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REPORT OF THE COMPTROLLER GENERAL OF THE UNITED STATES

LM102458

Actions Needed To Increase The Safety Of Dams Built By The Bureau Of Reclamation And The Corps Of Engineers

After reviewing procedures and practices used by the Bureau of Reclamation in constructing the Teton Dam which collapsed in 1976, GAO found that the Bureau

--used questionable design practices and did not use an independent review process to confirm its design decisions,

--did not always implement designer's intent,

--took unnecessary risks and relied too much on the adequacy of its design instead of monitoring and controlling dam safety during reservoir filling,

--did not heed a lesson on reservoir filling which it identified 10 years earlier when another dam almost failed, and

--did not establish an effective emergency preparedness plan.

GAO makes recommendations to improve dam safety which apply to both the Bureau and the Corps of Engineers.

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JUNE 3, 1977

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

B-125045

The Honorable Leo J. Ryan
Chairman, Environment, Energy, and
Natural Resources Subcommittee
Committee on Government Operations
United States House of Representatives

Dear Mr. Chairman:

As requested in your July 20, 1976, letter, this report discusses the dambuilding procedures and practices used by the Bureau of Reclamation and the Corps of Engineers relating to the safety of dams.

As discussed with your office, restricted copies of this report are being provided to Senator Walter Huddleston of Kentucky with the stipulation that any further distribution of the report by the Senator must be cleared first with your office.

In accordance with discussions with your office, the agencies were given fifteen days to provide their written comments. Written comments were received within this time frame from the Department of the Interior and the Federal Coordinating Council for Science, Engineering, and Technology. The matters covered in the report, however, were discussed with Department of Defense officials and their comments are incorporated where appropriate.

This report contains recommendations to the Secretary of the Interior, the Secretary of Defense, and the Chairman of the Federal Coordinating Council for Science, Engineering, and Technology on pages 40, 41, 45, 64, 65, 72, 78, 79, 80, and 81. As you know Section 236 of the Legislative Reorganization Act of 1970 requires the head of a Federal agency to submit a written statement on actions taken on our recommendations to the House Committee on Government Operations and the Senate Committee on Governmental Affairs not later than 60 days after the date of the report and to the House and Senate Committees on Appropriations with the agency's first request for appropriations made more than 60 days after the date of the report. We will be in touch with your office in the near future to arrange for release of the report so that the requirement of Section 236 can be set in motion.

Sincerely yours,

Elmer B. Staats

Comptroller General
of the United States

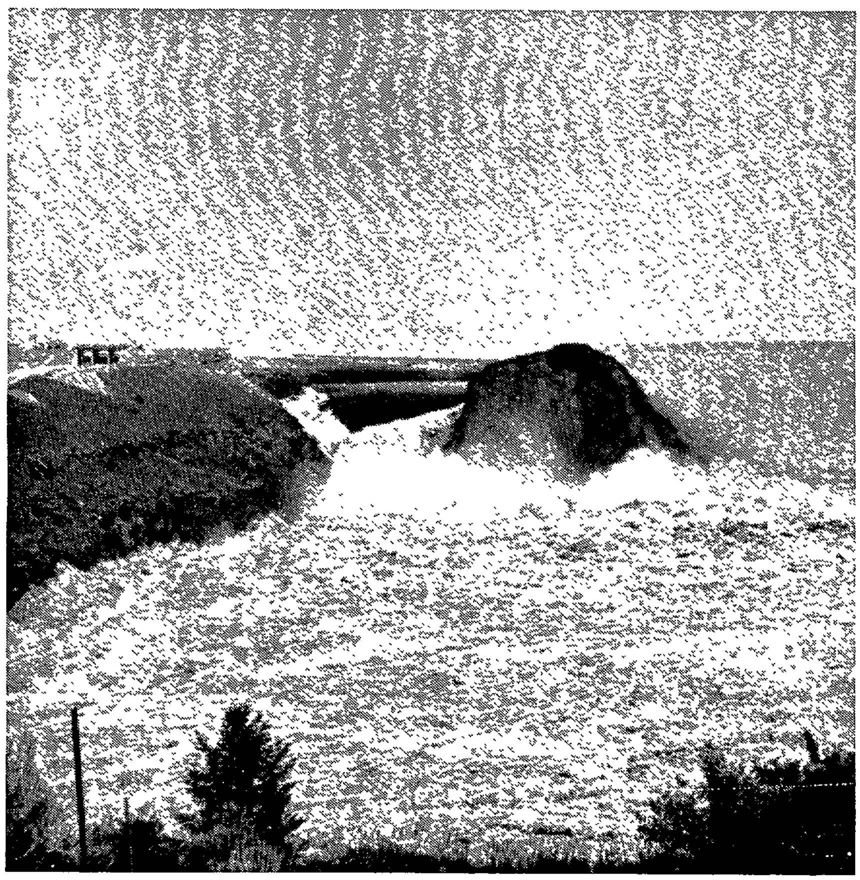
COMPTROLLER GENERAL'S REPORT
TO THE SUBCOMMITTEE ON ENVIRONMENT,
ENERGY, AND NATURAL RESOURCES
COMMITTEE ON GOVERNMENT OPERATIONS
HOUSE OF REPRESENTATIVES

ACTIONS NEEDED TO INCREASE THE SAFETY OF DAMS BUILT BY THE BUREAU OF RECLAMATION AND THE CORPS OF ENGINEERS

D I G E S T

In the aftermath of the 1976 Teton Dam disaster, GAO reviewed the dambuilding procedures and practices used by the Bureau of Reclamation--which designed and constructed Teton--and by the Corps of Engineers to determine whether changes are needed relating to the safety of dams being built.

GAO made a comparative analysis of the procedures and practices used at the Bureau's Teton Dam and



WATER GUSHING THROUGH THE RIGHT SIDE OF THE 305–FOOT TETON DAM IN THE EARLY AFTERNOON ON JUNE 5, 1976

SOURCE: BUREAU OF RECLAMATION

Tear Sheet. Upon removal, the report cover date should be noted hereon.

CED-77-85

the Corps' Ririe Dam, both located in Eastern Idaho. Also, GAO compared aspects of these procedures and practices with those used on 17 other Bureau and Corps dams located in the Western States and those used by the Tennessee Valley Authority and others. (See pp. 1, 4 and 5.)

WHAT WENT WRONG AT TETON DAM

Circumstances leading to the Teton Dam collapse showed that the Bureau of Reclamation:

--Used questionable practices of design relating to safety. (See p. 31.)

--Did not use an independent review process to confirm its decisions as to design. (See p. 38.)

--Did not always carry out during construction the intent of its designers. (See p. 42.)

--Took unnecessary safety risks and relied too much on the adequacy of its design instead of keeping watch over, and controlling, dam safety during reservoir filling. (See p. 46.)

--Did not heed a seemingly valuable lesson about controlling reservoir filling which it identified when another dam almost failed about 10 years earlier. (See p. 60.)

--Did not establish an effective emergency preparedness plan for notifying people downstream what to do in the event of dam failure. (See p. 66.)

In its December 1976 report, the Independent Panel to Review Cause of Teton Dam Failure--established at the request of the Secretary of the Interior and the Governor of Idaho--concluded that an unfortunate choice of design together with less than conventional precautions led to the failure of Teton. (See pp. 23 and 24.)

GAO found that the Corps, unlike the Bureau at Teton, emphasized multiple defenses in its dams to prevent erosion from seepage. (See pp. 35 and 38.) Also, independent consultants were used more frequently by the Corps and other Federal and State agencies involved in dambuilding to confirm design adequacy and other decisions on which designs were based. (See pp. 38 and 39.)

Although the principal Bureau designer said that he intended for open cracks in the foundation of Teton to be sealed, other Bureau officials said that this intent was not fully carried out because of unclear instructions, drawings, and specifications and misunderstandings by project staff. Another factor was that designers made only a few visits to the damsite and none when the cracks were to be filled. Moreover, the construction engineers at the site said the designers did not provide adequate direction or guidance on the treatment of open cracks. The possible consequence of the inadequate treatment of certain cracks was addressed by the Panel, who said that this was a contributing factor in the failure of Teton Dam. (See pp. 42 to 45.)

In addition, several key monitoring and controlling measures were neither available nor used when Teton failed. For example:

--Bureau designers did not intend to install appropriate seepage detecting instruments at the Teton Dam because they were confident that Teton was adequately designed to protect against erosive seepage. (See pp. 48 to 50.)

--Pertinent information available to the Bureau at the damsite during the weeks preceeding the failure, which, according to Bureau designers, could have given a clue as to the seepage conditions affecting the dam, was sent routinely from the project to the designers. It arrived the day after the failure. (See pp. 50 to 55.)

--Visual observations at the dam were not made on a 24-hour basis during the critical reservoir filling stage; consequently, evidence of erosion from the leak in the Teton Dam could not be observed and remedial actions begun until after the project staff arrived at the damsite about 5 hours before the failure. (See pp. 55 and 56.)

--When this evidence was discovered, the Bureau's staff at Teton could not immediately open the main river outlet drain because a contractor was behind schedule in completing work on this structure. (See pp. 58 and 60.)

--Bureau designers intended to fill the Teton Dam reservoir slowly to observe the behavior of the dam and allow them to take remedial actions if problems developed, but deviations of up to 4 times more than the filling rate originally approved were permitted by the Bureau, apparently to avoid the possibility of incurring contractor claims. (See pp. 56 to 60.)

No one knows whether the leak at Teton would have developed as quickly as it did, or whether the failure could have been prevented, if the reservoir had been filled slowly and the main river outlet drain had been available, as planned, to release water. With no instrumentation available to determine whether the leaky foundation rock had been sealed or whether potentially dangerous cracks were developing, with no adequate means for quickly recognizing conditions that could adversely affect dam safety, and with no means to open the main river outlet drain immediately when an emergency is recognized, the Bureau took unnecessary risks and placed too much reliance on the adequacy of its design.

RECOMMENDATIONS

While GAO was making its study, the Bureau announced that a review of its design for all storage dams would be made by independent consultants. In addition, the Department of the Interior asked for bids from consulting firms to study whether the Bureau's internal review system and its technical procedures used in planning, designing, and constructing dams follow reasonable safety standards within the limits of existing technology. (See pp. 38 to 40.)

GAO fully supports the actions announced by the Bureau and the Department. It is also recommending that:

--Independent review for all storage dams be made part of the Bureau's instructions.

--Independent review of the Bureau's technical procedures specifically address the questionable design practices identified by the Independent Panel.

--The Corps revise their procedures and practices to make sure that their designs for all storage dams, where there is or could be a potential hazard to public safety, be reviewed by independent consultants since GAO found that this was not always done. (See pp. 40 and 41.)

GAO is also recommending that:

--The Bureau develop instructions and drawings that more clearly reflect the intent of its designers.

--Bureau designers visit the site frequently to be as sure as possible that design intent is achieved. (See p. 45.)

Although Corps practices for monitoring and controlling dam safety during reservoir filling generally were found to be better than those used by the Bureau at Teton, both the Corps and the Bureau have procedural gaps which could seriously reduce their capabilities to detect and rectify problems that develop in a dam during initial reservoir filling.

GAO is recommending that:

--Improved policies and procedures in both organizations be established regarding (1) requirements for the amount and use of instrumentation for monitoring changing conditions inside the dam and the abutments, (2) requirements for visual inspections during reservoir filling, (3) availability and capacity of outlet drains, and (4) appropriate reservoir filling criteria.

--The independent design review process also be used by both the Bureau and the Corps to be as sure as possible that designers and others who formulate monitoring programs systematically evaluate various surveillance methods and recommend appropriate solutions. (See pp. 64 and 65.)

This report also contains GAO's conclusions and recommendations concerning Bureau and Corps site investigation procedures and practices, emergency preparedness plans and procedures, the systems for considering information obtained from Geological Survey, and problems identified by other agencies, groups, or individuals. (See chs. 2, 6 and 7.)

On April 23, 1977, the President issued a memorandum directing the head of each Federal agency that has a role affecting the safety of dams to immediately undertake a thorough review of its practices. These reviews will be used to coordinate dam safety programs and develop proposed Federal dam safety guidelines. GAO is recommending that actions taken or planned by the Bureau and the Corps on GAO's recommendations be specifically addressed in the reports on the reviews performed in accordance with the April 23, 1977, memorandum and that the applicability of GAO's recommendations to Federal agencies in addition to the Bureau and the Corps be evaluated in developing the proposed Federal dam safety guidelines. (See pp. 80 and 81.)

Copies of this report were sent, for review and comment, to the Secretaries of the Interior, Defense, and Army; to the Office of the Chief of Engineers; and to the Chairman of the Federal Coordinating Council for Science, Engineering, and Technology. Their comments were considered in finalizing this report. Bureau and Corps officials agree that the report was accurate; they and the Chairman of the Federal Coordinating Council stated that GAO's recommendations would be considered in developing improved policies and procedures.

Contents

ABBREVIATIONS

DPR	Definite Plan Report
E&R Center	Engineering and Research Center
GAO	General Accounting Office
OCE	Office of the Chief of Engineers
TVA	Tennessee Valley Authority
USGS	United States Geological Survey

CHAPTER 1

INTRODUCTION

On June 5, 1976, the newly constructed Teton Dam in Eastern Idaho collapsed. The flooding caused 11 deaths, an estimated $400 million in property damage, and a disruption of the lifestyle of thousands of people residing in the basin. The failure also created a great deal of interest and concern among dam experts throughout the world, the Congress, and the general public. As a result, several studies were initiated to determine the causes for the failure and to evaluate procedures and practices for siting, designing, and building Federal dams.

On July 20, 1976, the Conservation, Energy, and Natural Resources Subcommittee (currently the Environment, Energy, and Natural Resources Subcommittee) of the House Committee on Government Operations requested that we examine the site selection process for Teton Dam, and other selected dams, to provide a comparative analysis of the adequacy of the methods and procedures used by the Bureau of Reclamation and the Corps of Engineers. The Subcommittee also asked us to review the adequacy of the procedures followed when potential problems are identified, particularly from external sources, during the site selection and/or construction process.

Findings of a major study to investigate specific causes of the Teton Dam failure completed in December 1976 by the Independent Panel to Review Cause of Teton Dam Failure--appointed by the Secretary of the Interior and the Governor of the State of Idaho--revealed a number of weaknesses in the way Teton was designed. (See ch. 3.)

In this report, GAO goes beyond the scope of the Independent Panel's work and findings and examines the site selection, design, and monitoring process to determine if the Bureau and Corps could significantly reduce the risk of future dam failures through improved policies, procedures, and practices.

In addition to the study by the Independent Panel and GAO's review, the Department of the Interior has been conducting or considering studies of both the cause of the Teton Dam failure and the overall policies, procedures, and practices used by the Bureau to construct dams. A report on the cause of the failure was issued in April 1977 by Interior's Teton Dam Failure Review Group and the following procedural reviews were completed, underway, or planned as of the end of April 1977:

--A non-technical review of the Bureau's administrative procedures (completed in December 1976).

--A technical review of the Bureau's decision-making procedures and criteria and its design practices (proposed to be under contract for about 1 year beginning after April 1977).

--An assessment of the criteria for evaluating and reviewing the safety of existing Bureau dams by the National Academy of Sciences' National Research Council (expected to be completed in February 1978).

Also, on April 23, 1977, the President directed that certain actions be taken to coordinate Federal dam safety programs and to develop proposed Federal dam safety guidelines. (See ch. 8.)

RESPONSIBILITIES AND FUNCTIONS OF THE BUREAU AND CORPS

Bureau

The Reclamation Act of 1902 (43 USC 371 et. seq.) authorizes the Secretary of the Interior to plan, build, operate, and maintain water projects designed to reclaim arid and semiarid lands in the 17 Western States. In achieving this end, the Bureau of Reclamation has designed and constructed more than 300 major dams and numerous other water distribution systems.

The organizational structure of the Bureau consists of the Office of the Commissioner in Washington, D.C., the Engineering and Research (E&R) Center in Denver, seven regions, and project and other operating offices within the seven regions. The Commissioner and his staff are responsible for establishing policy and for working with congressional delegations and committees in obtaining authorizations of projects by the Congress. They are also instrumental in securing funds for investigations, construction, and operations and maintenance of reclamation projects.

Organizational components within the E&R Center include, among others, the Office of Design and Construction and the Division of Planning Coordination. The Office of Design and Construction, which comprises most of the E&R Center staff, is responsible for the design of virtually all Bureau projects and for overseeing the construction of these projects. The Division of Planning Coordination provides planning guidelines and technical assistance and reviews planning products. In this role, the Division works with both the Commissioner's office and the regional offices.

Each region has responsibilities within its boundaries for planning Bureau projects, for providing administrative services and technical supervision associated with construction, and for operating and maintaining existing projects. Each region has several satellite offices whose functions are to carry out responsibilities within a local area.

Corps

The Corps has both civil and military functions within the Department of the Army. One important civil function of the Corps is the construction, operation, and maintenance of navigation, flood control, and multiple-purpose projects throughout the Nation. Since the inception of its civil works responsibility in 1824 (4 Stat. 32), the Corps has built more than 400 dams.

The Corps is organized in three basic tiers--the Office of the Chief of Engineers (OCE), under which are the 11 divisions and 36 districts. Decentralization is a basic tenet of Corps organization and structure.

OCE is the Chief of Engineer's headquarters staff and assists him in planning and controlling Corps activities. As a basic policy, OCE provides staff supervision while field offices plan, direct, and execute operations. The Director of Civil Works is responsible for civil works functions at the OCE level, including supervision of planning, design construction, and operation and maintenance of civil works projects. OCE provides the divisions and districts guidance as to policies and criteria for use in planning, designing, and constructing water resource projects. The Board of Engineers for Rivers and Harbors, also at the OCE level, makes independent reviews of planning documents and reports prepared to determine the advisability of authorizing water resources projects.

The bulk of the Corps' work is accomplished in its field offices. The divisions are responsible for administration, supervision, and coordination of the work of the districts within their geographical boundaries. This includes review and approval of the major plans and programs developed by the districts. The districts are the principal planning and project implementation offices of the Corps. They prepare and submit water resource needs and development studies in response to congressional resolution, and develop the design for, construct, operate, and maintain water resource projects. The districts have area or resident offices at projects under construction for immediate supervision and inspection of the work as it progresses and for maintenance of operating projects.

SCOPE OF REVIEW

We reviewed records, instructions, guidelines, and other data on the site selection, design, construction, and monitoring process in both the Corps and Bureau. In the Bureau, work was performed at the Pacific Northwest, Mid-Pacific, and Upper Colorado Regions; the Engineering and Research Center, Denver, Colorado; and the Office of the Commissioner, Washington, D.C. We visited Teton, Soldier Creek, Current Creek, Palisades, and Auburn dams and talked with Bureau project people at these sites when available.

We obtained and evaluated similar data at Corps Districts in Walla Walla, Washington; Portland, Oregon; and Sacramento, California; the North Pacific Division; and OCE, Washington, D.C. We visited Ririe Dam in Eastern Idaho and talked with the Project Engineer.

To better understand and evaluate the Bureau and Corps dambuilding processes, we reviewed in detail site selection, design, and monitoring practices and procedures for Teton and Ririe dams. We also reviewed certain aspects of this process in relation to the Bureau's Auburn, Crystal, Pueblo, Sugar Pine, Ridgeway, Tyzack, Scoggins, Savory, and Pot Hook dams and the Corps' Applegate, Buchanan, Little Del, Lost Creek, New Melones, Marysville, Hidden, and Lakeport Lake dams.

Except for certain delays in a construction contractor's performance (see pp. 58 and 60) and an apparent misunderstanding among the Project Construction Engineer, a construction contractor, and the Bureau's designers regarding the treatment of cracks in the Teton Dam's foundation (see pp. 42 to 45), we did not review construction practices or contractor performance during our study because our preliminary investigations and those of the Independent Panel, formed to identify the causes for the Teton Dam failure, disclosed no other major weaknesses in this area.

We identified procedures and practices of other organizations that design and construct major dams in the United States. Also, we visited Bechtel, Inc., Aluminum Corporation of America, Tennessee Valley Authority (TVA), and the State of California Department of Water Resources, all of which have built major dams in the United States or elsewhere.

We also held discussions with officials at the U.S. Geological Survey (USGS) headquarters in Washington, D.C., and its regional office in Denver, Colorado; the Federal Power Commission, Washington, D.C.; and the Nuclear Regulatory Commission, Washington, D.C., regarding the siting and designing of dams.

Two consultants--Herbert D. Vogel and William L. Wells--highly qualified in dam siting, design, and construction assisted us in our review.

Copies of this report were sent, for review and comment, to the Secretaries of the Interior, Defense, and Army; to the Office of the Chief of Engineers; and to the Chairman of the Federal Coordinating Council for Science, Engineering, and Technology. Written comments were received from the Department of the Interior and the Federal Coordinating Council. (See apps. I and II.) Discussions were held with Bureau of Reclamation officials and Department of Defense officials including the Corps. Bureau and Corps officials agreed that the report was accurate; they and the Chairman of the Federal Coordinating Council stated that our recommendations would be considered in developing improved policies and procedures.

CHAPTER 2

A COMPARISON OF BUREAU AND CORPS SITE INVESTIGATION PROCEDURES AND PRACTICES

Site investigations to select the most suitable damsites are an integral part of the planning and design processes for the Bureau and Corps. The investigations are made to select the most suitable damsite on the basis of engineering and economic considerations and to accumulate sufficient data to properly design a safe dam for that site.

The ultimate selection of a damsite is based on an evaluation of many factors including safety, economic feasibility, environmental impact, local support, and its suitability in meeting local water resource needs. Significant problems related to any one of these factors may lead to site abandonment. As long as considered sites are safe, cost is often the primary factor in choosing the final site.

Bureau and Corps officials told us that there are no problem-free damsites, but rather each site has different conditions that bear on dam safety. Some are of such difficulty or complexity that building a dam within available funds is not feasible, while others can be safely and economically dealt with through proper engineering.

The Bureau, unlike the Corps and many other organizations, generally did not utilize an independent review process to assess the adequacy of site investigations to reaffirm geology and design decisions. (See ch. 3.) This is particularly important because many remaining damsites are considered more difficult sites which must be thoroughly investigated before dam design and construction.

BUREAU SITE SELECTION AND INVESTIGATION PROCESS

The site selection process typically takes several years and involves three phases, or levels, of investigation: appraisal, feasibility, and advance planning. Site investigations--defining surface and subsurface geologic conditions, analyzing hydrology conditions, and obtaining other information needed to assess the suitability of damsites and satisfactorily define site conditions--generally become increasingly more detailed through each of these phases. These investigations continue into the preconstruction and construction of a project.

Bureau instructions and guidelines define the types of investigative work to be performed during various project phases. However, the Bureau has no criteria that specifically defines acceptable site conditions, the scope of investigations at alternative damsites, or the thoroughness of investigations needed for design purposes. Bureau officials do not believe these can be defined because each site has unique conditions requiring different degrees of work. The Bureau relies on the judgment of their geologists, designers, and other experienced personnel for decisions on these matters. Officials from the Corps, TVA, and the State of California agreed and said that they too rely on the judgment and experience of their personnel.

We found no significant difference in the site selection process as carried out in various Bureau regions. Each phase is discussed primarily on the basis of comments made by regional and E&R Center officials.

Appraisal

The appraisal level investigation (formerly called reconnaissance) is the first phase of the Bureau's project planning process. This phase involves a relatively brief analysis of a study area's water resources needs and alternative plans to meet the needs. The purpose of the study is to determine if more detailed analyses of the alternatives are warranted.

Regional offices are responsible for conducting appraisal studies and preparing the report. The E&R Center reviews the reports for completeness and technical adequacy and will assist, if requested by the regions, in the investigations and design studies. The Bureau's alternative plans considered to meet resource needs may include various combinations of storage or diversion dams and reservoirs, water conveyance and distribution systems, and hydroelectric power and pumping plants. The most favorable plan (or plans) is discussed in more detail to include an analysis of costs and benefits. The report provides the basis for congressional authorization of the more detailed feasibility level studies.

If the appraisal level alternatives being considered involve one or more dams, possible damsites will be investigated. This usually begins by an office research effort, utilizing such sources as topographic maps and any previous studies of area damsites conducted by the Bureau or others. For example, the Bureau reviews available maps, bulletins, and periodicals prepared by USGS or State geologists relative to areas encompassing the damsites under review. This research is followed by onsite inspections by engineers and geologists. From these visits some sites can often be eliminated from further consideration on the basis of observed unsafe conditions (e.g., high potential for large landslides) or conditions that would make construction at that site uneconomical.

From those sites judged to be feasible from safety and engineering standpoints, the most favorable site is then chosen on the basis of other factors such as cost, environmental impact, and suitability to meet project needs. Thus, geologic conditions and problems have a two-fold bearing on the selection of the most favorable site; they affect judgments on site safety and affect project cost.

More detailed analyses are then prepared on the site judged to be the most favorable. Benefits associated with the site are better defined. A geologic report is prepared, containing conclusions on such matters as foundation rock conditions, available construction materials, and stability of the damsite. The report, however, is considered preliminary as only limited geologic investigations are performed at the appraisal phase. Subsurface drilling is normally not done. Geologic data is based on visual observations and on readily available data (e.g., previous geologic studies done by the Bureau or others).

Appraisal level design drawings may also be prepared to facilitate the estimate of project cost. Such drawings for earth dams would include general plan and profile views of the proposed structure, which would show dimensions of the embankment and locations of major features (e.g., spillway, powerhouse outlet works). A maximum section drawing would also be made showing the proposed composition of the dam and the location of various internal features (e.g., cutoff trench, filters, impervious fill, etc.).

Feasibility

The feasibility level investigation is the second phase of the Bureau's project planning process. Basically, this phase continues in more detail the activities carried out during the appraisal level studies. The purpose of the study is to firmly identify the best plan for meeting the water resource needs of the area under study and the costs and benefits associated with that plan.

Regional offices are responsible for conducting the feasibility study and preparing the report. During this phase, the E&R Center takes a more active role in planning needed investigative work and providing technical assistance.

It reviews the feasibility report for completeness and technical adequacy. Congressional authorization for construction is based on the report.

The study area's resources and needs are reevaluated and better defined. The alternative plans to meet these needs are also reevaluated. If a dam is considered one of the best alternatives, the site judged most favorable will be investigated in more detail to ensure that a dam is technically feasible and to fully identify the costs and benefits associated with that site.

A drilling program is laid out by geologists and designers to determine subsurface conditions at key locations, such as abutments, possible spillway and outlet works locations, and the valley floor. The number of holes drilled during feasibility investigations may vary significantly; about four holes are considered the minimum but many more may be drilled depending upon site conditions. Generally, alternative sites would not be drilled unless (1) the initial drilling program indicated unsatisfactory or doubtful geologic conditions or (2) another site was judged to be more favorable because of such factors as environmental impact, project cost, or suitability to better meet project needs. Based on the drilling program, other geologic activities carried out, and other available information, a report is prepared on the geologic conditions at the damsite and in the reservoir.

Although feasibility level design drawings of the dam are considered tentative because they are based on limited data, they are prepared to provide a better basis for determining project cost. These would be similar in nature to those prepared during the appraisal level as discussed previously.

Advance planning

During the advance planning phase the feasibility level studies are reevaluated and updated, if necessary, in light of any changed conditions (e.g., inflation, new developments in the area, changes in local interest) that take place between project authorization and appropriation of construction funds. This may cause substantially more field investigations and changes in the feasibility plan, including changes of the damsite and the type of dam.

Usually, the Bureau finds its project plan, as updated by the advance planning effort, consistent with the authorizing legislation. In this case, preconstruction level exploration work is started to provide data needed for the detailed design of the structure. Also, the Bureau executes contracts with water users for repayment of reimbursable costs and other groups that will operate various project features (e.g., wildlife reserves and recreation facilities). If its project plan is inconsistent with the authorizing legislation, the Bureau resubmits the project to the Congress for authorization.

The regional offices are responsible for conducting the advance planning effort and for preparing a Definite Plan Report (DPR). The DPR is an internal report of the advance planning findings for the Commissioner. The E&R Center provides technical assistance, develops the exploration program, and reviews the DPR report.

Post planning processes impact on site selection

After the three planning phases, detailed site investigations continue in the "preconstruction" phase to provide the data needed to develop project design specifications. Bureau designers told us that the project investigation is not finished until the dam is essentially complete, and that design changes frequently occur during construction. For example, early in the construction phase, excavation of the foundation may disclose new data on specific aspects of the site which can change the design.

By the time a project reaches the construction phase, the general suitability of the site should be well established and changes would not be likely. Bureau officials told us there have been cases where sites have been abandoned after starting the construction phase because of environmental or economic reasons or lack of public support, but they said that the Bureau has never changed or abandoned a site after beginning construction because of engineering or geologic deficiencies. However, Bureau officials told us that if at any time information indicates a safe structure cannot be built at a particular site, the site will be abandoned.

The degree or magnitude of site investigations varies from project to project depending on the site conditions encountered and the exploratory work deemed necessary by Bureau personnel. Certain aspects of site investigations at three different projects are described below to illustrate this point and to provide a basis for better understanding the process.

Site selection and investigation for Teton Dam

The first time a large multipurpose dam was considered on the lower reaches of the Teton River was during a 1955-60 joint Bureau-Corps broad survey of developmental opportunities in the Upper Snake River Basin. Among the potential projects identified was a 300-foot high earthfill dam at the Fremont damsite to provide flood control, irrigation, and other benefits.

The Bureau's Pacific Northwest Regional Office conducted a reconnaissance level investigation of the Teton Basin during 1959-61. A geologic report was completed on the Fremont damsite in January 1961, and a reconnaissance level design was prepared the following April. The final project reconnaissance report, completed in October 1961, concluded that multipurpose development of the lower division of the Teton Basin would have technical, economic, and financial feasibility. The project, including a 310-foot high earth dam at the Fremont site, was estimated to cost $52 million with a benefit-cost ratio of 1.79 to 1.

Throughout the reconnaissance and subsequent investigation phases, only one site, Fremont (later named Teton), was ever studied in detail by the Bureau. While other sites were visually inspected, they were not investigated by subsurface drilling. Bureau officials told us that a dam at the Teton site would hold more water for irrigation, power, and flood control purposes than other sites. They also told us that the site was closer to the water users and that the terrain at the site was suitable for construction of a spillway and other project features. These factors, in the opinion of Bureau officials, made the Teton site more economically favorable than other potential sites. From a safety standpoint, Bureau geologists believed that the Teton site was geologically similar to other sites, and Bureau designers believed that a safe dam could be constructed there.

The Bureau began a drilling program for feasibility level studies in July 1961. In the 1961-62 period, 12 holes were drilled--10 near the damsite and 2 in the reservoir area. Another geologic report was prepared in February 1963 and a feasibility design was completed the following June. However, a project feasibility report was never prepared. Because of the seriousness of an alternate drought and flooding cycle in the Teton area in 1961-62, there was pressure for early authorization of the project. At the request of the Commissioner, the Pacific Northwest Regional Office prepared a special report in March 1962 based primarily on reconnaissance data. This report was used to seek congressional authorization rather than waiting for the completion of a feasibility level report which is normally required for authorization. The project was authorized for construction at the Fremont damsite on September 7, 1964.

In April 1967 the subsurface drilling program resumed. One year later the preliminary geology report prepared during the feasibility stage was updated on the basis of additional geological explorations, including a reservoir seepage loss study and subsurface drilling. In February 1969 the Pacific Northwest Region submitted its Definite Plan Report to the Commissioner. The Regional Director noted that the plan for development of the first phase of the lower Teton division--which included the Teton dam, reservoir, and powerplant--remained essentially the same as at the time of authorization. He recommended that construction of the first phase proceed. The estimated construction cost was about $48.5 million, with a total estimated benefit-cost ratio of 1.55 to 1.

Detailed site investigations continued throughout the preconstruction phase. In April 1971, a preconstruction geologic report was prepared that summarized the results of site and reservoir investigations conducted. The E&R Center completed design specifications for the project, and the invitation for bids was issued on July 22, 1971. The construction contract was awarded on December 13, 1971, and construction commenced in February 1972.

Throughout the various levels of investigation, Bureau officials were confident that a dam at the Fremont site was technically feasible and that a safe structure could be built. The site was considered to be away from all known faults and to have structurally competent rock on both abutments, at the surface as well as at depth. There were ample supplies of construction materials near the site.

There were also site problems. For example, the damsite was in a seismically active region and some sections of the foundation rock were highly jointed and capable of enabling large quanities of water to flow through. However, the Head of the Bureau's Earth Dam Section did not believe the site problems were insurmountable or that the site was more difficult than others built on by the Bureau.

This confidence no doubt stemmed from the Bureau's previous success in building dams as well as from confidence that the site conditions and problems had been adequately identified and explored. From 1957 through 1975 a variety of site and reservoir studies were conducted that provided information on the overall adequacy of the damsite and data necessary to develop detailed designs. Site investigative work included:

--Exploratory drilling: A total of 111 core holes, involving 21,653 linear feet, had been drilled and logged.

--Permeability testing: Percolation and extended pump-in tests were made to test the permeability of the foundation.

--Pilot grouting: A pilot grouting program was performed to test the feasibility of effectively grouting the foundation.

--Rock core testing: Bureau laboratories in Denver made various tests to determine physical and mechanical properties of foundation rock.

--Construction materials testing: The Bureau conducted various tests in its Denver and field laboratories to determine the physical properties of soils and rock to be used in building the dam.

The type and scope of these and other investigations conducted by the Bureau appeared satisfactory for the purpose of assessing the general adequacy of the site and developing a satisfactory design. This is based on the findings of the Independent Panel who concluded the following in respect to adequacy of site investigations.

"The foundation exploratory drilling, geologic mapping, pumping tests, groundwater observations, and pilot grouting tests which had been completed prior to the adoption of the final design for Teton Dam were sufficiently detailed to provide the designers with adequate knowledge of the site conditions. The jointed character of the foundation rock, with the large water-carrying capacity of the joint system, was well documented from the results of the core borings, water testing of drill holes, groundwater table studies and the pilot grouting tests. The presence of the basalt flow in the canyon at the base of the left abutment was also well defined. Therefore, it can be concluded that the preliminary investigations had disclosed the major characteristics of the foundation and abutments needed to develop a satisfactory design."

<u>Site selection process for other Bureau dams</u>

At Teton, the site initially selected as the most favorable was ultimately built on. However, as illustrated by the Tyzack Dam and Auburn Dam examples below, the Bureau does make changes in the site initially selected due to such factors as unfavorable geologic conditions, changes in project goals, or environmental considerations.

Tyzack Dam

The Tyzack Dam, a 145-foot-high earthfill dam, is currently in the preconstruction phase in Utah. During Bureau site investigations, three possible reservoir sites were identified--Ratliff, Boan, and Tyzack. In 1965, the Ratliff location was judged to be the most economical. Five possible damsites were identified and a drilling program was started. Six holes were drilled at one site and this site was determined to be geologically sound; thus, no other Ratliff sites were drilled.

In 1971 the Bureau determined that a larger reservoir capacity was needed for the project; therefore, a dam at the Tyzack location would be the most economical in meeting the project's needs. Three possible damsites at the Tyzack area were identified; the one judged most economical was drilled first. However, this was found to have geologic conditions that would require expensive construction methods; hence, the next most favorable site was drilled. This was found to be acceptable from both economic and geological standpoints so the decision was made to build at this site. The potential site at the Boan location was never drilled because surface inspections and preliminary cost estimates showed other locations were more favorable.

Auburn Dam

The Auburn Dam, a double-curvature, thin arch concrete dam, 685 feet high, is currently under construction in California. In 1956 the Bureau began its feasibility level studies for a dam having a reservoir capacity of 1,000,000 acre feet. A subsurface drilling program was initiated at two damsites considered the best during a previous reconnaissance study--one site for an earth dam at river mile 19.1 and one for a concrete gravity dam at river mile 20.5. After one hole was drilled at river mile 20.5, Bureau personnel concluded that the site had poor geologic conditions for a gravity dam. The earth damsite was considered adequate after about 30 core holes were drilled.

In 1962 the Bureau increased the capacity of the planned reservoir to 2.5 million acre feet after reassessing the needs of the area. Bureau personnel reviewed the previous geologic investigations and concluded that the river mile 19.1 site was suitable for a larger dam. In 1965 the Congress authorized Auburn Dam on the basis of the Bureau's plan for an earthfill dam about 690 feet high at river mile 19.1.

Subsequent to authorization, Bureau personnel began comparative studies of a thin arch dam at river mile 20.1 with the planned earth dam at river mile 19.1 primarily due to an increasing need to minimize environmental damage caused by construction. To obtain needed materials for the proposed earth dam, the Bureau would have had to strip 4 to 7 square miles of land planned for residential and small acreage development. Bureau designers told us that the cost of necessary restoration had not been adequately estimated in feasibility studies. They said that a thin arch dam would minimize environmental damage, but that this type of dam had not been seriously considered during previous studies. They stated that during the years of investigations at Auburn, there were several important evolutionary developments in arch dam design that made a large arch dam a more favorable alternative. In 1967 the engineering, environmental, geologic, and economic studies culminated in the selection of a double-curvature, thin arch dam for construction at river mile 20.1. The studies found the cost of the two dams to be about the same, but environmental considerations strongly favored the arch dam.

CORPS SITE SELECTION AND INVESTIGATION PROCESS

Dam planning in the Corps is typically spread over many years. Dams must be authorized by Congress before selection of the final site and completion of project design. Thus, the planning process breaks conveniently into two phases: preauthorization and postauthorization study and planning. The preauthorization phase includes preliminary selection of a damsite but the final site selection is left until postauthorization planning; therefore, expensive exploration work on many projects studied but never authorized is avoided.

General geology and foundation conditions are an important consideration in the selection of a damsite because of their impact on judgments as to the safety of the sites and cost estimates of building a dam at those sites. After foundation conditions are judged to be safe, the final site determination is based on other factors, such as hydrology, economics, and environmental and social impacts.

Guidance for planning studies and geological investigations is provided in a series of planning and engineering and design manuals. These manuals set forth the site selection process and steps for subsurface investigation, but do not provide criteria as to what may provide an acceptable damsite from a geologic or safety standpoint or the scope of investigations at alternate sites.

Corps officials told us that the amount of subsurface exploration needed to select a site and gather design data for a project is a matter of judgment, and the extent of exploration varies according to the complexity of the geology and the foundation conditions encountered. Corps officials also stated, however, that the extent of exploration is related to the size of the project, because (1) safety considerations become more critical for high dams because of the greater pressure of the reservoir against the dam and (2) the high cost of large dams increases the potential for significant cost savings through greater knowledge of foundation conditions.

The districts of the Corps are responsible for the conduct of both pre and postauthorization study and planning work, including problem identification, formulation of alternate solutions, and assessment of the alternate solutions. Involvement of the divisions and OCE is limited to review of a district's assessments, conclusions, and recommendations.

Preauthorization studies

Planning for Corps dams begins with regional or river basin studies to identify long-range water resource problems and to develop action plans to resolve them. The basin study is followed by a survey or feasibility study undertaken by the Corps to solve more localized problems. These studies identify the problem, formulate alternate solutions, and assess these alternate solutions in terms of national economic development, regional development, social well-being, and effect on the environment. The reports of these survey studies are submitted to the Congress and provide the basis for project authorization.

The first subsurface or geological investigation of prospective project sites is done during the survey study. At this point the scope of geological field investigation is very limited because its purpose is to tentatively identify (1) a favorable site, (2) engineering feasibility, and (3) the project's cost estimate.

During this study phase, the district develops a preliminary project design to include the type of dam, and its length, height, and cross section in the case of an embankment dam. Site selection and the type of dam to be built are interdependent because the foundation and topographic conditions may be adequate for one type of structure but not another. Certain sites, for example, may be suitable for an embankment dam, but not adequate for a concrete gravity dam because of foundation, rock quality, overlying material, and the depth to suitable foundation rock.

Geologic investigations begin with a review of available geologic literature and reports, topographic and geologic maps, and aerial photographs. This material may be available as a result of earlier Corps investigations or of investigations of other Federal agencies, such as USGS or the Bureau of Reclamation, State or local entities, or of private utilities or industrial enterprises.

The preliminary investigations are followed by a surface study of the prospective sites by planning engineers and geologists and subsurface investigation at one or two of the sites which appear most favorable.

Corps engineering instructions do not specify the scope or detail of subsurface investigations, but do set out what information should be obtained. The Corps' engineering instructions provide that survey investigations should include determination of bedrock profiles along the dam or embankment axis; at off-channel spillway, tunnel, and conduit locations; and where elusive and important geologic conditions, such as buried channels, are suspected or possible. The explorations should also include surface and subsurface drainage; type, occurrence, and thickness of the soil overlying bedrock; type, stratigraphic relationships, and geologic structure of rock; presence of cavernous formations; ground water conditions; sources of construction material; and other conditions, such as earthquake activity and slide areas that may affect the site location.

The results of these studies are summarized in the survey report, which goes to the Congress and serves as the basis for project authorization. The survey reports are successively reviewed within the Corps at division level, in the OCE (including the Board of Engineers for Rivers and Harbors), and by other interested or affected agencies, such as the Bureau of Reclamation, USGS, Environmental Protection Agency, and State and local agencies.

Corps officials told us the Corps' philosophy was to limit subsurface investigation for preliminary site selection before project authorization because subsurface exploration is costly and many projects are studied but never authorized. They stated that the purpose of subsurface investigation at this stage is to (1) determine that a dam can be built at the site and (2) get an idea of foundation conditions to provide a basis for preliminary cost estimates. Extensive subsurface investigation of this preliminary site or other alternative sites is delayed until after feasibility has been established and a project has been authorized.

Postauthorization studies--plan formulation

Postauthorization planning begins with Phase I plan formulation studies to reaffirm and update the basic plan presented to the Congress in the survey report and conform it to physical, economic, environmental, and social changes which have occurred since preparation of the survey report. The plan formulation study includes final site selection for the project. Additional geologic explorations are conducted at the preliminary site selected in the survey phase and other viable alternate sites identified.

Corps officials stated that as a general practice, subsurface explorations are made at alternate sites to determine the location where a safe dam can be built for the least cost as related to benefits. They said this means, together with other considerations, a site requiring the least amount of excavation and foundation treatment. The Corps officials stated that although the rationale for geologic exploration of alternate sites is basically economic, ordinarily this goes hand-in-hand with the relative safety of the sites because extensive foundation treatment usually tends to increase project costs. Thus, the poorer sites are often rejected because of economic considerations.

Geologic and subsurface investigations conducted during the plan formulation stages may vary in scope, but should support the final site selection and the determination of the type of structure best suited to that site. In the three districts reviewed, the extent of exploration varied greatly from project to project and site to site. Generally, the investigations included an evaluation of earthquake activity in the area. Subsurface explorations included drill holes, tunnels, surface stripping, and test pits. Where available, the districts also utilized the results of exploratory drilling by other agencies such as the Bureau of Reclamation, State and and local governments, or private industry.

Site selection is documented in the plan formulation memorandum or in a separate site selection memorandum. If major changes in the project plan, as described in the survey report, result from Phase I plan formulation studies, the Districts prepare a report of these postauthorization changes for congressional authorization of further planning. The kinds of changes which require reporting include the addition of other uses for the project water, a major change in the site, or a significant change in total cost, cost allocations, or benefits. If significant changes from the project as originally authorized have not occurred, the districts proceed directly to Phase II postauthorization planning.

Postauthorization--project design

Postauthorization study, Phase II project design, is concerned with the technical design of the plan developed in the preauthorization survey and reaffirmed or reformulated in the Phase I plan formulation. Subsurface investigation in the immediate vicinity of the site selected in the Phase I study continues during project design, but site changes are limited to minor variations in the locations of structures. At this point, the purpose of exploration is to provide information on foundation conditions and construction materials for use in project design.

During this period, information is obtained on such things as the depth of overburden, depth to unweathered rock, amount of excavation required, need for grouting, permeability of the foundation and abutments, and foundation flaws such as faults and clay seams. Subsurface explorations performed should be sufficient to show (1) what foundation treatment is needed; (2) the quantity of excavation required for the foundation and abutments, and whether this material is suitable for use in construction; (3) the characteristics of the borrow material to be used as the impervious core materials and other zones in an embankment dam; and (4) the strength of rock and overburden so as to be able to establish stable slopes. The means of acquiring this data will include

--core drilling, including borehole photography and hydraulic pressure testing of holes;

--soil borings and excavation of test pits;

--tunneling, depending on type of proposed structures;

--test grouting, depending on quality of rock and type of structures; and

--laboratory testing of foundation and construction materials.

Subsurface investigation continues during construction of a project. However, these explorations are directed at determining final foundation grades and treatment of localized foundation problems. They should not have an impact on the site selection or basic project design.

Site investigation and selection for Ririe and Marysville Dams

The Corps often moves from the site originally selected. These examples portray the Corps' site selection and investigation processes and the various factors that influence the selection of a particular site.

Ririe Dam

Ririe Dam was recently completed at a cost of $36.5 million by the Walla Walla District. It is a flood control and irrigation project located on Willow Creek in Idaho about 30 miles from Teton. Ririe is an earth and rockfill dam somewhat smaller than Teton; the embankment is about 180 feet high and 840 feet in length and creates 100,000 acre-feet of reservoir storage capacity. It is located in an eroded canyon with steep abutments of volcanic rock, a geologic setting similar to Teton.

Subsurface investigation for Ririe Dam began with the joint Bureau and Corps Upper Snake River Basin study in 1957. Initial field investigation included geologic reconnaissance and exploratory drilling of three holes at a narrow point in the canyon about 5 miles above the entrance of Willow Creek to the Snake River Plain. A dam at this site, described in the 1962 Interim Report, resulted in congressional authorization of the project. Topography for this site was ideal because (1) the embankment would be short, (2) the spillway would be away from the toe of the embankment, and (3) construction of the embankment would not interfere with spillway and outlet work construction.

Further exploration of this site was done in 1963 for final site selection. Two other sites, 2.5 and 5 miles downstream, as well as two other locations in the immediate vicinity of the site described in the Interim Report, were considered during postauthorization final site selection. A field reconnaissance and surface geologic check indicated the original and the furthest downstream sites were superior; the other sites were dropped without subsurface investigation.

A total of 16 holes were drilled at the abutments and in the valley floor at the original site before it was abandoned because of unstable sediments underlying rock strata at the right abutment. Subsequently, 20 holes were drilled in both abutments and the valley floor at the downstream site. The District concluded this site had more uniform abutments which could be more easily analyzed and treated. Based on the superiority of the foundation conditions and safety requirements for storage dams, the District recommended it as superior to any other available site. Our consultant reviewed the site selection for Ririe Dam and concluded that the procedures followed were entirely adequate and in accordance with the best engineering practices. He also agreed with the selection of the downstream site although he believed a dam could have been built at either site.

Marysville Dam

Marysville is primarily a power project planned by the Sacramento District. Its site on the Yuba River in California has been selected, but construction has not started. Project costs are currently estimated at over $700 million. The Sacramento District's Marysville Lake Project, as now planned, will consist of a main dam on the Yuba River, an auxiliary dam on Dry Creek, and a regulating dam downstream on the Yuba River. The main dam on the Yuba River at Parks Bar about 10 miles above Marysville, California, will be about 360 feet high and 7,000 feet in length. Gross reservoir storage capacity will be 916,000 acre-feet.

Four sites were considered for the project: the present Parks Bar site, a site near Browns Valley about 4 miles downstream, and two other sites. A dam at the third site would have inundated an existing dam and power plant and was eliminated without subsurface investigation. The fourth site was located much higher on the drainage basin, would have controlled a much smaller drainage area than the downstream sites, and was also eliminated without subsurface exploration.

The Corps began subsurface explorations for preliminary site selection in 1964 at the Browns Valley site. A dam at this site was recommended in the 1966 review report which resulted in congressional authorization of the project. During 1974 the fuel and energy shortage prompted reassessment of power benefits and reevaluation of the alternate Parks Bar site. Subsequent subsurface exploration of this site included 10 core drill holes in both abutments and the valley, as well as a seismic survey and a fuel evaluation study. The Parks Bar/Dry Creek site had been previously investigated by the State of California, including a total of 16 core drill holes at the two locations.

The District estimated that contruction costs at the Parks Bar site would be higher than at the Browns Valley site, but projected that a dam at the Parks Bar site would also have a higher benefit-cost ratio. This site also had better foundation conditions, but the District cited social betterment, higher benefit-cost ratio, and environmental factors in its selection. The changes in site and power installation were described in the July 1975 Post-Authorization Change Report.

CONCLUSIONS

Except for the Bureau's very limited use of an independent review process to assess the adequacy of site investigations for individual projects, we found no major difference in Bureau and Corps procedures for investigating and selecting damsites from the standpoint of safety. A wide variety of investigations are performed in both agencies to define site conditions so that safe designs can be developed. Designers in both agencies play key roles in determining what types of investigations are needed and how much exploration should be done. Both agencies evaluate alternative damsites and will abandon a site if it is judged unsafe.

Following site selection procedures, however, will not necessarily lead to adequate investigations of damsites. Designers and geologists must use a great deal of judgment to determine how much exploration is needed to define the unique conditions of each site. As such, we believe the use of consultants to independently evaluate site investigations is a prudent practice.

The Bureau recently began to use independent consultants to review site investigations and designs for major dams. (See ch. 3.) Independent consultants frequently have been used for such purposes in the Corps and many other agencies we visited. We believe that the use of these consultants, coupled with existing site selection procedures, will better assist in adequately defining site conditions and developing safe designs. We also believe that the independent reviews will become even more important in the future due to the relative complexity of the remaining damsites.

CHAPTER 3

QUESTIONABLE DESIGN PRACTICES INDICATE A NEED FOR INDEPENDENT REVIEW PROCESSES

In December 1976 the Independent Panel completed their investigation of the failure of the Bureau's Teton Dam. The Panel concluded that,

> "* * *under difficult conditions that called for the best judgment and experience of the engineering profession, an unfortunate choice of design measures together with less than conventional precautions was taken to ensure the adequate functioning of the Teton Dam, and these circumstances ultimately led to its failure."

Some of the design measures that the Independent Panel questioned are as follows:

--The extensive and costly program to seal the leaky foundation under the dam with a cement and sand mixture, called grout, may have been ineffective in preventing erosive seepage from occurring. The Panel questioned both the design of this "grout curtain" in the rock foundation and the high degree of dependence placed on it. It said the design should have provided other means to render inevitable seepage harmless.

--There were not adequate defenses in the dam such as filters and proper drainage to neutralize seepage going through the dam. Erodible silt material was placed against many open cracks in the foundation rock instead of first placing coarser material over the rock that would help to prevent erosion by preventing the movement of fine grained soil by seepage water. Also, the material used to provide drainage within the dam may not have been porous enough to provide adequate drainage. The Panel concluded that inadequate provisions for the safe discharge of seepage was one of the design decisions that caused the failure of the Teton Dam.

--The development of cracks in the dam could initiate dam failure because of the inadequate measures taken to control seepage. The Panel said that the shape of a deep trench, called "key trench", excavated in the canyon walls to control seepage was conducive to the development of cracks.

Corps officials stressed the importance of providing multiple defenses in dams to prevent erosion from seepage. They told us that they use grout curtains only in conjunction with other measures to control seepage. For example, in addition to a grout curtain at the Corps' Ririe Dam, cracks in the rock were filled with grout, and a foundation blanket was placed on the rock surface to protect the erodible silt material. In addition, a downstream drainage system was provided that consisted of multiple layers of increasingly more porous material to safely discharge seepage.

We believe the findings of the Independent Panel illustrate the need for having an independent review of designs to confirm the adequacy of design decisions made. Independent consultants were not used to review the Teton designs. We found that the Corps and other Federal and State agencies used independent consultants more frequently than the Bureau to confirm their design decisions and other decisions upon which the designs were based. The Corps does not, however, use independent consultants on all its dams.

During the course of our review, the Bureau announced that an independent review of its designs for all storage dams will be made by outside consultants. In addition, the Department has asked for bids from consulting firms to study whether the Bureau's technical procedures used in planning, designing, and constructing dams follow reasonable safety standards within the limits of existing technology.

In light of the findings of the Independent Panel, we fully support the actions announced by the Bureau and believe that (1) the independent review process for all storage dams needs to be made part of the Bureau's instructions and (2) the independent review of the technical procedures needs to specifically address the questionable design practices identified by the Independent Panel. We also believe that the Corps needs to revise its procedures and practices to require that its designs and site investigations are reviewed by independent consultants for all their storage dams where there is or could be a potential hazard to public safety.

GEOLOGY OF THE TETON DAMSITE

The Teton Dam is located in Eastern Idaho on the Teton River about 3 miles northeast of Newdale, Idaho. At this location, the Teton River flows through a steep-walled canyon, with walls rising about 280 feet above the canyon floor. The canyon floor is relatively flat and about 750 feet wide. A simplified geologic cross section of the damsite is shown on page 26.

Foundation

At the bottom of the canyon there is up to 100 feet of stream-deposited alluvial material consisting of two distinct layers--one of sand and gravel and another of compacted silt and clay. Buried by the alluvium are the erosional remains of an intracanyon basalt lava flow, which is hard but intensely cracked and broken. The most extensive rock at the damsite is rhyolite (welded ash-flow tuff) which comprises most of the foundation for the dam. Rhyolite is a hard rock derived from distant volcanoes no longer active. Although extensive cracks are common in this rock, the Bureau considered it to be strong and competent. There were numerous open cracks in both dam abutments, which increased the permeability (extent to which water can flow through the rock) of the foundation.

Permeability of the rhyolite

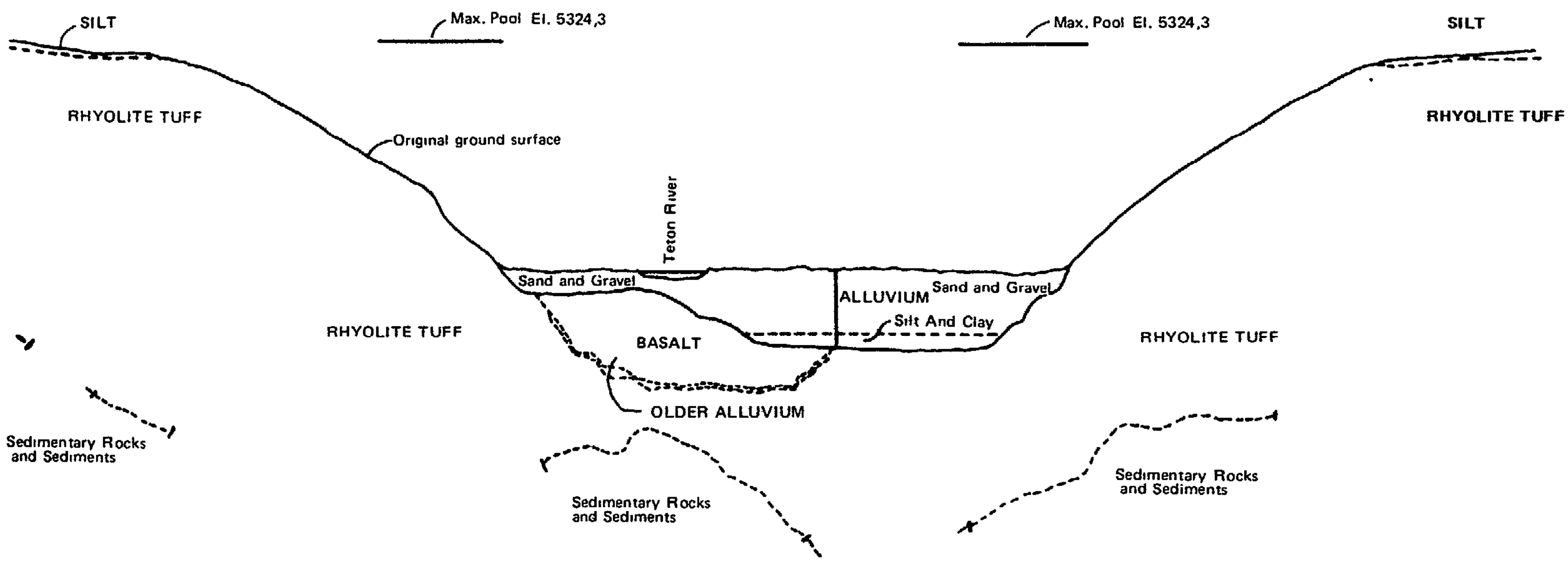
The Bureau conducted a number of tests to assess the permeability of the foundation. While tests showed thay many sections of the rhyolite are fairly impermeable, they also showed that cracks in other sections are capable of carrying large volumes of water. This is well illustrated by Bureau pump-in tests where known quantities of water were pumped at no pressure into holes drilled in the rock over an extended period of time. At one hole in the right abutment area, 450 gallons of water per minute were pumped into the hole over a 2-week period without ever filling it up. The Head of the Bureau's Earth Dam Section later said that the Teton damsite was one of the most pervious foundations on which the Bureau has ever built a dam.

Rock cavities

During excavation of the foundation, large openings or fissures in the rock were found in both the left and right abutments. One opening, for example, was explored by a Bureau employee for a distance of about 100 feet both downstream and upstream of the dam's axis. He described the cavity on the downstream side as being about 4 feet wide. He said further exploration was blocked by a large rock. He said a room or passage could be seen beyond but that the opening into it was too small to enter. The Independent Panel concluded that these cavities increase the permeability of the foundation.

TETON DAMSITE

SIMPLIFIED GEOLOGIC CROSS SECTION ALONG DAM AXIS (VIEW DOWNSTREAM)



EXPLANATION

100 0 100 200
SCALE OF FEET

SILT- Windblown silt on the uplands
ALLUVIUM- Stream-deposited sand, gravel, silt, and clay
BASALT- Intracanyon basalt flow, dark purple to black, dense to slightly vesicular, fairly fresh, hard, highly fractured
OLDER ALLUVIUM- Stream-deposited silt, sand, and gravel that is present in Teton River canyon directly beneath the intracanyon basalt
RHYOLITE TUFF- Light brown to purple-gray, dense to moderately vesicular, porphyritic, lightly to locally highly fractured and jointed
SEDIMENTARY ROCKS AND SEDIMENTS- Siltstone, claystone, sand and gravel and other sediments that underlie the rhyolite tuff

SOURCE- "INTERIM REPORT ON THE TETON DAM FAILURE" DATED JULY 14, 1976, U.S. DEPARTMENT OF THE INTERIOR, TETON DAM FAILURE REVIEW GROUP.

Available building materials

For economic reasons, designers like to use materials for construction of earth dams that are at or near the damsite. Available building materials at Teton included a fine grained windblown silt material, and alluvial deposits containing sand and gravel. The sand and gravel was used to provide drainage in the dam and the silt material formed the dam's water barrier. Characteristics of the silt material include low permeability; however, it is also brittle when compacted, subject to cracking, and highly erodible.

Seismicity and faulting

The Teton Dam is in a general region classified by USGS as being subject to earthquake damage. However, both Bureau and Independent Panel officials concluded that the specific area of the Teton damsite is relatively seismically quiet. Bureau officials stated that their conclusion is based on historical data and, since 1974, on a joint Bureau/USGS program to monitor earthquake activity in the project area. Bureau and Independent Panel officials also concluded that seismic activity was not a factor in the Teton failure.

Few faults have been identified near the damsite. The closest two are located about 10 miles upstream and downstream from the dam. USGS, in 1973, suggested the possible existence of a fault near the right abutment of the dam. (See ch. 7.) However, Bureau and Panel officials said their investigations failed to show that such a fault existed.

TETON DESIGN

The Teton Dam was of a zoned, earthfill embankment that rose 305 feet above the valley floor. It was about 3,100 feet long at the crest and contained about 10 million cubic yards of material. A zoned embankment has a central impervious core which acts as a water barrier. This central core is flanked by zones of more pervious materials which enclose, support, and protect the impervious core. The upstream zone provides stability to the dam if the reservoir is quickly lowered, and the downstream zone acts as a drain to control seepage through the embankment. Specific zones used at Teton and other significant design features--cutoff trench, key trench, and foundation grouting--are discussed below.

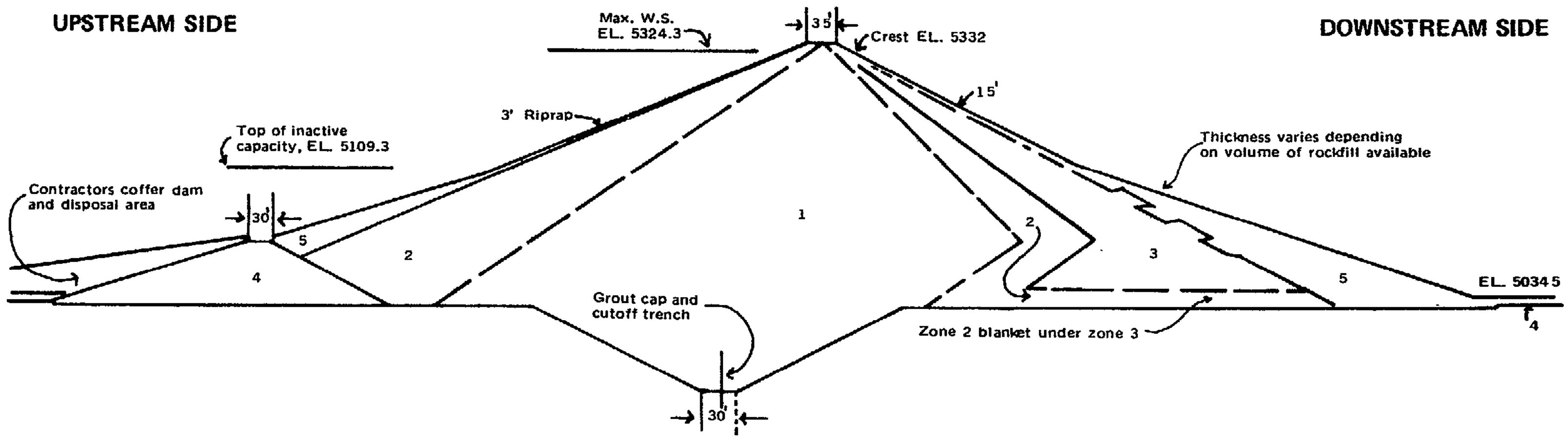
Zones in the embankment

The Teton Dam, as shown on the drawing on page 28, was composed of five different zones plus a 3-foot thickness of rock (riprap) dumped on the upstream slope to provide

TETON DAM

EMBANKMENT EXPLANATION

1. Selected clay, silt, sand, gravel, and cobbles compacted by tamping rollers to 6-inch layers.
2. Selected sand, gravel, and cobbles compacted by crawler-type tractors to 12-inch layers. Acted as filters.
3. Miscellaneous material compacted by rubber-tired rollers to 12-inch layers.
4. Selected silt, sand, gravel, and cobbles compacted by rubber-tired rollers to 12-inch layers.
5. Rockfill placed in 3-foot layers.



MAXIMUM SECTION WITHOUT CAMBER

100 0 100 200

Scale of feet

Source: Bureau of Reclamation drawing as modified by GAO protection from wave action. Zones 1 and 2 were the most significant zones from the standpoint of leakage.

Zone 1 was the central impervious core and was intended to form the water barrier of the dam. It was composed of the windblown silt material and made up over one-half the volume of the embankment. Bureau officials recognized that this material was not ideal because of its brittleness and erodibility. However, it was the only material available in the area that was suitable for the impervious zone. Bureau officials said similar material had been successfully used in nine other Bureau dams, including the Palisades Dam, which is a 260-foot high structure built in the 1950's.

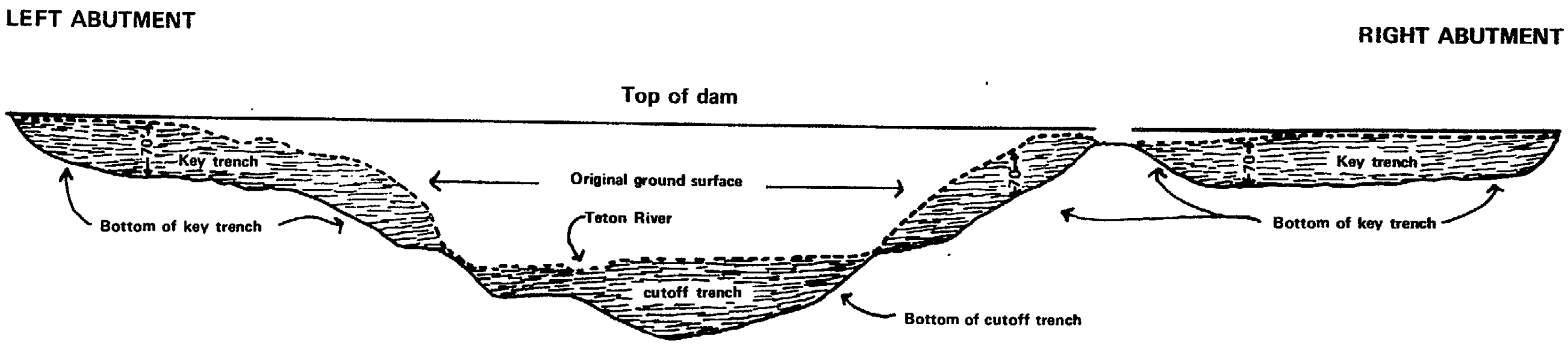
Zone 2 was a sand-gravel-silt mixture used between the impervious core and other zones of the embankment. On the downstream side of the dam it was intended to form a drain to control seepage through the embankment without allowing the seepage to carry away the fine grained, silt material.

Cutoff trench

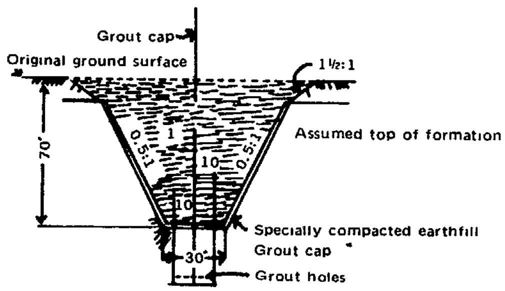
Bureau criteria for earth dams specifies that whenever economically possible, seepage through a pervious foundation, such as at Teton, should be cut off by extending a trench to bedrock or other impervious areas of the foundation and filling the trench with impervious material. The Teton design incorporated such a trench, called a cutoff trench, under the Zone 1 material. Across the canyon floor the trench was excavated through river-deposited alluvial material until firm rock was reached. A cross-section of the trench at this location can be seen on page 30. Similarly, on the abutments, the trench was excavated through weathered and loose rock until firm rock was reached. The cutoff trench was backfilled with the silt material.

Key trench

Bureau designers concluded it would be more economical to remove the upper 70 feet of rock on the abutments rather than try to seal or grout the cracked rock there. As the result, the Teton design called for the excavation of a deep trench--key trench--into the rock on both abutments. As shown on the drawing on page 30, the key trench was to be constructed about 70 feet into the abutment walls, with a base width of 30 feet and steeply sloping sides. Bureau designers told us that the key trench was contained within the cutoff trench. They told us the cutoff trench in the abutments was only excavated a few feet into the rock. The key trench was backfilled with the silt material to provide a seepage barrier.



PROFILE OF KEY AND CUTOFF TRENCHES



FOUNDATION KEY TRENCH
CROSS SECTIONAL VIEW

TETON DAM

Source: Bureau of Reclamation drawing as modified by GAO

The Bureau design manuals we reviewed do not discuss a key trench such as the one built at Teton. Bureau designers said that Teton was the first dam constructed by the Bureau that had a key trench of this size.

Grouting

Erosive seepage under the Teton Dam was to be eliminated through a foundation grouting program. Foundation grouting is a process of injecting under pressure a fluid sealing material, such as cement, into the foundation through specially drilled holes for the purpose of sealing or filling cracks and fissures.

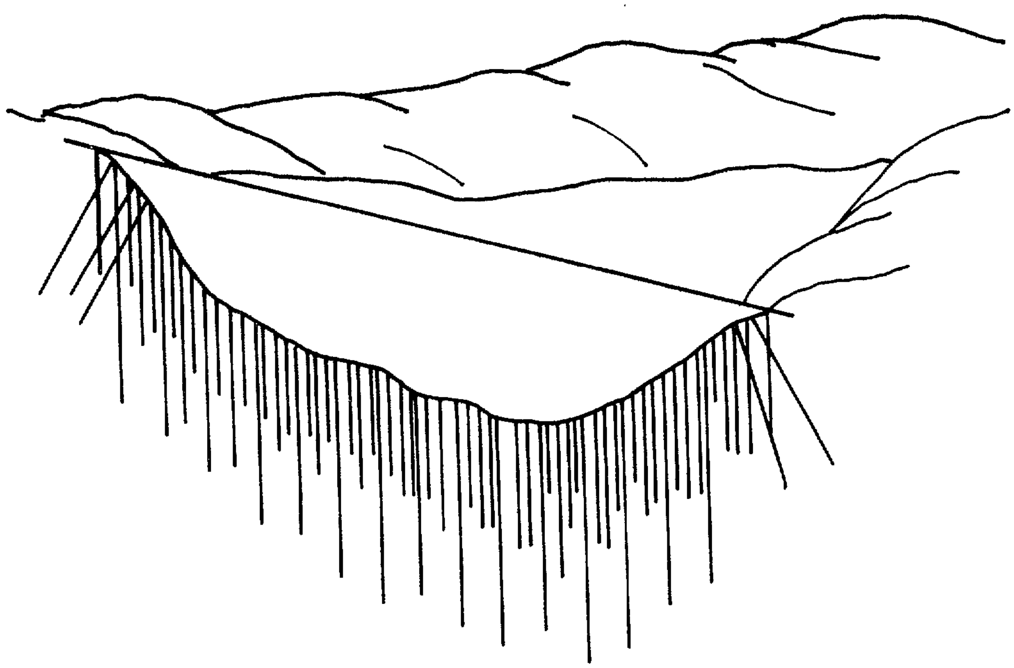
According to a Bureau design manual, the grouting of a foundation is usually performed along a single line of holes centered 10 to 20 feet apart in the rock foundation for the purpose of creating a deep, impermeable water barrier referred to as a grout curtain. Multiple grout curtains may be used when severely fractured or highly permeable rock is encountered. The Bureau manual also notes that "blanket grouting" may be used to reduce leakage in fractured rock zones and provide a firmer foundation for the dam. Under blanket grouting, a wider area of cracked rock will be grouted to a shallow depth, usually 10 to 30 feet, using a grid pattern of grout holes instead of a single line of holes. Curtain and blanket grouting methods are illustrated on page 32.

In 1969, before final designs were prepared, the Bureau conducted a pilot grouting program to determine if the Teton foundation could be effectively sealed. Based on the findings of this program and other investigations, two significant decisions were made. First, three parallel lines of grout holes were needed in the bottom of the cutoff and key trenches, rather than the one line previously planned. Second, a key trench (see p. 30) would be excavated in the abutments rather than attempting to grout the highly permeable upper levels of the foundations. The Teton design also provided for blanket grouting in the bottom of the cutoff and key trenches at locations to be determined as work progressed.

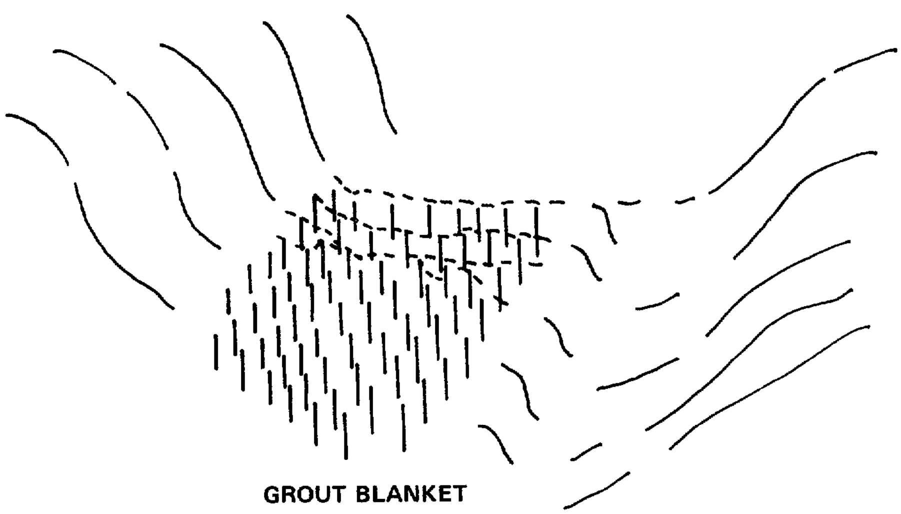
QUESTIONABLE DESIGN PRACTICES AT THE TETON DAM

Grout curtain

The grouting program at the Teton Dam was one of the most extensive efforts of its kind ever undertaken by the Bureau. The total program involved drilling 118,000 linear feet of holes and injecting nearly 600,000 cubic feet of cement, sand,



GROUT CURTAIN



GROUT BLANKET

Source: GAO illustration based on information provided by the Bureau of Reclamation and Corps of Engineers and other materials into the foundation at a cost of about $4 million. Yet, the grout curtain may not have been effective in controlling seepage as intended. The Independent Panel concluded from its postfailure tests that water could pass through the grout curtain at several locations. Thus, it concluded that the grout curtain may not have been fully effective in controlling seepage in the critical key trench area. The Independent Panel questioned the adequacy of the design of the grout curtain as well as the heavy reliance placed on it to control seepage. In addition, there is a question whether additional measures should have been taken to test the adequacy of the grout curtain after it had been constructed.

The Independent Panel concluded that the construction of multiple grout curtains at Teton would have been justifiable in light of the known rock conditions. Although the Bureau generally used three rows of grout holes at Teton, only the center row of holes was intended to form a water barrier. As such, the Panel concluded that only a single grout curtain was constructed. In addition to the construction of multiple grout curtains, the Panel concluded that closer spacing of grout holes and drilling the holes at cross angles, instead of in one direction, may have been warranted to better ensure the formation of a water-tight barrier.

The Independent Panel also concluded that the Bureau placed too much reliance on the grout curtain and that the design should have provided further means to control inevitable seepage. While we found that construction of grout curtains is standard practice in the other design organizations we visited, we found that others do not rely extensively on a grout curtain to control seepage. Corps officials told us that grout curtains are never 100-percent effective and are used only in conjunction with other methods to control seepage. For example, although the Corps constructed a grout curtain at Ririe Dam, other measures such as filters and the sealing of all cracks in the foundation (see p. 35) were also used to control seepage.

Bureau officials told us that before grouting a hole, water was pumped in under pressure to determine if it would leak out of the hole through cracks in the rock. If such leaks occurred, they said, grout would be pumped in under pressure to fill the cracks.

However, the Bureau did not test the adequacy of the grout curtain after it had been constructed, either through instrumentation (discussed in ch. 5) or by other means such as drilling into the constructed grout curtain and water testing for leaks. While we were told that postconstruction water tests are normally not done by dambuilding organizations we visited, our consultants and TVA officials told us that such testing is sometimes warranted depending upon conditions encountered, such as when the amount of grout pumped into areas of the foundation is very large. At Teton, some areas of the foundation took large amounts of grout; the actual amount pumped into the foundation was over twice that originally estimated. Therefore, we believe postconstruction water testing may have been appropriate for Teton. The following reasons also justify our belief.

--The Teton damsite was considered one of the most pervious sites ever built on by the Bureau.

--The Teton design placed a great reliance on the effectiveness of the grout curtain.

--Multiple grout curtains were not built at Teton and the relative ineffectiveness of single-row grout curtains had been questioned for many years.

--Instrumentation to test the effectiveness of the Teton grout curtain was not planned or installed.

Filters and drainage

A basic criteria for the safe design of earthfill dams is that seepage flow occurring through the embankment must be controlled so that no internal erosion will occur. The proper design, construction, and use of drainage and filter systems can help achieve this end. The Bureau defines a filter as a layer or combination of layers of pervious materials designed and installed in such a manner as to provide drainage, yet prevent the movement of soil particles.

While the Teton Dam design made provisions for filtration and drainage, the Independent Panel raised questions regarding the lack of filters in key trench areas and the effectiveness of the downstream drainage system. The Independent Panel concluded that one critical design decision that allowed the Teton failure to occur was that inadequate provisions were made for the collection and safe discharge of leakage or seepage.

The Bureau relied on the Zone 2 material to collect seepage that would penetrate the impervious core and carry the seepage safely out of the dam. (See p. 28.) However, the Independent Panel questioned whether this zone provided effective drainage because test results indicated that the

Zone 2 material was nearly as impermeable as the Zone 1 material.

Bureau officials said that the material for Zone 2 was used because it was judged to be adequately permeable to handle the small volume of seepage that was anticipated. The material was available in large quantities near the damsite and, according to Bureau officials, it is both strong and stable and of the type used in many other dams.

The Independent Panel also questioned the lack of a filter on the downstream side of the key trench. As previously described, the fine, highly erodible Zone 1 material was placed directly against the highly cracked rock. Thus, there were many places where seepage going through the key trench could escape and carry with it the fine grained Zone 1 material.

Bureau designers told us that they considered the use of a filter in the key trench, but they felt that the water flow would not be sufficient to cause erosion of the silt material, and therefore, a filter was not necessary.

We discussed the use of filters and drainage systems with Corps designers in three districts. They told us their practice is to always provide for adequate drainage downstream from the impervious core material. Normally, they said, this is accomplished through the use of relatively narrow filter and drainage zones of processed material, many times more permeable than the core material. Ririe Dam is an example of the Corps use of filters in an earth and rockfill dam which contains an impervious core constructed of silt material similar to that used at Teton. The impervious zone was protected on all sides by a multizone filter system. The first filter zone was about 10,000 times more permeable than the impervious core.

We also reviewed the Corps policy for preventing the movement of core material into cracks in the foundation rock. We found that its policy is to either fill or cover all the cracks in the rock surface with concrete or grout to make such movement impossible. For silt cores, a foundation blanket of material slightly more coarse than the fine grained silt core material may also be laid between the core and the foundation rock to prevent movement of the silt into cracks in the rock. At Ririe Dam, for example, a 3-foot thick foundation blanket was placed between the silt core and the foundation rock. In addition, large cracks were backfilled with concrete and all small cracks were filled by broomgrouting.

Shape of the key trench and elimination of irregularities

The Independent Panel concluded that poor compaction of the Zone 1 silt material or cracks in the soil placed in the key trench could have contributed to the failure of the Teton Dam.

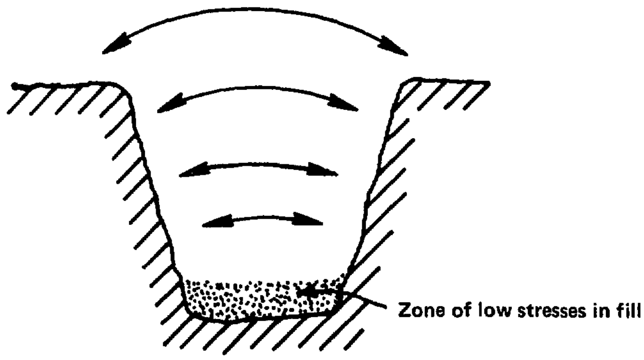
Cracking of soils in earth dams is a well-known phenomenon due to differences in the amount of settlement at various places in the embankment of the dam. However, as pointed out by the Independent Panel, the mere presence of cracks is not an indication of unsatisfactory design, as there is a variety of defenses available to the designer to prevent erosion. At Teton Dam, however, it should have been apparent, according to the Panel, that cracks through the key trench would inevitably lead to erosion and create remarkably efficient avenues for breaching the key trench and initiating failure. Bureau designers did not provide defenses for large concentrated water flows through the key trench if cracking of the relatively brittle silt material took place.

The Independent Panel said that the shape of the key trench, with its rigid rock walls and steep slopes, was favorable to the development of cracks through arching and hydraulic fracturing. Arching (see p. 37) prevents the full weight of the overlying embankment from bearing on the underlying material. If the arching effect reduces the pressure on the underlying materials sufficiently, water pressure can crack the soil by the process known as hydraulic fracturing. Based on observations, tests, and analyses, the Panel concluded that hydraulic fracturing of the soil in the key trench was a highly probable mechanism for the initial breaching of the key trench.

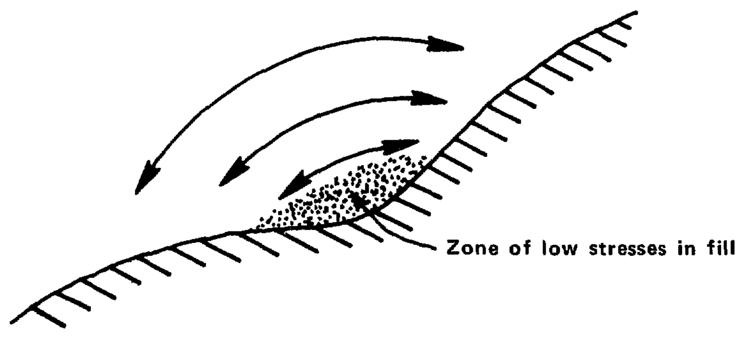
The Bureau has stated that the phenomenon of arching and hydraulic fracturing was not well understood at the time of design and construction of the Teton Dam. The Panel similarly reported that hydraulic fracturing is not yet fully understood and deserves research under controlled laboratory conditions. We believe, however, that the lack of understanding of these concepts illustrates that the state-of-the-art of dambuilding has not reached a point where designers can predict all probelms that must be dealt with. As such, we believe it is important to design adequate defenses into a dam to handle expected, as well as unexpected, conditions.

The Panel said that in the bottom of the key trench in the vicinity of the failure, there was a concentration of steps and overhanging rocks which made proper compaction of soil in the trench difficult and was conducive to arching as

EROSION DIAGRAMS



First order arching in fill over and between walls of key trench



Second order arching produced by longitudinal topography of rock surface in key trench

Source: Report to U.S. Department of the Interior and State of Idaho on "Failure of Teton Dam" dated December 1976, Independent Panel to Review Cause of Teton Dam Failure.

well. (See p. 37.) Compaction was important to provide a good bond between the silt material and the foundation rock and to seal the small cracks in the foundation.

We discussed the elimination of overhanging rocks and other foundation irregularities with Corps and TVA officials. They said there is a practical limit on how much can be realistically done to eliminate all irregularities that might be conducive to poor compaction or cracking. For this reason, they said, it is important to design adequate defenses into the dam, such as drainage and filter systems to control seepage conditions. Corps officials added, however, that under no circumstances would overhangs be permitted to remain in the foundation or abutment contacts beneath the impervious core. They said the overhangs would be eliminated by excavation or by placing concrete under the overhanging rock.

Actions being taken

On February 11, 1977, the Department of the Interior issued a request for proposal for an independent review of its technical procedures for building dams. The general objective is to determine if the procedures used in planning, design, research, construction, operation, and maintenance follow reasonable safety standards. One of the specific objectives is to determine the degree to which the Bureau is applying state-of-the-art technology in the design of concrete and earthfill dams. Another aspect of this review is discussed on page 40.

NEED FOR INDEPENDENT REVIEW PROCESSES

Until February 1977, the Bureau did not have an independent site investigation and design review process for all dams. Detailed, technical review of the design, and the adequacy of the site investigations upon which that design was based, was generally limited to the branch responsible for preparation of the design. Reviews were made at higher levels, but these reviews were not detailed, and the reviewers often did not have the background necessary to make a detailed technical review. For example, the former Chief of the Division of Design's detailed experience was primarily in designing steel structures, including power plants. Even the Section Head may not have detailed design experience for the type of dam designed by his section. We found the former Head of the Concrete Dam Section was not experienced in the detailed design of concrete dams.

In addition, outside consultants were used sparingly to review an overall project design for Bureau dams. Bureau instructions permit use of outside consultants to do design work where unusual or special problems are involved and it would be uneconomical to staff for these special problems. However, as reported by an Interior Review Team in a December 1976 study of Bureau procedures, the Bureau has made very little use of outside consultants and this use has generally been limited to input on specific problems as opposed to design review. Of the five projects we reviewed where the Bureau had started or completed construction, independent consultants were used on one project to perform an overall review of the project design, as of December 1976.

In contrast, the Corps has a comprehensive and multilevel system for independent internal review of the planning and design of its dams, and the adequacy of the site investigations upon which the designs were based. In addition to informal reviews at the district responsible for preparing the design, the Corps conducts more independent, formal reviews at the division and OCE levels.

Also, Corps officials in the OCE and the three districts we reviewed told us that the Corps frequently has independent consultants assist in or review the design of major or complex projects. Corps instructions provide that consultants may be used in the planning and design of projects of major importance or involving unusual or complex engineering problems. These instructions also state that the consultants can be used for (1) guidance and advice on site selection and investigation, project design, and construction and (2) independent review of the safety and efficiency of the Corps' design. However, independent consultants were not used for advice or design review for two of the nine Corps projects included in our review.

Other dam design organizations we contacted told us that they routinely use outside consultants to review designs for major dams. TVA officials told us that they use an independent consulting board to perform an overall design review for any dam they build of considerable height and/or difficulty. Federal Power Commission officials told us that they require all applicants for licenses on major non-Federal hydroelectric projects to hire an independent consulting board to perform an overall design review. State of California Department of Water Resources officials told us that they require an independent review of all non-Federal dams in the State.

Actions being taken

Since the failure of the Teton Dam, the Bureau has taken two significant actions to improve its review processes.

First, in January 1977, the Commissioner of Reclamation announced that the Bureau will use independent consultants to evaluate Bureau designs for all future major dams. According to the Bureau's Chief of General Engineering, this review process will be applied to all Bureau storage dams. On February 25, 1977, the Commissioner advised the E&R Center that independent reviews would be approved and the Bureau instructions should be modified to recognize this change in policy. At the conclusion of our review in April 1977, the Bureau was using independent consultants on its Lonetree Dam, but Bureau instructions had not been changed.

Second, on February 11, 1977, the Department of the Interior issued a request for proposal for a contractor to review the adequacy of the Bureau's procedures for building dams. One of the objectives is to evaluate the effectiveness of the Bureau's internal review system and to make appropriate recommendations for improvements necessary. At the conclusion of our review in April 1977, the contract for this review had not been awarded.

RECOMMENDATIONS

In light of the questionable design practices the Bureau used at the Teton Dam, and the apparent weaknesses in its internal review system, we fully support the Bureau's decision to use independent consultants to review project designs and the corresponding site investigations for all storage dams. We recommend that the Secretary of the Interior ensure that this policy change is incorporated into Bureau instructions.

We also recommend that the Secretary of Defense require that the Corps of Engineers revise their procedures and practices to ensure that designs and site investigations are reviewed by independent consultants for all its storage dams where there is, or could be, potential hazard to public safety.

We also support the Department's decision to retain an independent consultant to review the Bureau's internal design and site investigation review process, and evaluate its technical procedures for investigating and designing dams. Regarding the technical review portion of this study, we recommend that the Secretary of the Interior ensure that the Bureau's policies, procedures, and practices be reviewed relative to

--relying on grout curtains,

--postconstruction testing of grout curtain effectiveness,

--controlling seepage through the use of drainage and filter systems within the embankment and against rock surfaces,

--removing irregularities in rock surfaces, and

--shaping key trenches and cutoff trenches.

We also recommend that this review be structured so that it can be used to help satisfy the requirements of the President's April 23, 1977, memorandum for a report on Bureau practices which could affect dam safety and integrity. (See ch. 8.)

CHAPTER 4

NEED TO BETTER ENSURE THAT THE INTENT OF BUREAU DESIGNERS IS CARRIED OUT

The Bureau needs to change its policies and procedures to better ensure that the intent of its designers is adequately implemented during project construction.

The principal Bureau designer of the Teton Dam told us that he had intended that all open cracks in the foundation rock under the highly erodible silt core should be sealed. Bureau officials told us that this intent was not fully carried out because of unclear instructions, drawings, and specifications and misinterpretations by project staff. Moreover, we found that the designers assigned to the project did not visit the Teton Dam site at critical points when the cracks should have been treated.

The possible consequence of the limited treatment of open cracks in the key trench was pointed out by the Independent Panel which concluded that the open untreated cracks were a contributing factor in the failure of the Teton Dam. The Panel said that wherever the highly erodible silt material was subjected to the action of flowing water, the material would be "attacked" and washed away rapidly. It said that the open cracks provided an access for flowing water to penetrate the upstream side of the silt-filled key trench and provided exits on the downstream side through which the water could erode the silt material.

We believe the circumstances regarding treatment of cracks clearly illustrates the need for the Bureau to develop clear instructions and drawings. Even then, however, misinterpretations can develop or site conditions actually found may necessitate changes in design. For these reasons, we believe that Bureau designers need to visit the site frequently to better ensure the design intent is achieved.

MISUNDERSTANDING OF DESIGNER'S INTENT

Sections of the "Design Considerations" supported the principal Bureau designer's intent that cracks next to the erodible silt should be sealed. The Design Considerations is a document developed by the designers and provided to assist onsite Bureau personnel in understanding the dam design and carrying out supervision and inspection of the construction effort.

The Design Considerations for Teton Dam said:

> "Open joints or cracks found in the bottom of the foundation key trench and cutoff trench are to be treated by (1) cleaning out the crack with air and/or water jets, (2) setting grout pipe nipples in the crack, (3) sealing the surface by caulking and/or grout, (4) drilling, if required, and (5) low-pressure grouting through the nipples."

The Bureau designers also showed us sections of the Design Considerations that said the foundation key trench was contained within the bottom of the cutoff trench. Therefore, they said, cracks in all of the key trench, including the walls, as well as areas outside the key trench under the erodible material, should have been treated. However, as pointed out by the Independent Panel and by the Project Construction Engineer at Teton, open cracks in all these areas were not filled with grout. The Project Construction Engineer told us that for the most part, open cracks in the key trench walls were not filled at all; the filling of cracks outside the key trench was limited to lower elevations in the dam, and then only for the larger cracks--about 1/2-inch wide or wider.

There appear to be several reasons why the actual treated areas differed from what was apparently intended. These reasons are described below.

<u>Unclear definition of cutoff trench boundary</u>

Bureau designers and the Project Construction Engineer told us that statements in the Design Considerations that define the boundaries of the cutoff trench are not clear. These statements are important because they define the areas under the Zone 1 silt material where cracks should be filled with grout. They added that the Design Consideration did not include drawings to clarify the relationship between the cutoff trench and the key trench, but the document refers to various drawings that are included in the construction specifications. However, according to the Project Construction Engineer and the designers, these drawings in the specifications do not clearly identify the boundaries of the cutoff trench on the abutments. Because both the Design Considerations and the design drawings are unclear, misinterpretations developed.

The Bureau's Project Construction Engineer told us he did not know that the designers considered areas outside the key trench to be within the cutoff trench; thus, this is one reason, he said, why he and his staff did not treat all open cracks in these areas. He also told us that even had he understood this, the Design Considerations does not clearly indicate that the key trench walls and areas outside the key trench should be treated.

Unclear construction specifications

The construction contractor is required to comply with the construction contract specifications, not the Design Considerations. However, the specifications did not contain provisions for the treatment of cracks other than through blanket and curtain grouting in the bottom of the cutoff and key trenches. Further, they did not contain statements similar to those contained in the Design Considerations. In regard to blanket grouting, the specifications did not say under what conditions blanket grouting was to be used, only that it was to be carried out as directed. Both the designers and the Project Construction Engineer said the contract specifications should have been more specific.

INADEQUATE INVOLVEMENT BY DESIGNERS IN THE CONSTRUCTION PHASE

The Project Construction Engineer told us that the designers did not provide adequate guidance or direction during construction concerning treatment of open cracks. He said, for example, that the suggestion to use slurry grout to fill large cracks in the foundation rock was made by his staff, not the designers. He told us that this suggestion was made because his staff believed that large cracks should be filled. He also told us that the designers did not question the extent to which cracks were treated until after the dam failed.

Bureau designers told us that it was now evident to them that the design group should have been more involved with the project throughout the construction phase. Based on a record of onsite trips by E&R Center personnel, we found that earth dam designers visited the Teton site three times after construction started in March 1972. The trips included one in October 1972 to inspect construction of the river outlet works and one in November 1973 to inspect the cutoff trench excavation before laying the embankment material. From November 1973 until November 1975, when the embankment was completed, only one trip--in March 1974 to examine voids exposed in the right abutment--was made by Bureau designers. Treatment of all of the cracks in the right abutment with slurry grout was performed between August 1974 and August 1975.

Bureau officials told us that there are no written instructions which specify when designers should visit the site during construction. In practice, they said that visits are generally made just before placing embankment material. After that, they said, trips are generally only made in response to specific problems rather than for a general inspection.

In contrast, a Corps engineering and design manual for earth and rockfill dams stresses the importance of making regularly scheduled visits to the damsite during construction by project designers. At the three districts we visited, we were told that damsite visits by designers were made monthly or more frequently if requested to do so by construction personnel. At Ririe Dam, for example, we were told that designers from the district visited the site about once a month, although records of all visits were not available.

RECOMMENDATIONS

We recommend that the Secretary of Interior direct the Bureau of Rèclamation to establish written procedures to better ensure that design intent is achieved. In so doing the Bureau should: (1) evaluate and implement ways to improve the clarity of instructions, specifications, and drawings; (2) evaluate and implement ways to better ensure that onsite personnel fully understand the intent of the designers; and, (3) develop and implement policies and procedures calling for more frequent onsite inspections by designers during construction.

CHAPTER 5

MORE EFFECTIVE SURVEILLANCE PROCEDURES NEEDED TO MONITOR AND CONTROL DAM SAFETY DURING RESERVOIR FILLINGS

Several key monitoring and control measures were not available when the Teton Dam failed. For example:

--Instruments for detecting seepage were not installed at the Teton Dam because Bureau designers were confident that Teton was adequately designed to protect against erosive seepage.

--Information available to Bureau personnel at the damsite during the weeks preceeding the failure which, according to Bureau designers, could have given a clue as to the seepage conditions affecting the dam routinely was sent from the project to the E&R Center arriving the day after the failure.

--Visual observations at the dam were not made on a 24-hour basis during the critical initial reservoir filling stage; consequently, evidence of erosion from the leak was not observed until the project staff arrived at the damsite about 5 hours before the failure.

--Bureau designers intended to fill the Teton Dam reservoir slowly to observe the behavior of the dam and to allow them to take remedial actions if problems developed. However, deviations of up to 4 times more than the filling rate originally approved had to be permitted by the Bureau because the filling began before the main river outlet drain was available. Apparently, the decision to begin filling the reservoir and to cointinue filling it without the availability of the main river outlet drain was made to avoid the possibility of incurring contractor claims because of another inconsistency between the Design Considerations and the contract specifications.

--When the evidence of erosion from the leak in the Teton Dam was discovered, the Bureau's staff at the project could not immediately open the main river outlet drain because another contractor was behind schedule in completing his work on this structure.

No one knows whether the leak at Teton would have developed as quickly as it did or whether the failure could have been prevented if the reservoir would have been filled slowly and the main river outlet drain had been available as planned to release water. However, with no instrumentation installed at the dam to determine whether the leaky foundation rock had been sealed or whether potentially dangerous cracks were developing, with no adequate means for quickly recognizing conditions that could adversely affect dam safety, and with no way to open the main river outlet drain immediately when an emergency is recognized, we believe the Bureau took unnecessary safety risks and placed too much reliance on the adequacy of its design.

Many of the circumstances described above are strikingly similar to those which previously occurred in 1965 when the Bureau's Fontenelle Dam on the Green River in Wyoming developed a very large leak in the right abutment. However, the leak developed much slower at Fontenelle and the Bureau was able to lower the reservoir before a failure occurred.

In a 1967 paper on the Fontenelle experience, the Bureau's Chief Engineer concluded that a slow, controlled filling of reservoirs was needed where unfavorable foundation conditions are known to exist. Nevertheless, at Teton over 10 years later, this seemingly valuable lesson was not applied.

Although Corps practices for monitoring and controlling dam safety during reservoir filling generally were better than those used by the Bureau at Teton, both the Corps and the Bureau have procedural gaps in their monitoring and control programs which could seriously reduce their capabilities to detect and rectify problems that develop in a dam during initial reservoir filling. Improved policies and procedures in both organizations are needed regarding (1) requirements for the amount and use of instrumentation for monitoring changing conditions inside the dam and the abutments, (2) requirements for visual inspections during reservoir filling, (3) availability and capacity of outlet drains, and (4) appropriate reservoir filling criteria.

Even when monitoring policies and procedures are established or better defined, designers and others will still have to use a good deal of judgment concerning the adequacy of instrumentation, capacity of outlet drains, and other factors. Because of the judgment required, we believe that an independent design review process, like that discussed in chapter 3, can be an effective means to better ensure that designers and others who formulate monitoring programs systematically evaluate various surveillance methods and recommend appropriate solutions. Together, an independent design review and improved monitoring and control procedures should provide a means of better ensuring dam safety.

INADEQUATE AMOUNT AND USE OF INSTRUMENTATION

The Head of the Bureau's Earth Dams Section told us that instruments that may have detected leaks at Teton Dam were not used because designers believed that Teton was adequately designed to protect the dam from erosive seepage. He said that because of their past experience, they believe they can predict the structural behavior of many earth dams as they are subjected to reservoir water pressures. As a result, they have decreased their instrumentation levels in earth dams over the last decade.

Because these instruments were not installed at Teton Dam, damsite personnel could not determine whether the leaky foundation rock had been sealed or whether potentially dangerous cracks were developing in the dam that would allow erosive seepage to occur. As a result, project officials had little advance warning that anything was wrong until major dam leaks appeared on the morning of the failure. By then, however, it was too late to remedy the extensive erosion that had already taken place.

Degree of instrumentation among agencies

None of the agencies we contacted had written procedures governing minimum types of instruments 1/ for dams.

1/Instruments commonly found at more recent major earthfill or rockfill dams being built include piezometers, observation wells, and weirs to monitor seepage characteristics and drainage, and surface monuments and other devices to measure earth movement. In concrete dams, instrumentation usually includes stress meters and strain gauges to measure internal stress; plumblines and collimation systems to monitor deflection of the dam; deformation meters to measure foundation deformation; drainage collection systems to monitor seepage; piezometers to measure uplift pressure; and thermometers to measure concrete and reservoir temperatures.

However, design personnel at the Corps, TVA, and the State of California Department of Water Resources told us that, as a matter of practice, they install certain minimum instruments at all major earth dams including devices to monitor seepage in the dam and/or its foundation.

In contrast, the Bureau designers told us that they do not install instruments that could detect seepage at all their major earth dams. Instead, decisions on the types and amounts of instruments needed are made by designers based largely on their experience and judgment.

In some cases, Bureau dams are instrumented extensively. For example, at the Auburn Dam, which will be a concrete arch structure, the Bureau will install a large number and a wide variety of instrumentation to measure movement in the dam and its foundation, pressures under the dam, earthquake motion, stresses and strains in the dam, and temperature of the dam and reservoir. Because of the importance of the project, uniqueness of the structure, and the complicated nature of the foundation, there will be, in most cases, two types of instruments to measure each behavioral characteristic on which the designers want data. Also, data on many of the instruments will be read and recorded automatically.

In contrast, Bureau designers told us that the only instruments 1/ to be installed at Teton were to measure movement of the dam and earthquake activity in the immediate area. However, Bureau officials told us that the contract specifications were not clear as to when these instruments would be installed. The contractor had not completed installation of these devices when the failure occurred.

A system of observation wells also was established near the dam to determine seepage losses from the reservoir and to monitor lowland areas where potential damage from reservoir seepage could occur. The purpose of the wells, however, had little relation to dam safety.

1/According to the Bureau designers, instrumentation at the Teton Dam was to consist of surface settlement points to measure earth movement, and strong motion accelographs at the crest and base of the dam to measure earthquake activity.

In reviewing the amount of instrumentation at Teton, the Independent Panel stated:

> "For a dam of this size and complexity, facilities for measurement usually would include surface monuments for gaging vertical and horizontal movements, cross-arm settlement devices and/or slope indicators to measure internal embankment movement, piezometers to monitor water pressures within the fill and in the foundation, weirs or other devices to measure seepage, wells for observation of water level in the reservoir environs, and instruments such as accelerometers to measure earth tremors."

Based on the Panel findings and practices of other agencies, we believe that instrumentation to monitor the Teton Dam was inadequate by most industry standards.

In 1965 the safety of the Fontenelle Dam, a 128-foot high structure on the Green River in Wyoming, was threatened when a very large leak developed in the embankment near the right abutment. Since there was no instrumentation inside the dam to measure seepage, the leak was not detected until it appeared on the dam face. However, unlike the Teton Dam, the Fontenelle reservoir could be lowered before the dam failed because of unusually large drains or outlets.

Because the leak at Teton appeared to develop very quickly, the dam may have failed despite any amount of instrumentation available. On the other hand, the Head of the Bureau's Earth Dams Section said that the cost of installing such instrumentation was very small in relation to the total project costs. We believe that more instrumentation at Teton, such as that discussed by the Independent Panel, would have provided an added margin of safety and would have been worth the extra money.

We also believe that the Bureau and the Corps should reevaluate their policies and establish procedures which set forth the number and types of instrumentation and the conditions under which they should be used. We further believe that the Bureau and the Corps should establish a requirement that all instrumentation should be installed prior to reservoir filling.

<u>Frequency of reading and reporting instrumentation data</u>

For about a month before the Teton Dam failure, water levels had been rising rapidly in observation wells which the Bureau set up to monitor ground water levels. At times, water levels in wells located on the right abutment, including one at the downstream end of the grout curtain, were rising faster than the water in the reservoir. (See pp. 52 and 53.) The rapid rises in the wells had different meaning and significance to various people associated with the project.

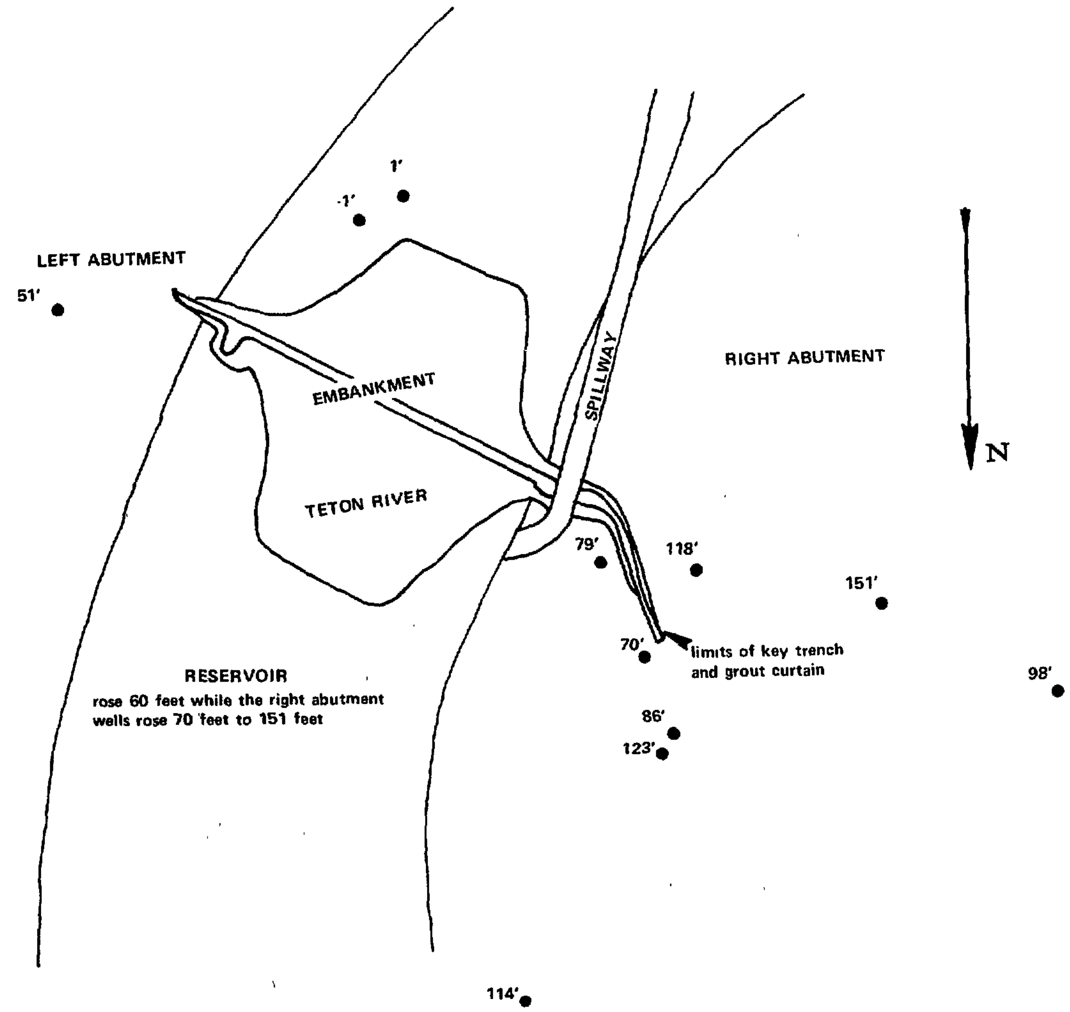
The Project Construction Engineer at the Teton site told us that he expected rapid rises in the wells and that he did not believe that such rises were alarming. Although the weekly frequency of well readings was changed to twice weekly, he said that the once-a-month schedule for transmitting the data to the E&R Center at Denver was not changed.

The ground water specialist at the E&R Center who helped set up the observation well system said that the well readings indicated to him that seepage at the site was greater than he expected. Further, he said the fact that water levels in the wells were in some cases rising faster than the reservoir was an unusual situation, which in retrospect, should have raised a "red flag" to more carefully monitor seepage near the dam.

Bureau designers told us that although the purpose of the wells had little relation to dam safety, they nevertheless provided clues to seepage conditions near the dam. The Head of the Bureau's Dams Branch said that he and others in the Branch routinely received and reviewed the observation well data. He said that there was no agreement with project personnel to immediately inform designers if water levels in the wells exceeded a certain level over a period of time. He and other designers told us that the increases of water levels in the wells for the final weeks in May indicated that the water was moving rapidly into the abutments; however, this data was sent routinely from the project to the E&R Center. It arrived the day after the failure. The onsite project staff, which had no criteria for evaluating the data, did not view the seepage data as unusual.

Bureau designers told us that had they seen such information earlier, they probably would have initiated action to check the accuracy of the data and to evaluate the effects of the seepage, if any, on dam safety. They told us that this could have led to opening the main river outlet to drain a portion of the reservoir.

This situation raises a question as to whether instrumentation systems at Bureau dams are read and analyzed by qualified personnel in a timely way so as to quickly recognize conditons that could adversely affect dam safety.



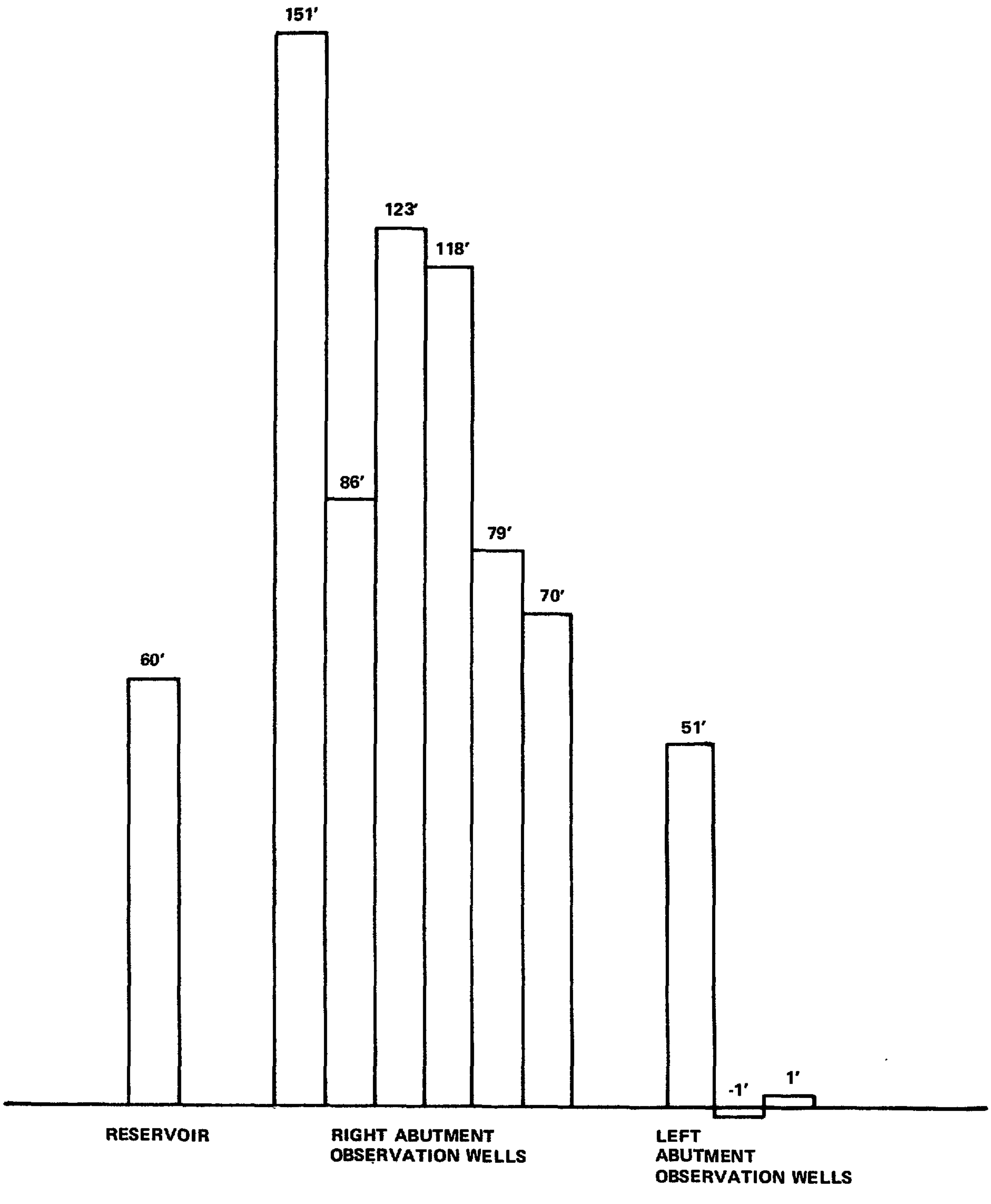
TETON DAM

Location of observation wells(●) and rises in feet for the wells and reservoir from May 13, 1976 to June 1, 1976

Source: GAO drawing based on data provided by the Bureau of Reclamation

RELATIONSHIP OF THE WATER RISE IN THE TETON DAM RESERVOIR TO THE WATER RISE IN THE SURROUNDING GROUND WATER OBSERVATION WELLS

(Cumulative Water Rise in Feet from May 13, 1976 to June 1, 1976)



Source: GAO graph based on data provided by the Bureau of Reclamation

Bureau designers told us that oftentimes project personnel would not be capable of recognizing abnormal instrumentation readings because they are not technically qualified to interpret the data or because expected ranges for instrumentation readings are not established to provide a basis for identifying potentially serious problems. Hence, most of the data is sent to the E&R Center where it is analyzed.

The ability of Bureau designers to identify any problems from instrumentation data is dependent to a large extent on how frequent the instruments are read at the site, and how fast the data is sent to the E&R Center. According to the Bureau's "Earth Manual," instrumentation in earth dams is read at least semiannually during the first year of operation. Piezometers, for example, which are instruments commonly found in earth dams to measure seepage conditions, are read monthly under normal conditions and twice monthly when the reservoir changes more than 10 feet in 15 days. The Head of the Bureau's Concrete Dams Section said that most instruments in the Bureau's concrete dams are read monthly during initial filling, and some may be read more frequently depending upon the situation at a particular dam. We were told that instrumentation data for both earth and concrete dams are normally sent to the E&R Center once each month.

Corps practices appear to differ substantially with those of the Bureau in this regard. Further, practices for reading and transmitting instrumentation data also varied among the three districts we reviewed. Based on discussions with district officials and a review of several Corps dams, we found that onsite personnel in the Walla Walla and Portland Districts read instruments such as piezometers and weirs daily during reservoir filling. The readings are also sent to the districts the same day. The Sacramento District requires weekly or monthly readings depending on the reservoir fill rate. District officials told us that the data is sent to them immediately.

The qualifications of the onsite personnel reading the instruments varied among the districts also. Walla Walla District officials told us that a designer is at the damsite during critical stages of reservoir filling to read and analyze the instruments and to initiate any action necessary if readings are abnormal. The Chief of the Foundation and Materials Branch in Portland said that the damsite staff in the district include engineers who understand design concepts and who are able to interpret instrumentation data to a certain degree. In the Sacramento District we found that

Corps park rangers and maintenance workers, with little dam design and construction background, read instruments and transmit the data to the district.

Because of the differences in this regard between the Corps and the Bureau and among Corps districts, and due to the importance of instrumentation systems as a means of detecting problems affecting the safety of the dam, we believe that the Bureau and Corps should reevaluate whether their current practices need improvement. There are a number of key questions to be considered. Should the Corps and Bureau establish expected ranges for instruments at a particular site so that onsite personnel can more readily recognize adverse conditions which may affect dam safety? What should be the qualifications for personnel who read and record instrumentation data at the damsite? Should certain types of instrumentation, such as piezometers, be read and reported more frequently by the Bureau during critical stages of construction and reservoir filling?

VISUAL INSPECTIONS

Since any instrumentation designed for Teton Dam was not completely operational when the reservoir was being filled, the Project Construction Engineer told us that daily visual observations by the project staff were the only means to monitor dam behavior. However, the effectiveness of the visual inspections as a means of identifying potential trouble spots in the dam was limited in as much as the inspections were generally made only during daylight hours. The possible consequences of such limited inspections at Teton depends on when the leak started. If, for example, the dam began leaking at night and project staff were at the site making periodic inspections, the Bureau would have had more time to devise strategies for controlling or remedying the leak.

The first indication that something was wrong at the Teton damsite came at about 7 a.m. on the day of the failure when the project staff arrived at the damsite and noticed muddy water coming out of the right abutment rock near the base of the dam. The project staff had noticed seepage in this area the day before the failure, but they stated that they considered it normal since the water was clear and there was no evidence of erosion. Since inspections had not been made of this area since 9 p.m. the night before, no one knows when the evidence of erosive seepage became visible. The dam collapsed at about 12 noon, only 5 hours after the first sign of erosive seepage was noticed.

In a broader context, Bureau officials told us that often surveillance at night or on weekends and holidays is minimal or lacking altogether at many of their dams during reservoir filling. Corps officials told us that sometimes surveillance is lacking at night for its dams. We believe the Corps and the Bureau should adopt a system of 24-hour surveillance during critical stages of construction because (1) dambuilders could detect a problem sooner and could immediately begin repairs and/or plans to notify downstream residents through radio and television announcements and other means and (2) if a problem surfaces quickly, as it did at Teton, a failure could occur at night and, without warning, result in far greater deaths and property damage. Local law enforcement officials in communities below the dam and many Bureau officials we talked with all agreed that if the Teton Dam had collapsed during the night, many more lives would have been lost.

INADEQUATE RESPONSE CAPABILITY

Bureau designers had intended to fill the Teton Dam reservoir slowly to observe the behavior of the dam and to allow remedial action if problems developed. Two drains or outlets--a main river outlet and a smaller auxiliary river outlet--were designed in the dam to regulate the height of the reservoir.

The following chronology of key events shows that the Bureau compromised dam safety by filling the reservoir before the main river outlet was available. Apparently, this was done by the Bureau to avoid the possibility of incurring contractor claims.

Moreover, the chronology also shows that when the leak in the dam was detected, the project staff could not open the main river outlet immediately and lower the reservoir because another contractor was behind schedule in completing his work.

Chronology of key events

October 1971 — The Bureau issued the Design Considerations for Teton Dam wherein Bureau designers gave the following instructions concerning initial filling and reservoir operation:

"The performance of the foundation, of the abutments, and of the embankment of Teton Dam during initial filling and reservoir operation is extremely important. * * * After the spillway, auxiliary outlet works, and dam embankment have been completed as required by the specifications, the river outlet works should be closed on October 1 (1975) of the final winter period * * *.

"When the river outlet works is closed, the auxiliary outlet works must be fully open and must be kept fully open until the river outlet works has been completed and ready for service * * *.

"After May 1 (1976) the flow in the Teton River exceeds the maximum allowable release from the auxiliary outlet works of 850 cubic feet per second, and the capacity of the river outlet works is needed in order to control the rate of filling in the reservoir. It is anticipated that with the river outlet works completed for service by May 1, storage in the reservoir could be commenced * * *.

"Unless adverse performance develops, unrestricted filling rates will be permitted to elevation 5,200 (feet). Above elevation 5,200 (feet), initial filling should not exceed 1 foot per day * * *."

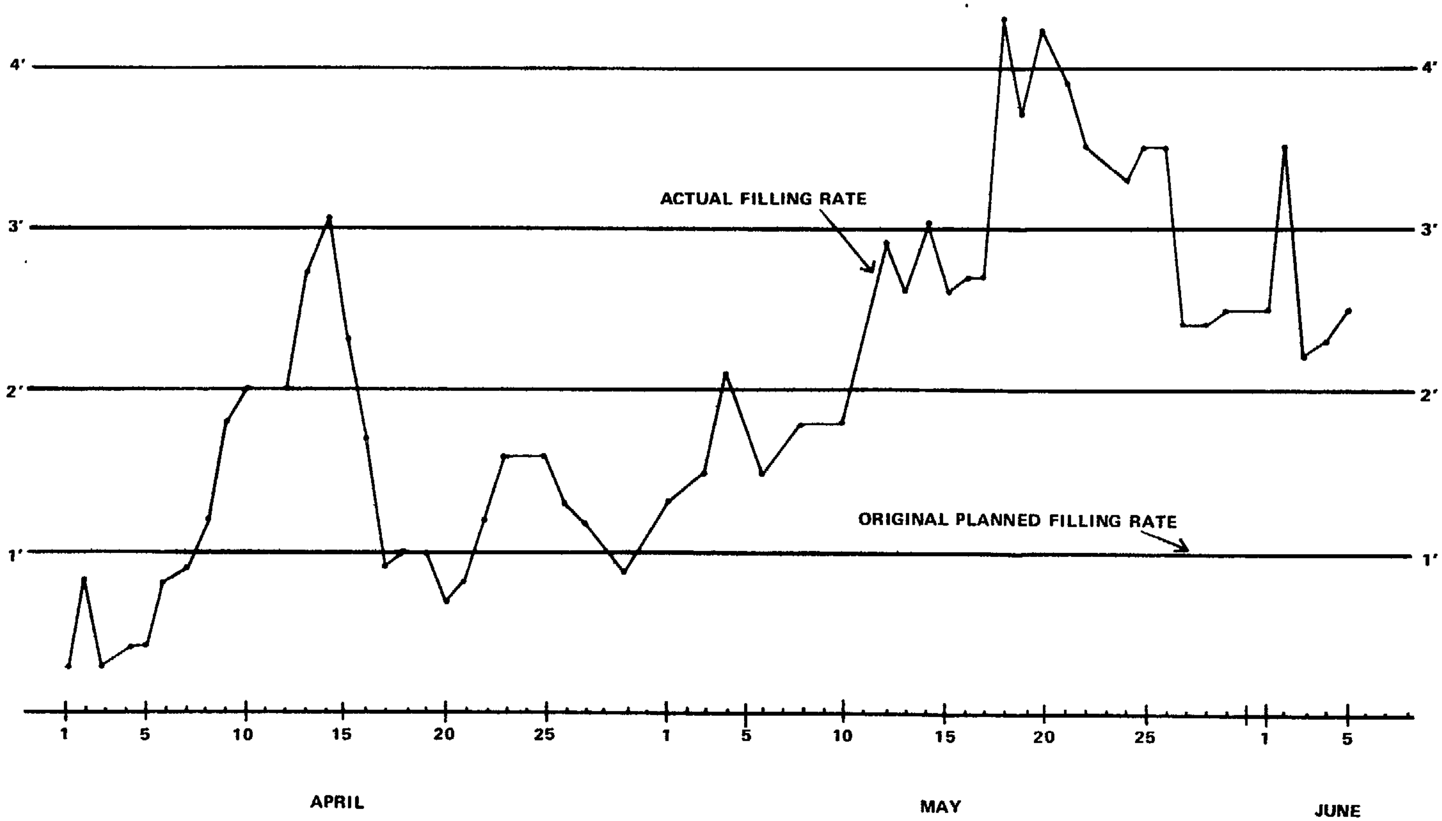
Late 1974 or early 1975

A decision was made to begin filling the reservoir in October 1975 instead of waiting until the main river outlet was complete in May 1976. The Project Construction Engineer at Teton told us that this decision was made mainly because the contractor that was to build and install the turbines in the power plant needed sufficient water in the reservoir by mid-May to complete his testing program. He further told us that the Bureau had earlier issued specifications which in effect required the contractor to test the turbines during May 1976. However, if instructions in the Design Considerations were followed, the reservoir would be almost empty at that time under normal circumstances. He said that after he discussed this conflict with cognizant designers in the Dams Branch at the E&R Center, the designers and he jointly agreed to begin filling early so that the turbines could be tested as scheduled in May, and possible claims from the contractor for late testing could be avoided.

October 3, 1975	The main river outlet was closed so that the contractor could complete its construction. Initially, the contractor was scheduled to complete the structure by April 30, 1976. The auxiliary outlet was opened only partially so that water would begin filling the reservoir.
March 3, 1976	The Project Construction Engineer at the damsite wrote the Director of Design and Construction at the E&R Center and asked that the 1-foot-per-day filling rate be increased so that the reservoir could fill more rapidly. He expressed doubt that the reservoir rise could be maintained at just 1 foot per day if river runoffs were large in the spring.
March 23, 1976	The Director of Design and Construction relaxed the filling rate for Teton to 2 feet per day. The Head of the Earth Dams Section later told us that the designers really had little choice in increasing the filling rate since the snowpack in the mountains feeding the Teton River was considerably above normal and the resulting runoff exceeded the capacity of the auxiliary river outlet.
April 8, 1976	For the first time, the filling rate exceeded 1 foot per day. (See p. 59.) The auxiliary river outlet was still partially closed at about one-third of its capacity.
April 14, 1976	The filling rate exceeded 3 feet per day with the auxiliary river outlet again open at one-third its capacity. The 2-feet-per-day criteria was exceeded again during the period May 11 to June 5, and on two occasions rose over 4 feet per day. During this period, the auxiliary river outlet was fully open.
April 30, 1976	According to Bureau officials, the main river outlet was not completed as originally scheduled because the contractor had not received the regulating gate from the manufacturer.

TETON DAM

DAILY INCREASE OF RESERVOIR HEIGHT IN FEET
FROM APRIL 1, 1976 TO JUNE 5, 1976



Source: GAO graph based on data provided by the Bureau of Reclamation.

May 14, 1976 — The Head of the Outlet and Spillway Section, Dams Branch, E&R Center told us that the main river outlet was essentially completed although it would have taken 6 to 8 hours to open because the contractor was still painting inside and that much time would have been needed to clear the tunnel and put the discharge pipe cover in place. Painting was scheduled for completion on June 10, 1976.

June 5, 1976 — The Teton Dam failed at 11:57 a.m. About 1 hour earlier one of the project staff was sent into the main river outlet to make ready its opening. However, the main river outlet could not be opened before the failure because the leak developed quickly and because of the 6- to 8-hour leadtime needed.

Given the river runoff experienced for the 3-week period before dam failure the Bureau said that they could have limited filling of the reservoir to any desired rate, and even lowered it at a rate of 1 foot a day, if the main river outlet had been available.

Near failure of Fontenelle Dam

A rapid filling rate played a crucial role in the near failure of the Fontenelle Dam. Although the 350,000 acre foot reservoir was lowered before a failure occurred, the circumstances at Fontenelle are strikingly similar to those at Teton:

--The foundations at both damsites contained fractured, cracked rock containing fissures and voids. The amounts of grout used in the foundations at both dams were very large.

--To ensure that the foundations at both locations were sealed, the designers planned to fill the reservoir very slowly so that if any leaks occurred, timely remedial actions could be taken. But the accumulation of an unusually heavy snowpack and corresponding runoff at each dam contributed to a much faster filling rate.

--Neither dam had any instrumentation to measure seepage conditions inside the dam.

--Both dams developed leaks during the first filling of the reservoir at a time when the main outlet works were not immediately available.

The leak developed much slower at Fontenelle and the Bureau was able to lower the reservoir before a failure occurred. (See p. 62.) This was posible due to the unusually large capacity of the main outlet (17,000 cubic feet per second versus 3,400 at Teton) and the availability of outlets in each abutment leading to canal systems. We were told that the capacity of the main outlet was oversized at Fontenelle because it was more economical to build a large outlet and a smaller spillway. Despite the remedial action taken at Fontenelle, over 10,000 cubic yards of embankment material was eroded from the dam before the leak was stopped.

In a 1967 paper on the Fontenelle experience, the Chief Engineer of the Bureau concluded:

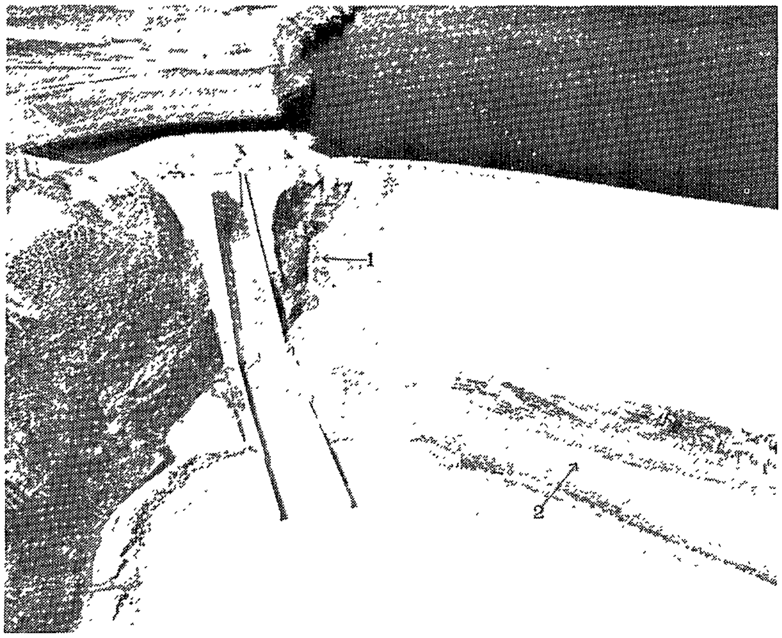
> "This difficulty occurred on first filling of the reservoir which was unusually rapid due to extremely large inflows and the fact that the outlet works were not being used so that some repair work could be performed. This experience illustrates the need for slow, controlled filling of reservoirs where unfavorable foundation conditions are known to exist."

Thus, by averting a disaster at Fontenelle, the Bureau had seemingly learned a valuable lesson regarding reservoir filling. Yet, at Teton, over 10 years later, the lesson was not applied. This time, however, the leak developed very quickly at a location over 100 feet below the reservoir water level, and the capacity of the auxiliary outlet, being much smaller than Fontenelle, could not lower the reservoir before failure occurred. (See p. 62.)

Procedures needed

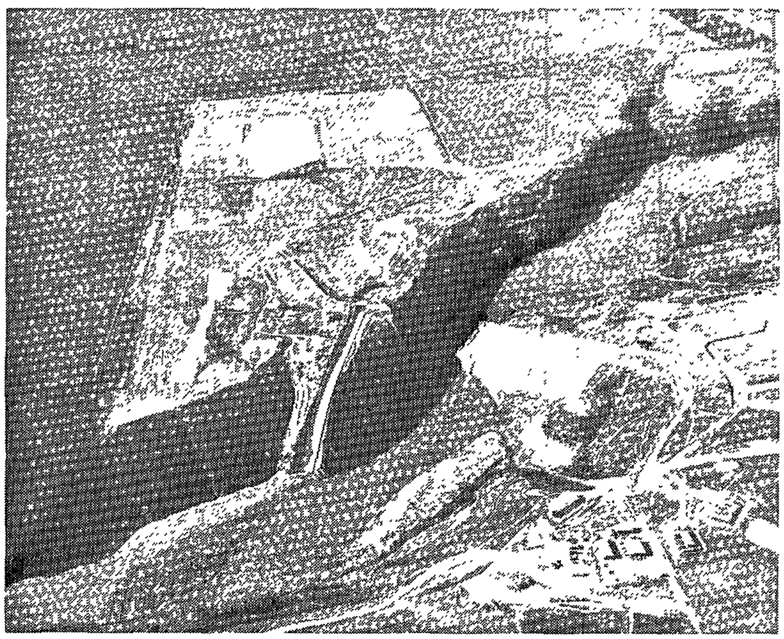
We believe that the failure of Teton Dam and the near failure at Fontenelle Dam should clearly illustrate to dam-builders the importance of (1) a slow, controlled filling rate during first filling to closely monitor the behavior of the dam and (2) an operable outlet of sufficient size to release enough water to lower the reservoir level when emergencies arise affecting dam safety.

In relation to the need for a slow, controlled filling rate, we found that none of the agencies we visited had any formal criteria. A 1-foot-per-day filling criteria has been specified by the Bureau for some dams during the initial



FONTENELLE DAM— LEAKAGE AND THE RESULTING EROSION OF THE RIGHT SIDE OF THE DAM (see arrow 1) AND EROSION ON THE FACE OF THE DAM (see arrow 2)

SOURCE: BUREAU OF RECLAMATION



TETON DAM— AFTER THE FAILURE

SOURCE: BUREAU OF RECLAMATION

filling process, but according to Bureau officials, this is an unwritten rule of thumb used in certain situations when designers think it is important to test the abutments and embankment. The Bureau believes that this cautious filling rate is slow enough to allow them to take remedial action before large pressures develop in the reservoir which may tend to increase leakage.

Corps officials told us that they do not attempt to limit the filling rate in many instances because their dams are designed to withstand any rate of fill. They did say, however, that where possible a slow filling rate is desirable to monitor the behavior of a dam. They also said that reservoir filling would be halted if instrument readings indicated a problem.

At the Teton Dam the main river outlet never became operational. Bureau designers told us that like the Teton Dam, outlets which are used to divert water are not usually completed on many of their dams before water begins storing in the reservoir because it is more economical to install these outlet works after the reservoir begins filling. They further stated that, consequently, no control over the water in the reservoir is available for a period of 4 to 6 months on many Bureau projects, but that these installations generally are performed during the nonflood season.

Corps guidelines do not specify when the outlets should be available in relation to the filling schedule. For every dam built by the three Corps districts we reviewed, however, the outlets were completed and available before the beginning of the reservoir filling process.

TVA and the State of California Department of Water Resources officials told us that their policy is to have ready the spillway and outlets before reservoir filling begins. However, TVA officials told us that the effectiveness of its outlets to control the reservoir water levels would be limited at many of its dams, especially during periods of high river runoffs because the outlets are not big enough.

TVA's comment about the size of the outlets brings up another important question: "Aside from the spillway at the top of the dam, how large should the outlets be to provide the capability to lower the reservoir during emergencies?" Bureau and Corps officials told us that the capacity of outlets in their dams are such that most of the water in the reservoirs could be emptied in 90 to 120 days. Officials in the State of California Department of Water Resources said that outlets designed for their dams are generally large enough to empty at least half of the reservoir in 14 days. Officials at all three agencies told us, however, that in the case of very large reservoirs, it would be impractical to build the huge outlets necessary to lower the reservoir.

We believe that the Bureau should establish a written policy requiring that outlets be complete before reservoir filling commences so that slower filling rates can be maintained. Also, we believe that the Bureau and Corps should evaluate the need for larger capacity outlets in dams they design in the future to provide more capability to lower the reservoir.

RECOMMENDATIONS

We recommend that the Secretary of the Interior direct the Bureau of Reclamation and the Secretary of Defense direct the Corps of Engineers to:

--Reevaluate their policies for instrumenting dams relative to the number and types of instrumentation that should be used and the frequency for reading instruments and reporting the data to designers. As part of this reevaluation, both agencies should (1) establish written policies for factors that should be measured at damsites at a minimum regardless of the site conditions, (2) better define those situations where more than the minimum instrumentation should be seriously considered and/or implemented, and (3) require that all instrumentation be installed before reservoir filling. Also, they should establish, where practical, expected ranges for instruments at a particular site so that onsite personnel can more readily recognize adverse conditions which may affect dam safety. Finally, they should either ensure that the people at the site are qualified to interpret the instruments or require that instrumentation data is immediately sent to knowledgeable designers for analysis.

--Issue instructions to require 24-hour surveillance of dams during critical phases of construction and reservoir filling for safety and security purposes.

--Establish guidelines for reservoir fillings, giving special consideration to situations where difficult foundation conditions exist at the damsite.

--Establish a written policy requiring that outlets be completed and in operating condition prior to the start of reservoir filling.

--Reevaluate the need for large capacity outlets (other than the spillway) to provide better capability to lower reservoirs when serious safety problems arise.

--Use the independent review process to better ensure that designers and others who formulate monitoring programs systematically evaluate various surveillance methods and recommend appropriate solutions. (See ch. 3.)

CHAPTER 6

NEED TO IMPROVE EMERGENCY PREPAREDNESS

PLANS AND PROCEDURES

Local officials and people living downstream from the Teton Dam were warned about an hour before the dam collapsed, and even then there was confusion about the urgency of the situation. In some instances, people could not be warned in time. For example, there were no effective means to alert several people hiking or fishing in the canyon below the dam, and one of these people died in the flood. In addition, the sheriff in one community, after receiving a call from the Project Construction Engineer at Teton, did not understand that the situation was urgent, and notification of residents did not begin immediately.

CHRONOLOGY OF KEY EVENTS DURING THE FAILURE

A chronology of events on the morning of the failure helps illustrate the need for improved emergency preparedness plans and procedures in the Bureau:

7 to 8 a.m.	Members of the project staff noticed muddy water leaking from the base of the dam.
9 a.m.	The Project Construction Engineer arrived at the dam and began assessing the situation. He said he saw a major leak at the downstream base of the abutment and another smaller leak estimated to be 900 gallons a minute about 130 feet from the top of the dam.
9:30 to 10:00 a.m.	The Project Construction Engineer said he called the Pacific Northwest Region in Boise, Idaho, and the E&R Center in Denver, Colorado, to inform them of the leaks.
10 a.m.	The Project Construction Engineer observed a larger leak estimated at 6,750 gallons a minute on the dam adjacent to the smaller one which he had seen earlier. He said from his point looking directly into the hole, it was a tunnel about 6 feet in diameter and extending back into the dam for about 35 feet.

10:30 to 10:45 a.m. Two bulldozers were sent to dump rock into the hole in an attempt to stop the leak. The Project Construction Engineer said he called the sheriffs' offices in in two counties below the dam and advised them to alert citizens of potential flooding and to be prepared to evacuate the area downstream. After receiving the message from the project office, the sheriff of one county told us that he began immediately to notify residents to prepare for possible evacuation.

The sheriff in the other county told us that he did not sense the urgency of the situation based on the Project Construction Engineer's comments that the dam was not in immediate danger, and that if a failure occurred, it would probably be a slow process. Hence, he said immediate action was not initiated to warn people. He dispatched a deputy to the dam and called a local radio station.

The radio station, however, allowed its taped programing to continue before broadcasting a warning because of the apparent lack of urgency of the situation. The sheriff told us the urgency of the situation was not apparent to him until his deputy called back to notify him that the dam had failed. The sheriff commented that if he had realized the seriousness of the problem, he could have notified residents immediately and evacuated everyone to safety, except perhaps those fishing and hiking in the canyon. He said that, as it was, county officials simply did not have enough time to explain the situation, and many people failed to understand the seriousness of a dam failure in relation to other floods they had lived through. Sheriffs in both counties said they had established no emergency preparedness plans in case of dam failure because no one thought that the dam would ever fail.

The Project Construction Engineer said he also tried to reach the two civil defense agencies in the county but their telephone lines were busy. He told us that he had no radio system to contact the civil defense offices and the sheriffs.

Some Corps districts we visited have a radio communication tie-in with project offices at their dams in case telephones are busy or inoperable during emergencies. We believe that the Corps and Bureau should consider such a system at all its dams, especially during reservoir filling.

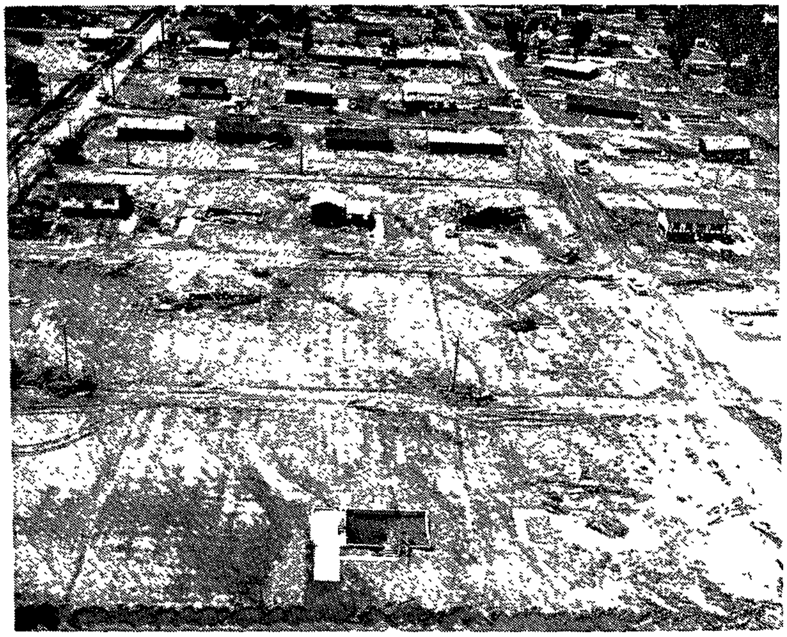
11 a.m.	Project staff noticed a whirlpool developing in the reservoir near the dam. The whirlpool grew large rapidly and some embankment fell into it.
11:20 a.m.	The bulldozers which were trying to fill the large hole on the face of the dam fell into it as the erosion progressed rapidly up the dam toward the top.
11:57 a.m.	The dam collapsed and two cities--Sugar City (see p. 69) and Rexburg (see p. 70) --were damaged heavily by the flood waters shortly thereafter.

NEED FOR BETTER EMERGENCY PREPAREDNESS PLANS AND PROCEDURES

As evidenced by the aftermath of the Teton Dam collapse, a workable system for notifying and evacuating local communities when critical conditions arise affecting dam safety is extremely important. Yet, we were told that the Bureau and Corps do not have definitive, written instructions or guidelines setting forth procedures for identifying adverse conditions at a damsite that require immediate notification and/or evacuation of people downstream of the dam, or for assisting and coordinating with local communities to ensure that an adequate preparedness plan is developed and understood.

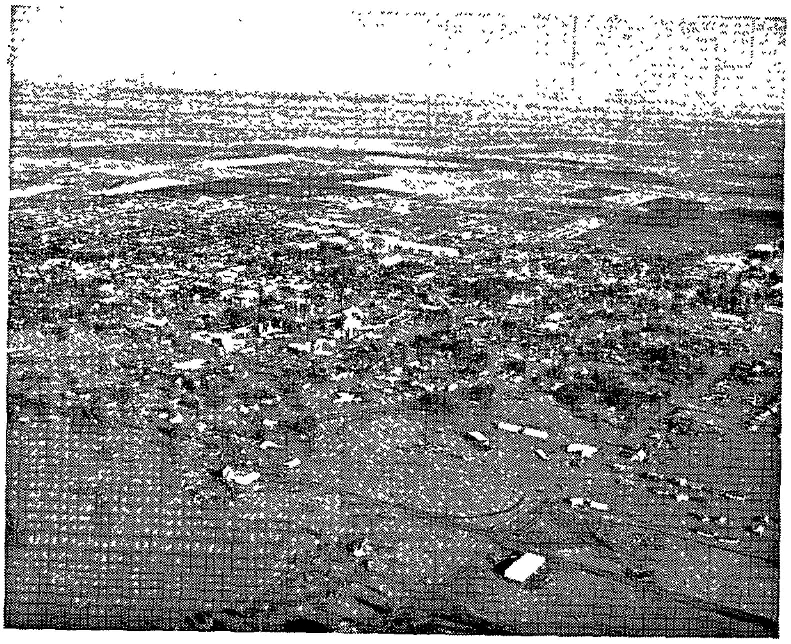
SUGAR CITY, IDAHO—— FLOODING ON JUNE 5, 1976, CAUSED BY THE FAILURE OF THE TETON DAM EARLIER THAT MORNING

SOURCE: BUREAU OF RECLAMATION



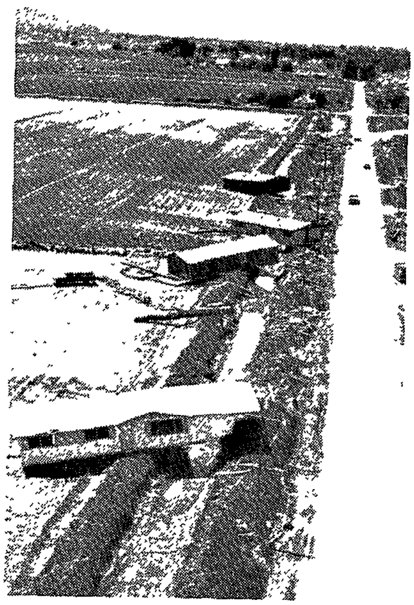
SUGAR CITY, IDAHO——VACANT FOUNDATIONS WHERE HOUSES WERE WASHED AWAY AS A RESULT OF THE TETON DAM FAILURE

SOURCE: BUREAU OF RECLAMATION



REXBURG, IDAHO--FLOODING ON JUNE 5, 1976, CAUSED BY THE FAILURE OF THE TETON DAM THAT MORNING

SOURCE: BUREAU OF RECLAMATION



REXBURG, IDAHO--HOUSES MOVED FROM THEIR FOUNDATIONS AS A RESULT OF THE TETON DAM FAILURE

SOURCE: BUREAU OF RECLAMATION

Additionally, the Bureau has no instructions which assign specific responsibilities for developing contingency plans for situations affecting dam safety.

The Project Construction Engineer for Teton Dam told us that through their own initiative, the project staff prepared a document entitled "Teton Emergency Notifications." It contained available Bureau instructions and memorandums covering internal reporting procedures when unusual or serious conditions arise, and information on fire prevention and medical facilities. The project staff also prepared a "Self Protection Plan" as part of the overall document. This plan contained instructions for certain types of emergency conditions including fire, bombings, enemy attack, and earthquakes. However, it did not contain procedures for notifying and evacuating residents downstream in case of a dam failure, because project officials did not anticipate that such a catastrophe would occur.

Sheriffs in both counties told us that the Bureau made no attempt before the failure to assist the counties in developing an evacuation plan or to discuss any other matters pertaining to a dam failure. They agreed that more coordination between the Bureau and community agencies was needed to ensure that an adequate emergency preparedness plan was developed and that emergency conditions are clearly communicated and the consequences understood. Both sheriffs suggested that public meetings would be a good way to help people understand the significance of a dam failure and the correct procedures to follow when evacuation warnings are given. In addition, they said that inundation maps would be useful to show the path of the water and areas of flooding after a failure. These maps would not only be useful to residents in deciding which areas were safe from flood waters, but also local officials would know whom to notify first. Currently, in the State of California, inundation maps are prepared for all dams recently constructed in the State.

Of the three Corps districts we visited, only the Portland District, had prepared formal contingency plans for the most recently constructed dams in the district. These plans include names, addresses, and phone numbers of Corps personnel and local officials who should be notified, and certain emergency procedures that should be followed. The other two districts provide only lists of names and telephone numbers of the Corps and local people that should be contacted. Corps officials told us that usually the project engineer is responsible for judging the seriousness of conditions that require notification of residents downstream of a dam.

The Sacramento District advised us that it has prepared contingency plans for earthquake situations--including a checklist for immediate post-earthquake inspection and a list of telephone numbers of local officials to call in the event dam failure is imminent or occurring--as well as inundation maps for dams in the area.

In our opinion, the confusion regarding the timeliness and unclear communications between the project staff and local officials before the Teton Dam collapsed, coupled with the fact that they were almost totally unprepared for the possibility of a dam failure, illustrates the need for improved emergency preparedness plans and procedures.

RECOMMENDATIONS

We recommend that the Secretary of Defense require the Corps of Engineers and the Secretary of the Interior direct the Bureau of Reclamation to:

--Revise guidelines and procedures to establish a stronger emergency preparedness program. Emergency preparedness plans should be prepared by project staff for all major dams before reservoirs are filled. These plans should be approved by regions or districts and by headquarters staff. The plans should be submitted for comments to the same independent consulting boards who review site investigations and dam design. Moreover, each plan should be developed and discussed with local community leaders so that people clearly understand evacuation procedures if an emergency arises. To the extent possible, the plans should contain a definition of emergency situations that require immediate notification of local officials. As a minimum, the plan should also include names, addresses, and telephone numbers of key project, regional or district, and headquarters staff, as well as community officials to contact. Further, the plan should include maps which show lands that would be flooded if a failure occurs.

--Evaluate the availability and use of radio systems between damsites and civil defense or other emergency offices as an alternative means of communications in case telephones are busy or inoperable during emergencies.

--Study the feasibility of using horns or other publicized alarm systems during emergencies to warn people that may be downstream near the dam. These systems should be thoroughly explained to the residents of the area to preclude any confusion as to their meaning.

CHAPTER 7

CONSIDERATION OF INFORMATION OBTAINED FROM GEOLOGICAL SURVEY AND PROBLEMS IDENTIFIED BY OTHER AGENCIES, GROUPS, OR INDIVIDUALS

As requested by the Subcommittee, we reviewed Bureau and Corps procedures for obtaining geologic information available from USGS and the process for handling and answering comments and inquiries received from other agencies, groups, or individuals concerning the safety of damsites or designs.

We found that both agencies obtained, on an informal basis, geological information and studies prepared by USGS pertaining to proposed damsites. Bureau and Corps representatives with whom we discussed this matter believe that a formal agreement would be beneficial to better ensure that all pertinent documents are submitted and that the information submitted had the official backing of USGS.

Regarding the answering of inquiries, we noted that the Corps and the Bureau appeared to have adequate procedures. They considered the comments and replied when a reply was requested. We did not evaluate the technical adequacy of the reponses, nor did we determine in all the cases we examined whether investigations made to answer these inquiries were adequate. We believe that in the future, because of the technical nature of the information, such inquiries and replies should be submitted to the independent consultants (referred to in chs. 2 and 3) for their consideration when they are retained to review the adequacy of site investigations and design on a particular project.

To determine the adequacy of the procedures used, we discussed them with geologists, engineers, and supervisors at all Bureau and Corps offices included in our review. Also, we reviewed all files on the Teton and Ririe projects to determine what comments or inquiries had been received relating to the safety of either the damsite or the design. At regions or districts we visited, we obtained correspondence from a number of sources relating to the safety of Auburn and New Melones Dams in California, Palisades Dam in Idaho, and the Corps' Applegate and Lost Creek Dams in Oregon. After discussing these inquiries with regional or district officials, we contacted USGS, the State of California Department of Water Resources and the Idaho Water Resources Board for comments about the nature of their inquiry to the Bureau and Corps on these matters. In total, we looked at 28 inquiries relative to the safety of five dams, and our specific comments follow.

INFORMATION OBTAINED FROM USGS

As stated earlier in chapter 2, Bureau and Corps planners, geologists, and designers informally obtain, early in the planning process, available geologic information such as topographic and geologic maps and written reports prepared by USGS. There is no formal arrangement or agreement between the Bureau or Corps and USGS requiring USGS to provide them with any information it may have regarding the geology of a damsite being considered.

The Chief of the Bureau's Geology and Geotechnology Branch stated that the Bureau has no particular problem with obtaining this information from USGS. They said, further, that sometimes the Bureau is unaware of work being performed by USGS in an area where the Bureau has a project under construction or in operation. A Bureau Division of Design official stated that formal agreement between the Bureau and USGS could better ensure that the Bureau receives all pertinent geologic reports. He suggested that such an agreement should require USGS to provide a listing of all past reports dealing with the area of interest, any current or planned effort in the area, and the names of USGS personnel performing this work. Corps officials at the district and OCE level stated they had a good informal working relationship with USGS field personnel for obtaining the results of survey work in areas where it was considering a damsite. Corps district officials stated, however, that a formal agreement between the two agencies at the headquarters level could be beneficial, and would better ensure that information obtained from USGS personnel had the official backing of the agency.

COMMENTS AND INQUIRIES OF OTHER AGENCIES, GROUPS, AND INDIVIDUALS

Both the Bureau and Corps receive numerous inquires and comments from other Federal, State, and local agencies, non-Government organizations, and private citizens concerning the location of sites and the design and construction of dams. While neither the Bureau nor the Corps has specific written guidelines for investigating and responding to these inquiries, in practice, they both have essentially the same methods for answering such inquiries.

Depending on the nature of the problem, inquiries are received at either the headquarters or regional or district offices, and are then directed to the responsible branch or section within each office for consideration and investigation if necessary. If the Bureau or Corps concludes that the matter has already been adequately considered, a letter explaining the situation will normally be written to the outside agency, organization, or individual. If the matter warrants further investigation, the Bureau or the Corps will perform necessary work and include their findings in the reply. Typically, as indicated by the examples shown below, the inquiries or comments are received after the site has been investigated and the project is under construction.

Many of the comments received by both agencies regarding dams concern environmental, social, or other impacts rather than safety of projects. Corps officials said that many comments now received are in response to draft environmental statements distributed for public comment.

The types of inquiries received from and information provided by other agencies, groups, and individuals relating to dam safety and the consideration given them by the Bureau and Corps are illustrated below. These are merely selected examples and should not be construed as being the only inquiries or comments received on these particular projects.

TETON DAM

Concern of USGS personnel about the seismic instability, presence of faults, and possibility of rock or earth slides in the area of the Bureau's Teton Dam has been brought out in congressional hearings held since the dam collasped. The concern grew out of geologic investigations that USGS conducted in the Snake River plain area during 1972-73. These studies indicated that the Teton damsite was in an active seismic area, the reservoir area was cut by faults and fractures, and on the surface it appeared that a fault existed on the right abutment near the dam. The USGS study was discussed with the Project Construction Engineer at Teton and Bureau geologists in Denver, Colorado in 1972-73.

In July 1973 USGS provided the Bureau with a copy of its draft "Preliminary Report on Geologic Investigation, Eastern Snake River Plain and Adjoining Mountains" based on initial field work done in 1972. The report pointed out that Southeastern Idaho, including the area of the Teton project, was subject to strong and frequent earthquakes, and that studies suggested that deformation was continuing along faults in and near the reservoir area. The report also pointed to the possibility of a fault near the right abutment of the dam.

Bureau engineering officials stated that the Bureau was already aware that the dam was in a seismically active region and that there was faulting in the reservoir area. They stated that the dam had been designed to withstand earthquake motion and the only new information that USGS had provided concerned the possible fault in the right abutment. Bureau officials told us that they drilled one hole on an angle in the area of the inferred fault and examined excavations and tunnels at the damsite and the canyon walls where the fault should have surfaced. They told us that they found no evidence that it existed. In any event, they believed that even if such a fault existed, it was probably inactive, because USGS investigations indicated that a significant earthquake probably had not occurred there in about 2 million years.

The Bureau considered the report provided by USGS to be informational in nature and that no response was required. A USGS official stated that no response was anticipated and, in any event, that USGS would not be qualified to assess the adequacy of any engineering determinations made by the Bureau.

RIRIE DAM

In mid-1976, after the failure of Teton Dam, the grouting subcontractor for the Corps' Ririe Dam wrote the prime contractor expressing concern regarding the methods used for grouting and the adequacy of the grouting operation. The prime contractor conveyed the subcontractor's concerns to the Corps, adding that the possibilities raised deserved a thorough appraisal by the Corps.

Although instrumentation at the dam and visual inspection indicated the dam was functioning as expected, the Corps initiated a detailed review of this matter. The review was made by the Chief of the Walla Walla District's Foundation and Materials Branch who reviewed the actual grouting operation in relation to the design and specifications. He concluded that the subcontractor's concerns were understandable, but in many instances not founded in fact. Instrumentation in the foundation clearly showed the grout curtain was functioning as designed, and no additional grouting should be done until instrumentation evidenced a need.

The report of this investigation had been reviewed by the Division and forwarded to OCE. The district had also advised the contractor that its investigation did not reveal any conditions which would be detrimental to the safety of the dam.

AUBURN DAM

The Bureau has received numerous inquiries and comments regarding the safety of the Auburn Dam which is currently under construction above Sacramento, California. Since early 1974, the Bureau has received many letters from individuals (engineers), the Association of Engineering Geologists, the State of California, and different Congressmen and Senators all concerned whether the dam would provide adequate safety during an earthquake. They also expressed concern regarding the use of a concrete arch dam given its length, the foundation conditions at the site, and earthquake activity in the area.

After the August 1975 Oroville earthquake, the State of California suggested that the Bureau reconsider its earthquake design criteria for the dam. The Bureau responded that strong earthquakes in the Oroville area were not necessarily out of the ordinary, but in light of this event the Bureau would reassess its design criteria for the dam.

In mid-1976, the Bureau appointed a consulting firm to review the design response of the Auburn Dam in relation to the possible earthquake activity in the Foothills Fault System. The possibility of a fault is being investigated by Bureau geologists. A board of consultants was retained to independently review and evaluate the findings of the studies by the first consultant. It will also review the design procedures followed in determining the safety of the structure. Bureau officials told us that the entire study activity should be completed in July 1977.

In September 1976 the State of California again wrote the Bureau, stating the State Division of Water Resources had reviewed the design earthquake criteria used by the Bureau for the dam and believed it was not adequate, but that the Bureau's retention of consultants to review the seismicity of the damsite resolved the concern for the time being. The State concluded that it could not support construction of the dam until its Division of Dam Safety had reviewed the reports and conclusions of the consultants and agreed the dam as designed would be safe.

NEW MELONES DAM

After the 1975 Oroville earthquake, the State of California Department of Water Resources asked the Corps of Engineers about the safety of site conditions and the design of the New Melones Dam being built on the Stanislaus River above Stockton, California. State personnel reviewed design memorandums for the dam, visited the site, and discussed the project with the Corps' engineers and geologist. The project is within the Foothills Fault System which, until the Oroville earthquake, had been considered inactive. The State, after its evaluation, suggested the Corps revise the compaction requirement for the embankment core from 95- to 99-percent average relative compaction to provide a greater margin of safety during earthquakes. The Corps agreed to the revision.

PALISADES DAM

Comments and inquiries received were not restricted to dams being built or recently completed. In August 1976 USGS pointed out to the Bureau that there were enormous slide masses along its 20-year old Palisades Reservoir for which the stability was not known. In November 1976 Bureau and USGS geologists jointly examined these slide masses. They concluded that the landslide masses were ancient and stable and did not pose a risk to Palisades Dam or Reservoir. Thereafter, both agencies considered the matter to be satisfactorily resolved.

RECOMMENDATIONS

To ensure that the Bureau and Corps receive all information from USGS on the geology or potential hazards of an actual or potential damsite under consideration, we recommend that the Secretaries of the Interior and Defense establish a formal agreement calling for the prompt transmittal of all existing reports and information relating to an actual or potential damsite from USGS to the Bureau and Corps. Also, the formal agreement should contain a provision whereby USGS would brief the Bureau or Corps on the information it has developed that has not yet been incorporated into a published report.

Also, we believe that inquiries and comments received from individuals and organizations can be useful to the Corps and Bureau in identifying or providing relevant data on conditions that could affect dam safety. To ensure that all inquiries or information on potential safety hazards of a damsite or dam design received from other agencies, groups, or individuals receive appropriate consideration, we recommend that the Secretaries of the Interior and Defense require the Bureau and Corps provide these communications to the independent boards of consultants for their evaluation when they are retained to review the adequacy of the site investigations and design on that particular project.

CHAPTER 8

ACTIONS BEING TAKEN TO COORDINATE FEDERAL DAM SAFETY PROGRAMS AND DEVELOP PROPOSED FEDERAL GUIDELINES

In an April 23, 1977, memorandum the President directed that the head of each Federal agency responsible for, or involved with site selection, design, construction, certification or regulation, inspection, maintenance and operation, repair, and ultimate disposition of dams immediately undertake a thorough review of practices which could affect dam safety and integrity. Based on this review and reports thereon, an interagency report and proposed Federal dam safety guidelines are to be prepared by an ad hoc interagency committee, convened by the Chairman of the Federal Coordinating Council for Science, Engineering, and Technology.

The interagency committee's report and proposed Federal guidelines are to be prepared by October 1, 1977. The purposes of this interagency report and the proposed Federal guidelines are to coordinate dam safety programs, seek consistency and commonality as appropriate, and provide recommendations as to the means for improving the effectiveness of the Government-wide dam safety effort.

In addition, the Director of the Office of Science and Technology Policy is to arrange for a review of the interagency report and the proposed Federal guidelines by a panel of experts who will obtain the views and advice of established organizations, professional societies, and others concerned with the safety of dams. This review and the report thereon is to be completed no later than October 1, 1978.

RECOMMENDATIONS

We recommend that the Secretaries of the Interior and Defense specifically address, in the reports to the Chairman of the Federal Coordinating Council for Science, Engineering, and Technology, the actions taken or planned by the Bureau of Reclamation and the Corps of Engineers on the recommendations in this report.

We further recommend that the Chairman of the Federal Coordinating Council for Science, Engineering, and Technology evaluate the applicability of the recommendations in this report, to Federal agencies in addition to the Bureau and the Corps, in the preparation of the proposed Federal dam safety guidelines.

United States Department of the Interior

OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

MAY 20 1977

Mr. Henry Eschwege
Director, Community and
Economic Development Division
U.S. General Accounting Office
Washington, D.C. 20548

Dear Mr. Eschwege:

We have reviewed your proposed draft report to the Chairman, Environment, Energy, and Natural Resources Subcommittee, House Committee on Government Operations entitled "Actions Needed to Increase the Safety of Dams Built by the Bureau of Reclamation and the Corps of Engineers." Because of time restrictions on our comments, we have found it expedient to provide, in lieu of detailed comments, the enclosed annotated copy of the report reflecting the Bureau of Reclamation's recommended changes.

In addition to those recommended changes, we believe that the discussion on Auburn Dam, page 117, should be revised to read as follows:

> In mid-1976, the Bureau appointed a consulting firm to review the design response of the dam in relation to the possible earthquake activity in the Foothills fault system. The possibility of fault is being investigated by Bureau geologists. A board of consultants was retained to independently review and evaluate the findings of the studies by the first consultant. It will also review the design procedures followed in determining the safety of the structure.

Presentation of the Department's comments in this manner has been discussed with and agreed upon by GAO representatives and the Department of the Interior.

Sincerely yours,

Deputy Assistant Secretary
Policy, Budget, and Administration

Enclosure

Note: The Bureau's annotations and the Department's comment on Auburn Dam were considered in finalizing the GAO report.

EXECUTIVE OFFICE OF THE PRESIDENT
FEDERAL COORDINATING COUNCIL FOR SCIENCE, ENGINEERING, AND TECHNOLOGY
WASHINGTON, D.C. 20500

May 16, 1977

Mr. Henry Eschwege
Director
Community and Economic Development Division
United States General Accounting Office
Washington, D.C. 20548

Dear Mr. Eschwege:

I appreciate having received copies of your draft report entitled "Actions Needed to Increase the Safety of Dams Built by the Bureau of Reclamation and the Corps of Engineers." The report is very timely.

As you know, the President has recently directed a major review of dam safety programs in the Federal Government. That review will have three parts: 1) Each agency responsible for dam design, construction, and regulation will review practices that affect the safety of dams under its jurisdiction; 2) An ad hoc interagency committee will coordinate dam safety programs and will develop recommendations for improving the Federal dam safety effort; and 3) A panel of experts established by the Office of Science and Technology Policy will review agency procedures and the recommendations of the interagency committee. The panel review is to be completed by October 1978.

The review is just beginning so we are not yet in a position to provide substantive comments on the GAO draft. The draft does highlight a number of issues that will be considered by the interagency committee and the outside panel. The information in the document will be useful to our staff in carrying out our review.

Sincerely,

Frank Press

Frank Press
Chairman

Enclosure:
Presidential Memorandum on Dam Safety
April 23, 1977

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