proposed computer library at the Waterways Experiment Station becomes operational, the Bureau will be supplied information on available engineering computer programs on a regular periodic basis. Bureau lists of available programs plus other information generated from the Bureau of Reclamation Engineering Computer Systems (BRECS) will be furnished to the Corps.

4. Exchange of information on schedules of intra-agency technical conferences will be made, including invitations for the other agency to attend when appropriate.

In any event, the publications or minutes generated from such conferences will be exchanged.

In regard to the last recommendation on page 42, we believe that alternative studies, using established engineering economic principles, are a basic professional requirement. Written procedures for making comparisons of alternatives for accomplishing engineering work are not generally considered necessary or appropriate. Alternatives and comparisons thereof usually involve different factors for each individual job. Feasibility, judgment, economics experience, new developments and intangibles are all part of the background considered in rendering an engineering decision.

We appreciate the opportunity to have commented on this report in draft.

Sincerely yours,

J. J. Hall, Jr.

Director of Survey and Review

COPY

TYPES OF DAMS

EMBANKMENT DAMS

An embankment dam is constructed of natural excavated materials placed without the addition of binding materials other than those inherent in the natural material. The materials are usually obtained at or near the dam site. Embankment dams are referred to types such as earth fill or rock-fill. Its chief disadvantage is that embankment sections can never be overtopped without damage; consequently, a spillway of adequate size must always be provided.

Site conditions which lead to the adoption of an embankment dam rather than a concrete dam usually are: (1) a wide stream valley, (2) lack of firm rock abutments, (3) considerable depths of earth overlying bedrock on the valley floor, (4) poor quality of bedrock from a structural point of view, (5) availability in adjacent borrow areas of sufficient quantities of suitable soils, (6) existence of a good site for a spillway of sufficient capacity to prevent overtopping, and (7) inaccessibility of site, which would render importation of construction materials expensive.

CONCRETE GRAVITY DAMS

The solid gravity dam is the most commonly used type of concrete dam structure. It relies solely on its weight for stability. This type of structure has an excellent record for safety and low-maintenance cost. An important feature of gravity dams is the relative simplicity in which a safe spillway and outlet works may be provided without the necessity of separate structures for these features.

Following are site conditions favoring the use of gravity dams.

1. Shallow depth of overburden.

2. A firm rock foundation which is capable of supporting the resulting vertical and horizontal loads without progressive crushing, shearing, or settlement.

3. An adequate source of acceptable fine and course aggregate for the required volume of concrete.

CONCRETE ARCH DAM

An arch dam is a solid concrete or masonry dam, curved upstream, which, in addition to resisting part of the pressure of the reservoir by its own weight, obtains a large measure of stability by transmitting the remainder of the water pressure or load by arch action into the canyon walls. The ideal site for an arch dam is a narrow, symmetrical V-shaped valley. Wide sites are less desirable because a greater portion of the load is carried vertically to the foundation in the central part of the dam. Therefore for sites that are less than ideal, arch dams must be thickened or shaped to improve their load-carrying ability.

PRINCIPAL MANAGEMENT OFFICIALS

RESPONSIBLE FOR

ADMINISTRATION OF ACTIVITIES

DISCUSSED IN THIS REPORT

	Tenure of office	
	From	To
DEPARTMENT OF DEFENSE		
SECRETARY OF DEFENSE:		
Melvin R. Laird	Jan. 1969	Present
Clark Clifford	Mar. 1968	Jan. 1969
Robert S. McNamara	Jan. 1961	Feb. 1968
DEPARTMENT OF THE ARMY		
SECRETARY OF THE ARMY:		
Stanley R. Resor	July 1965	Present
Stephen Ailes	Jan. 1964	July 1965
Cyrus R. Vance	July 1962	Jan. 1964
Elvis J. Stahr, Jr.	Jan. 1961	June 1962
CHIEF OF ENGINEERS:		
Lt. Gen. Frederick J. Clarke	Aug. 1969	Present
Lt. Gen. William F. Cassidy	July 1965	Aug. 1969
Lt. Gen. Walter K. Wilson, Jr.	May 1961	June 1965
DEPARTMENT OF THE INTERIOR		
SECRETARY OF THE INTERIOR:		
Rogers C. B. Morton	Jan. 1971	Present
Fred J. Russell (acting)	Nov. 1970	Jan. 1971
Walter J. Hickel	Jan. 1969	Nov. 1970
Stewart L. Udall	Jan. 1961	Jan. 1969

	Tenure of office	
	From	To
DEPARTMENT OF THE INTERIOR (continued)		
ASSISTANT SECRETARY FOR WATER AND POWER DEVELOPMENT:		
James R. Smith	Mar. 1969	Present
Kenneth Holum	Jan. 1961	Jan. 1969
COMMISSIONER OF RECLAMATION:		
Ellis L. Armstrong	Nov. 1969	Present
Floyd E. Dominy	May 1959	Oct. 1969

U.S. GAO Wash., D.C.