For: SMITHS FORK PROJECT
LEVEL II STUDY
FINAL REPORT

For: WYOMING WATER DEVELOPMENT COMMISSION

G.B.R. CONSULTANTS GROUP, INC.
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February 15, 1985

Wyoming Water Development Commission
Herschler Building, 3rd Floor East
Cheyenne, Wyoming 82002

Attention: Mr. Michael O'Grady
Smiths Fork Project Manager

Re: Final Report
Smiths Fork Project
Contract No. 9-00246 and Addendum

Dear Mr. O'Grady:

In accordance with the provision of contract No. 900246 and Addendum
GBR Consultants Group, Inc. respectfully submits one hundred (100) copies of
the final report for the Smiths Fork Project Level II Study.

Sincerely,
GBR CONSULTANTS GROUP INCORPORATED

John L. Probasco, P.E. & L.S.
President

JLP:jd
ACKNOWLEDGEMENT

During the preparation of the Level II Report GBR received support, needed information and excellent cooperation from among individuals and agencies. We wish to acknowledge the following agencies:

Wyoming Water Development Commission
State of Idaho Department of Water Resources
Utah Division of Water Resources
Bear River Commission
Bear Lake Regional Planning Commission
Wyoming Water Division Four
Wyoming State Engineers Office
Wyoming Game and Fish
Utah Power and Light
United States Soil Conservation Service, Cokeville
Lincoln County Agriculture Agent
Representatives of the Covey Canal Co.
Local Residents

We Express our thanks and deepest appreciation to all concerned for the assistance offered and given.
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EXECUTIVE SUMMARY

This summary presents the results of a Level II Feasibility Study for a project on Smiths Fork of the Bear River. The need for this study was determined by the Wyoming Water Development Commission. As proposed, the project consists of constructing a dam and a 125,000 acre-foot storage reservoir at a location identified in a Level I Feasibility Study as the Lower Teichert-Bagley Site. The site is north of Cokeville in Lincoln County, Wyoming.

A second reservoir site identified by GBR Consultants Group is approximately 2,900 feet downstream from the Teichert-Bagley site. The lower site is similar in character to the upper site. The sides of the Smiths Fork valley have uniform slopes that will make good dam abutments. There is a saddle on the west side which can be used as a borrow area for the dam and also will serve as an emergency spillway for the reservoir. Following a field review of both sites with representatives of the Wyoming Water Development Commission, it was decided to include the lower site in the Level II study.

In July, 1984, the Water Development Commission retained GBR Consultants Group, Inc. to complete the Level II Feasibility Study. Specific tasks to be completed by the Engineer were detailed in Contract No. 9-00246, between the Water Development Commission and GBR Consultants Group, Inc.
Smiths Fork Dam and Reservoir are intended to create a multi-purpose facility. Storage of irrigation and municipal waters, hydropower generation, flood control, recreation and enhancement of downstream water quality are the principal benefits anticipated.

The Level II Feasibility Study evaluates in detail the potential of the project and identifies conditions that would impair or preclude advancement of the project into final design and construction. Specific technical areas evaluated in the Study include:

- Advanced Hydrologic Analyses
- Legal and Institutional Impact Analyses
- Hydropower Potential Analysis
- Geotechnical Analyses
- Preliminary Design and Cost Analyses
- Formulation of an Operating Plan
- Aerial Mapping and Ground Survey
- Economic Analysis Emphasizing Agricultural Benefits
- Downstream Water Quality Impacts Analysis

The following paragraphs summarize the results obtained in completing the various analyses identified above. Since two (2) dam sites were ulti-
mately investigated, the first being the Lower Teichert-Bagley Site identified in the Level I Study and the second located approximately 2,900 feet downstream from the first site, appropriate reference is made in the summaries where conditions are applicable.

HYDROLOGIC ANALYSIS

Reservoir simulations utilizing the State of Utah's Bear River Model and a model developed by GBR were based on in the following assumptions:

- 60,000 acre-feet of water storage rights would be transferred from Bear Lake to Smiths Fork. This storage would be released during the irrigation season, with total release in the year in which it was stored.

- The minimum release for downstream aquatic life would be 65 cfs.
- Minimum pool storage would be 25,000 acre-feet.
- Maximum pool storage would be 125,000 acre-feet.

The model indicates that after all Bear River Compact, irrigation, municipal and low flow demands or allocations have been satisfied, shortages
would occur in eighteen of the fifty-three years of record while maintaining a 25,000 acre-foot pool. In addition, the analysis shows that the projected inflow to the reservoir will exceed 65 cfs 77 percent of the time, and an outflow greater than 65 cfs, including spills, can be met 93 percent of the time. Minimum flows for hydropower generation, 50 cfs, can be met 98 percent of the time and hydropower bypasses will occur 10 percent of the time.

FLOOD ROUTING

Probable Maximum Flood Flows were computed for the sites. The analyses indicated a potential for inflow rates in excess of 40,000 cfs, and a total volume of storm inflow amounting to 55,686 acre-feet. In the past stream flows in excess of 1,200 cfs have caused downstream flood damage. The design and operations plans therefore propose to regulate release flows to approximately 1,000 cfs. The emergency spillway has been designed to pass the full probable maximum flood, if such an event should occur while the reservoir is at the 125,000 acre-foot level.

LEGAL AND INSTITUTIONAL IMPACTS

The legal and institutional impacts of storage and discharge of water
at Smiths Fork were researched and evaluated. It was determined that an agreement must be drafted and implemented whereby the States of Idaho and Utah and Utah Power & Light Co. agree to the proposed transfer of downstream storage rights to Smiths Fork. Further, storage and discharge must occur in accordance with a procedure approved by the Bear River Commission.

HYDROPOWER ANALYSIS

The potential capacity to generate hydro-electric power has been analyzed for both sites. Studies were completed to determine the impacts of fluctuating flows and available heads, voltage to be produced, maintenance costs, physical limitations, initial purchase costs and installation costs. Equipment was selected in full consideration of these factors.

Predicted annual power generation is 13,905,336 kW hrs at either site based on flows fluctuating between 50 cfs and 475 cfs. at heads varying from 110 to 150 feet. Two (2) 2.5 MW Francis turbines/synchronous generators with spare high head runner to accommodate peak flows were selected. Power output level of the facility will be 25 KV, 3 phase, 60 hertz.

The cost of the hydroplant is estimated to be $3,552,788. Total annual
revenues, less expenses, after an initial pay off period of 7 1/2 years, and assuming the life of the plant at thirty-five years, is anticipated to be $18,311,068 assuming levelized avoided cost payments for a 20-year period equal $0.052 per kW-hr.

GEOTECHNICAL ANALYSIS

A preliminary geotechnical evaluation of both sites was completed along with core boring analyses, field geologic studies, seismic refraction studies, bore hole permeability testing and a laboratory testing program.

Three major considerations resulted from the geotechnical studies.

• An absence of high quality construction materials in the project area.

• Evidence of highly permeable foundation conditions within the bedrock foundation of the dams.

• Knowledge that the project exists within a seismically active region. Although evidence of active faulting was not discerned in the investigation.
These factors indicate that the mass of the embankment must be increased, the geometrics of the embankment will require incorporation of filter zones, and extensive grouting will be required in the foundation area.

State-of-the-art geotechnical techniques are available to compensate for the noted conditions. Utilizing these techniques in the final design will assure construction of an acceptably safe structure.

PRELIMINARY DESIGN AND COST ESTIMATES

An earthfill/rock dam has been designed with provision to accommodate the physical dimensions of either site.

Basically, the dam as designed incorporates three horizontal to one vertical slopes, both upstream and downstream. A central core of impervious material extends through a cut-off trench excavated into bedrock. An upstream filter zone between the core material and random fill comprises the bulk of the upstream section. Downstream, three (3) specially graded filter zones provide a transition from the core material to the random fill.
Preliminary cost estimates for the facilities are:

- Upper Site: Dam and Powerhouse  $79,266,650
- Lower Site: Dam and Powerhouse  $61,632,125

The Lower Site was found to be more favorable from the standpoint of cost and construction and is the recommended location for the structure.

OPERATING PLAN

An operating plan to meet the intents of the project and adhere to known legal and institutional requirements has been formalized. The plan provides for maintaining downstream flow demands during the initial filling of the reservoir. Once the reservoir is filled, downstream demands will be met by adjusting the inlet structure gates, turbine valves, outlet structure valves and the by-pass valve.

The Wyoming allocation will be released to meet local demand and any excess will be carried over as storage from one water year to the next. Transferred storage will be released in the water year in which it is stored.
Flows through the principal spillway in excess of 500 cfs, the upper capacity of the turbines, will be routed through a bypass to the stream.

AGRICULTURAL ECONOMICS

Initially an attempt was made to gather data from agricultural users for input into the AGNET program to evaluate the economic benefits to agricultural users. The standard AGNET questionnaires were distributed to a representative group of individuals who were generally unanimous in stating that they have not maintained records in sufficient detail to complete the questionnaire. A subjective area-wide analyses replaced the AGNET analysis.

Contact was made with a representative sampling of agricultural users in an attempt to determine their willingness to purchase supplemental irrigation water and establish an agreed to cost. Approximately one-half of those surveyed indicated a willingness to pay for supplemental water, but expressed no price they would consider reasonable. Other users expressed no interest and an unwillingness to participate.

In an attempt to identify a reasonable cost that could be used in the economic analysis, data was obtained from the Covey Canal Company, an irri-
gation system in the Smiths Fork area. Covey distributes irrigation water to three (3) sub-systems, Covey A, Covey B and Mau. Rates vary from a low of $1.35 per acre irrigated/per year in the Mau sub-system to $5.24 per acre irrigated/per year in the Covey B sub-system. Rates in the Covey A sub-system are $2.04 per acre irrigated/per year.

CONCLUSIONS

The following conclusions are based on an evaluation of data generated during the course of the Level II Study.

• Strictly from the standpoint of economics the Smiths Fork Project is not feasible. The cost-benefit analysis prepared as part of the study indicates a ratio of less than 0.5. The analysis was prepared using primary benefits only and did not attempt to monetarily quantify secondary socio-economic factors.

• The Lower Site is more favorable than the Upper Site.

• The transfer to Smiths Fork of a minimum of 60,000 acre-feet of downstream storage rights is required to make the project feasible. In the event storage rights from downstream in excess of the
60,000 acre-feet are identified and negotiated the probability of meeting low flow hydropower demands will be enhanced.

- A Bear River Compact "Commission Approved Procedure" is required to accommodate accounting procedures covering the storage and distribution of the newly revised water rights.

- Hydropower generation is feasible at either damsite. Analyses indicate 13,905,336 kW-hrs of energy can be generated dependent upon the successful negotiation of downstream storage rights transfers.

- Geotechnical studies identified three (3) major areas of concern:
  
  (a) the absence of high quality construction materials in the project area creates the need to zone the dam to provide internal drainage and prevent migration of the core soils into the coarser random fill.

  (b) bore hole permeability testing identifies numerous zones of highly porous bedrock that require extensive consolidation grouting during construction.

  (c) although no indications were discerned to indicate the presence of active faults at either damsite, the location of the project
in a seismically active region requires the design of the structure to include measures minimizing damage a seismic event could create.

State of-the-art geotechnical techniques are available for utilization in final design. It is anticipated such techniques will ensure construction of a safe structure.

- The construction of the dam will enhance downstream water quality. It is anticipated that phosphate removal by treatment at Bear Lake will require less effort, and thus be less costly.

- Primarily, agricultural benefits will be in the potential availability of supplemental water in dry years. Flood protection will mainly result within the river banks due to the ability of controlling the volume of flow from the facility during periods of peak run-off.

- Agricultural water rates in effect as of December, 1984, in the Smiths Fork area range from $1.35 to $5.24 per acre irrigated/per year. These rates were obtained from the Covey Canal Company. Anticipated fees for supplemental water from the Smiths Fork Project are in excess of the upper limit of this range. In a representative
sampling of agricultural users those interviewed who expressed an interest in participating were unanimous in stating that they could not place a value on supplemental water. In this study a figure of $5.70 per acre irrigated/per year has been used.

RECOMMENDATIONS

1. Unless either or both of the following scenarios become reality the Smiths Fork Project is not recommended for further development as it is presently constituted:

a. Conditions unknown to the Consultants exist that will bring the cost-benefit ratio nearer to unity. Examples of such factors could include the necessity for Wyoming to store its Smiths Fork allocation in a reservoir that is part of a long range plan comprising the entire Upper Bear River Basin.

b. Downstream States elect to participate financially in construction of the project based on flood protection, primarily for regulating flows during peak run-off, and in conjunction with other plans for regulating flows or transferring water rights on an inter-basin basis.
2. In the event that neither of the above scenarios can be satisfied, the Wyoming Water Development Commission should consider studying the possibility of a smaller project at Smiths Fork.

3. In the event that the cost-benefit ratio is amended as defined in Recommendation I above, or a smaller project is selected, the Lower Dam site studied in this investigation should be advanced for final design. In the case of a smaller reservoir, and thus a smaller dam, it will be necessary to revise the geometric configurations of the structure. For example, an over-the-crest chute type emergency spillway would prove satisfactory and eliminate the excessive depth of excavation and waste associated with constructing an off-site spillway to an elevation compatible with a lower reservoir. Materials for construction of the embankment would then be obtained from borrow sources.

4. Efforts should be made to obtain downstream storage rights agreements before proceeding to final design.

5. Bear River Commission criteria governing the resolution of questions identified in the Legal and Institutional Impacts Chapter of this report should be established prior to undertaking final project design efforts.
CHAPTER 1

ADVANCED HYDROLOGY
CHAPTER I
ADVANCED HYDROLOGY

Introduction

A. Site:

The proposed Smiths Fork dam and reservoir project is located approximately twenty miles northeast of Cokeville, Wyoming on the main stream of Smiths Fork. Smiths Fork is a tributary to the Bear River, therefore the stream flow is included in the Bear River Compact. (A copy of the Compact and Amendment is included in the Appendix of this report.)

Smiths Fork drainage basin is approximately twenty-eight miles long and varies in elevation from 6,670 at the damsite to 10,100 at the high peaks. The terrain is typical narrow mountain valleys with steep side slopes. Ground cover varies from grasslands and sagebrush to quaking aspen and pine.

Two dam sites have been studied for this report, one of which is the Tiechert-Bagley Site identified in the Level 1 Study and is referred to as the Upper Dam for this study. The second site is approximately 2,900 feet downstream and is called the Lower Dam. The location of dam sites are shown on Figure 1-1. The reservoir outlines for the Upper and Lower Dams are shown on Figures 1-2 and 1-3.
B. **Hydrology:**

Smiths Fork is the water source for irrigating approximately 16,300 acres. In order to control water delivery to the water rights, several gaging stations have been constructed on Smiths Fork and the Bear River. Stream flow records from these stations were used as data base for the hydrologic study. Flood flow determinations for probable maximum flood were calculated using the Corps of Engineers procedure for the Colorado River and Great Basin Drainages.

C. **Water Demands:**

The quantity of water required for irrigation is calculated from crop water demand data obtained from the Soil Conservation Service. This data confirms the irrigation demands used in the Level 1 Study. Delivery of irrigation water from the reservoir system assumes that the irrigation requirements will be met from stream flow. When the stream flow is greater than the irrigation demand, water is stored and released as necessary to supplement the stream flow to meet the demand.

A municipal annual demand of five hundred acre feet for Cokeville has been used. It is assumed that the municipal release will occur in equal increments with the release occurring during the irrigating season.
Water in excess of the Wyoming allocation is assumed to be available for temporary storage during high flow periods but must be released during the water year of such storage.

D. **System Constraints:**

The irrigated lands to be served by the reservoir were divided into two areas in order to estimate the impact of the reservoir on the flow at the Border gaging station and the inflow of Bear Lake. The irrigation season is assumed to run from May through September each year. The irrigation diversion is adjusted for efficiency and monthly variation in crop demand.

The area-volume-elevation data from mapping was used to develop the curves shown in Figures 1-4 & 1-5 and the tabular data required for the computer.

The Bear River Compact includes the flow from Smiths Fork. Smiths Fork waters must be allowed to flow downstream during water emergencies defined in the Compact as a divertable flow at the Border gaging station of less than 350 cfs or a divertable flow at Stewart Dam of less than 870 cfs. In this study it is assumed that water emergencies for Smiths Fork occur when the gaging station flow at the Border station is less than 350 cfs. The Compact allows no storage at Smiths Fork during periods of water emergencies. Monthly flows were analyzed resulting in no allowance for storage during those months which have flows less than the Border minimum. An analysis without the Border restraint was also run.

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Figure 1-4
SMITHS FORK RESERVOIR
UPPER DAMSITE

SURFACE AREA (acres)

RESERVOIR CAPACITY (1000 acre-feet)

ELEVATION (feet)

SURFACE AREA

RESERVOIR CAPACITY

SMITHS FORK RESERVOIR
UPPER DAMSITE
The Bear River Compact and Wyoming State Engineer have allocated storage and depletion limits to Smiths Fork. The 1958 Bear River Compact provided a storage allocation of 4,100 a.f. for Smiths Fork. This allocation was subject to no depletion. The 1980 Compact Amendment provides for an additional 10,420 a.f. storage with a depletion limit of 2,200 a.f. Irrigation diversions have a depletion of .50 and municipal diversions are .45 by definition in the Compact.

Additional considerations for the project are possible water use requirements by the Game and Fish Department, consideration of a 20 percent of reservoir maximum capacity for fish propagation, and an instream flow equal to one-third of the annual daily average stream flow or when the stream flow is less than one-third of the annual stream flow.

E. Computer Model:

The State of Utah Water Resources Division Bear River Computer Model was used to determine Smiths Fork Reservoir Capacity. This model uses the Smiths Fork gaging station flow records. The Model calculates the irrigation demand from the crop area, an average monthly demand coefficient and an efficiency. Municipal and industrial uses are considered to be an annual demand allocated by a percentage of the annual total for each month of use. Return flow is calculated as a percentage of the initial diversion and includes
a lag to simulate actual flow conditions in the stream below the use area. Irrigation releases and shortages are tabulated to indicate the reservoir efficiency. Data are reduced to monthly and annual mean values as is appropriate.

The model tabulates the end of the month storage, surface area pool elevation, available hydropower head, stream inflow, outflow, hydropower spills and shortages. The stream flow data is used to develop a duration curve.

The following assumptions were made for the computer runs on Smiths Fork Dam sites:

Storage from downstream could be transferred to Smiths Fork Reservoir. The transferred storage would be released in even increments during the five-month irrigating season. This storage transfer represents a fixed annual demand to be met by reservoir release and not reduced by spills when the reservoir is full. Shortages are made up from reservoir storage.

The following data was used for Smiths Fork reservoir runs:

• Irrigated area: 15,700 acres.

• Crop demand data was obtained from the S.C.S. office at Cokeville.
• Average monthly demand data resulted in uniform annual demand released by month over the irrigating season.

• A 100-acre foot per month demand for Cokeville Municipal use for the five-month irrigating season.

• Irrigation has first right to stream flow with shortages made up from available storage releases.

• A Wyoming depletion of 2,200 acre-feet is included as a 4,400 acre foot demand released in equal increments over the irrigating season.

• Downstream storage transfer to the Smiths Fork Site - This water to be released in equal increments concurrent with the irrigating season.

• Minimum stream flow one-third of annual daily average of the flow or the stream inflow when it is less than one-third of the annual daily average. No releases are made to make up the minimum stream.

Several computer runs at various proposed transfer volumes determined the maximum volume which could be met. At the 60,000 a.f., transferred storage level shortages would have occurred in eighteen of the fifty-two years of record.
A computer run made with the reservoir at a minimum pool of 25,000 acre feet and no withdrawals allowed below that level revealed the inflow data includes the drought period of 1931 to 1935 during which the total annual stream flow was 44,275 acre feet, the recorded minimum. Shortages occurred from 1931 to 1934, 1937 to 1942, 1944 and 1945, 1955, 1960, 1961, 1977 and 1981. These shortages represent times that the total demand for irrigation, municipal, allotted depletion and transferred storage could not be met by release from the reservoir storage. No priority for curtailing a specific use at low inflow was made. The resulting quantity is the maximum that can be made available for storage transfer.

The Bear River Compact imposes conditional restrictions on storage and diversions from the Bear River flows. The central division is considered to have a water emergency when the divertable flow in the Bear River is less than 870 cfs or the Bear River at the Border Gaging station is less than 350 cfs. No storage can be made during an emergency.

The concept of storage transfer has been discussed briefly with Wally Jibson, Consulting Water Engineer for the Bear River Commission. He expressed that the Compact does not specifically address transferring storage from one location to another. Any upstream changes in diversion, water use, added storage or other improvements must not adversely affect the downstream water rights. Smiths Fork Dam will have a regulating impact on the stream flow.
by reducing high runoff. Storage releases to meet the late summer demands will result in a more uniform flow in the stream and a greater utilization of the available water.

A second computer model was written to approximate the impact of the Compact on the stream flow. The water emergency condition of a flow less than 350 cfs in the Bear River at Border was considered in the model. All low flow emergency was ignored during the winter months, and water in excess of one-third of the annual daily average flow was stored. The stream inflow was bypassed when it was less than the one-third requirement. No release from storage to maintain one-third of annual daily average was made during the period of low flow.

The model assumes that downstream demands will be met from the stream flow, and adds to storage during excess or releases from storage when stream flow is less than the demand. The program is written to store the maximum Wyoming allocation in all years that quantity is available. Transferred storage volume is limited to the remaining reservoir capacity. The transferred storage is released in the year when stored with none made up from Smiths Fork storage. Assuming that 60,000 a.f. were transferred to Smiths Fork, there would have been fourteen years out of the forty years on record that shortages would have occurred.
The storage allocation of 14,520 a.f. per year for Wyoming results in thirteen years when shortages occurred in the period covered by the data. The Compact provides for additional upstream storage when the Bear Lake is spilling. This provision of the Compact has not been addressed, as data to determine when Bear Lake is full have not been adequately identified and is dependent on the Bear Lake operating plan.

Hydropower generation assumes flows greater than 50 cfs and less than 475 cfs. The turbines and generators are sized to operate between the minimum and maximum flows.

The flow regulation provided by Smiths Fork reservoir will impact the downstream reaches of the Bear River and Bear Lake. The stream flow in the spring runoff will be reduced by the amount of water stored at Smiths Fork. This will reduce the flooding potential.

Outflow from the reservoir will be releases required to meet all downstream demands. In addition, the transferred storage will be released, resulting in a change from an unregulated minimum annual average flow of 56 cfs in February and a maximum annual average of 603 cfs in June, to a regulated minimum flow of 64 cfs in February and a maximum 384 cfs in June. This stream flow can by-pass the Bear Lake and eliminate part of the phosphate and other deleterious materials which would be added to the Bear Lake if the water were stored.
F. Synopsis of Reservoir Computer Model:

The purpose of the computer model developed by GBR Consultants Group, Inc., is to provide a means of modeling Smiths Fork reservoir operation with consideration of the Bear River Compact constraints.

G. Constraints:

Specifically, the constraints used within the model are: a maximum amount of water stored in any given year of 14,520 acre-feet for Wyoming and an emergency condition that a flow less than 350 cfs in the Bear River at the U.S.G.S. border station requires a 57 percent streamflow bypass. The program is also constrained by a number of parameters, listed as follows:

1. A minimum release as suggested by the Wyoming Game and Fish of 65 cfs.

2. A maximum capacity of 125,000 acre-feet.

3. A minimum pool capacity of 25,000 acre-feet.

The irrigation and municipal water requirements placed on the model are based on actual or expected amounts for the Cokeville area.
H. Input:

Input is received by the model through four files, namely Inter, Indat, Updat, and Downdat.

Inter supplies the initial parameters for the reservoir given on the first page of printout, i.e., years simulated, reservoir parameters, release requirements, etc. Indat gives the various "factors" along with the surface area capacity curve data.

Updat and Downdat are, respectively, recorded Smiths Fork River flow, and Bear River recorded flow at the Border gaging station.

I. Bypass and Releases:

Bypasses are assumed to be water requirements taken directly from river flow through the reservoir and therefore not included in storage calculations. For purposes of this model only water for irrigation is taken as a bypass.

Releases are those water requirements taken from reservoir storage. Such as power releases, irrigation requirements which cannot be supplied by river flow, and municipal requirements.
The order in which the releases are taken is 1 - Irrigation, 2 - Power and 3 - Municipal. Each is supplied based on the amount of water available up to the maximum amount required.

J. Assumptions:

The program assumes a certain specified amount of water is "borrowed" from downstream. In other words, flow which will eventually reach Bear Lake is stored in Smiths Fork to be released in equal increments over the summer months for power generation.

In addition, evaporation is assumed to occur May through October, all releases are assumed to occur May through September and municipal releases are assumed to be divided equally over the five months. Irrigation efficiency is assumed to be 50 percent.

K. Flowchart and Definitions:

Figure 1-6 is a basic flow chart showing the layout of the operation of the program.
Figure 1-6. Flowchart for GBR computer model.
L. Definition of Program Output

1. Years Simulated: The number of years for which streamflow records were available for both Smiths Fork and Border Stations, including the beginning and ending years.

2. Starting Year: Beginning year of data. In this case, data from 1943 to present was used. Border data was not regressed to 1931.

3. Reservoir Parameters:
   a. Maximum Capacity: The maximum capacity of the proposed reservoir at this level of analysis.
   b. Minimum Pool: The minimum capacity of the proposed reservoir, assumed to be present at all times.
   c. Initial Storage: Amount of storage assumed to be present the month prior to the month in which simulation begins.
   d. Maximum Available Storage Per Year: This amount includes the 14,520 acre-feet annually allotted Smiths Fork by the Bear River Compact plus the assumed 60,000 acre-feet transferred storage for power generation. Smiths Fork may not cumulatively
store more than the sum of these two in any given year. Transferred storage is stored and released in the same water year. The Wyoming allocation not required for shortages is carried over for future use.

4. Release Requirements:

a. Irrigated Land: The amount of land below the reservoir requiring irrigation (irrigation occurs May through September).

5. Irrigation Efficiency: Efficiency of water used for irrigation. This increases the amount of water released from the reservoir to include losses due to irrigation.

6. Municipal Demand: Estimated amount of water to be released for municipal use (distributed May through September).

7. Borrowed Storage: Amount of water "borrowed" from Bear Lake and subsequently released for power generation at Smiths Fork. ("Borrowed Storage" is synonymous to "Transferred Storage").

8. Minimum Flow Allowed in Downstream River before Reservoir can keep inflow: Amount of flow at Border station below which, the Bear River Compact defines an emergency condition. In this event, the Compact requires that 57 percent of the inflow to Smiths Fork
Reservoir be bypassed without regard to normal flow requirements.

9. Surface Area, Capacity Table: This table gives the planimetered reservoir surface areas at the corresponding elevations from enlarged U.S.G.S. quadrangle maps. It also gives the reservoir volume for each elevation.

10. Consumptive Use Factors: Consumptive use typical of land irrigated in the Cokeville, Wyoming area during irrigation season.


13. Seepage: Seepage through the earth dam, input in a.f./month. In this case it is assumed to be zero.


15. Recorded Smiths Fork Inflow: U.S.G.S. recorded flows at Smiths

17. Irrigation Bypasses or Minimum Streamflow: Amount of streamflow bypassing reservoir storage to meet irrigation or minimum streamflow requirements (subject to Bear River Compact).

18. Power Releases: Amount released from transferred storage and used for power generation. Transferred storage demand is to be equal to a storage of 60,000 a.f. released in equal increments over the irrigating season.

19. Monthly Available Storage: Amount of streamflow that may be stored after bypass requirements are met.

20. End of Month Storage: Reservoir storage after all releases and losses are included.

21. Irrigation Releases (shortages): Amount of irrigation requirement not met by streamflow (irrigation bypass) which is delivered by using reservoir storage.

22. Municipal Releases: Amount released from reservoir storage to meet
municipal demands.

23. Spills: Water released because available storage has exceeded the maximum storage allowed in any given year, or because reservoir is full.

24. Reservoir Yield: Water available for use (usable storage) after bypasses and losses are accounted for.

25. Evaporation: Calculated by multiplying net evaporation rates by reservoir surface area.

26. Downstream Flow: Amount occurring downstream of the reservoir assuming irrigation and municipal requirements return 50 percent including spills and power bypasses. (The Compact depletion for Municipal use is 45 percent.)

27. Percent of Recorded Inflow: Downstream flow appearing as a percentage, greater or less, than Smiths Fork recorded flow.

The inflow duration curves are shown as Figure 1-7 and the outflow duration curves are Figure 1-8.

An inflow mass curve, Drawing No 18 of 24, was developed as a check for calculated values. The annual stream flow was accumulated and plotted to show the total quantity of water in the Smiths Fork for the data period. Various operating demands were plotted to determine the storage required to meet that
Figure 1-7
INFLOW FLOW DURATION CURVE
SMITHS FORK RESERVOIR
UPPER DAMSITE
AND
LOWER DAMSITE
Figure 1-8
OUTFLOW FLOW DURATION CURVE
SMITHS FORK RESERVOIR
UPPER DAMSITE
AND
LOWER DAMSITE

DISCHARGE (cfs)

PERCENT TIME
demand. This graph substantiates the use of a 125,000 acre foot reservoir for the project.

The computer program was modified to provide for two irrigated areas and treating the Wyoming and transferred storage as separate operations.

An analysis was made of the impact on the various gaging stations. This analysis is based on the assumption that the flow data at the Smiths Fork gaging station at the dam site represents the full stream flow before irrigation diversions.

The upstream flow rate of the Bear River at Cokeville is assumed to be the gaging station flows less Smiths Fork adjusted for irrigation diversions and returns. The adjustments to the Smiths Fork flows are calculated for conditions before and after the proposed dam. Similar adjustments were made for the Border and Rainbow gaging stations. The analysis assumes that the changes in flow would affect only the Rainbow gaging data and the diversions at Stewart Dam would not change.

The quantity of water stored for Wyoming is restricted to 14,520 acre-feet of annual storage and a 40,000 acre-feet maximum reservoir volume. The water available for storage was assumed to be the stream flow in excess of that required to be diverted to meet the irrigation demand of the water right holders on the Smiths Fork. Irrigation diversions are assumed to be the theoretical crop demand and only that amount of water is diverted and no
additional releases would be made. These diversion requirements were to be made from the stream flow as was the assumed instream flow requirement. The instream flow was assumed to be one third of the average daily flow.

The instream flow requirement does not have a significant impact on the Wyoming segment of the reservoir operation as the total annual Wyoming storage allowed is 14,520 acre-feet which is available for thirty-nine of the forty-one years of the analysis. Figure I-9 shows the annual flow available for storage with lines showing the requested instream demand and no instream demand. The Wyoming storage demand is less than the 20,000 acre feet minimum shown on the graph. This clearly indicates that there are two years when the available storage is less than 20,000 acre feet. The total storage demand line is the sum of the Wyoming allocated storage and the proposed transferred storage. Transferred shortages occur in twenty-three of the forty-one years if the instream flow is required. If no instream demand is required and all flow can be stored shortages occur in ten of the forty-one years of record. These shortages assume that no carry over for transferred storage will be allowed and that no release for shortage will be made from the Wyoming allocation. If the Border flow minimum requirement can be waived the transferred storage shortages are reduced to two years of the forty years of record.

The transferred storage in the computer model was charged with an evaporation loss that is proportioned to the amount of Wyoming and transferred storage each month. This evaporation deduction shows as a shortage in the September release which is not considered to be a short year.
Reservoir yield for the model is defined as the reservoir releases made to meet municipal demands, and irrigation shortages plus the end of the month storage at the end of the year. With this definition the minimum reservoir yield is the first year and is 13,438 acre feet. A low yield of 25,334 acre feet occurred in 1978. The maximum yield is near the 40,000 acre feet of the reservoir.

The maximum long term yield of the reservoir is limited by the 14,520 acre feet of annual storage and the maximum annual depletion allowance of 6,600 acre feet. The depletion limit, using the fifty percent efficiency would require a release of 14,300 acre feet which is within the yield of the reservoir and could be met as either supplemental irrigation or potential additional water rights. This is assuming that the shortages of present irrigation rights are made up from carried over stored water that is not subject to the annual depletion allowances.

The transferred storage yield based on the project criteria is zero which occurs once in the period of record and a maximum of 59,054. If there is no instream flow the minimum yield is 15,970 acre-feet and the maximum is 59,070 acre-feet.

A Wyoming reservoir of 40,000 acre-feet will provide adequate storage to meet the proposed 500 acre-feet future municipal release and meet the calculated irrigation shortages for present water rights. A firm yield of 13,340 acre-feet can be provided for future development. Computer runs are included in the Appendix.
M. FLOOD ANALYSIS:

An evaluation of precipitation and resulting runoff for the Smiths Fork drainage basin was performed to determine the following:

1. Storage and/or discharge requirements for downstream flood protection.

2. Emergency spillway design.

3. Flow routing during construction of the dam.

4. Operating plan and reservoir routing through the primary spillway (lower pipe discharge).

5. Supplement historical stream flow data developed for reservoir yield, discharge requirements and hydropower analysis previously developed.

In accordance with the requirements of the Wyoming State Engineer's procedures, rainfall and runoff were computed using methods developed by the Department of Commerce National Oceanic and Atmospheric Administration (NOAA) and the U.S. Army Corps of Engineers (COE) for the geographical region in which the reservoir is located. Since this procedure predicts extreme condit-
tions, and as a check on the initial results, additional evaluations were made utilizing other accepted procedures such as those used by the U.S. Bureau of Reclamation, Design of Small Dams, The U.S. Soil Conservation Service and by developing intensity-duration-frequency curves for the site from historical precipitation data.

The format in which the raw data has been developed and the information stored, will permit the rapid evaluation of operating scenarios and flood spillway discharges other than those used in this study. As an example, storage may be provided for the Probable Maximum Precipitation (PMP) coincident with "bank-full" natural runoff without emergency spillway discharges.

N. Description of the Smiths Fork Watershed:

The proposed dam site is on the Smiths Fork located near Cokeville in Lincoln County, Wyoming. For this study, the point of interest is coincident with Department of Interior-Geological stream gaging station 1003200 at latitude 42° 16' 52" and longitude 110° 52' 05".

The watershed is generally the shape of a pear with its main axis north to south, contains approximately 167.5 square miles and ranges in
elevation from 6,640 near the dam to peaks of elevation 10,323. The maximum reach of the basin is along the narrow main stem of Smiths Fork and is 28.2 miles.

The drainage basin is comprised of four sub-drainage areas:

1. Smiths Fork - main channel
2. Hobble Creek
3. Coantog Creek
4. Lake Alice

Figure 1-10 shows the general boundaries of the subbasins. Table 1-1 tabulates the areas, length, outlet-to-dam site distance and stream slope. For the purpose of this study, slopes were calculated using elevations and distance between points 10 percent from the outlet to the upper 85 percent of the reach. By eliminating the high peaks from the slope calculation, the resulting slope is a better approximation of the basin hydraulic gradient.

<p>| TABLE 1-1 |
| SMITHS FORK RESERVOIR SUB-DRAINAGE AREAS |</p>
<table>
<thead>
<tr>
<th>Area</th>
<th>Total Length</th>
<th>Distance to Month</th>
<th>Length 10% to 85%</th>
<th>Elev. 10% to 85%</th>
<th>Slope 10% to 85%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Smith Fork Main Channel sq mi</td>
<td>82</td>
<td>28.2 mi</td>
<td>-0-</td>
<td>21.1 mi</td>
<td>1680 ft</td>
</tr>
<tr>
<td>2. Hobble Creek sq mi</td>
<td>39.5</td>
<td>17.4 mi</td>
<td>8.9 mi</td>
<td>13.1 mi</td>
<td>1060 ft</td>
</tr>
<tr>
<td>3. Coantog Creek sq mi</td>
<td>28</td>
<td>11.4 mi</td>
<td>14.0 mi</td>
<td>8.5 mi</td>
<td>1280 ft</td>
</tr>
<tr>
<td>4. Lake Alice (+220A) sq mi</td>
<td>18</td>
<td>6.8 mi</td>
<td>17.0 mi</td>
<td>5.1 mi</td>
<td>955 ft</td>
</tr>
</tbody>
</table>
The smallest of the basins, Lake Alice, contains a lake of approximately 220 acres. This lake will alter the instantaneous peak flow from the basin to Smiths Fork reservoir but will not significantly affect the total storm volume. No attempt has been made to route the storm flow through this basin. We believe this to be reasonable because the flow rate from Lake Alice basin is conservative and no reduction in discharge volume is assumed.

The characteristics of the sedimentary geologic environment above the reservoir high water elevation can generally be classified as siltstone, limestone and sandstone. Generally the soils can be classified as inorganic clays of low to medium plasticity, gravelly clays, sandy clays and clean clays. The soil supports herbaceous ground cover with shallow root systems and fair pine grasses. For runoff evaluations, it is considered to be Soil Conservation Service Hydrological Group C.

0. Development of Probable Maximum Precipitation Estimates (PMP):

In accordance with the requirements of the Wyoming State Engineer, PMP's were developed following the procedures of the NOAA and Corps of Engineer's Hydrometeorological Report No. 49 "PMP Estimates, Colorado River and Great Basin Drainages." The method provides for calculating both general storm and local storm probable maximum precipitation estimates for a specific area. These calculations were made for Smiths Fork drainage basin above...
the project. General storm estimates are given for durations between six and seventy-two hours and local storm estimates cover durations between fifteen minutes and six hours.

Total PMP is the sum of convergence and orographic components. Estimates can be made for each month of the year. For the Smiths Fork Site, both General Storm and Local Storm PMP's were developed for the Months of June and August.

Tables 1-2 and 1-3 show the result of these calculations. Detailed calculation sheets of the development of these figures along with the appurtenant charts and graphs used in the calculation are included in the Appendix.

<table>
<thead>
<tr>
<th>Table 1-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probable Maximum Precipitation</td>
</tr>
<tr>
<td>Smiths Fork</td>
</tr>
<tr>
<td>General Storm (inches of rainfall)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hours</th>
<th>6</th>
<th>12</th>
<th>18</th>
<th>24</th>
<th>48</th>
<th>72</th>
</tr>
</thead>
<tbody>
<tr>
<td>Month</td>
<td>June (inches)</td>
<td>3.47</td>
<td>5.16</td>
<td>6.40</td>
<td>7.63</td>
<td>10.03</td>
</tr>
<tr>
<td>Month</td>
<td>August (inches)</td>
<td>3.40</td>
<td>5.50</td>
<td>6.50</td>
<td>7.40</td>
<td>9.70</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 1-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>PMP - Local Storm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Increments</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>June</td>
<td>0.30</td>
<td>0.37</td>
<td>0.94</td>
<td>3.31</td>
<td>0.66</td>
<td>0.34</td>
</tr>
<tr>
<td>(4 largest 15 minutes)</td>
<td>1.59</td>
<td>0.84</td>
<td>0.48</td>
<td>0.40</td>
<td>inches</td>
<td></td>
</tr>
<tr>
<td>August</td>
<td>0.30</td>
<td>0.70</td>
<td>0.90</td>
<td>3.1</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>1.5</td>
<td>0.7</td>
<td>0.5</td>
<td>0.4</td>
<td>inches</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The procedure also permits refinement of the local storm given the areal distribution of the PMP. These calculations are included for the June storm. The use of this refinement did not significantly alter the flows for this size basin and were not further applied in the analysis.

For check and reference, procedures as outlined in U.S. Department of Interior, Bureau of Reclamation, "Design of Small Dams," Flood Flow for General Type Storm West of 105° Longitude were followed. This produced:

- Probable maximum six hour point source rain = 4.0 inches.
- Ratio of point rainfall to area rainfall, 167.5 sq. mi. 0.84.
- Six hour general rainfall (4.0 inches x 0.84 = 3.36 inches).

This does not significantly differ from the June 3.47 inches developed from the NOAA procedure.

Utilizing the intensity/duration curves developed for the site, the 100 year, six hour storm produced 2.70 inches of rainfall.

P. Storm Runoff
In order to estimate the impact of the precipitation event developed in Section 0, the rate of runoff and the total volume of storm contribution was estimated utilizing Soil Conservation Service procedures. The watershed soils and ground cover are sufficiently similar to justify using one classification for the entire basin. As described in section N, the soils have been classified as S.C.S. group C which have a slow rate of infiltration into the soil surface when wetted and a slow transmission rate through the soil. The land use and ground cover includes fair pasture range and good herbaceous cover. The hydrologic soil-cover complex for Smiths Fork has been identified to have a S.C.S. Curve Number of CN75 for an average antecedent moisture content II, or average prestorm moisture conditions during the previous thirty days.

For the purpose of predicting the maximum runoff from the PMP storm, this factor has been adjusted to an antecedent moisture condition of III which assumes heavy rainfall and nearly saturated soil conditions have occurred during the previous five days or that the ground is frozen. Since the maximum general storm potential occurs in June, the potential for saturation and/or residual snow cover is possible for this area. The direct runoff resulting from the projected rainfall is based on an adjusted S.C.S. curve number of eighty-eight because of the above soil and moisture conditions. Table 1-4 shows the projected runoff from the general storm and table 1-5 shows the runoff projected for the intense local storm under these conditions.
### Table 1-4
*Projected Runoff - PMP General Storm*

<table>
<thead>
<tr>
<th>Hour (Ending)</th>
<th>Incremental Rainfall (inches)</th>
<th>Total Rainfall (inches)</th>
<th>Total Runoff (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.18</td>
<td>0.18</td>
<td>0.01</td>
</tr>
<tr>
<td>2</td>
<td>0.22</td>
<td>0.40</td>
<td>0.10</td>
</tr>
<tr>
<td>3</td>
<td>0.55</td>
<td>0.95</td>
<td>0.30</td>
</tr>
<tr>
<td>4</td>
<td>1.94</td>
<td>2.89</td>
<td>1.80</td>
</tr>
<tr>
<td>5</td>
<td>0.39</td>
<td>3.28</td>
<td>2.20</td>
</tr>
<tr>
<td>6</td>
<td>0.20</td>
<td>3.48</td>
<td>2.35</td>
</tr>
<tr>
<td>12</td>
<td>1.69</td>
<td>5.16</td>
<td>3.90</td>
</tr>
<tr>
<td>18</td>
<td>1.24</td>
<td>6.40</td>
<td>5.15</td>
</tr>
<tr>
<td>24</td>
<td>1.23</td>
<td>7.63</td>
<td>6.30</td>
</tr>
</tbody>
</table>

### Table 1-5
*Projected Runoff - PMP Local Intense Storm*

<table>
<thead>
<tr>
<th>Hour (Ending)</th>
<th>Incremental Rainfall (inches)</th>
<th>Total Rainfall (inches)</th>
<th>Total Runoff (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.30</td>
<td>0.30</td>
<td>0.01</td>
</tr>
<tr>
<td>2</td>
<td>0.37</td>
<td>0.67</td>
<td>0.13</td>
</tr>
<tr>
<td>3</td>
<td>0.94</td>
<td>1.61</td>
<td>0.72</td>
</tr>
<tr>
<td>4</td>
<td>3.31</td>
<td>4.92</td>
<td>3.70</td>
</tr>
<tr>
<td>5</td>
<td>0.66</td>
<td>5.58</td>
<td>4.30</td>
</tr>
<tr>
<td>6</td>
<td>0.34</td>
<td>5.92</td>
<td>4.75</td>
</tr>
</tbody>
</table>

**N. Runoff Hydrographs:**

The theoretical probable maximum storm and the runoff from these storms were modeled onto each of the four subdrainage basins above the proposed reservoir. Time of concentration, lag time, time to peak, and runoff for one inch of rainfall were developed for these storms for each area, and hydrographs were plotted. Hydrographs were constructed utilizing manual procedures and by computer modeling. The Appendix includes the calculated data.
FIGURE 1-11
SMITH FORK RESERVOIR
INFLOW HYDROGRAPH
PMF GENERAL STORM
JUNE
Total drainage basin hydrographs were developed by "adding" the subbasin hydrographs and routing these flows to the reservoir site. Figure 1-11 shows the individual hydrographs for each subbasin and the combined total drainage basin hydrograph for the June PMP general storm. This shows a general storm peak inflow rate of 40,000 cfs with a short duration peak of 45,000 cfs. Since Lake Alice discharges are not controlled, an accurate flood routing through the lake has not been studied. Such routing could reduce the instantaneous peak, but it does not alter the total volume of storm contribution.

Figure 1-12 shows the individual hydrographs of each of the subbasins for the PMP Intense Local Storm. A combination of these storms over the entire basin has not been added because the combination probability of these storms simultaneously occurring is extremely remote. Figure 1-13, however, shows the combination of the intense Local PMP occurring over the main stem of Smiths Fork, coincident with the PMP General Storm occurring over the other subbasins. This scenario produces a peak inflow rate of 38,000 cfs.

Figure 1-14 shows a hydrograph developed utilizing the probable 1-in-500-year storm utilizing S.C.S. rainfall data.

Table 1-6 shows the total inflow volumes predicted by the hydrograph analysis.
SMITH FORK RESERVOIR
SUB-BASIN INFLOW HYDROGRAPH
PMP INTENSE LOCAL STORM
JUNE

FIGURE 1-12

FLOW (cfs)

SMITH'S FORK
HOBBLE CREEK
COANTOG CREEK
LAKE ALICE

TIME (min)

0 150 300 450 600 750 900 1050 1200 1350
Figure 1-13

SMITH FORK RESERVOIR
INFLOW HYDROGRAPH
PMF INTENSE LOCAL STORM
ON SMITH FORK PLUS
PMF GENERAL STORM ON
HOBBLE CREEK, COANTOG
CREEK, & LAKE ALICE
BASINS
Table 1-6
Total Projected Storm Volume
(Acre Ft.)

<table>
<thead>
<tr>
<th>Drainage Basin</th>
<th>PMP General Storm</th>
<th>PMP Local Storm</th>
<th>SCS 500 yr. Storm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7.63&quot; rain</td>
<td>5.92&quot; rain</td>
<td>5.10&quot; rain</td>
</tr>
<tr>
<td></td>
<td>6.20&quot; runoff</td>
<td>4.55&quot; runoff</td>
<td>3.76 runoff</td>
</tr>
<tr>
<td></td>
<td>24 hours</td>
<td>90 Minutes</td>
<td>24 hours</td>
</tr>
<tr>
<td>Smith's Fork</td>
<td>27,280</td>
<td>19,990</td>
<td>16,545</td>
</tr>
<tr>
<td>Hobble Creek</td>
<td>13,140</td>
<td>9,630</td>
<td>8,000</td>
</tr>
<tr>
<td>Coantog Creek</td>
<td>95,207</td>
<td>6,830</td>
<td>5,670</td>
</tr>
<tr>
<td>Lake Alice</td>
<td>5,950</td>
<td>4,368</td>
<td>3,620</td>
</tr>
<tr>
<td>Total</td>
<td>55,690 AF</td>
<td>40,810 AF</td>
<td>33,840 AF</td>
</tr>
</tbody>
</table>

Q. Application of Hydrological Data to Design:

In order to provide maximum downstream flood protection, spillway design considerations were based on the assumption that the normal or base line stream flow will be routed through the reservoir utilizing the principal spillway. The maximum flow of record is 1,800 cfs. Estimations of flood damages below the dam site indicate stream flows of 1,200 cfs have caused minor damage. The proposed operating plan would regulate total discharges to less than 1,000 cfs under normal conditions. At maximum pool elevation the principal spillway (drain) will be capable of discharging approximately 2,700 cfs. Figure 1-15 shows the stage discharge relationship of the main spillway control valve at various openings.

If a PMF occurs at reservoir full pool, the flood waters will be routed through an emergency spillway.
The proposed emergency spillway will pass the PMP storm at a maximum discharge rate of 26,000 cfs and a surcharge depth of nine feet. The flow line of the emergency spillway has been set five feet above the full reservoir pool to preclude overtopping due to wind-created waves in the reservoir at full pool.

R. EVAPORATION:

The evaporation rate used in the study is the loss due to evaporation minus precipitation.

Precipitation Data for the Smiths Fork area was obtained from NOAA Data, Wyoming, Station Border 3N for the years 1972 though 1982. The monthly values shown in Table 1-7 are the averages of the monthly records over the eleven year period.

Gross evaporation for Smiths Fork was estimated from the U.S.G.S. professional paper, Evaporation from the 17 Western States "Average Annual Lake Evaporation," to be 36 inches per year. The monthly distribution of this total evaporation correlates with that used by Banner and Associates, based on records from an evaporation pan located near Green River, Wyoming.

Table 1-7 gives the various monthly average evaporation, precipitation and net evaporation used in calculation of the reservoir evaporation.
Evaporation loss is calculated within the computer model by multiplying the net monthly evaporation loss factor in feet by the average monthly surface area of the reservoir.

<table>
<thead>
<tr>
<th>Month</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sept</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation (in.)</td>
<td>1.34</td>
<td>1.15</td>
<td>1.27</td>
<td>1.39</td>
<td>1.00</td>
<td>1.10</td>
<td>1.01</td>
<td>1.08</td>
<td>1.22</td>
<td>1.16</td>
<td>1.53</td>
<td></td>
</tr>
<tr>
<td>Gross Evap. (in.)</td>
<td>2.16</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.00</td>
<td>0.0</td>
<td>0.0</td>
<td>4.68</td>
<td>5.04</td>
<td>7.44</td>
<td>6.12</td>
<td>3.84</td>
</tr>
<tr>
<td>Net Evap. (in.)</td>
<td>0.82</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>2.76</td>
<td>3.96</td>
<td>6.22</td>
<td>4.96</td>
<td>2.31</td>
</tr>
<tr>
<td>(ft.)</td>
<td>0.07</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
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<td>0.23</td>
<td>0.33</td>
<td>0.52</td>
<td>0.41</td>
<td>0.19</td>
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CHAPTER II

LEGAL & INSTITUTIONAL
A. Assumptions and Bear River Compact

The assessment of the impact upon existing water rights associated with Bear Lake are based on the following assumptions:

1. To satisfy Wyoming's portion of additional storage rights under the amended Bear River Compact of 1980 the storage of water in the dam will be utilized primarily to supplement and satisfy the delivery of water for the identified down-stream water right holders as specified in the tabulation of adjudicated water rights - Water Division No. 4 (May 1983) published by the Wyoming State Board of Control, a copy of which is attached hereto. This tabulation of water rights is summarized in Table 1-1 of the Level 1 Feasibility Study, page 11. We have confirmed that as of the date of this study, October, 1984, this tabulation is still current insofar as the office of the Wyoming State Engineer is concerned and the administration of the stream by the superintendent of Water Division No. 4, John Tiechert, is concerned.

2. The delivery of water to the vested irrigation water rights as
specified in Table I-1 Level I Feasibility Study, will be in accordance with the schedule adopted and administered by the Superintendent of Water Division 4. The hydrologic model as developed in this study contemplates delivery of said water based upon the historic demands and requirements of said water right holders.

3. Any additional storage beyond that amount of water stored by the State of Wyoming to satisfy water rights and its allocation under the Bear River Compact of 1958 or as amended in 1980 shall be water stored in conjunction with a transfer of storage rights from Bear Lake now held by Utah Power and Light as discussed below.

4. The depletion allocations considered are from the Wyoming State Engineers "Final River Allocations, November 1983 For Amended Bear River Compact, 1980." The transfer of storage rights from the Bear Lake are in addition to the Wyoming rights.

5. The water rights held by Utah Power and Light in Bear Lake are those specified in Table II-1 attached hereto which summarize the existing water rights related to the operation of the Bear Lake and Bear River.

6. Any proposal to store water in the Smiths Fork Project based on a transfer of storage rights by the State of Utah in addition to those rights for storage which have been allocated in Bear Lake could not
satisfy the criteria necessary for delivery of domestic water for the area below Bear Lake in the State of Utah. This assumption is based on the fact that the low flow periods of the Bear Lake already have ample and sufficient storage capacities to be held in the Bear Lake proper. Additional storage constructed beyond this capacity would be useful only to capture extraordinary flows in those years where the requirement for delivery of water downstream has been satisfied and would not occur at a frequency sufficient to guarantee a long-term domestic water supply under current policies and procedures for use of water for year-round domestic water supplies in the State of Utah. If however, certain exchanges or agreements could be entered into between other entities and other drainages to allow for supplemental deliveries and/or exchanges, such a use of storage water in the Smiths Fork System could be accommodated. For purposes of this study, the assumption is that the sole option of storage beyond the Wyoming Allocation would be to transfer certain existing storage rights now held in the Bear Lake by Utah Power and Light into the Smiths Fork System, as discussed below.

Storage allocation in the reservoir based on the above assumptions shall include the following or a combination thereof:

(a) Water stored pursuant to Article 6A of the Bear River Compact as amended.
Therein, the state of Wyoming has allocated under its appropriation system 4,100 acre/feet of its entitlement under this article to the Town of Cokeville and the Cokeville Development Association for domestic and industrial use. This allocation is from the 1958 Compact and does not have a depletion limitation.

(b) Water stored pursuant to Article 6B of the Bear River Compact as amended.

Under this provision, the State of Wyoming has allocated by its appropriation system and through the office of the State Engineer 10,420 acre/feet of storage water rights to the Cokeville interests as specified above with the limitation of 2,200 acre/feet of annual depletion.

(c) Water stored on a temporary annual basis, which otherwise would be storable in the Bear Lake proper under the vested water rights held by the Utah Power and Light Company in the State of Idaho and State of Utah. Such water could be held for only a part of the season and would have to be released to flow downstream to the Bear Lake at a point specified in any agreement and as required under the current vested rights
deliveries which have priority to any subsequent temporary storage allotment in the Smiths Fork Dam.

(d) Water stored pursuant to Article 6C of the Bear River Compact as amended.

Such waters under this article, once stored, become the property of a project i.e. sponsors thereto, and would not be subject to releases for Bear Lake storage rights as specified in the above other options. There is no depletion limitation attached to this storage. Storage options 1 and 2 under the Articles 6A and 6B, respectively are the bearers of a compact by the State of Wyoming and would be subject only to the demands and requirements for releases and be dictated thereto by those demands and requirements for releases of Wyoming water rights according to the tabulations discussed above in the basic assumptions in this analysis. Storage right no. 4 under Article 6C of the Bear River Compact, specifies that the "storage rights under this paragraph shall be exercised with equal priority on the following bases: 6 percent thereof to Idaho, 47 percent thereof to Utah and 47 percent thereof to Wyoming." The term "exercised with equal priority" contained in the Compact does not specify how this clause is to be applied where storage is constructed jointly between two states. For example, if Utah and Wyoming participated in
the construction of this project, one interpretation may be that both states can share equally in the storage created under this option in the project. Another interpretation could be that whatever storage is constructed above Bear Lake under this paragraph is required to be allocated in the proportions set forth in the Compact. Contained in the paragraph is a statement as follows. "The availability of such water and the operation of reservoir space to store water above Bear Lake under this paragraph shall be determined by a Commission approved procedure." Currently, there is no specific procedure for this storage and operation of reservoir space, therefore, it would be necessary to have a Commission adopted procedure to be implemented prior to the operation of the reservoir to interpret this paragraph and clarify the operation of any reservoir storage space under this paragraph to satisfy the conditions set forth therein.

Relative to priorities of other water stored in the reservoir, Article 6C, water clearly would be subject to the downstream requirements of vested water right holders and other direct flow rights downstream. This would also include, of course, the water rights downstream from the project within the States of Idaho and Wyoming, as specified in the tabulations. Because water stored under storage rights No. 3 (temporary Utah
Power and Light transfer) considered to be existing storage rights in Bear Lake delivery release of water from this temporary storage would theoretically satisfy replacement of the storage downstream in Bear Lake. Under this assumption, Article 6C, water could be managed independently of the release schedule for water stored under the temporary transfer.

Under the proposed project there are certain instream flow and minimum pool requests to be assumed in the hydrologic model. There is no specification in the Bear River Compact of the existing water rights allocated in Wyoming as to whose responsibility or what entity's responsibility it is to satisfy the instream flow demands and minimum pool demands. In the hydrologic model as developed herein, the instream flow demands will not jeopardize any water rights of downstream users within the State of Wyoming or storage rights in Bear Lake owned by Utah Power and Light. The major question remaining is, of the storage rights discussed above to be allocated to the reservoir, how are the allocations for a minimum pool demand to be divided among the various storage rights existing in the reservoir? Before any such storage right is approved as discussed through the procedures below, an allocation should be determined between the various storage rights to be put within the existing reservoir as to allocations for satisfying the
minimum pool volume and minimum pool requests. This issue will become critical in years of relative shortage of stream flows above the dam wherein requirements to satisfy the various downstream water rights for Wyoming and Bear Lake will be beyond the capacity of the storage within the reservoir. It is recommended herein that an agreement be entered into between the State of Wyoming, State of Idaho, and State of Utah under the auspices of the Bear River Commission to allocate among the various storage rights in the reservoir.

B. Application Procedures and Discussion

Based on the above assumptions and the above possibilities for storage within the project, the following are the procedures which must be followed and complied with relative to the storage rights in the reservoir:

1. An application must be filed in the State Engineer's Office of the State of Wyoming titled, "Applications Permit To Appropriate Surface Water." This application must be filed by all entities who desire to store water in the reservoir. Each application must specify the legal source for such application of storage. For example, the town of Cokeville, or Cokeville Water Development Association as applicants, would file to store 14,520 acre/feet
pursuant to the entitlement for a water right received from the State of Wyoming under paragraph 6A of the Bear River Compact as amended. For water to be transferred to Bear Lake by Utah Power and Light, the application would be specified to be a temporary application and would be pursuant to an agreement with Utah Power and Light as discussed below. This application would also reference the water rights held by Utah Power and Light in Idaho.

2. For water temporarily transferred by Utah Power and Light, an application for transfer, a point of diversion and use would be filed with the State of Idaho Department of Water Resources to allow temporary upstream storage of Bear Lake water belonging to Utah Power and Light. This application would also reference the agreement with Utah Power and Light discussed below as a condition governing such application for transfer.

3. Any supplemental storage to augment or increase irrigated lands in the State of Wyoming must proceed formally through the application procedures of the Wyoming State Engineer's Office. The allocation of any storage to these augmentations or increases in irrigated lands would also have to an application for storage in the project and relating to the specific water rights so obtained in areas irrigated and specifying points of diversion.
C. Agreement With Utah Power and Light Company

As discussed above, one option for increasing storage would be to have Utah Power and Light consent and apply to temporarily transfer part of its storage rights into the reservoir from existing storage rights related to Bear Lake. Under the Bear Lake storage rights management, certain requirements for releases and storage affect the review and assessment of potential flood damage and liability. Because of this liability issue and other requirements imposed in protecting existing water rights, it is recommended herein that a formal agreement ultimately approved by the Bear River Commission be drafted between Utah Power and Light Company, the State of Idaho, the State of Wyoming and the State of Utah. It is suggested herein that this Agreement be ratified by the Bear River Commission to assure compliance and compatibility with the existing Bear River Compact as amended. This Agreement would be both an enabling agreement allowing the transfers to occur as well as the appropriate permitting by the State of Wyoming and the State of Idaho. This Agreement would also govern the operation to the extent that it affect the required releases of that water temporarily stored, to satisfy downstream water rights and other agreed to conditions. Legally, this Agreement would supercede and preempt any intervention by the State of Idaho, State of Wyoming or any other operating entity which may adversely affect the required release criteria as specified in the Agreement. This would help insure Utah Power and Light's concern as to the liabilities for entering into and in fact trans-
ferring the water rights herein. Another part of this Agreement would include the relationship between temporarily stored water and any water stored under Article 6C as discussed above. The Agreement would specify the required releases and priorities thereof between the two different storage rights. It is assumed herein that the Commission would adopt procedures for Article 6C and those criteria and procedures would be incorporated into this Agreement by reference. Another part of this Agreement would include clarification as to assignment and assignability, and beneficiaries of the storage rights so transferred including the relationship between the temporary storage and any hydropower generation occurring as a result of this project. Theoretically, a subsequent hydropower nonconsumptive right could be filed on for the site including any releases from the reservoir governed by this Agreement and any other requirements so imposed on the operation of the reservoir. This subsequent hydropower right would obviously be subject to these releases and have no ability to pre-empt or modify the necessary releases specified in the Utah Power and Light Agreement which is discussed further in the hydropower analysis.

D. Depletion Effects

A determination must be made and must be included in this operation plan from above discussed applications procedures as to the allocation of
depletion to the various storage rights in the reservoir. The Bear River Commission has not adopted a procedure for charging depletion against developments of storage projects therefore, it is necessary here to recommend that the Commission adopt a procedure at least relative to these applications and storage rights for making such a determination. The only water which carries a depletion limit in this assessment and project is the 10,420 acre-feet which could be stored under Article 6B of Bear River Compact. Assuming a combined state storage facility is constructed, the states will have to evaluate evaporative loss from storage, and make an equitable apportionment for evaporation depletion.

If the studies show that there would be a net decrease and depletion from temporary storage of water in a smaller reservoir over water stored in the Bear Lake, a credit could conceivably be given in the accounting procedures under the management of the Bear River system. Ultimately, a method for accounting for chargeable quantities of water either depleted or saved on this project must be presented to the Bear River Commission at one of its regular meetings and the concurrence of the Commission obtained prior to the ultimate approval of the net storage rights under the above discussed applications.
<table>
<thead>
<tr>
<th>Source</th>
<th>Date</th>
<th>Water Rights</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lifton - Dietrich Decree</td>
<td>1911</td>
<td>3,000 cfs</td>
<td>BR into BL</td>
</tr>
<tr>
<td></td>
<td>1912</td>
<td>2,500 cfs</td>
<td>&quot;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>300 cfs</td>
<td>BL trib.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>200 cfs</td>
<td>ML trib.</td>
</tr>
<tr>
<td>Water License 8962</td>
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<td>BL storage</td>
</tr>
<tr>
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<td>direct flow</td>
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<td>Claim No. 13-4128</td>
<td>1980</td>
<td>16,4712 ac. ft.</td>
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</tr>
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<td></td>
<td></td>
<td>700 cfs</td>
<td>direct flow</td>
</tr>
<tr>
<td>Grace - Dietrich Decree</td>
<td>1905</td>
<td>500 cfs</td>
<td>direct flow</td>
</tr>
<tr>
<td></td>
<td>1908</td>
<td>500 cfs</td>
<td>direct flow</td>
</tr>
<tr>
<td>Cove - Dietrich Decree</td>
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<tr>
<td></td>
<td></td>
<td>4,000 ac. ft.</td>
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<td>Oneida - Dietrich Decree</td>
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<td>1,000 cfs</td>
<td>direct flow</td>
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<td>direct flow</td>
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<td></td>
<td></td>
<td>700 cfs</td>
<td>direct flow</td>
</tr>
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<td>1906</td>
<td>135 cfs</td>
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<td></td>
<td>1912</td>
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<td>direct flow</td>
</tr>
<tr>
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<td>1,434 cfs</td>
<td>direct flow</td>
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<td>1624</td>
<td>75,000 ac. ft.</td>
<td>storage</td>
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<td></td>
<td></td>
<td>2,500 cfs</td>
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</tr>
<tr>
<td>*Paris - Water License 6032</td>
<td>1911</td>
<td>70 cfs</td>
<td>direct flow</td>
</tr>
</tbody>
</table>

Note: Paris Creek, tributary to Bear River
E. FEDERAL ENERGY REGULATORY COMMISSION PERMIT FOR CONSTRUCTION AND OPERATION OF NON-FEDERAL HYDROELECTRIC POWER PROJECT

The Federal Energy Regulatory Commission (FERC) is the primary federal agency responsible for the issuance of licenses or exemptions from licensing for non-federal hydroelectric projects under its jurisdiction.

Hydroelectric projects fall under the jurisdiction of FERC if any of the following apply:

1. The project will be located on, or will use water from, a navigable waterway.

2. The project will affect interstate commerce i.e. will be connected with regional transmission grid.

3. The project will utilize, wholly or partially, federal land.

4. The project will use water from a federal dam or impoundment.

The intended project will certainly be subject to FERC jurisdiction and must comply with FERC permitting, licensing or exemption procedural requirements. FERC requirements will govern the construction, operation and
maintenance of project features, including impoundments, water conduits, power houses, transmission lines and other works necessary for the development, transmission and utilization of power.

FERC regulations offer a number of alternative procedures to the project owner, and to complete the licensing process in the most cost-effective and timely manner. A careful screening of permitting or licensing alternatives will be required.

F. **Preliminary Permit**

As a first step, the prospective developer may elect, to apply to FERC for a preliminary permit, which is issued for a period of eighteen months to three years and secures the developer a priority for later filing for a license or exemption. The preliminary permit allows the developer time to prepare economic, engineering and environmental studies and analyses as necessary to support the license or exemption application. This is an optional step and the developer may choose to file directly for the license or exemption. The determination of whether or not to apply for a preliminary permit must be made after careful consideration of project characteristics and the length and complexity of preliminary studies and analyses. (18 CFR 4.80 through 4.83).
G. Licensing

FERC issues licenses to construct and operate hydroelectric projects for a term of up to 50 years. There are several categories of FERC licenses, and several possible categories of exemption from licensing depending on project characteristics. In the case of the intended project it is doubtful that an exemption from licensing would be available, although a short form license application may be a valid option.

The license application is required as well as to consulting with an extensive list of local, state and federal agencies during the process of the license application preparation. Evidence of consultation is required with the application. The details of FERC license application requirements are set forth at 18 C.F.R. 4.30 through 4.35, 18 C.F.R. 4.40 and 4.41, 18 C.F.R. 4.50 and 4.51, 18 C.F.R. 4.60 and 4.61.

All required forms and further information are available from:

Federal Energy Regulatory Commission
825 North Capital Street, N.E.
Washington, D.C. 20476

The following list of Exhibits required in connection with a FERC license application for a major project is included to indicate the general scope of information that must be included in a major project license application:

Exhibits Required for FERC License Application - Major Projects
A. Organization Papers
B. Authorization for Application
C. Pertinent Hydroelectric, Waterpower, or Irrigation Laws
D. Compliance with State Laws
E. Water Rights
F. Ownership of Lands
G. Financing of Project
H. Operation of Project
I. Capacity and Energy Generated
J. General Map
K. Detailed Map
L. General Design Drawings
M. General Description of Mechanical, Electrical, and Transmission Equipment
N. Cost Estimate
O. Construction Schedule
R. Public Recreational Use Plan
S. Effect on Fish and Wildlife
T. Statement on Benefits of Development by Non-Federal Entity
U. How Generated Power Will be Utilized
V. Architectural Design, Landscaping, and Scenic Values
W. Environmental Report

Source: 18 CFR 4.41
CHAPTER III

HYDROPOWER ANALYSIS
A. Introduction

This section presents the results of a study performed to determine the feasibility of including hydropower in the Smiths Fork project.

The results of the hydrologic analyses for the upper site and lower site were used to determine available heads, maximum and minimum flows and heads at the hydroturbine facility. The generating capacity was analyzed under maximum, normal and minimum flow conditions with due consideration for the release demands.

Equipment was selected considering the fluctuations of flow, available head, voltage to be produced, maintenance costs, physical limitations and purchase and installation costs. Conceptual drawings were prepared to show layout of the hydropower plant and miscellaneous equipment including switchgear and transformers.

A preliminary power house design and cost estimate for the configuration selected was prepared for the Upper and Lower sites.
Operating and maintenance costs were estimated along with revenue from power sales based on a levelized avoided cost of $0.052 KW-hr over a 20 year period. The avoided cost payment of $0.052 KW-hr is in accordance with discussions between the Wyoming Water Development Commission and Utah Power and Light Company.

Figure 3.1 shows the hydropower calculations utilized in the economic analysis.

All data preparation, studies, preliminary design, reports and recommendations were prepared considering FERC licensing requirements.

B. Annual Energy

Annual energy is defined as the quantity of energy that a hydropower turbine will produce at a given site over a period of one year. It is a function of the flow and head available.

Annual energy is extremely useful in comparing alternate designs and estimating revenue for computing the return on investment.

When calculating annual energy potential it is assumed that the turbine
Figure 3.1
Annual Energy Production

\[ N = 600 \text{ RPM} \quad D = 34.0" \]

<table>
<thead>
<tr>
<th>Month</th>
<th>Gross Head (ft)</th>
<th>Disch. (cfs)</th>
<th>Head Loss (ft)</th>
<th>Net Head (ft)</th>
<th>#Units</th>
<th>Turbine Eff. (%)</th>
<th>Turbine Output (KW)</th>
<th>Gen. Eff. (%)</th>
<th>Gen. Output (KW)</th>
<th>#Days</th>
<th>Total Energy (KW-hrs)</th>
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<td>58.5</td>
<td>0.1</td>
<td>114.0</td>
<td>1**</td>
<td>90.0</td>
<td>506</td>
<td>93.4</td>
<td>473</td>
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<td>113.1</td>
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<td>93.7</td>
<td>507</td>
<td>28</td>
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<td>455</td>
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<td>60.7</td>
<td>0.1</td>
<td>116.6</td>
<td>1**</td>
<td>90.0</td>
<td>538</td>
<td>93.7</td>
<td>504</td>
<td>30</td>
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<td>198.5</td>
<td>0.7</td>
<td>130.3</td>
<td>1</td>
<td>92.3</td>
<td>2015</td>
<td>96.0</td>
<td>1934</td>
<td>31</td>
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<td>455.7</td>
<td>3.6</td>
<td>141.6</td>
<td>2</td>
<td>90.0</td>
<td>2451</td>
<td>96.0</td>
<td>2353</td>
<td>30</td>
<td>3,388,320</td>
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<td>539.3*</td>
<td>3.9</td>
<td>135.6</td>
<td>2</td>
<td>88.0</td>
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<td>96.0</td>
<td>2263</td>
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<td>123.5</td>
<td>330.6</td>
<td>1.9</td>
<td>121.6</td>
<td>2</td>
<td>92.2</td>
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<td>1500</td>
<td>31</td>
<td>2,232,000</td>
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<td>Nov.</td>
<td>113.3</td>
<td>61.0</td>
<td>0.1</td>
<td>113.2</td>
<td>1**</td>
<td>90.0</td>
<td>525</td>
<td>93.6</td>
<td>491</td>
<td>30</td>
<td>353,520</td>
</tr>
<tr>
<td>Dec.</td>
<td>113.9</td>
<td>59.0</td>
<td>0.1</td>
<td>113.8</td>
<td>1**</td>
<td>90.0</td>
<td>510</td>
<td>93.5</td>
<td>477</td>
<td>31</td>
<td>354,888</td>
</tr>
</tbody>
</table>

*Turbin Flow Limited to 475 cfs
**Low Flow Runner Applied

TOTAL 13,905,336

KW-hrs.
is operated at maximum possible output. Figure 3.2 is a turbine performance curve for the equipment that was considered in this study.

Data required for conducting the annual energy study, are available flow and head as functions of time and the operational characteristics of the plant.

Numerous methods exist to summarize hydrologic data so that flow duration curves can be constructed. Tabular data exists for the Smiths Fork stream flow from an established gaging station.

This data was used to develop in-flow and out-flow duration curves for the project. For the purpose of the annual energy calculations, the Utah State Water Resources, Bear River Model was used to estimate the annual energy. It summarizes monthly flow, storage, reservoir elevation and out flow to calculate the energy produced.

Monthly mean flows can be misleading in calculating annual energy. In periods of low monthly flow, several days of high flow due to localized storms may result in exceeding the volume utilized by all of the turbines at the site. These high flows may bias the monthly average to an extent that higher energy outputs are calculated than realistically exist. The monthly flow data is considered to be sufficiently accurate for the assumptions of the model.
The hydropower estimates derived by the computer show the expected variation in flow and head during the operation of the reservoir. The stream bypasses and reservoir releases required to meet downstream demands are considered to be available for power generation. This data indicates that the minimum flow will be 50 cfs and the minimum net head is 108 ft. the maximum flow is 550 cfs and the maximum net head is 145 ft.

Computer runs were made for minimum pools of 25,000 acre-foot and 5,000 acre-foot. The annual power generated when considering no instream demand or an instream demand is approximately the same. With no instream flow provided throughout the year power generation is limited to the period of May through September. This generating period coincides with the summer peak months and may provide the maximum sale price for the power.

C. Equipment

The hydraulic information has been reviewed by turbine manufacturers for equipment selection. Preliminary investigation indicates that two units will be required to match the available flow. The first suggestion is that standard Francis turbines and generators be installed. Due to the wide
variation in flow the turbines will have to be equipped with high head runners. The wide range of flow and head will result in a varying efficiency in the system. Equipment which will function under the encountered conditions at the sites available.

D. **Capital Cost Estimate**

Cost estimates were prepared, based on two 2.5 MW Standard Francis turbines and generators. powerhouse construction costs were estimated on the basis of simple, straightforward construction. Capital cost estimates for the proposed scheme is presented in Figure 3-3.
<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rock excavation</td>
<td>$ 725</td>
</tr>
<tr>
<td>Earth excavation</td>
<td>$ 5,041</td>
</tr>
<tr>
<td>Backfill</td>
<td>$ 13,971</td>
</tr>
<tr>
<td>Concrete foundation</td>
<td>$ 99,552</td>
</tr>
<tr>
<td>Concrete walls</td>
<td>$ 27,760</td>
</tr>
<tr>
<td>Concrete columns</td>
<td>$ 3,840</td>
</tr>
<tr>
<td>Membrane waterproofing</td>
<td>$ 30,060</td>
</tr>
<tr>
<td>Concrete roofing</td>
<td>$ 41,300</td>
</tr>
<tr>
<td>Concrete steps</td>
<td>$ 1,140</td>
</tr>
<tr>
<td>Stilling basin</td>
<td>$ 50,833</td>
</tr>
<tr>
<td>Miscellaneous steel</td>
<td>$ 44,449</td>
</tr>
<tr>
<td><strong>Building subtotal</strong></td>
<td>$ 318,671</td>
</tr>
<tr>
<td><strong>Equipment including:</strong></td>
<td>$1,975,000</td>
</tr>
<tr>
<td>2 horizontal 2.5 MW Francis</td>
<td></td>
</tr>
<tr>
<td>turbine generators, governing systems, inlet valves, excitation systems, low voltage switch gear, control cabinets, high voltage modules, main power transformers</td>
<td></td>
</tr>
<tr>
<td><strong>Other plant equipment:</strong></td>
<td>$ 279,367</td>
</tr>
<tr>
<td>SCADA system, instrumentation, sump pumps, HVAC, cone valves, etc.</td>
<td></td>
</tr>
<tr>
<td><strong>Power plant subtotal</strong></td>
<td>$2,573,038</td>
</tr>
<tr>
<td>Installation of power equipment</td>
<td>$ 493,750</td>
</tr>
<tr>
<td>Shipping</td>
<td>$ 100,000</td>
</tr>
<tr>
<td>Engineering and Design</td>
<td>$ 386,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>$3,552,788</td>
</tr>
</tbody>
</table>
E. Assumption for Hydropower Benefits

The use of a 5.2 cent/kwh figure in the hydropower economic feasibility analysis is based upon the following factors and assumptions:

1. U.P.& L. has indicated an intent to file the order of the Utah PSC in other states having jurisdiction over the U.P.& L. system, to include Wyoming.

2. In communications with the Wyoming Public Service Commission staff, they indicate a significant probability that the Wyoming PSC would follow the determination of the Utah PSC regarding avoided costs for the U.P. & L. System. The avoided costs are to be determined on the basis of the whole U.P.& L. service area and the above findings of the Utah PSC would carry great weight in any subsequent Wyoming hearings.

3. A hydroelectric project on the proposed site may be appropriately sized and designed to meet the necessary criterion to receive the full capacity payment indicated above.

Economic Evaluation

A preliminary assessment was made to evaluate the economic merits of
development of the upper and lower sites. The annual costs were calculated in terms of a percentage of capital costs.

The benefits were calculated as revenue derived using replacement power costs. Avoided cost is the term used in the FERC regulations implementing section 210 of PURPA to indicate that a qualifying facility must receive a price roughly equal to the utility energy cost savings and demand cost savings, if the utility can eliminate or delay new capacity construction or retire an existing inefficient plant. The current value of avoided cost of the power to be generated at Smiths Fork is estimated to be $0.052/kwhr levelized for 20 years. Replacement cost is defined as the payment to the PURPA qualified facility including both the fixed payment for the capacity the utility does not have to install and the variable payment based on the current price for the fuel, operation and maintenance costs that the utility will avoid paying. In this way, the qualifying facility receives the full value of avoided costs even as energy prices change.

A cost analysis assuming the Construction Cost estimate to be the hydro-power cost, and an annual production of 13,905,336 KWH per year and twenty year levelized cost of $0.052 per KWH is shown in figure 3.4. The analysis assumes 9 percent debt service, 1 percent operating and maintenance and 3 percent down time. The twenty-year period of levelized power cost was used as the time for the analysis.
FIGURE 3.4
SMITHS FORK PROJECT
HYDROPOWER ANALYSIS

Capital Cost ........................................ $ 3,552,788.00
Annual Production. .................................. 13,905,336.00 KWH
Avoided Cost (Levelized for 20 YR Contract) ....... .052/KWH

Total Sales ($13,905,336.00 x .052) .................... $ 723,077.00/YR
Debt Service (9% for 35 YRS) ......................... 336,221.00/YR
O & M (1% C.C.) ....................................... 35,528.00/YR
Downtime (3%) ......................................... 21,692.00/YR

Total Annual Revenue ................................. $ 723,077.00
Total Annual Expenses (Debt Service, O & M, Downtime) .... 393,441.00
Total Profit ........................................... $ 329,636.00

REVENUE (35 YEAR LIFE) ............................ $11,537,260.00

TOTAL NET ANNUAL REVENUE APPLIED TO DEBT SERVICE

Total Sales ........................................... $ 723,077.00
O & M and Downtime .................................. 57,220.00
Balance ................................................. $ 665,857.00

@ 9%
Payment @ $665,857.00/YR
Term = 7½ YRS.
Hydroplant Paid Off In 7½ Years
Total Annual Revenues Less Expenses X 27½ Years
= $18,311,068.00

Scenario #1 NPV = $3,483,205.00        #2 NPV = $3,514,080.00

TOTAL NET PRESENT VALUE

HYDROPOWER FACILITY = $3.5 MILLION
CHAPTER IV

GEOTECHNICAL INVESTIGATION
CHAPTER IV
GEOTECHNICAL INVESTIGATION

I. DATA COLLECTION AND REVIEW

A. General Geology

1. Physiography: The dam site is located in southwestern Wyoming in a mountainous area near the western section of the Western Wyoming Over Thrust Belt.

This section of Wyoming exhibits signs of intense folding and faulting. Smiths Fork lies in a north-south trending synclinal valley resulting from the intense tectonic activities that took place during the late Jurassic and early Eocene time. The slopes of Smiths Fork Valley are moderate to steep. In the vicinity of the proposed dam, the slopes on the east are approximately two horizontal to one vertical, while on the west the slopes are about two-and-a-half or three horizontal to one vertical. The proposed dam sites and reservoir area exhibit relief of about 1,000 feet. In the immediate area of the proposed dam sites, the relief is about 430 feet on the west and about 500 feet on the east.

Smiths Fork is the major stream flowing through the area. Its upper
reaches and tributaries comprise the drainage basin for the proposed dam. The ridges on either side of the valley exhibit a rectangular drainage pattern, more pronounced to the east than to the west. Possibly the reason for this is that the strata on the east do not dip as steeply as those on the west. The dip of the strata in the east is about 30° to 60° west, while in the west the dip is about 65° to 85° east.

Other than those associated with perennial streams, no springs were visible during the time of the field investigation in the months of July, August, and September. Erosion gullies were observed on the valley slopes indicating wet weather springs. Since Smiths Fork lies in a synclinal valley, conditions exist for artesian ground water conditions.

Few land owners reside in the dam site or reservoir area. Those interviewed indicated that the area is used primarily for summer cattle grazing. Severe weather conditions exist throughout this area during the winter months. During the period of the field investigation, the weather was hot and dry with an occasional afternoon thunder shower.

Access to the area is limited to one all weather, improved surface light-duty dirt road on the east side of the valley.
2. **Stratigraphy and Lithology:** Bedrock formations in the study area are units of the Lower Cretaceous Period of the Mesozoic Era. The sequence of rocks that will be encountered during the construction of the dam and spillway at both proposed dam sites, ranging from oldest to youngest, are the Smiths Formation overlain by the Thomas Fork Formation overlain by the Cokeville Formation. Quaternary alluvium and colluvium are found at various locations along Smiths Fork. The following description of units was obtained from the United States Geological Survey Bulletin 1372-I and Map I-11129 and observations made in the field.

a. **Smiths Formation:** The Smiths Formation contains interbedded quartzitic sandstone, shale and an occasional thin limestone. The prominent characteristics of the rocks of this formation are ferruginous black fissile shale and tan fine-grained quartzitic sandstone. The sandstone rocks grade laterally into shale and siltstone in the upper part of the formation, while the main sandstone development is in the lower portion of the formation. Limestone strata present in this formation are generally one foot or less in thickness. The limestone strata may contain fossils. Some may contain hard ferruginous concretions.

b. **Thomas Fork Formation:** The Thomas Fork Formation overlies
the Smiths Formation and consists of banded and variegated red, purple, brown, and green mudstone and gray, tan, and buff sandstone. The sandstones are conglomeritic in part with pebbles as much as four inches in diameter. These beds may be the parent bedrock for some of the reddish soils observed in the study area.

c. **Cokeville Formation**: The Cokeville Formation overlies the Thomas Fork Formation and is the youngest bedrock formation present in the dam site area. This formation consists of light-gray to medium-gray fossiliferous sandstone and sandy siltstone, light to dark gray claystone and mudstone, calcareous concretions, abundantly fossiliferous tan limestone, and some beds of light gray, tan, and pink porcelanite and bentonite. A few thin coal seams are present in the upper portion of the formation. Reference material indicates the soils derived from this unit are sandy in nature. Soil samples obtained from the core borings contain high percentages of silt and clay.

d. **Quaternary Deposits**: Present at various locations along Smiths Fork are Quaternary recent alluvium and older alluvium terrace gravel deposits. The recent alluvial soils consist of poorly to moderately well-sorted clay/silt, sand and gravel
found in the floodplains bordering Smiths Fork. Older alluvial terrace gravel deposits are present mainly on the higher terraces at various locations along Smiths Fork. These terrace deposits consist of silt, sand and gravel, poorly to moderately sorted and are unconsolidated and dissected. Some of these terrace deposits probably contain glacial outwash.

A short distance south of the dam site older gravel deposits (Pleistocene and Pliocene) are present. These deposits consist of clay, silt, and pebble to boulder-size gravels. These deposits may be a suitable source of gravel for construction.

3. **Structure:** The study area is located in the Idaho-Wyoming Overthrust Belt which is the eastern unit of the Cordilleran Mountain System. Concentric (disharmonic) folds and their associated zones of detachment are typical of deformation in the Idaho-Wyoming Overthrust Belt (Conrad, 1977). This type of folding indicates that the shape of the folds varies greatly with depth below the erosional surface and the competency of the rock units.

The proposed dam sites lie within a synclinal valley across the axis of an unnamed syncline. Attitude measurements taken on outcrops on the valley slopes indicate that the structure is a syncline. Approximately one-and-a-half miles west of the dam site lies the
Muddy Ridge Fault, and to the east about one-and-a-half miles lies an unnamed fault. Both these high angle faults dip to the west. No review of geologic references or examination of aerial photographs indicate any faults directly at the dam site.

4. **Geomorphology:** Both proposed dam sites are located in a synclinal valley that is tightly folded in the dam area and is less tightly folded as the syncline extends to the north. A series of parallel ridges is present on either side of the valley. The ridges are formed by resistant sandstone strata with valleys or saddles between the ridges. One of these valleys will be utilized for the spillway. These valleys are formed by the weathering of the soft, less resistant shales and mudstones.

The nose on the west side of the valley on the axis of the upper dam site is possibly the remnant of a slump block that may have originated on the steep western slope. This condition is indicated by the dip direction measured on the north side of the nose. Bedding planes in the rock outcropping on the north of the nose dip to the west.

5. **Site-Specific Geology and Cross Sections:** A geologic reconnaissance of the site was performed and observations made of bedrock outcrops. The observations are listed in Figure 4-1 and the locations are
<table>
<thead>
<tr>
<th>OBSERVATION NO.</th>
<th>ROCK DESCRIPTION</th>
<th>STRIKE</th>
<th>ATTITUDE</th>
<th>FEATURES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Light grey claystone</td>
<td>N 07 E 43 NW</td>
<td></td>
<td>BEDDING</td>
</tr>
<tr>
<td>1A</td>
<td>Black fissile shale, highly weathered, iron-stained</td>
<td>N 07 E 65 NW</td>
<td></td>
<td>BEDDING</td>
</tr>
<tr>
<td>2</td>
<td>Tan fine-grained sandstone</td>
<td>N 09 E 36 NW</td>
<td></td>
<td>BEDDING</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N 60 W 86 SE</td>
<td></td>
<td>JOINT</td>
</tr>
<tr>
<td>3</td>
<td>Tan fine-grained sandstone, bedding visible</td>
<td>N 04 E 62 NW</td>
<td></td>
<td>BEDDING</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N 08 E 48 SE</td>
<td></td>
<td>JOINT</td>
</tr>
<tr>
<td>4</td>
<td>Tan grey medium-grained sandstone, bedding visible, cross bedded</td>
<td>N 10 E 40 W</td>
<td></td>
<td>BEDDING</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N 35 E 55 SE</td>
<td></td>
<td>JOINT</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N 55 W 73 NE</td>
<td></td>
<td>JOINT</td>
</tr>
<tr>
<td>5</td>
<td>Grey siltstone, massive</td>
<td>N 11 W 41 NW</td>
<td></td>
<td>BEDDING</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N 45 W 64 SW</td>
<td></td>
<td>JOINT</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N 54 W 78 SW</td>
<td></td>
<td>JOINT</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N 16 E 55 NW</td>
<td></td>
<td>JOINT</td>
</tr>
<tr>
<td>6</td>
<td>Dark grey arenaceous limestone, some fossils</td>
<td>N 07 E 45 NW</td>
<td></td>
<td>BEDDING</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N 45 W 64 NE</td>
<td></td>
<td>JOINT</td>
</tr>
<tr>
<td>7</td>
<td>Grey white conglomerate, containing, sandstone, chert, and limestone gravel</td>
<td>N 07 E 37 NW</td>
<td></td>
<td>BEDDING</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N 05 W 64 NE</td>
<td></td>
<td>JOINT</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S 65 E 82 SW</td>
<td></td>
<td>JOINT</td>
</tr>
<tr>
<td>8</td>
<td>Light grey claystone</td>
<td>N 02 W 60 SW</td>
<td></td>
<td>BEDDING</td>
</tr>
<tr>
<td></td>
<td></td>
<td>E - W 80 N</td>
<td></td>
<td>JOINT</td>
</tr>
<tr>
<td>8A</td>
<td>Black fissile shale, highly weathered, iron-stained</td>
<td>N 02 W 60 SW</td>
<td></td>
<td>BEDDING</td>
</tr>
<tr>
<td></td>
<td></td>
<td>E - W 80 N</td>
<td></td>
<td>JOINT</td>
</tr>
<tr>
<td>10</td>
<td>Tan fine-grained sandstone</td>
<td>N 07 W 30 SW</td>
<td></td>
<td>BEDDING</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N 40 E 34 E</td>
<td></td>
<td>JOINT</td>
</tr>
<tr>
<td>11</td>
<td>Tan grey fine-grained sandstone, bedding visible</td>
<td>DUE N 45 W</td>
<td></td>
<td>BEDDING</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N 20 W 40 NE</td>
<td></td>
<td>JOINT</td>
</tr>
<tr>
<td>12</td>
<td>Light grey medium-grained sandstone, calcareous</td>
<td>N 08 E 34 NW</td>
<td></td>
<td>BEDDING</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N 64 W 90</td>
<td></td>
<td>JOINT</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N 16 W 50 NE</td>
<td></td>
<td>JOINT</td>
</tr>
<tr>
<td>13</td>
<td>Grey brown medium to coarse-grained sandstone, bedding visible</td>
<td>N 06 W 65 NE</td>
<td></td>
<td>BEDDING</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S 70 W 65 NW</td>
<td></td>
<td>JOINT</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S 85 W 73 SE</td>
<td></td>
<td>JOINT</td>
</tr>
<tr>
<td>OBSERVATION NO.</td>
<td>ROCK DESCRIPTION</td>
<td>STRIKE</td>
<td>DIP</td>
<td>FEATURES</td>
</tr>
<tr>
<td>----------------</td>
<td>-------------------------------------------------------</td>
<td>----------</td>
<td>-------</td>
<td>----------</td>
</tr>
<tr>
<td>14</td>
<td>Light grey fine-grained sandstone</td>
<td>N 09 W</td>
<td>07 NE</td>
<td>BEDDING</td>
</tr>
<tr>
<td></td>
<td>iron-stained, thin bedded, calcite filled fractured</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Light grey coarse-grained sandstone</td>
<td>N 01 W</td>
<td>79 NE</td>
<td>BEDDING</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S 70 W</td>
<td>77 NW</td>
<td>JOINT</td>
</tr>
<tr>
<td>16</td>
<td>Light grey fine-grained sandstone, bedding visible</td>
<td>N 13 W</td>
<td>56 NE</td>
<td>BEDDING</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S 81 W</td>
<td>75 NW</td>
<td>JOINT</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N 07 W</td>
<td>32 SW</td>
<td>JOINT</td>
</tr>
<tr>
<td>17</td>
<td>Light grey fine-grained sandstone</td>
<td>N 15 W</td>
<td>40 NE</td>
<td>BEDDING</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S 85 W</td>
<td>90</td>
<td>JOINT</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N 40 E</td>
<td>44 NW</td>
<td>JOINT</td>
</tr>
<tr>
<td>18</td>
<td>Light grey fine-grained sandstone, trace carbonaceous</td>
<td>N 14 W</td>
<td>72 NE</td>
<td>BEDDING</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N 77 E</td>
<td>66 SE</td>
<td>JOINT</td>
</tr>
<tr>
<td></td>
<td></td>
<td>E - W</td>
<td>90</td>
<td>JOINT</td>
</tr>
<tr>
<td>19</td>
<td>Grey siltstone, massive</td>
<td>N 05 W</td>
<td>85 NE</td>
<td>BEDDING</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N 07 W</td>
<td>76 SW</td>
<td>JOINT</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N 65 E</td>
<td>30 NW</td>
<td>JOINT</td>
</tr>
<tr>
<td>20</td>
<td>Dark grey shale</td>
<td>N 07 E</td>
<td>78 NW</td>
<td>BEDDING</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N 85 E</td>
<td>90</td>
<td>JOINT</td>
</tr>
<tr>
<td>21</td>
<td>Grey medium-grained sandstone calcite</td>
<td>N - S</td>
<td>62 W</td>
<td>BEDDING</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N 52 W</td>
<td>75 NE</td>
<td>JOINT</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N 50 E</td>
<td>48 SE</td>
<td>JOINT</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N - S</td>
<td>20 E</td>
<td>JOINT</td>
</tr>
</tbody>
</table>
shown on Drawing 9. The outcrops observed were primarily those of Smiths Formation and younger rocks. The Thomas Fork Formation above Smiths Fork Formation outcrops periodically throughout the area, however, the Thomas Fork Formation is overlain by the Cokeville Formation. Recent and older gravel formations of Pleistocene and possible Pliocene age are also present on benches throughout the study area. The ferruginous black shale at the bottom or base of Smiths Fork Formation was observed both to the east and west of Smiths Fork. (It is noted in Geological Survey Bulletin 1372-1.)

The fine-grained quartzitic sandstones noted in this publication are also present as a resistant zone formation. The approximate location of this unit can be noted on the Geologic Cross Section, Drawing 8.

The Thomas Fork Formation, although not specifically defined or noted in the field, is probably outcropping in the study area. The lithologic descriptions in the literature describe units typical to those observed in the field. The mudstones and tan and buff sandstones noted in Geological Survey Bulletin 1372-I indicate characteristics similar to outcrops measured near the dam locations. The formation above the Thomas Fork formation and the Cokeville Formation, is also present and outcropping in the study area. Field observations indicate rock units that correspond with the general lithologic descriptions in the literature. The gravel formations,
primarily the bench areas directly above Smiths Fork, are typical of glacial deposits with a poorly sorted nature. Stratification mentioned in the literature was not observed in the field. The alluvial deposits along Smiths Fork, of Quaternary age, seem to consist heavily of silt-sized and clay-sized particles however, there is a definite sand and gravel concentration within the matrix. Near surface conditions indicate a fairly well-sorted silt size particle makeup. The older formations, that is those formations older than the Smiths Formation, consist of the Gannett group. These are a series of mudstones, limestones, and conglomerates that were noted somewhat to the east of the project site. However, they are well out of the immediate project area.

6. Airphoto Interpretation: Three sets of aerial photographs were used in the interpretation of geologic features in the study area, 1:24000 color, 1:24000 black and white, and 1:40000 black and white. The 1:24000 photographs were obtained from the Bureau of Land Management and are dated 1981. The 1:40000 photographs were obtained from the U.S. Department of Agriculture and are dated 1976. These photographs were studied to delineate outcrops for measurement during field observations and to observe any indications of structural features primarily significant faulting that might have an effect on the proposed dam site. Numerous outcrop locations were noted. Field observations indicate a correlation at what is
probably the base of the Smiths Formation defining a black shale utilized as a marker bed.

11. Seismic

A. Site Seismicity

1. Seismic Zone: Any damsite is subject to earthquake activity, the risk being greater in some regions than in others. The map appearing as Figure 4.2 is a seismic risk map prepared by the Water and Power Resources Services, U.S. Department of the Interior and is based on the known distribution of earthquakes, earthquake intensities associated with known earthquakes, and evidences of strain release associated with earthquake activity. Proposed sites for the Smiths Fork Dam are located in an area classified as Zone 2.

2. Active Faults: Earthquakes result from movement along faults in the earth's crust. The area of the fault surface over which movement occurs determines the magnitude of a particular earthquake. Faults exist to the east and west of the project site and are
1. Zone 0 - No Damage
2. Zone 1 - Minor Damage
3. Zone 2 - Moderate Damage
4. Zone 3 - Major Damage
5. Zone 4 - Great Damage

SEISMIC ZONE MAP OF THE CONTIGUOUS STATES AND PUERTO RICO

Figure 4.2
described in the previous section of this report.

However, according to "Preliminary Map Showing Known and Suspected Active Faults in Wyoming," U.S.G.S. Open File Report No. 75-279 dated 1976, the nearest fault to the site on which movement was reported during historic times is the Rock Creek Fault about 6 miles southeast of the site. A section of this map is included as Figure 4.3. Figures 4.3A and 4.3B provide additional fault data including names for those faults which have been named.

3. **Historic Earthquakes:** The record of earthquakes in the past 100 years within 200 miles of the site obtained from the National Oceanographic and Atmospheric Administration (NOAA) shows the earthquake nearest the site occurred 13.6 miles northeast of the site in 1965 and was of low intensity. A series of earthquakes is listed from 1884 to 1981 centered from 16.8 to twenty-five miles southwest of the site. The Modified Mercalli Scale intensities for these earthquakes range from very low to VII, with the VII for the 1884 quake, which is of limited reliability. A table of the Modified Mercalli Intensity Ratings is reproduced in Figure 4.4. An earthquake having an intensity of VIII occurred 139 kilometers southwest of the site in March, 1975.

4. **Conclusions:** No faults were observed at either proposed site.
Figure 4.3. A KNOWN AND SUSPECTED ACTIVE FAULTS
Source: USGS Open File Report No. 75-279

EXPLANATION

FAULT--Known and inferred; approximately located

NUMBER IDENTIFYING FAULT--See accompanying material describing fault

CATEGORIES OF FAULTS

R
Break along fault that occurred during historic time.

O
Youngest beds broken are of Holocene age.

Y
Youngest beds broken are of late Quaternary age (essentially Wisconsin time in the Pleistocene).

G
Youngest beds broken are of Quaternary age (essentially Pleistocene time).

B
Fault has been recurrently active since middle Miocene time (essentially during last 20 million years).

P
Other fault that may be active.
FAULT NUMBER 16
Name of fault—Rock Creek Fault
Latest movement—Historic--100 yrs old (Red)(Age of fault)
Type of fault—High angle normal
Rel. dir. movement—Downthrown on west
Length of fault—24–25 miles
Attitude of fault—Trends about N., dips valleyward (westward)
Susceptibility to eq.—High
Confidence (reliability) level—High
Recurrence interval—
Fault density—One scarp

Source—Steve Oriel
Address—USGS, Fed. Ctr.
Denver, Colo., 80225
Phone—(303) 234-3337
State map—Wyoming
County—Lincoln
Reference—Geo1. map Sage Quad.
Cokeville quad—N. edge of Rock Creek fault
Province—
Remarks—
1—Steve indicates that this fault has moved in past 100 yrs.
2—Scarps 50–60 ft in alluvium.

FAULT NUMBER 17
Name of fault—En echelon sower of faults
Latest movement—Cut Mio–Plio(?), Late Cenoz(Yellow)(Age of fault)
Type of fault—High angle normal
Rel. dir. movement—Downthrown on west
Length of fault—25 miles
Attitude of fault—Trends about N.S.E., dips NW
Susceptibility to eq.—Low-moderate
Confidence (reliability) level—
Recurrence interval—
Fault density—En echelon series

Source—Steve Oriel
Address—USGS, Fed. Ctr.
Denver, Colo., 80225
Phone—(303) 234-3337
State map—Wyoming
County—Lincoln
Reference—Rubey, Tracey, Oriel, Pre geo1. map of Sage Quad., Lincoln Co., Wyo.
Province—
Remarks—

FAULT NUMBER 18
Name of fault—Unnamed fault east side of groben, West side Subb1ette Rg.
Latest movement—Late Cenoz(Blue)
(Age of fault)
Type of fault—High angle normal fault
Rel. dir. movement—Downthrown valleyside (west side down)
Length of fault—45 miles ±
Attitude of fault—Trends generally north, dips west
Susceptibility to eq.—High
Confidence (reliability) level—High
Recurrence interval—
Fault density—No modern movement

Source—Steve Oriel
Address—USGS, Fed. Ctr.
Denver, Colo., 80225
Phone—(303) 234-3337
State map—Wyoming
County—Lincoln
Reference—Preston 2° sheet Sage Quad.—Rubey, Tracey, Oriel
Province—
Remarks—
1—Connects with fault in Utah along west front of Crawford Mtns. East fault of groben, epicenter near Randolph, Ut. Preston 2° sheet. See also Ogden AMS sheet.
FAULT NUMBER 19

Name of fault-Unnamed fault-west flank groben (West side Bear River Valley) (East side Boundary Ridge), west of Cokeville

Latest movement-Late Cenoz(Blue) (Age of fault)

Type of fault-High angle normal

Rel. dir. movement- East side (valley) downthrown

Length of fault-Uncertain, but prob. about 10 miles

Attitude of fault-Trends N., dips east

Susceptibility to eq.-Low to moderate

Confidence (reliability) level-Low

Recurrence interval-

Fault density-No modern scarpets

Source-Steve Oriel
Address-USGS, Fed. Ctr., Denver, Colo., 80225
Phone-(303) 234-3337
State map-Wyoming
County-Lincoln
Reference-Preston 2° Cokeville Quad-Unpubld
Province-
Remarks-

Historic-Red- 1237
Holocene-Orange- 1214
Maj. Late Quat.-Yellow- 1209
Maj. Quat.-Green- 1208
Late Cenoz.-Blue- 1206
Other anom.-Purple- 1210

-106-
<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.</td>
<td>Not felt except by a very few under especially favorable circumstances. (I Rossi-Forcel Scale)</td>
</tr>
<tr>
<td>II.</td>
<td>Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing. (I to II Rossi-Forcel Scale)</td>
</tr>
<tr>
<td>III.</td>
<td>Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration like passing truck. Duration estimated. (III Rossi-Forcel Scale)</td>
</tr>
<tr>
<td>IV.</td>
<td>During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, and doors disturbed; walls make creaking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably. (IV to V Rossi-Forcel Scale)</td>
</tr>
<tr>
<td>V.</td>
<td>Felt by nearly everyone; many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster, unstable objects overturned. Disturbances of trees, poles and other tall objects sometimes noticed. Pendulum clocks may stop. (V to VI Rossi-Forcel Scale)</td>
</tr>
<tr>
<td>VI.</td>
<td>Felt by all; many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight. (VI to VII Rossi-Forcel Scale)</td>
</tr>
<tr>
<td>VII.</td>
<td>Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures. Some chimneys broken. Noticed by persons driving motor cars. (VII Rossi-Forcel Scale)</td>
</tr>
<tr>
<td>VIII.</td>
<td>Damage slight in specially designed structures; considerable in ordinary substantial buildings, with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving motor cars disturbed. (VIII to IX Rossi-Forcel Scale)</td>
</tr>
<tr>
<td>IX.</td>
<td>Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken. (IX Rossi-Forcel Scale)</td>
</tr>
<tr>
<td>X.</td>
<td>Some well-built wooden structures destroyed, most masonry and frame structures destroyed with foundations, ground badly cracked, Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks. (X Rossi-Forcel Scale)</td>
</tr>
<tr>
<td>XI.</td>
<td>Broad, if any (masonry) structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly. (XI Rossi-Forcel Scale)</td>
</tr>
<tr>
<td>XII.</td>
<td>Damage total. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown upward into the air. (XII Rossi-Forcel Scale)</td>
</tr>
</tbody>
</table>
There is no indication of geologic features which would preclude construction of the Smiths Fork Dam. The dam will be located in a seismically active zone. Modern earth dam design procedures are available to reduce the risks associated with construction of an earth dam in a seismically active zone. For example, the Palisades Dam, completed in 1958 about 70 miles north of Smiths Fork is an earth dam 249 ft. high and 1,401,000 acre-feet capacity constructed in Seismic Zone 2 in an area with a greater concentration of faults than Smiths Fork.

Stability analyses performed for this study included a horizontal acceleration of 0.15 g from an earthquake. Features to provide flexibility, must be included in the design of the concrete outlet conduit. The gradation of the filter zones and the moisture content and compaction of the core zone should be selected to accommodate possible earthquake movements.
111 SUBSURFACE INVESTIGATION

A. Exploration

The subsurface investigation was conducted from August 9, to October 2, 1984. The drilling and test pit excavation work was performed by Fred Anderson and Son Exploration Drilling, Inc., 711 West 1400 South, Woods Cross, Utah 84087.

B. Core Borings

Eleven standard core borings were drilled at the approximate locations shown on the "Test Boring and Test Pit Locations," Drawing No. 2. About 1,224 lineal feet of test borings were drilled. The depth of the borings ranges from a maximum of 230 feet in TB-1 to a minimum of fifty feet below the existing ground surface in TB-2.

Soil samples were generally obtained at three-foot depth intervals using a standard two-inch O.D. split spoon sampler and the Standard Penetration Test, ASTM Method D-1586. The penetration test results are plotted to the left of the core borings on the "Test Boring Logs and Seismic Data," Drawing Nos. 3 through 6.

Samples of bedrock were obtained from each test boring using standard
rotary coring methods. A double tube core barrel of NX size was used. The percent core recovery and the Rock Quality Designation (RQD) is indicated to the left of the test borings on the drawings referenced above.

The subsurface material obtained from the core borings was visually examined and described in the field. Copies of the drilling logs are included in the Appendix to this report.

C. Pressure Testing

Pressure testing of the bedrock was completed at selected depths in TB Nos. 3, 4, 5, 6, 7, and 8. The testing was conducted in the drill holes by using a single packer directly after each core sample had been retrieved. The data obtained was used to determine the apparent permeability of the material tested.

In many zones pressure testing was not possible because the strata were so pervious the packer tests would not hold pressure and the permeability of the materials exceeded the capacity of the pumps. Where pressure testing was possible the rate of permeability ranged from $10^{-2}$ to $10^{-5}$. Full details of pressure and permeability test results are shown on the Pressure Tests Data Sheets, Figures 4.5 through 4.20.
## PRESSURE TESTS

### FIGURE 4-5

**TB NO. 3**

**ELEV. 6713**

**PRESSURE GAGE HT. (HG) 4.4**

<table>
<thead>
<tr>
<th>DEPTH INTERVAL</th>
<th>TIME</th>
<th>ΔT (MIN)</th>
<th>METER (GALLONS)</th>
<th>ΔQ (GALLONS)</th>
<th>PRESSURE (PSI)</th>
<th>HP (FT)</th>
<th>HD (FT)</th>
<th>H</th>
<th>K (FT/YR)</th>
<th>K (CM/SEC)</th>
</tr>
</thead>
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<td>16' - 23'</td>
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<td>30' - 34'</td>
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<tr>
<td>34' - 44'</td>
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</tbody>
</table>

**23' - 30' LOST CIRCULATION - CORE VERY FRAC'TURED**

**30' - 34' NO PACKER**

**34' - 44' LOST CIRCULATION - CORE VERY FRAC'TURED**

---

**FOR NX HOLE 10' INTERVAL**

\[
K(\text{FT/YR}) = \frac{C_p \Delta Q}{H}
\]

**PRES. HEAD = Hp**

\[
\left(\frac{H}{\text{SI}}\right) \left(\frac{144 \text{ SI}}{\text{SF}}\right) \left(\frac{\text{CF}}{62.4^{\text{SI}}}\right) = \text{FT}
\]

\[
\left(\frac{-\text{PSI}}{\text{PSI}}\right) \left(2.308\right) = \text{FT}
\]

\[
\frac{\text{FT}}{\text{YR}} \times \frac{30.48 \text{ CM}}{\text{FT}} \times \frac{\text{YR}}{365 \text{ DAYS}} \times \frac{\text{DAYS}}{86,400 \text{ SEC}} = \frac{\text{CM}}{\text{SEC}}
\]

\[
\frac{\text{FT}}{\text{SEC}} \times 9.665 \times 10^{-7} = \text{CM/SEC}
\]

**BY GPL**

**DATE: 10-9-84**
## Pressure Tests

### Figure 4-6

<table>
<thead>
<tr>
<th>Depth Interval</th>
<th>Time</th>
<th>( \Delta t ) (Min)</th>
<th>Meter (Gallons)</th>
<th>( \Delta Q ) (Gallons)</th>
<th>Pressure (Psi)</th>
<th>HP (FT)</th>
<th>HD (FT)</th>
<th>( H_{\text{HP+HDHG}} )</th>
<th>K (FT/YR)</th>
<th>K (CM/Sec)</th>
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<td>44'-54'</td>
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<td>20</td>
<td>46.2</td>
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<td>787.1</td>
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<td>7.6 X 10^-4</td>
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<tr>
<td></td>
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<td>17</td>
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<td>&quot;</td>
<td>&quot;</td>
<td>99.6</td>
<td>836.3</td>
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<td>54'-64'</td>
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<tr>
<td>Lost circulation - Core Fractured</td>
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<td>1</td>
<td>1172.0</td>
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<td>70</td>
<td>161.5</td>
<td>69</td>
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<td>1176.0</td>
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<td>9.1 X 10^-5</td>
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<td>74'</td>
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<td>Lost circulation - Core Fractured</td>
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<td></td>
</tr>
</tbody>
</table>

### Formulas

- \( K(\text{FT/YR}) = \frac{C_p \Delta Q}{H} \)
- \( \text{Pres. Head} = \frac{144}{SF} \left( \frac{C_F}{62.4} \right) = FT \)
- \( \frac{\text{FT}}{\text{YR}} \times \frac{30.48 \text{CM}}{\text{FT}} \times \frac{\text{YR}}{365 \text{ DAYS}} \times \frac{\text{DAYS}}{86,400 \text{ SEC}} = \frac{\text{CM}}{\text{SEC}} \)
- \( \frac{\text{FT}}{\text{YR}} \times 9.665 \times 10^{-7} = \frac{\text{CM}}{\text{SEC}} \)

**By**: GPL  
**Date**: 10-9-84
### Pressure Tests

**Figure 4-7**

<table>
<thead>
<tr>
<th>Depth Interval</th>
<th>Time</th>
<th>ΔT (Min)</th>
<th>Meter (Gallons)</th>
<th>ΔQ (Gallons)</th>
<th>Pressure (PSI)</th>
<th>HP (FT)</th>
<th>HD (FT)</th>
<th>K (FT/YR)</th>
<th>K (CM/SEC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>74'-84'</td>
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<td>1220.0</td>
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<td>79</td>
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<td>14.0</td>
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<td>14.5</td>
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<td>2.7 x 10^-4</td>
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<td>1</td>
<td>1291.0</td>
<td>14.0</td>
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<td>&quot;</td>
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<td>2.7 x 10^-4</td>
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<td>84'-94'</td>
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</tr>
</tbody>
</table>

94' Drill without water circulating - Core fractured

For Nx hole 10' interval

\[ K(\text{FT/YR}) = \frac{C_p \Delta Q}{H} \]

Pres. Head = \(\frac{H_p}{\left(\frac{144 \text{ SI}}{SF}\right)}\left(\frac{CF}{62.4^2}\right) = \text{FT} \)

\(\frac{\text{FT}}{\text{YR}} \times 30.48 \text{ CM} \times \frac{\text{YR}}{365 \text{ DAYS}} \times \frac{\text{DAYS}}{86,400 \text{ SEC}} = \text{CM/SEC} \)

\[ \frac{\text{FT}}{\text{YR}} \times 9.665 \times 10^{-7} = \text{CM/SEC} \]

by GPL

Date 10-9-84
## PRESSURE TESTS

**Figure 4-8**

### Table 1: Pressure Test Data

<table>
<thead>
<tr>
<th>Depth Interval</th>
<th>Time (Min)</th>
<th>Depth (Gallons)</th>
<th>ΔQ (Gallons)</th>
<th>Pressure (PSI)</th>
<th>HP (FT)</th>
<th>HD (FT)</th>
<th>K (FT/YR)</th>
<th>K (CM/SEC)</th>
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</thead>
<tbody>
<tr>
<td>94'-104'</td>
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<td>99</td>
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<tr>
<td></td>
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<td>1437.5</td>
<td>15.7</td>
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<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
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<td>&quot;</td>
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<td>104' DRILL</td>
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<td>1:36</td>
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<tr>
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<td>1:37</td>
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<td>&quot;</td>
<td>&quot;</td>
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</tr>
<tr>
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<td>1:40</td>
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<td>&quot;</td>
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<tr>
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<td>&quot;</td>
<td>&quot;</td>
<td>442.8</td>
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<td>1:42</td>
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<td>16.5</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>456.2</td>
</tr>
</tbody>
</table>

**Notes:**
- 104' DRILL WITHOUT WATER CIRCULATING - CORE FRACTURED

### Pressure Calculations

- **PRES. HEAD** = \( H_p \)
- **K (FT/YR)** = \( \frac{C_p \Delta Q}{H} \)
- **K (CM/SEC)** = \( \frac{H_p \text{(in ft)}}{144 \text{ in.}} \times \frac{\text{in.}}{2.54 \text{ cm}} \times \frac{\text{cm}}{\text{yr}} \times \frac{\text{yr}}{365 \text{ days}} \times \frac{\text{days}}{86,400 \text{ sec}} = \text{cm/yr} \)

**Conversion Factors:**
- \( \frac{1 \text{ ft}}{30.48 \text{ cm}} \times \frac{1 \text{ yr}}{365 \text{ days}} \times \frac{1 \text{ yr}}{86,400 \text{ sec}} = \text{cm/yr} \)
- \( \frac{1 \text{ cm/sec}}{9.665 \times 10^{-7} \text{ cm/sec}} = \text{cm/yr} \)

**Dates:**
- **BY** GPL
- **DATE** 10-9-84
## PRESSURE TESTS

**FIGURE 4-9**

<table>
<thead>
<tr>
<th>DEPTH INTERVAL</th>
<th>TIME (MIN)</th>
<th>ΔT (MIN)</th>
<th>METER (GALLONS)</th>
<th>ΔQ (GALLONS)</th>
<th>PRESSURE (PSI)</th>
<th>HP (FT)</th>
<th>HD (FT)</th>
<th>H (FT/HG)</th>
<th>K (FT/YR)</th>
<th>K (CM/SEC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>114' - 124'</td>
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<td>0</td>
<td>1667.0</td>
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<td>&quot;</td>
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<td>119</td>
<td>192.6</td>
<td>460.5</td>
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<tr>
<td></td>
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<td>1685.4</td>
<td>1703.5</td>
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<td>4.5 × 10^4</td>
</tr>
<tr>
<td></td>
<td>3:22</td>
<td>1</td>
<td>1703.5</td>
<td>1721.8</td>
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<td>&quot;</td>
<td>&quot;</td>
<td>465.6</td>
<td>4.5 × 10^4</td>
</tr>
<tr>
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<td>3:23</td>
<td>1</td>
<td>1721.8</td>
<td>1740.1</td>
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<td>4.5 × 10^4</td>
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<td>470.7</td>
<td>4.5 × 10^4</td>
</tr>
<tr>
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<td>3:25</td>
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</tbody>
</table>

124' DRILL WITHOUT WATER CIRCULATING - CORE FRACTURED

---

**FOR NX HOLE 10' INTERVAL**

\[
K(\text{FT/YR}) = \frac{C_p \Delta Q}{H}
\]

\[
PRES. \ HEAD = HP = \left( \frac{\text{Psi}}{\text{SI}} \times \frac{144 \ \text{SI}}{\text{SF}} \right) \left( \frac{\text{CF}}{62.4^2} \right) = \text{FT}
\]

\[
= \left( \frac{\text{Psi}}{\text{SI}} \times 2.308 \right) = \text{FT}
\]

\[
\text{FT/YR} \times \frac{30.48 \ \text{CM}}{\text{FT}} \times \frac{\text{YR}}{365 \ \text{DAYS}} \times \frac{\text{DAYS}}{86,400 \ \text{SEC}} = \text{CM/SEC}
\]

\[
\text{FT/YR} \times 9.665 \times 10^{-7} = \text{CM/SEC}
\]

**BY GPL**

**DATE 10-9-84**
**PRESSURE TESTS**

**FIGURE 4-10**

TB NO. 4  ELEV. 6760  PRESSURE GAGE HT. (HG) 4.5

<table>
<thead>
<tr>
<th>DEPTH INTERVAL</th>
<th>TIME (MIN)</th>
<th>ΔT</th>
<th>METER (GALLONS)</th>
<th>ΔQ</th>
<th>PRESSURE (PSI)</th>
<th>HP (FT)</th>
<th>HD (FT)</th>
<th>H</th>
<th>HP+HD+HG</th>
<th>K (FT/YR)</th>
<th>K (CM/SEC)</th>
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</thead>
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<tr>
<td>65'-75'</td>
<td>4</td>
<td>30</td>
<td>69.2</td>
<td>70</td>
<td>143.7</td>
<td>136.4</td>
<td>1.3 x 10^-4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>30</td>
<td>69.2</td>
<td>70</td>
<td>143.7</td>
<td>136.4</td>
<td>1.3 x 10^-4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>30</td>
<td>69.2</td>
<td>70</td>
<td>143.7</td>
<td>136.4</td>
<td>1.3 x 10^-4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>30</td>
<td>69.2</td>
<td>70</td>
<td>143.7</td>
<td>136.4</td>
<td>1.3 x 10^-4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>30</td>
<td>69.2</td>
<td>70</td>
<td>143.7</td>
<td>136.4</td>
<td>1.3 x 10^-4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**POOR CORE RECOVERY TO 65'**

| 75'-85'        | 4          | 30 | 69.2            | 80 | 153.7         | 127.5   | 1.2 x 10^-4 |
|                | 4          | 30 | 69.2            | 80 | 153.7         | 127.5   | 1.2 x 10^-4 |
|                | 4          | 30 | 69.2            | 80 | 153.7         | 127.5   | 1.2 x 10^-4 |
|                | 4          | 30 | 69.2            | 80 | 153.7         | 127.5   | 1.2 x 10^-4 |
|                | 4          | 30 | 69.2            | 80 | 153.7         | 127.5   | 1.2 x 10^-4 |

**FOR NX HOLE 10' INTERVAL**

\[ K(FT/YR) = \frac{Cp \Delta Q}{H} \]

\[ \text{PRES. HEAD} = \frac{H}{S} \left( \frac{144 \text{ SI}}{SF} \right) \left( \frac{CF}{62.4} \right) = FT \]

\[ \left( \frac{\text{PSI}}{10} \right) \left( 2.308 \right) = \text{FT} \]

\[ \frac{\text{FT}}{\text{YR}} \times \frac{30.48 \text{ CM}}{\text{FT}} \times \frac{\text{YR}}{365 \text{ DAYS}} \times \frac{\text{DAYS}}{86,400 \text{ SEC}} = \frac{\text{CM}}{\text{SEC}} \]

\[ \frac{\text{FT}}{\text{YR}} \times 9.665 \times 10^{-7} = \frac{\text{CM}}{\text{SEC}} \]

**BY GPL**

**DATE 10-9-84**
### Pressure Tests

**Figure 4-11**

<table>
<thead>
<tr>
<th>Depth Interval</th>
<th>Time</th>
<th>ΔT (Min)</th>
<th>Meter (Gallons)</th>
<th>ΔQ (Gallons)</th>
<th>Pressure (PSI)</th>
<th>HP (FT)</th>
<th>HD (FT)</th>
<th>H (FT/YR)</th>
<th>K (CM/SEC)</th>
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</thead>
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<tr>
<td>90'-100'</td>
<td>1</td>
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<td>&quot;</td>
<td>&quot;</td>
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<td>69.2</td>
<td>95</td>
<td>145.2</td>
<td>1.4 x 10^-4</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>5</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>145.2</td>
<td>1.4 x 10^-4</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>5</td>
<td>&quot;</td>
<td>&quot;</td>
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<td>&quot;</td>
<td>145.2</td>
<td>1.4 x 10^-4</td>
</tr>
<tr>
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<td>1</td>
<td>5</td>
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<td>&quot;</td>
<td>&quot;</td>
<td>145.2</td>
<td>1.4 x 10^-4</td>
</tr>
</tbody>
</table>

**Formula:***

\[
PRES. \ HEAD = HP = \frac{2x}{S1} \left(\frac{144 \ SI}{SF}\right) \left(\frac{CF}{62.4}\right) = FT
\]

\[
PRES. \ HEAD = \left(\frac{2x}{S1}\right) \left(\frac{2x}{S1}\right) \left(\frac{2x}{S1}\right) = FT
\]

\[
\frac{FT \times 30.48 \ CM}{YR \times FT} \times \frac{YR}{365 \ DAYS} \times \frac{DAYS}{86,400 \ SEC} = \ CM \ SEC
\]

\[
\frac{FT}{YD} \times 9.665 \times 10^{-7} = \ CM \ SEC
\]

**Note:**

- **TB NO. 4**
- **ELEV. 6760**
- **Pressure Gage HT. (HG) 4.5**
- **For NX HOLE 10' INTERVAL**
- **Cp = 4900**
- **K(FT/YR) = Cp \frac{\Delta Q}{H}**

**By: GPL**

**Date:** 10-9-84
**PRESSURE TESTS**

**FIGURE 4-12**

<table>
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<tr>
<th>DEPTH INTERVAL</th>
<th>TIME</th>
<th>ΔT (MIN)</th>
<th>METER (GALLONS)</th>
<th>ΔQ (GALLONS)</th>
<th>PRESSURE (PSI)</th>
<th>HP (FT)</th>
<th>HD (FT)</th>
<th>H</th>
<th>K (FT/YR)</th>
<th>K (CM/SEC)</th>
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</thead>
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<td>PUMP RUNNING AT FULL CAPACITY</td>
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<td>0</td>
<td>2.5</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>72' - 82'</td>
<td>PUMP RUNNING AT FULL CAPACITY</td>
<td>0</td>
<td>0</td>
<td>2.5</td>
<td>7</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>82' - 92'</td>
<td>3:07</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td>2.5</td>
<td>7</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>82' - 92'</td>
<td>3:08</td>
<td>18.5</td>
<td>8.5</td>
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<td></td>
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<td></td>
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<tr>
<td>82' - 92'</td>
<td>3:09</td>
<td>28.5</td>
<td>10.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7000</td>
<td>6.7 X 10^{-3}</td>
</tr>
<tr>
<td>82' - 92'</td>
<td>3:10</td>
<td>41.5</td>
<td>13.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9100</td>
<td>8.8 X 10^{-3}</td>
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<td>82' - 92'</td>
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<td>59.0</td>
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<td></td>
<td></td>
<td></td>
<td>12,250</td>
<td>1.2 X 10^{-2}</td>
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<tr>
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<td>66.0</td>
<td>7.0</td>
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<td>4.7 X 10^{-3}</td>
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<tr>
<td>92' - 102'</td>
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<td>0</td>
<td>66</td>
<td>DIDN'T * 6</td>
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<td>2.5</td>
<td>20.8</td>
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</tr>
<tr>
<td>92' - 102'</td>
<td>5:27</td>
<td>3</td>
<td>66</td>
<td>TAKE * 6</td>
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</tr>
<tr>
<td>92' - 102'</td>
<td>5:29</td>
<td>2</td>
<td>66</td>
<td>* 6</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

* PRESSURE FROM GAGE OBTAINED FROM ACETYLENE TANK - NOT CORRECT DOES NOT PORTRAY WATER PRESSURE

HD = 2.5'

FOR NX HOLE

\[ K(\text{FT/yr}) = \frac{C_p \Delta Q}{H} \]

PRES. HEAD = \( H_{\text{p}} = \left( \frac{144 \text{ SI}}{62.4 \text{ SI}} \right) \left( \frac{\text{CF}}{2.308} \right) = \text{FT} \)

\[ \text{CM/SEC} = \frac{30.48 \text{ cm}}{\text{FT}} \times \frac{\text{YR}}{365 \text{ DAYS}} \times \frac{\text{DAYS}}{86,400 \text{ SEC}} = \text{CM/SEC} \]

\[ \text{CM/SEC} = 9.665 \times 10^{-7} \]

BY GPL

DATE 10-9-84
PRESSURE TESTS

FIGURE 4-13

<table>
<thead>
<tr>
<th>DEPTH INTERVAL</th>
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<th>ΔT (MIN)</th>
<th>METER WATER (GALLONS)</th>
<th>ΔQ (GALLONS)</th>
<th>PRESSURE (PSI)</th>
<th>HP (FT)</th>
<th>HD (FT)</th>
<th>H (FT)</th>
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<th>K (CM/SEC)</th>
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ELEV. G.W. = 6665.5
HD = 6670 - 6665.5 = 4.5'
FOR NX HOLE 10' INTERVAL
Cp = 4900

\[
PRES. HEAD = HP = \left(\frac{\text{SI}}{\text{SI}}\right) \left(\frac{144 \text{ SF}}{62.4^3}\right) = \text{FT}
\]
\[
\left(\frac{-\text{PSI}}{2.308}\right) = \text{FT}
\]
\[
\frac{\text{FT}}{\text{YR}} \times \frac{30.48 \text{ CM}}{\text{FT}} \times \frac{\text{YR}}{365 \text{ DAYS}} \times \frac{\text{DAYS}}{86,400 \text{ SEC}} = \frac{\text{CM}}{\text{SEC}}
\]
\[
\frac{\text{FT}}{\text{CM}} \times 9.665 \times 10^{-7} = \frac{\text{CM}}{\text{SEC}}
\]

BY GPL
DATE 10-9-84
## PRESSURE TESTS

**FIGURE 4-14**

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<th>METER (GALLONS)</th>
<th>ΔQ (GALLONS)</th>
<th>PRESSURE (PSI)</th>
<th>HP (FT)</th>
<th>HD (FT)</th>
<th>H HP+HD+HG (FT/YR)</th>
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<td>31.5</td>
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</table>

**HD = 4.5'**

### FOR NY HOLE 10' INTERVAL

\[
K(\text{FT/YR}) = \frac{\Delta Q}{H} \times \left( \frac{144 \text{ SI}}{\text{SF}} \right) \left( \frac{\text{CF}}{62.4^3} \right) = \text{FT}
\]

\[
\frac{\text{FT}}{\text{YR}} \times \frac{30.48 \text{ CM}}{\text{FT}} \times \frac{\text{YR}}{365 \text{ DAYS}} \times \frac{\text{DAYS}}{86,400 \text{ SEC}} = \frac{\text{CM}}{\text{SEC}}
\]

\[
\frac{\text{FT}}{\text{YR}} \times 9.665 \times 10^{-7} = \text{CM/SEC}
\]

**BY GPL**

**DATE 10-9-84**
### PRESSURE TESTS

**FIGURE 4-15**

**TB NO. 6**

**ELEV. 6670**

**PRESSURE GAGE HT. (HG) 4.5**

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<th>METER (GALLONS)</th>
<th>ΔQ (GALLONS)</th>
<th>PRESSURE (PSI)</th>
<th>HP (FT)</th>
<th>HD (FT)</th>
<th>H (FT/HG)</th>
<th>K (FT/YR)</th>
<th>K (CM/SEC)</th>
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<td>70</td>
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<td>170.5</td>
<td></td>
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<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>83.3</td>
<td>8.1 × 10⁻⁵</td>
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<tr>
<td>6:29</td>
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<td>281.6</td>
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<td>290.3</td>
<td>2.8 × 10⁻⁴</td>
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</table>

| 73'-80'        |      | DIDN'T TAKE |               |              |               |         |        |            |           |            |

HD = 4.5

- **FOR Ν HOLE**
- **10' INTERVAL**
- Cp = 4900

\[
K(\text{FT/YR}) = \frac{\Delta Q}{H} = \frac{\text{Cp}}{\text{H}}
\]

**PRESS. HEAD = Hp**

\[
\left(\frac{\Pi}{\text{SI}}\right) \left(\frac{144 \text{ SI}}{\text{SF}}\right) \left(\frac{\text{CF}}{62.4^{\text{SI}}}\right) = \text{FT}
\]

\[
\left(\frac{\Pi}{\text{PSI}}\right) \left(2.308\right) = \text{FT}
\]

\[
\frac{\text{FT}}{\text{YE}} \times \frac{30.48 \text{ CM}}{\text{FT}} \times \frac{\text{YE}}{365 \text{ DAYS}} \times \frac{\text{DAYS}}{86,400 \text{ SEC}} = \text{CM/SEC}
\]

\[
\frac{\text{FT}}{\nu_D} \times 9.665 \times 10^{-7} = \text{CM/SEC}
\]

**BY** GPL

**DATE** 10-9-84
## PRESSURE TESTS

**FIGURE 4-16**

<table>
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### Pressure Test Data

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<th>ΔQ (GALLONS)</th>
<th>PRESSURE (PSI)</th>
<th>HP (FT)</th>
<th>HD (FT)</th>
<th>HP+HD (FT)</th>
<th>H (FT/YR)</th>
<th>K (FT/YR)</th>
<th>K (CM/SEC)</th>
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<td>74.55</td>
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<tr>
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<td>10:21</td>
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<td>21.7</td>
<td>47</td>
<td>72.3</td>
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<tr>
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<td>10:22</td>
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<td>47</td>
<td>72.3</td>
<td>61.00</td>
<td>5.9 x 10^-5</td>
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</table>

### Conversion and Calculation Formulas

- **K (FT/YR)** = \( \frac{Cp \Delta Q}{H} \)
- **Pres. Head ( PSI)** = \( \frac{H^2}{2g} \)
- **Head Loss ( PSI)** = \( \frac{144 \times SF}{62.4^2} \)
- **Flow Rate (CM/SEC)** = \( \frac{\text{FT}}{\text{MIN}} \times 30.48 \times \frac{\text{CM}}{\text{MIN}} \times \frac{\text{FT}}{365 \text{ DAYS}} \times \frac{\text{SEC}}{86,400 \text{ SEC}} \)

- **By AR**
- **Date** 9-19-84
# PRESSURE TESTS

**Figure 4-17**

<table>
<thead>
<tr>
<th>TB NO. 7</th>
<th>ELEV. 6738</th>
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<td>1</td>
<td>840.10</td>
<td>9.30</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td></td>
<td>1:30</td>
<td>1</td>
<td>850.7</td>
<td>10.60</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
</tbody>
</table>

82'-92' LOST CIRCULATION DURING DRILLING - ALSO POOR CORE RECOVERY

*FOR NX HOLE
10' INTERVAL
Cp = 4900*

\[
PRES. \ HEAD = \frac{\Delta Q}{H} = \frac{Cp \Delta Q}{H} \quad (\frac{H}{S}) \left(\frac{144 \text{ SI}}{SF}\right) \left(\frac{\text{CF}}{62.4 \text{ SI}}\right) = \text{FT}
\]

\[
\text{FT/YR} \times \frac{30.48 \text{ CM}}{\text{FT}} \times \frac{\text{YR}}{365 \text{ DAYS}} \times \frac{\text{DAYS}}{86,400 \text{ SEC}} = \frac{\text{CM}}{\text{SEC}}
\]

\[
\frac{\text{FT}}{\text{CM/YR}} \times 9.665 \times 10^{-7} = \frac{\text{CM}}{\text{SEC}}
\]

**BY AR DATE 9-19-84**
## PRESSURE TESTS

### FIGURE 4-18

<table>
<thead>
<tr>
<th>DEPTH INTERVAL</th>
<th>TIME (MIN)</th>
<th>ΔT (GALLONS)</th>
<th>ΔQ (GALLONS)</th>
<th>PRESSURE (PSI)</th>
<th>HP (FT)</th>
<th>HD (FT)</th>
<th>H (FT)</th>
<th>HP+HD-HG (FT/yr)</th>
<th>K (CM/SEC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>22'-32'</td>
<td>1</td>
<td>16</td>
<td>&quot;</td>
<td>&quot;</td>
<td>69.2</td>
<td>27</td>
<td>100</td>
<td>384.0</td>
<td>7.6 X 10^-4</td>
</tr>
<tr>
<td>32'-42'</td>
<td>1</td>
<td>3</td>
<td>&quot;</td>
<td>&quot;</td>
<td>69.2</td>
<td>37</td>
<td>110</td>
<td>133.6</td>
<td>1.3 X 10^-4</td>
</tr>
</tbody>
</table>

**Lost Circulation at 22'**

### FORMULATION

**PRES. HEAD** = \( \frac{\text{CG} \cdot \Delta Q}{\text{H}} \)

**K(FT/YR)** = \( \frac{\text{CG} \cdot \Delta Q}{\text{H}} \)

\[
\text{CM/SEC} = \frac{\text{FT} \times 30.48 \text{ CM} \times \text{YR} \times 86,400 \text{ SEC}}{\text{FT} \times 365 \text{ DAYS} \times \text{DAYS}}
\]

\[
\text{CM/SEC} = \frac{\text{FT} \times 9.665 \times 10^{-7}}{\text{YR}}
\]

**FOR NX HOLE 10' INTERVAL**

\( \text{CG} = 4900 \)

**Cp = 4900**

**K(FT/YR) = \( \frac{\text{CG} \cdot \Delta Q}{\text{H}} \)**

**Pres. Head = \( \frac{\text{CG} \cdot \Delta Q}{\text{H}} \)**

\[
\text{FT} \quad \text{(144 SF) \left( \frac{\text{CF}}{62.4} \right)} = \text{FT}
\]

\[
\text{PSI} \quad (2.308) = \text{FT}
\]

**BY GPL**

**DATE 10-9-84**
### PRESSURE TESTS

**FIGURE 4-19**

TB NO. **8**  
ELEV. **6670**  
PRESSURE GAGE HT. (HG) **3.8**

<table>
<thead>
<tr>
<th>DEPTH INTERVAL</th>
<th>TIME</th>
<th>ΔT (MIN)</th>
<th>METER (GALLONS)</th>
<th>ΔQ (GALLONS)</th>
<th>PRESSURE (PSI)</th>
<th>HP (FT)</th>
<th>HD (FT)</th>
<th>H (FT/YR)</th>
<th>K (CM/SEC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>42'-52'</td>
<td>1</td>
<td>5</td>
<td></td>
<td></td>
<td>30</td>
<td>69.2</td>
<td>47</td>
<td>120</td>
<td>204.2</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>204.2</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>204.2</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>204.2</td>
</tr>
<tr>
<td>52'-62'</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**NO TAKE**

---

FOR NX HOLE  
10' INTERVAL  
Cp = 4900

\[
K(\text{FT/YR}) = \frac{C_p \cdot \Delta Q}{H}
\]

PRES. HEAD = \(H_p\)

\[
\left(\frac{\Delta x}{S_1}\right) \left(\frac{144 \text{ Sf}}{\text{CM}}\right) \left(\frac{\text{CF}}{62.4}\right) = \text{FT}
\]

\[
\left(\frac{\text{PSI}}{\text{CM/SEC}}\right) \left(2.308\right) = \text{FT}
\]

\[
\frac{\text{FT}}{\text{YR}} \times \frac{30.48 \text{ CM}}{\text{FT}} \times \frac{\text{YR}}{365 \text{ DAYS}} \times \frac{\text{DAYS}}{86,400 \text{ SEC}} = \frac{\text{CM}}{\text{SEC}}
\]

\[
\frac{\text{FT}}{\text{SEC}} \times 9.665 \times 10^{-7} = \frac{\text{CM}}{\text{SEC}}
\]

BY **GPL**  
DATE **10-9-84**
### PRESSURE TESTS

**FIGURE 4-20**

<table>
<thead>
<tr>
<th>DEPTH INTERVAL</th>
<th>TIME (MIN)</th>
<th>ΔT (GALLONS)</th>
<th>ΔQ (GALLONS)</th>
<th>PRESSURE (PSI)</th>
<th>HP (FT)</th>
<th>HD (FT)</th>
<th>H (FT)</th>
<th>K (FT/YR)</th>
<th>K (CM/SEC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>62'–72'</td>
<td>NO TAKE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>72'–80'</td>
<td>NO TAKE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**FOR NX HOLE 10' INTERVAL**

\[
K(FT/YR) = Cp \frac{\Delta Q}{H}
\]

**PRES. HEAD = Hp**

\[
\left(\frac{H}{SI}\right) \left(\frac{144 SI}{SF}\right) \left(\frac{CF}{62.4^H}\right) = FT
\]

\[
\left(\frac{PSI}{SI}\right) \left(2.308\right) = FT
\]

\[
\frac{FT}{YR} \times 30.48 \text{ CM} \times \frac{YR}{365 \text{ DAYS}} \times \frac{DAYS}{86,400 \text{ SEC}} = \frac{CM}{SEC}
\]

\[
\frac{FT}{YR} \times 9.665 \times 10^{-7} = \text{CM/SEC}
\]

**DATE** 10-9-84
D. Test Pits

A total of ten test pits were excavated at the approximate locations shown on "Test Boring and Test Pit Locations," Dwg. No. 2. The depth of the test pits varied from ten feet in TP-4 to sixteen feet in TP-7. The test pits were excavated in order to provide data on subsurface conditions and to obtain soil samples for visual classification and laboratory testing. Descriptions of the material encountered in each test pit appear on "Test Pit Logs", Drawing No. 7.

IV LABORATORY INVESTIGATION

A. Visual Descriptions

Soil samples obtained from the core borings and test pits were visually examined and described by our geologist. To aid in classifying the soils and to determine general soil characteristics, natural moisture content, grain size distribution, specific gravity, Atterberg limits and Standard Proctor compaction tests were performed on selected samples. In addition, one-dimensional consolidation and direct shear tests were performed on samples selected to be critical based on the preceding test program.

The results of all tests, with details shown as necessary, are summarized...
in Appendix H of this report.

V CONCLUSIONS - UPPER SITE

A. Soil Conditions

1. Flood Plain Section

a. General: The soils sampled in the test borings drilled in the valley flood plain consisted of a layer of clayey silt or silty clay overlying sandy gravel. A layer of residual soil was encountered overlying bedrock in all three test borings drilled on the valley flood plain. The total thickness of soils overlying bedrock varied from about twelve feet at TB No. 8, drilled near the west side of the valley flood plain, to about thirty-seven feet at TB No. 5, drilled near the center of the valley.

The seismic refraction survey indicates that the depth to bedrock is about thirty feet over most of the middle portion of the valley flood plain.

b. Clayey Silt or Silty Clay: The layer of clayey silt or silty
clay sampled beneath the ground surface varied from about two feet thick at TB No. 5, near the center of the valley, to about six feet thick in TB Nos. 6 and 8, near the east and west sides of the valley flood plain. The clayey silt or silty clay is alluvial in origin and was observed to vary in consistency from soft to firm and in moisture from damp to wet. The clayey silt or silty clay is unsuitable as a foundation for the dam because of its estimated low shear strength and moderate compressibility. The clayey silt or silty clay is suitable for use in the core section of the dam if the surface organic soil and organic material is removed.

c. **Sandy Gravel:** The sandy gravel layer underlying the clayey silt or silty clay was not encountered in TB No. 8, drilled near the west side of the valley flood plain. The thickness of this soil type was about thirty-one feet at TB No. 5, near the center of the valley, and about four feet at TB No. 6, near the east side of the valley. The sandy gravel varied from medium to very dense based on resistance to penetration of the split spoon sampler, and contained from a trace to little silty clay. This material is alluvial in origin and probably is glacier related material transported and deposited by running water. (The sandy gravel layer is very permeable.) It is suitable as a foundation for the dam if a cutoff is provided to reduce
seepage. Settlement of the dam due to compression of the sandy gravel is not estimated to be large and would probably largely occur during dam construction. The sandy gravel is suitable for use in filter and drain zones in the dam if processed to appropriate gradations.

d. Residual Soil: The layer of soil originating from the in-place weathering of bedrock varied in thickness from about five or six feet in TB Nos. 6 and 8, at the edges of the valley flood plain, to about twelve feet in TB No. 5, near the center of the valley. The residual soil types reflect the type of parent bedrock and varied from clayey silts to silty clays. The soils sampled varied in consistency from soft to hard and in moisture from damp to wet. In TB No. 5, the residual soil and weathered bedrock was hard. Residual soil and weathered bedrock similar to that sampled in TB No. 5 are suitable as foundation for the dam. Hard residual soil will probably contribute only slightly to the settlement of the dam if the dam is constructed on the residual soil zone. In that case, the cutoff or core of the dam should extend through the residual soil zone. The material excavated should be suitable for use in the core zone of the dam.

2. Right Abutment
a. **General:** TB No. 4 was drilled at about a 10° angle westward from the vertical in the right abutment area.

b. **Silty Clay:** Silty clay soil was sampled to a depth of about twelve feet below the existing ground surface. The consistency of the silty clay sampled was firm and the soil was damp. This soil will be stripped to prepare the abutment. The excavated soil will be suitable for incorporation into the core zone of the dam if organic topsoil and other organic matter are removed and the material compacted at an appropriate moisture content.

3. **Left Abutment**

   a. **General:** TB No. 7 was drilled at about a 10° angle eastward from the vertical in the left abutment area.

   b. **Clayey Silt:** Clayey silt soil was sampled to the top of bedrock at a depth of about five feet below the existing ground surface. The consistency of the soil was firm and the soil was damp. This soil will be stripped to prepare the left abutment. The excavated soil will be suitable for incorporation into the core zone of the dam if organic material is removed and if
compacted at the appropriate moisture content.

4. **Topographic Nose**

a. **General:** A topographic anomaly exists at the west side of the valley flood plain on the axis of the dam. The surface of the nose is about forty feet above the valley floor to the east. TB No. 3 was drilled through this material. The thickness of the soil zone overlying bedrock was about sixteen feet at TB No.3.

b. **Silty Clay:** The soil sampled beneath the ground surface in TB No. 3 was a silty clay layer about six feet thick. The silty clay sampled is firm in consistency and damp in moisture. This soil will be excavated in preparing the site. The excavated soil will be suitable for incorporation into the core zone of the dam if organic material is removed and if compacted at the appropriate moisture content.

c. **Gravel:** The soil sampled in TB No. 3 beneath the silty clay and overlying the bedrock was a coarse, subrounded to angular gravel about ten feet thick. This soil will be excavated during site preparation. The excavated material will be suitable for incorporation into the downstream drain zone of the dam.
5. Emergency Spillway

a. General: The proposed location of the emergency spillway at the upper site is a topographic saddle north and west of the axis of the dam. TB No. 1 was drilled on the axis of this saddle. TB No. 2 was drilled on the east side slope of the saddle. The total thickness of soil sampled was about sixteen-and-a-half feet in TB No. 1 and about ten feet in TB No. 2.

b. Calcareous Silts and Silty Clays: The soils sampled in both TB Nos. 1 and 2 varied from silts to silty clays. The soils were brownish or tan in color with significant white calcareous material. The calcareous material occurred both as small inclusions and as incrustations on soil particles in thin, lenticular zones.

c. Caution: While these soils are probably suitable for incorporation into the core zone of the dam, with a risk that seepage through the core may dissolve the calcareous material possibly increasing the permeability. The resulting increase flow of water could cause underground erosion. The downstream filter should be designed to reduce this risk. Laboratory tests performed during the current study indicate that the amount of soluble material is less than 1 percent by weight. Additional
tests to measure the quantity of calcareous material should be performed.

B. Bedrock

1. Flood Plain Section

a. Bedrock Types: The bedrock cored in TB Nos. 5, 6 and 8 generally consisted of siltstone. A layer of fine grained sandstone about four-and-a-half feet thick was cored through at a depth of about thirty-one feet in TB No. 6 on the east side of the valley flood plain. A layer of silty fine grained sandstone about eight feet thick was cored through at a depth of about three feet in TB No. 5 in the center of the valley. A layer of fine grained sandstone about four-and-a-half feet thick was cored through at a depth of about thirty-nine feet in TB No. 8 on the west side of the valley flood plain. Probably the sandstone layers do not correlate based on the elevations and observed bedding plane dips. The color of the bedrock observed in the bedrock cores was generally gray with occasional reddish brown zones.

b. Bedrock Condition: The bedrock sampled varied from soft to hard. The RQD varied from 0 percent to 100 percent and the
bedrock varied from very broken to massive. Frequent irregular fractures were observed. These fractures were generally calcite filled. Disintegrated sections of core represented by fragments were observed in the core box. Sections of core placed in water deteriorated rapidly to rock fragments. Some sections deteriorated to silt size particles when placed in water.

c. Structure Attitude: Bedding planes were observed in the sandstone layers previously mentioned. The bedding was observed to dip about 45° in the sandstone in TB No. 5 and to be about horizontal at a depth of about twenty feet in TB No. 8. However, dips of about 40° at depths of twenty-one feet, thirty feet and forty-three feet were observed in TB No. 8. No bedding was observed in the rock cored in TB No. 6. The axis of the syncline may be close to TB No. 8 based on published maps and on the bedrock attitude observed in the sandstone in TB No. 8. However, the bedding planes observed in the sandstone cores might represent cross bedding depositional features. The attitude observed might not indicate true bedding.

d. Permeability: The pressure tests performed in TB Nos. 6 and 8 indicate that the bedrock joints are open and with large effective permeability of the bedrock. A program of pressure grouting to reduce underseepage through bedrock will be required.
2. **Left Abutment**

a. **Bedrock Types**: The upper about five feet of bedrock cored in TB No. 7 was a quartzitic sandstone. The bedrock cored beneath the sandstone and to the bottom of boring at a depth of 100 feet was generally a siltstone. A one foot thick section of fine grained quartzitic sandstone was cored through at a depth of about eighty-two feet. The sandstones were gray and the siltstone color varied from dark gray to reddish gray.

b. **Bedrock Condition**: The top five-foot section of sandstone was massive. Frequent irregular calcite filled and stained fractures were observed. The rock was hard. The rock cored beneath the sandstone to the bottom of the boring varied from massive to very broken and from medium hard to hard. Several sections were very broken with frequent calcite filled fractures.

c. **Permeability**: The results of the pressure tests in TB No. 7 indicate that the bedrock is very permeable.

d. **Suitability for Abutment**: Excavation to key the dam into
bedrock at the left abutment will probably encounter quartzitic sandstone and massive to very broken siltstone. An appropriate program of pressure grouting will be required to reduce the risk of excessive seepage.

3. Right Abutment

a. **Bedrock Types:** The bedrock types cored in TB No. 4 drilled on the right abutment include limestone, siltstone, sandstone and claystone with occasional shaley layers. The limestones cored were fossiliferous. The bedrock color varied from dark gray to light brown.

b. **Bedrock Condition:** The bedrock cored varied from very broken to massive and from soft to hard. Frequent irregular-calcite filled joints were observed. RQD values were typically low and varied from 0 percent to a maximum of about 56 percent.

c. **Bedding Plane Attitude:** The dip of bedding plane features observed in sandstone cored in TB No. 4 varied from about 80° at about forty-five feet to about 45° at about eighty feet. The observed bedding might be cross bedding depositional features and may not represent the attitude of true bedding.
d. **Permeability:** The bedrock at the location of TB No. 4 is very permeable based on the loss of water during drilling and the pressure test results.

e. **Suitability as Abutment:** The quality of bedrock at the right abutment is probably generally poor. Removal of highly fractured bedrock with excavation of a key into bedrock should be performed. The excavated bedrock will be suitable for incorporation into the upstream and/or downstream random fill zones of the dam if large fragments are broken down or removed. An appropriate program of pressure grouting should be performed to reduce the risk of excessive seepage.

4. **Topographic Nose**

a. **Bedrock Types:** The bedrock types cored in TB No. 3 drilled to a depth of 124 feet in the topographic nose at the west of the valley flood plain included layers of sandstone, siltstone, and shale. The sandstone layers were gray and calcareous. The siltstone layers were dark gray to light brown. A two foot thick layer of black shale was cored through at ninety-three feet depth.

b. **Bedrock Condition:** The bedrock cored in TB No. 3 varied from
soft to hard. RQD values varied from 31 percent to 100 percent and the rock brokenness from blocky to massive. Frequent calcite filled fractures were observed.

c. **Bedding:** Bedding planes were observed in the sandstone cored from about seventy-seven feet to ninety-three feet and from thirty-nine feet to about fifty-nine feet. The observed dip was about 55°. The direction of dip cannot be determined from the bedrock core alone. Observations of outcrops on the north side of the nose indicate that the bedrock dips in an easterly direction in the upper portion. The direction of the dip at depths of seventy-seven feet to ninety-three feet in the rock cored is not known.

d. **Landslide Feature:** Aerial photo interpretation and the anomalous dip of bedrock observed in outcrops along the north end of the nose indicate that the nose is probably a slump block type landslide feature. If the nose is a landslide feature, then a failure zone exists between the nose and bedrock west of the nose and beneath the block over in-place bedrock. A zone indicative of sliding was recovered in TB No. 4 at a depth of about forty feet.

e. **Foundation Preparation:** The nose should be excavated and removed to a depth matching the foundation preparation in the
valley flood plain east of the nose. An appropriate pressure grouting program should be performed to match the pressure grouting in the valley flood plain to the abutment grout program.

f. Permeability: Based on water loss during drilling and the pressure test results, the rock in the nose at TB No. 3 is very permeable.

g. Suitability of Excavated Material: Bedrock excavated during removal of the nose will be suitable to incorporate in the random fill zone of the dam if adequately broken down and the large pieces removed.

5. Emergency Spillway

a. Bedrock Types: Bedrock cored in TB No. 1 to a depth of 230 feet and TB No. 2 to a depth of about fifty feet generally consisted of siltstone, sandstone, claystone, and shale. Sandstone layers were cored through from a depth of forty-four feet to about forty-seven feet, from 106 feet to 107 feet, and from 170 feet to 182 feet in TB No. 1. The remainder of the bedrock cored in TB No. 1 was siltstone. In TB No. 2, a two foot layer of claystone was cored at the top of bedrock. Black shale was cored through from about nineteen feet to twenty-
eight feet and twenty-nine feet to the bottom of the boring at a depth of about fifty feet.

b. **Bedrock Condition**: The bedrock cored varied from soft to hard. RQD values varied from 7 percent to 100 percent and the degree of brokenness from very broken to massive. Frequent disintegrated layers were observed in the bedrock core. These layers probably disintegrated as a result of drilling. Sections of rock core disintegrated rapidly when immersed in water in the laboratory, some disintegrated to silt. Frequent irregular calcite-filled fractures were observed in the rock core.

c. **Suitability as Embankment Material**: The bedrock material excavated will be suitable to construct the random fill zones of the dam if sufficiently broken down and large pieces removed and thoroughly compacted. Compaction with appropriate equipment to break down the material and the removal of large pieces should be performed to reduce the risk of pieces breaking down following compaction. There is a risk that poor construction procedures could result in undesirable voids in the embankment.

d. **Erodibility**: The bedrock exposed as a result of spillway excavation will probably be siltstone or shale. Either rock type will deteriorate rapidly upon exposure to air and will be
subject to erosion. Riprap or special vegetation should be used to reduce the risk of erosion of the exposed spillway surface.

6. **Groundwater Conditions**

   a. **Valley Flood Plain:** The groundwater levels in the valley flood plain are probably controlled by the water elevation in Smiths Fork. The only water encountered during drilling was in T.B. No. 5.

   b. **Abutments and Spillway:** No water was encountered in the test borings drilled in the abutment zones and in the spillway. It was reported that water was lost during core drilling. The fractured condition of bedrock and the results of the pumping tests indicate that the permeability of bedrock is high.

VI. **CONCLUSIONS - LOWER SITE**

A. **Soil Conditions**

1. **Flood Plain Section**

   a. **General:** No test borings were drilled in the center portion
of the valley flood plain. TB No. 9 was drilled at the western edge of the flood plain and TB No. 11 was drilled at the eastern edge. Silty clay and clayey silt soils were sampled in TB No. 9. Silty clay and clayey silt soils overlying sandy gravel were encountered in TB No. 11. A three foot thick layer of clayey silt, probably residual in origin was sampled overlying bedrock in TB No. 11. The thickness of soil overlying bedrock was twenty-eight-and-a-half feet in TB No. 9 and twenty-one feet in TB No. 11. The seismic survey results indicate a depth to bedrock varying from thirty-five feet to forty-five feet over the valley flood plain.

b. **Clayey Silt and Silty Clay:** The clayey silt and silty clay encountered to a depth of twenty-eight-and-a-half feet in TB No. 9 and to a depth of about nine feet in TB No. 11 was firm in consistency and damp to wet in moisture. These soils will be removed during site preparation. The excavated material will be suitable for incorporation into the core zone of the dam if organic topsoil and organic material is removed, and the soil placed and compacted at an appropriate water content.

c. **Sandy Gravel:** A layer of sandy gravel was encountered from a depth of nine feet to eighteen feet in TB No. 11. Sandy gravel similar to that encountered in TB No. 5 at the upper dam site probably exists across the flood plain valley. This is
indicated by the seismic survey results. The seismic velocity of 6,000 ft./sec. across the valley flood plain is similar to 6,000 to 7,000 ft./sec. across the upper site valley flood plain. The sand and gravel condition and suitability as foundation material for the dam is probably similar to that at the upper site. A cutoff will be required to reduce underseepage through the sandy gravel.

d. Clayey Silt (Residual): The clayey silt overlying bedrock encountered in TB No. 11 is probably residual in origin. The clayey silt sampled was very stiff in consistency and was moist. Soil similar to the soil sampled would not be expected to contribute significantly to settlement of a completed dam. It will be excavated through during construction and the excavated soil will be suitable for incorporation into the core zone if compacted at an appropriate moisture content.

2. Abutment Zones

a. Similar to Upper Dam Site: No borings were drilled in either the right or left abutment zones. Based on the results of the seismic survey, the soil depths and conditions in the abutment zones are probably similar to those encountered in TB Nos. 4 and 7 drilled at the upper site.
3. **Emergency Spillway**

a. **Clayey Silt:** TB No. 10 was drilled on the axis of the saddle to the west of the dam. It is proposed that the emergency spillway be excavated through this saddle. Clayey silt with little rock fragments was encountered to a depth of sixteen feet in TB No. 10. The clayey silt soil was moist and stiff to hard in consistency. The excavated soil will be suitable for incorporation in the core zone of the dam if compacted and placed at an appropriate moisture content.

b. **Weathered Claystone:** A two feet thick layer of weathered calcareous claystone was encountered overlying bedrock in TB No. 10. The soil sampled was soft and damp. The excavated soil will be suitable for incorporation in the core zone of the dam if placed at an appropriate water content and compacted.

B. **Bedrock Conditions**

1. **Valley Flood Plain Section**

   a. **General:** TB No. 9 was drilled near the west edge of the valley flood plain and TB No. 11 was drilled near the east
edge. No borings were drilled near the center of the valley flood plain. No water was found in either of these borings. Ground water can be expected in the areas near the stream. The elevations of the ground water will be controlled by the stream level.

b. **Bedrock Types:** Shale, siltstone and limestone bedrock were cored in TB No. 9. Sandstone, siltstone and limestone were cored in TB No. 11. The seismic survey results indicate that a lower velocity bedrock layer may outcrop beneath soil west of the valley center.

c. **Bedrock Condition:** The bedrock cored in TB No. 9 varied from soft to hard. The RQD varied from 69 percent to 95 percent and the rock cored was broken to massive. Frequent irregular calcite-filled and stained fractures were observed in the rock cores. The RQD of the bedrock cored in TB No. 11 varied from 17 percent to 90 percent and the rock cored was very broken to massive. Based on the results of the seismic survey, the condition of bedrock across the valley flood plain is probably similar to that encountered in TB Nos. 9 and 11.

d. **Permeability:** The condition of bedrock and the assumed similarity to conditions at the upper dam site indicate that
the bedrock joints are open and that the effective permeability of the bedrock is probably large. A program of grouting to reduce underseepage through bedrock will be required.

2. Abutments

a. Similar to Upper Dam Site: No test borings were drilled in the abutment zones at the lower dam site. Based on the seismic velocities measured in the seismic survey, bedrock conditions in the abutment zones are probably similar to those encountered in TB No. 7 drilled at the upper site. Bedrock conditions on the right abutment may not be similar to those at TB No. 4 because of the absence of the topographic nose.

3. Emergency Spillway

a. Bedrock Types: The bedrock cored in TB No. 10 drilled on the proposed axis of the emergency spillway consisted generally of siltstone. A two feet thick section of limestone was cored at a depth of about ninety-nine feet. Another two feet thick layer of limestone was cored through at a depth of about 106 feet.

b. Bedrock Condition: The bedrock cored varied from soft to medium hard. The RQD varied from 8 percent to 100 percent and
the rock cored varied from very broken to blocky. Irregular calcite-filled and stained fractures were observed.

c. Similar to Upper Dam Site: The bedrock conditions and the tendency of the bedrock to disintegrate when exposed to water are probably similar to conditions existing at the upper site. This is because the seismic velocities measured in the seismic survey are similar and because the aerial photos indicate that the rock formation involved is probably the same as the upper site.

d. Suitability as Embankment Material: The bedrock material excavated will be suitable to construct the random fill zones of the dam if sufficiently broken down, large pieces removed and thoroughly compacted. Compaction with appropriate equipment to break down the material, and removal of large pieces should be performed to reduce the risk of pieces breaking down following compaction. There is a risk that poor construction practice could result in undesirable open void spaces in the embankment.

e. Erodibility: The bedrock exposed as a result of spillway excavation will probably be siltstone or shale. Either rock type will deteriorate rapidly upon exposure to air and will be
subject to erosion. Riprap or special vegetation should be used to reduce the risk of erosion of the exposed spillway surface.

VI1 SEISMIC REFRACTION STUDY

A. Introduction

During the month of August, 1984, GBR Consultants Group, Inc. performed seismic refraction studies at both the proposed Smiths Fork Dam Sites. The study areas are in the Smiths Fork Drainage Basin northwest of Cokeville, Wyoming.

B. Purpose

The purpose of the seismic refraction investigation was to provide subsurface geotechnical information to be used as part of GBR's geotechnical study of the proposed dam locations.

Information obtained in this survey was used to estimate depths of soil, and the depths to the soil-rock interface. The seismic velocities measured were used to estimate bedrock type and condition. The results of
this investigation used in conjunction with the subsurface boring program further defined the subsurface geologic conditions of the proposed dam locations.

C. Procedures

Instrumentation used in the seismic survey was a Bison Instruments, Inc., Model 1580 six-channel signal enhancement seismograph. The seismic signal was initiated both by a hammer and by detonated charges. Charges were detonated after the initial procedure using the hammer was determined inadequate to produce strong signals at the required depths. Investigation procedures used in this survey are described below:

1. Twelve geophones or seismic detectors were placed at either twenty foot or thirty foot intervals along the seismic survey lines.

2. At the end of each survey line a signal setup was placed at the twenty or thirty foot interval depending on the geophone spacing. Either the hammer at the twenty foot intervals or the explosive charges at the thirty foot intervals were utilized at these locations. When the hammer was used, the procedure consisted of striking an aluminum plate on ground surface with the sledge hammer to initiate the signal. When charges were used, about half pound of dynamite was detonated about two feet below the ground surface. Where physical restrictions were encountered, the length of the
seismic line and geophone spacing were increased or decreased to comply with restrictions of the site.

3. When explosive charges were utilized to initiate the seismic signal, a blaster box was used as a remote detonating device. When the hammer was used, an accelerometer on the handle of the hammer triggered the seismograph when the aluminum plate was struck.

4. The travel time from the signal initiation point to the various geophones was measured in milliseconds by the signal enhancement seismograph. A recording of this signal was made using a strip-chart recorder.

5. The travel time of the waves to the various geophones was computed and used to make a velocity determination. The velocity determinations identify the approximate physical character of the bedrock. A change in velocity indicates a change in materials present. The most obvious changes, those noted in this survey, are between soil and rock. This information is used to estimate the depth of rock in the study areas.

D. Approximate Locations of the Seismic Profiles
There were two proposed dam and spillway locations investigated in this seismic resistivity study, referred to as the upper and lower dam sites. Seismic profiles were performed along the centerline and parallel to the centerline of the upper dam site. There were also two seismic profiles performed perpendicular to the baseline of the spillway. At the lower dam site one seismic profile was performed along the centerline of the dam and another perpendicular to the centerline of the proposed spillway location.

E. Presentation of Results

Results from the seismic resistivity survey are plotted as profiles on "Test Boring Logs and Seismic Data," Dwgs Nos. 3 through 6. Information presented on these profiles consists of estimated depth of rock and the velocities of material encountered.

F. Classification of Velocities

General velocity material classifications are presented based on published information and GBR's past field experience. The classifications presented in table 4.1 below are typical but great variation in seismic velocities of materials can occur.
Typical Seismic Velocities

<table>
<thead>
<tr>
<th>Range</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,000-2,000 ft./sec.</td>
<td>dry unconsolidated overburden, containing soil and broken rock fragments.</td>
</tr>
<tr>
<td>2,000-4,000 ft./sec.</td>
<td>clay, colluvium, very badly weathered shale.</td>
</tr>
<tr>
<td>3,500-5,000 ft./sec.</td>
<td>fractured bedrock, highly weathered, in a fracture system often associated with poor energy transmission.</td>
</tr>
<tr>
<td>4,500-5,500 ft./sec.</td>
<td>ground water.</td>
</tr>
<tr>
<td>4,000-6,000 ft./sec.</td>
<td>shale, badly weathered rock.</td>
</tr>
<tr>
<td>6,000-8,000 ft./sec.</td>
<td>sandy shale, calcareous shale.</td>
</tr>
<tr>
<td>8,000-10,000 ft./sec.</td>
<td>sandstones, slightly weathered limestones.</td>
</tr>
<tr>
<td>10,000-14,000 ft./sec.</td>
<td>limestones.</td>
</tr>
</tbody>
</table>

As can be seen from the above tabulation, there are no distinct boundaries between the seismic wave velocities of some materials. General rules in evaluating the engineering significance of a seismic velocity would be:

1. Velocities below 3,000 ft./sec. indicate dry "non-rock" material.
2. Velocities between 3,000 and 6,000 ft./sec. indicate potential areas of high weathering and/or potential groundwater saturation.
3. Velocities above 6,000 ft/sec/ normally represent "rock" materials.

Observation of the above table shows clearly that there is no distinct division between materials interpretations. Seismic resistivity studies should take this point into consideration. Although there are some general rules that may be followed when interpreting seismic resistivity data, what may be the most important in this type of study is that velocities above 6,000 ft/sec...
ft./sec. usually indicate consolidated material, i.e., rock. The nature of some of the glacial material, however, may indicate somewhat higher velocities than 6,000. Approximately 7,000 ft./sec. may be encountered in glacial till.

G. Discussion of Results

1. **Upper Dam Site:** As shown on the seismic profile for the upper dam site, the velocities of 4,500 ft./sec. to 7,000 ft./sec. encountered in the soil or unconsolidated zone materials indicate the possibility of glacial outwash and inundated unconsolidated material. The rock velocities of 9,000 ft./sec. to 10,500 ft./sec. correspond to the limey siltstones or limestones encountered in Borings TB-5 and TB-6.

2. **Upper Dam Spillway Location:** Interpretations of the seismic profiles conducted perpendicular to the spillway centerline indicate fairly shallow soil zones along the slopes and deeper zones near the centerline of the spillway. Velocities indicate materials similar to those encountered along the Smiths Fork flood plain zones.

3. **Lower Dam Site Centerline:** Velocities in the soil or unconsolidated zone along the lower dam site centerline range from 4,000 ft./sec. to 6,000 ft/sec. across the Smiths Fork flood plain area. Velocities measured in the abutment areas were somewhat lower, ranging from
2,500 ft./sec/ to 3,500 ft./sec. The range in velocities in the consolidated zone is primarily in the 8,000 ft./sec. to 10,000 ft./sec. range. Thus the bedrock may be similar to the bedrock encountered in the upper dam spillway. However, there are several zones as noted on the profile that are in the 7,000 ft./sec. range. This indicates a slightly different bedrock condition than that encountered along the majority of the dam centerline. Causes for the variation could be parent material, stream channelization, or depositional environment of the unconsolidated material.

4. Lower Dam Site Spillway

The spillway location exhibits several velocities of 5,000 ft./sec. in the saddle area and lower velocities of 2,500 ft./sec. to 3,000 ft./sec. in the upslope areas. This change in velocity may be attributable to the more loosely compacted colluvial material on the upslopes, and/or the residual nature of the unconsolidated zone at the center of the saddle location. Depth to rock is typically deeper in the saddle area with a shallower soil zone in the upslope area. The rock velocities in the 7,000 ft./sec. to 8,000 ft/sec. range should correlate with the lithologic units in the spillway of the upper dam site.

H. General Conclusions

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An overview of the seismic refraction study indicates no major structural dislocations at either dam site, with the exception of the potential block displacement at the west embankment of the upper dam site. There is no indication of any significant faulting at either site.

VIII SUMMARY AND RECOMMENDATIONS

A. Conclusions

1. The results of the soils testing and a preliminary dam design indicate that a dam for 125,000 acre foot reservoir can be constructed and will have a minimum safety factor of 1.15 for the upstream site and 1.13 for the downstream site under seismically loaded conditions.

2. The bedrock excavated from the spillway area is suitable for random fill to construct the upstream and downstream sections of the dam, if the recommended slopes are used. The rock cored was generally a siltstone. Many sections of core disintegrated during drilling. Selected sections of core disintegrated when placed in water in the laboratory. When placed in a fill, it is expected that some of the excavated rock will be broken down to a soil size material while
other portions will not. Compacted rock will be subject to further deterioration as water seeps through the dam. This will probably lead to the existence of zones of varying permeability and the risk of interior erosion.

3. A core section should be used to reduce the quantity of seepage through the dam. This is because of the probable zones of varying permeability and possibility of zones of high permeability in the random fill shell sections if constructed of rock from spillway excavation.

4. A drain should be included downstream of the core to reduce the risk of downstream slope failure due to high pore water pressures in the downstream random fill shell section. The drain will also reduce the risk of the phreatic line existing on the downstream slope of the dam which could lead to erosion and piping. It will also control leakage in case of cracks through the core and seepage from the bedrock.

5. A filter zone should be included between the downstream drain and the core. Soil sampled from test pits in the vicinity of the proposed construction is generally classified as CL-ML according to the Unified Classification System based on laboratory tests. Based on the laboratory classification tests and observations of existing erosion gulleys in the field, the available soil would probably be
highly erodible if used for the core. A filter is required to reduce the risk of piping fines from the core into the downstream drain during steady state seepage. The filter also offers protection against a piping failure should cracking of the core occur during an earthquake.

6. A filter zone should be included between the downstream drain and the downstream random fill shell. The purpose of the filter is to reduce the risk of clogging the downstream drain due to piping fines as water seeps from the downstream random fill zone into the drain. Water may flow from the downstream random fill zone into the drain when the flow of water in the drain is reduced after a period of high pool.

7. A filter zone should be included in the dam section between the core and the upstream random fill zone to reduce the risk of piping fines from the core into coarser or more permeable zones in the upstream random fill zone as water seeps from the core after drawdown of pool.

8. The upstream and downstream slopes should be 3H:1V to provide acceptable factors of safety for operating conditions. This conclusion is based on stability analyses. The stability analyses utilized soil and rock strengths obtained from laboratory tests and
included a .15g horizontal earthquake acceleration.

The shear strength values used were as follows:

**Core**

a. Long term stability $\phi = 28^\circ$ $c = 1000$ psf based on the results of laboratory S direct shear tests.

b. Drawdown: $\phi = 23^\circ$ $c = 840$ psf these values are the average of laboratory S direct shear test results and R strength values calculated from the S test results by assuming a pore pressure parameter $A = 1/2$.

c. Earthquake: Same as for drawdown

**Random Fill Zones:**

a. Long Term stability: $\phi = 30.5^\circ$ $c = 500$ psf based on laboratory S direct shear tests.

b. Drawdown: $\phi = 27^\circ$ $c = 400$ psf these values are the average of laboratory S direct shear test results and R strength values calculated from the S test results by assuming a porc
pressure parameter $A = 0.3$.

c. Earthquake: Same as for drawdown.

Drain and Filter Zones:

Values of $\varnothing = 35^\circ$, $c = 0$ were assumed for all conditions. These values are typical for granular material such as will be used in the filter and drain zones.

The calculated Safety Factors based on the above strength values are:

<table>
<thead>
<tr>
<th>Condition</th>
<th>Calculated Safety Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Upper Site</td>
</tr>
<tr>
<td>Downstream Slope, Steady Seepage,</td>
<td></td>
</tr>
<tr>
<td>Full Pool</td>
<td>2.14</td>
</tr>
<tr>
<td>Downstream Slope, Steady Seepage,</td>
<td></td>
</tr>
<tr>
<td>Earthquake</td>
<td>1.24</td>
</tr>
<tr>
<td>Upstream Slope, Full Pool,</td>
<td></td>
</tr>
<tr>
<td>Earthquake</td>
<td>1.15</td>
</tr>
<tr>
<td>Upstream Slope following 100 ft.</td>
<td></td>
</tr>
<tr>
<td>drawdown from full pool</td>
<td>1.49</td>
</tr>
</tbody>
</table>
9. The results of the pressure tests performed in the test borings in the field indicate high apparent hydraulic conductivities, in excess of $10^{-2} \text{ CM/sec}$ in several tests. Based on these values, the dam foundation must be grouted. A grout curtain in the foundation bedrock consisting of three rows of grout holes 200 feet deep has been assumed for preliminary design purposes.

10. While ground water was observed in TB-5 only the material above bedrock is highly permeable. The extent and quantity of ground water to be expected during construction is not expected to be a significant problem from the results of this study. Addition test borings required for final design should be located and analyzed to determine the areas and quantities of ground water that can be expected during construction.
CHAPTER V

PRELIMINARY DESIGN & COST ESTIMATES
CHAPTER V
PRELIMINARY DESIGN & COST ESTIMATE

A. Introduction

1. Alternative Locations: Two alternative locations were considered for the axis of the dam in this study. The upper location is that recommended in the Level I study. The lower location is about 2,900 feet downstream. The lower location was selected for study based on the narrower valley and the more favorable location for the emergency spillway. Drawings 10 and 11 of 24 show the proposed plans of the two facilities.

B. Dam Cross Sections

1. Emergency Spillway Elevation: The inlet elevations of the emergency spillways at both dam locations were set five (5) feet above the elevation required for storage of a 125,000 acre-foot pool. The five (5) foot freeboard will minimize loss of water caused by wave run-up due to wind forces during full reservoir periods. The emergency spillway has been sized and designed to pass the full Probable Maximum Flood (PMF). In computing the PMF the Probable Maximum Precipitation (PMP) from a general storm over the watershed was utilized.
2. **Dam Crest Elevation:** The dam crest elevations were designed to provide a storage capacity equal to 125,000 acre-feet plus fifteen feet of freeboard.

3. **Upstream and Downstream Slopes:** Three horizontal to one vertical were used for both upstream and downstream slopes. The 3H:1V slope was selected based on stability analyses. The stability analyses considered soil strength values based on laboratory test results and included consideration of horizontal pseudo-static forces using 0.15g acceleration from an earthquake.

4. **Random Fill Zones:** The bulk of the dam will be constructed using random fill. Most of the random fill will be obtained from excavation for the emergency spillway. The bedrock cored in the proposed emergency spillway area contained many sections where the rock had disintegrated. Typically, sections of core placed in water disintegrated. It is expected that the rock will break down during excavation and further disintegrate upon contact with water.
It is anticipated that, when placed in the random fill zones and compacted, variability in the grain size distribution will occur resulting in some variation in permeability. For example, some areas may consist of relatively sound rock fragments broken down during excavation and compaction. Other zones may contain disintegrated or decomposed rock with a high percentage of sand and silt-sized particles, resulting in zones of high and low permeability.

In the zones of high permeability, long term disintegration and underground erosion are possible, and considerations to eliminate the risk of adverse effect on the completed dam must be included in the design.

5. Low Permeability Core Zone: Because of the expected variable permeability and zones of high permeability in the random fill zones, a core zone of low permeability has been included in the dam cross section. The core zone will be incised into relatively sound bedrock.

6. Cutoff Trench: The core zone will be continuous with a cutoff trench excavated into bedrock below the core.
7. **Drain Zone**: A drain zone consisting of graded coarse gravel has been included in the dam cross-section downstream of the core zone. The drain zone continues horizontally on the top of bedrock to the toe of the dam where it connects with the toe drain. The purpose of the drain is to collect water seeping through the bedrock under the dam and core zone and transport it to the toe drain with little risk of water seeping into the downstream random fill zone.

The drain zone is shown on the dam cross section on drawing No. 12 of 24.

8. **Filter Zones**:

   a. Filter zones are included to prevent loss of fines from fine grained zones such as the core zone, into more permeable zones such as the drain. Filters must be constructed to a gradation based on accepted filter criteria and considering the material on both sides of the filter. Four filter zones are included in the design and are shown on the dam section on drawing No. 12 of 24 and described as follows:

   Filter Zone 1, between the core zone and the drain, has been included in the downstream section of the dam. This filter
zone continues to bedrock on the downstream side of the cutoff trench. The filter zone consists of sand and gravel with a grain size distribution selected to prevent fines from piping from the core zone into the drain.

b. Filter Zone 2, between the drain and the downstream random fill zone has been provided to prevent piping of fines from the random fill section into the drain. While the risk is slight, piping of fines from the downstream random fill section into the drain could occur during periods when the reservoir level is low.

c. Filter Zone 3, between the core zone and the upstream random fill zone is included to prevent piping of fines from the core zone into the upstream random fill zone during periods of reservoir drawdown when water may drain from the saturated core zone.

d. Filter Zone 4, is included to prevent piping of fines from the upstream random fill zone into the riprap during periods of reservoir drawdown and wave action.
9. Riprap: Riprap has been included on the upstream face of the dam to reduce the risk of erosion due to wave action and rainfall. Other options for downstream face stabilization should be investigated during final design.

10. Toe Drain: A toe drain has been included in the preliminary design. The purpose of the toe drain is to:
   
   a. Collect discharge from the drain zone.
   
   b. Concentrate and collect underseepage through bedrock.
   
   c. Collect seepage which may pass through to the downstream random zone.

11. Crest Width and Camber: A crest width of thirty feet has been used. The elevation of the crest at the middle of the dam axis has been established four-and-a-half feet higher than the elevation at the abutments. The camber is provided to compensate for possible settlement of the embankment. Longitudinal sections of the dam are shown on drawing No. 13 of 24.
C. Foundation Treatment

1. Strip to Bedrock: The area in the valley floor to be covered by the dam should be cleaned and stripped to the top of bedrock. The topsoil should be stockpiled for future use. The silty clay and clayey silt should be stockpiled for use in the core zone. The sandy gravel should be stockpiled for processing to use in drain and filter zones.

2. Excavate Cutoff Trench: The cutoff trench should be excavated into bedrock. Excavation should be continued into bedrock to remove very broken and weathered bedrock. The excavated material should be stockpiled for use in the random fill zones.

3. Slush Grout: Slush grout the exposed surface of bedrock beneath the core zone and the sides and bottom of the cutoff key.

4. Foundation Grouting: A stage grouting program to form a grout curtain should be designed and implemented. Grouting should be performed from the bottom of the cutoff trench excavation. The depth of the grout curtain and staging should be designed based on an extensive exploration program. For preliminary design purposes a grout curtain 200 feet deep with three rows of holes on an average spacing of fifteen feet center to center has been assumed.
D. **Abutment Treatment**

1. **Strip to Sound Bedrock:** The areas on the right and left slopes which will form the dam abutments should be excavated to relatively sound bedrock. The depth of excavation for preliminary estimating purposes has been based on data obtained at the test boring locations. Additional test borings prior to final design will be required to better establish the estimated depth of excavation. However, the actual depth of excavation should be based on observations in the field during excavation. The estimated excavation is as follows:

a. **Upper Dam-Right Abutment:** At the right abutment edge of the valley a topographic nose exits. The origin of this nose is not known but examination of airphotos indicates that it is probably a landslide or rockslide remnant. This nose should be completely removed. TB No. 4 drilled in the right abutment slope above the nose and encountered material containing bedrock fragments in a clay matrix which may be the slide plane on which the landslide occurred or may represent deep weathered bedrock. In either case, the excavation should extend to a depth of about sixty feet in this area to reach reasonably sound bedrock. Thus it is assumed for preliminary design purposes that the right abutment zone at the upper dam should
be excavated to a depth of sixty feet at the base of the dam and fifteen feet at the crest.

b. **Upper Dam-Left Abutment:** Based on the data obtained at TB No. 1, it is assumed that the upper twenty feet will be excavated from the left abutment zone, over the entire contact area.

c. **Lower Dam:** Only limited information is available at the lower dam site. Based on TB Nos. 9 and 11 and the seismic survey information, it is assumed that about twenty-five feet of soil and bedrock should be excavated at the base of the dam at both the right and left abutment zones tapering to an excavation of about fifteen feet at the crest. It is assumed that an excavation of about twenty-five feet over the valley flood plain will be required to reach relatively sound bedrock.

2. **Grout:** The foundation curtain grouting program should be extended up both abutments. For preliminary design it has been assumed that the three rows of grout holes, on the average of fifteen feet center-to-center-spacing will be extended to the crest of the dam. The depth of grout holes is assumed to be about 200 feet.

E. **Principal Spillway:**

1. **Upper Dam Site:**
a. **Location and Size:** The principal spillway at the upper dam is a reinforced concrete conduit. The conduit is located at the extreme east of the valley flood plain. The total length of the outlet conduit is about 1,500 feet. The inlet to the outlet conduit will be at the mouth of Tuffield Creek.

In the design the principal spillway and outlet works are combined. Flows between 50 cfs and 500 cfs are routed through two 36" diameter conduits to the turbines for power generation. Flow in excess of 500 cfs by-passes the turbines and discharges directly into the afterbay.

b. **Installation:** The outlet works should be placed on or in bedrock. The grade of the conduit should be selected based on test borings conducted during the final design phase along the selected conduit alignment.

The outlet conduit should be low enough to pass through the cutoff trench incised into bedrock. Concrete should be used to backfill the trench beneath the cutoff. To reduce the risk of rupture of the conduit during an earthquake, special consideration should be given to the size and spacing of joints and the joint detail to provide flexibility. Frequent joints
appropriately designed to allow flexibility should be included in the conduit and concrete encasement where the conduit passes beneath the cutoff trench. Seepage collars should be provided on the concrete conduit where it passes through the cutoff key.

c. **Upstream Control:** The upstream inlet structure to the outlet conduit should be designed to bypass stream flow during construction. The inlet works should include protection for fish in addition to a trash rack and should permit withdrawing reservoir water at several depths for downstream temperature control and water quality control. The lowest inlet gate should be placed near the bottom of the inlet structure or could be combined with the gating system for the construction bypass to allow the total storage to be released if required.

2. **Lower Dam Site:**

a. **Location and Size:** The outlet conduit for the lower dam can be located in the east abutment with the same size and capacity as that assumed for the upper dam site. The principal spillway and outlet works are combined. Flow will be routed in the same manner as described for the Upper Dam Site.

b. **Installation:** The outlet works at the lower dam site should
be installed in bedrock below the bottom of the cutoff key in the left abutment zone. The trench should be backfilled with concrete to reduce the risk of underground erosion of bedrock. The design of the joints in the conduit and encasement should include joints to provide flexibility in case of an earthquake.

c. **Upstream Control:** The upstream inlet details should be designed to bypass stream flow during construction. A trash rack and fish protection should be included. Provisions for withdrawing water at several depths in the reservoir should be provided for control of downstream water temperature and water quality control. The lowest inlet gate should be placed near the bottom of the inlet.

F. **Emergency Spillway:**

1. **Upper Dam Site:**

   a. **Purpose:** The emergency spillway has been provided to protect the dam from overtopping by the PMF.

   b. **Location:** The emergency spillway location proposed for the upper dam site is located in a topographic saddle beyond the west abutment.
c. **Size and Grade:** The emergency spillway shown for the upper site is 100 feet wide and about 3,700 feet in length. The flow line grade is 0.28 percent. Cut slopes above the invert are designed on a slope of two-and-a-half horizontal to one vertical.

d. **Capacity:** The emergency spillway has been designed to pass the full PMF when the pool elevation is at the 125,000 acre-foot storage elevation plus five (5) feet of freeboard and ten feet of flood surcharge.

e. **Erosion Protection:** The bedrock through which the emergency spillway is cut is probably extremely erodable. It is likely that considerable erosion damage would occur to the emergency spillway and the stream channel into which it discharges if significant water should flow. The first 100 feet of the emergency spillway is shown as paved with concrete and the next 400 feet as paved with riprap. The remainder of the cut for the emergency spillway should be enriched, mulched and seeded with appropriate grasses.

2. **Lower Dam Site:**

   a. **General:** The emergency spillway for the lower dam site has the
same purpose as the emergency spillway at the upper dam site. It has been sized and designed with the same criteria and consideration.

b. Size: The emergency spillway at the lower dam site is 400 feet wide and 1,300 feet long. The flow line slope is 0.32 percent.

The spillway width has been established to provide sufficient excavation for the construction of the random fill zones of the dam.

The side slopes have been selected at three horizontal to one vertical. The side slopes will be subject to erosion and should be enriched, mulched and seeded with appropriate grasses to minimize their erosion. No concrete lining or riprap is included as the flood flow velocity will not be high enough to create high erosion in the rock layers of the bottom of the ditch.

G. Material Sources:

1. Random Fill Zone: The following sources will contribute material
for the random fill zones:

a. Spillway excavation
b. Rock stripping on abutment zones
c. Rock stripping beneath core zone
d. Excavation for cutoff key and outlet conduits

2. **Core Zone:** The following sources will contribute material for the core zone:

a. Silty clay and clayey silt soil below topsoil stripped from the dam and spillway areas and from borrow areas.
b. Residual clayey soil overlying bedrock.
c. Borrow areas in the alluvium of the side valleys (Tuffield Creek, Preacher's Creek, Claudia's Creek).

3. **Drain Zone and Filter Zones:** Material from the following sources can be processed through an aggregate processing plant to provide material with appropriate gradations for the drain zone and filter zones:

a. Sandy gravel excavated from the flood plain valley over the area to be covered by the dam.
b. Sandy gravel excavated from borrow pits in the flood plain valley upstream from the dam.
4. **Riprap**: No suitable source has been located for durable riprap in the immediate vicinity of the dam. Riprap will have to be quarried and imported from an offsite location.

### H. Quantity and Cost Estimate

#### a. Quantities

The construction of an earth embankment dam and hydroelectric facility at the upper and lower sites has been separated into identifiable construction items. The quantities of each item have been estimated based on the preliminary design presented in this report. The items and quantities are listed in Tables 5.1 and 5.2 "Preliminary Cost Estimate." The quantities listed may change with final design.

#### b. Costs

Unit costs for the construction items identified above were estimated based on data supplied by the WWDC, our experience, published unit costs, published bids on similar projects and discussions with local contractors. The actual unit costs and actual estimated project cost may vary from that presented and cannot be known until final design is complete and bids are received.
FIGURE 5.1
COST ESTIMATE - UPPER SITE

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Description</th>
<th>Quantity</th>
<th>Unit</th>
<th>Estimated Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Mobilization</td>
<td>L.S.</td>
<td></td>
<td>1,158,000</td>
</tr>
<tr>
<td>2.</td>
<td>Dewatering</td>
<td>L.S.</td>
<td></td>
<td>190,000</td>
</tr>
<tr>
<td>3.</td>
<td>Clear &amp; Grub</td>
<td>200 Acres</td>
<td>3,000.00</td>
<td>600,000</td>
</tr>
<tr>
<td>4.</td>
<td>Excavate Cut off Key</td>
<td>88,000 C.Y.</td>
<td>8.00</td>
<td>704,000</td>
</tr>
<tr>
<td>5.</td>
<td>Slush Grout Cut off Key</td>
<td>50,000 bags</td>
<td>6.00</td>
<td>300,000</td>
</tr>
<tr>
<td>6.</td>
<td>Drill Grout Holes</td>
<td>132,000 L.Ft.</td>
<td>7.25</td>
<td>957,000</td>
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<tr>
<td>7.</td>
<td>Portland Cement Grout</td>
<td>200,000 bags</td>
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<td>1,200,000</td>
</tr>
<tr>
<td>8.</td>
<td>Excavate, Transport, Place and Compact Core Material</td>
<td>2,118,000 C.Y.</td>
<td>3.75</td>
<td>7,942,500</td>
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<td>10.</td>
<td>Excavate, Transport, Place and Compact Random Fill Material</td>
<td>7,960,000 C.Y.</td>
<td>2.75</td>
<td>21,890,000</td>
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<td>11.</td>
<td>Haul &amp; Place Riprap (from off-Site Source)</td>
<td>237,500 C.Y.</td>
<td>18.00</td>
<td>4,275,000</td>
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<tr>
<td>12.</td>
<td>Excavate for Outlet Conduit</td>
<td>22,000 C.Y.</td>
<td>6.75</td>
<td>148,500</td>
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<tr>
<td>13.</td>
<td>Outlet Conduit</td>
<td>17,200 C.Y.</td>
<td>275.00</td>
<td>4,730,000</td>
</tr>
<tr>
<td>14.</td>
<td>Inlet Works &amp; Controls</td>
<td>L.S.</td>
<td></td>
<td>750,000</td>
</tr>
<tr>
<td>15.</td>
<td>Pave Spillway Entrance</td>
<td>6,000 sq. yd.</td>
<td>18.00</td>
<td>108,000</td>
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<tr>
<td>16.</td>
<td>Riprap Spillway 400'</td>
<td>7,000 C.Y.</td>
<td>18.00</td>
<td>126,000</td>
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<tr>
<td>17.</td>
<td>Seed &amp; Mulch</td>
<td>132 Acres</td>
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<td>18.</td>
<td>Power House</td>
<td>L.S.</td>
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<td>3,553,000*</td>
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* Includes $200,000 for cone valve
### Table 5-1 Cont.

<table>
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<th>Item No.</th>
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<th>Quantity</th>
<th>Unit</th>
<th>Total Price</th>
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<tr>
<td>19.</td>
<td>Stilling Basin &amp; Discharge Works</td>
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<tr>
<td>20.</td>
<td>Upstream and Downstream Flow Measuring and Instrumentation</td>
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<td>L.S.</td>
<td>250,000</td>
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<td>21.</td>
<td>Demobilization</td>
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<td>L.S.</td>
<td>150,000</td>
</tr>
<tr>
<td>22.</td>
<td>Road Relocation 9 miles @215,000/per mi</td>
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<td></td>
<td>1,935.000</td>
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<tr>
<td>23.</td>
<td>Land Acquisition</td>
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**Estimated Cost**

- **Subtotal Engineering**: $62,661,650
- **Subtotal**: $68,927,650
- **Contingency**: $10,339,000
- **Total Estimated Cost**: $79,266,650
**TABLE 5.2**  
**COST ESTIMATE - LOWER SITE**

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Description</th>
<th>Quantity</th>
<th>Unit</th>
<th>Price</th>
<th>Total</th>
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<tbody>
<tr>
<td>1.</td>
<td>Mobilization</td>
<td>L.S.</td>
<td></td>
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<td>1,100,000</td>
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<td>2.</td>
<td>Dewatering</td>
<td>L.S.</td>
<td></td>
<td></td>
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<tr>
<td>3.</td>
<td>Clear &amp; Grud</td>
<td>135 A.C.</td>
<td>3,000.00</td>
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<td>405,000</td>
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<tr>
<td>4.</td>
<td>Excavate Cutoff Key</td>
<td>70,000 C.Y.</td>
<td>8.00</td>
<td></td>
<td>560,000</td>
</tr>
<tr>
<td>5.</td>
<td>Slush Grout Cutoff Key</td>
<td>50,000 bags</td>
<td>6.00</td>
<td></td>
<td>300,000</td>
</tr>
<tr>
<td>6.</td>
<td>Drill Grout Holes</td>
<td>115,000 L.F.</td>
<td>7.25</td>
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<td>833,750</td>
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<td>7.</td>
<td>Portland Cement Grout</td>
<td>175,000 bags</td>
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<td>8.</td>
<td>Excavate, Transport, Place &amp; Compact Core Material</td>
<td>1,649,000 C.Y.</td>
<td>3.75</td>
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<td>6,183,750</td>
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<tr>
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<td>Excavate, Transport, Place &amp; Compact Random Fill Material</td>
<td>5,231,000 C.Y.</td>
<td>2.75</td>
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<td>14,385,250</td>
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<td>11.</td>
<td>Install riprap (From Off Site Source)</td>
<td>168,700 C.Y.</td>
<td>18.00</td>
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<td>3,036,600</td>
</tr>
<tr>
<td>12.</td>
<td>Excavate for Outlet Conduit</td>
<td>18,500</td>
<td>6.75</td>
<td></td>
<td>124,875</td>
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<td>13.</td>
<td>Outlet Conduit</td>
<td>14,300 C.Y.</td>
<td>275.00</td>
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<td>14.</td>
<td>Inlet Works &amp; Controls</td>
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<td>750,000</td>
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<td>15.</td>
<td>Seed &amp; Mulch</td>
<td>65 A.C.</td>
<td>1,200.00</td>
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<td>78,000</td>
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<td>16.</td>
<td>Power Plant</td>
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<td>3,553,000*</td>
</tr>
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<td>17.</td>
<td>Stilling Basin and Discharge Works</td>
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<td></td>
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<td>610,000</td>
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</table>

* Includes $200,000 for cone valve
### Table 5-2 cont.

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Description</th>
<th>Quantity</th>
<th>Unit</th>
<th>Total</th>
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<tbody>
<tr>
<td>18.</td>
<td>Upstream and Downstream Gaging Stations and Instrumentation</td>
<td>250,000</td>
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<td>19.</td>
<td>Demobilization</td>
<td>150,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20.</td>
<td>Road Construction 9 miles</td>
<td>@215,000 per mi</td>
<td>1,935,000</td>
<td></td>
</tr>
<tr>
<td>21.</td>
<td>Land Acquisition</td>
<td></td>
<td>2,000,000</td>
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</table>

<table>
<thead>
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<th></th>
<th>Estimated Cost</th>
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<tr>
<td>SUBTOTAL</td>
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<td>ENGINEERING</td>
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<td>$4,872,000</td>
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<td>SUBTOTAL</td>
<td>$53,593,225</td>
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<tr>
<td>10% CONTINGENCY</td>
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<td>8,038,900</td>
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<tr>
<td>TOTAL ESTIMATED COST</td>
<td>$61,632,125</td>
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CHAPTER VI

OPERATING PLAN
A. Introduction:

The operations of the completed dam and power facilities include consideration for instream flow, reservoir storage, irrigation demand, municipal demand, transferred storage release requirements, recreational use and flood control.

For the reservoir to provide an adequate water supply to meet all of the downstream demands on a firm basis, the full Wyoming storage allocation must be made in all years that flow is available. Streamflow measuring devices and recording equipment are proposed that will measure streamflow into the reservoir above the reservoir and at a location downstream from the dam to measure instream flow including dam seepage and reservoir spills. The data from the measuring devices will be sent to a control room where the operator can make storage and release adjustments as conditions require.

B. Facilities:

The Smiths Fork facilities include an earth fill dam that develops a
125,000 acre foot reservoir, controlled outlet works, powerhouse, instrumentation for flow control, power generation and an emergency spillway.

The outlet works will be a reinforced concrete chamber designed with multiple inlets to provide a dead storage of 10,000 acre feet and gated outlets to provide variable draw off elevations through the operating range of 25,000 to 125,000 acre feet. The different levels for the outlets will allow the dam operator to adjust levels of discharge to meet downstream water quality requirements.

The outlet structure will connect to a pressure conduit through the dam. The conduit will supply the turbines and provide the release capacity when downstream demand is greater than the flow requirements of turbines or when a reservoir spill must be made. The turbine supply has been designed to reduce the head loss to the turbine. The conduit will have control valves for flow control to the turbines and bypass releases. The controls will be located in the power house with remote operators on the valves.

A powerhouse building will house the turbines, generators, controls, and operator's room. Main transformers will be outdoor type.

C. Initial Filling:
After the completion of the dam construction the gates of the construction bypass will be closed to store streamflow. During the filling operation a low level bypass will be used to maintain flow for downstream requirements. Once the reservoir has reached the 25,000 acre foot minimum pool elevation, reservoir outflow will be switched to the outlet structure gates and the low level bypass closed. The low level bypass is an emergency outlet that would be used in the event that the reservoir would have to be completely emptied for some unforseen reason. The outflow can be adjusted as required to meet the irrigation and downstream demand during the filling operation.

D. Normal Operation:

After the reservoir reaches the minimum 25,000 acre foot pool elevation there will be sufficient head available to begin power generation. The turbines have a minimum operating flow of 50 cfs. When the downstream demand is greater than 50 cfs, flow from the reservoir will be diverted through the turbines to generate power. The turbines are equipped with valves that allow flow control. These valves will be operated to meet the variation in downstream demand. Each turbine has a maximum flow capacity of 250 cfs. Flow for each turbine can be varied from the 50 cfs minimum to the 250 cfs maximum. During periods when the downstream demand is greater than the flow capacity of one turbine and less than that which will operate both turbines the bypass
cone valve will operate to provide the additional flow capacity required. Once
the total outflow is sufficient to operate both turbines the flow will be
divided between them and the bypass closed. The bypass will operate again
during periods when the outflow requirements are greater than the capacity of
both turbines. Flows through the bypass are hydropower spills that do not
contribute to power generations. A minimum 25,000 acre foot pool for fish
and recreational use can be maintained by limiting reservoir releases to
stream inflow at this elevation.

E. Release Requirements

The operation of the reservoir requires that downstream prior water
rights be met and that storage allocations and depletion allowances are not
exceeded. An accounting procedure must be developed which will provide
sufficient data for the reservoir operator to determine the Wyoming storage
carried over each year that will be available for future Wyoming demand
requirements during shortage years, current year storage that will contribute
to Wyoming's storage allocation, and the amount that is the transferred
storage. During years when the total inflow is sufficient to store the total
transferred storage quantity, the release will be the total transferred
quantity with no provision for holdover. During shortage years the prorated
transferred storage quantity will be held and only that quantity will be
released. A shortage year storage and release plan, acceptable to all
parties, must be prepared to describe the transferred storage outflows. For this study the flow which would result from releasing the full transferred storage amount during the five month irrigating season was assumed. This flow rate would be maintained during shortage years until the annual stored quantity was reached then flow would be discontinued. All transferred storage shall be released in the water year stored unless otherwise agreed to by the parties and adopted by the Bear River Commission.
CHAPTER VII

PHOTOGRAMMETRY & MAPPING
CHAPTER VII
PHOTOGRAMMETRY AND MAPPING

A. Introduction

The photogrammetry and mapping for the project provided the data to determine the reservoir stage-area-volume curve and the earth work quantities for the proposed dams.

B. Reservoir Maps

The one inch to 200-foot maps required for the project were obtained by enlarging the U.S.G.S. Contour Maps which were combined to make a map that included all of the Smiths Fork drainage basin. The area that will be covered by the reservoir was identified and a control grid drawn on the map. This was photographed and enlarged to the required one inch to 200-foot scale. The resulting mapping was photographed on mylar sheets so that blue line prints could be run. Additional contours were drawn on the larger maps by interpolation from the original contours. These contours were planimetered to determine the stage-area-volume curves for each site.
C. Field Work and Photogrammetry

The County and Bureau of Land Management records were obtained to identify the nearest land corners in the vicinity of the dam sites. Several land corners were found and included as part of the control set for the aerial photography. A preliminary center line for the dam was selected and staked in the field. These points and those required for photography control were marked with aerial targets. The points were tied together by a field survey that measured the horizontal and vertical location of each point. The final mapping was drawn on mylar from the photography. The scale of the maps of the dam sites and spillway are one inch to 100 feet and have five foot contours drawn on them. Ground control data are shown on Drawings 10 and 11 of 24.

The proposed centerline of the dams were temporarily staked in the field to provide control for the seismic survey and to locate the drill holes.
CHAPTER VIII

AGRICULTURAL BENEFITS
CHAPTER VIII
AGRICULTURAL BENEFITS OF DAM CONSTRUCTION

A. INTRODUCTION

A very important factor in the development of the potential impact of dam construction is the assessment of possible economic benefit to agricultural producers located in the affected drainage area.

The scope of work for the dam feasibility study requests the analysis of the benefits attributable to an increased supply of water to existing irrigated lands. The Wyoming Water Development Commission suggested that a Consultant assess the economic impact to agricultural producers by use of the AGNET crop analysis computer program developed by the University of Nebraska.

B. METHODOLOGY

In response to the suggestion of the Water Development Commission, the Consultant gained access to the AGNET program. The program provides a questionnaire which when properly completed provides the detailed cost information from the agricultural producers and allows the information to be analyzed to determine current profitability of the farm operations. With the
assistance of Mr. Demont Grandy, Soil Conservation Service, Cokeville, several farm operators were identified as representative of the local agricultural enterprise and were personally contacted by the Consultant. A questionnaire was presented to each operator to complete. As the operators perused the questionnaire; they were generally unanimous in their reaction that they do not maintain records in sufficient detail to thoroughly complete the questionnaire.

Several operators made their best effort, however, and their questionnaires were returned to the Consultant. Some of these questionnaires, which are included in the Appendix, were processed by the use of the AGNET program. After a substantial number of hours of time at the computer, it became apparent that because of the lack of detailed information and the variations in farm operation that could not be adopted to the computer program, the results would be unreliable and misleading.

It was the Consultant's judgement, therefore, that a more useful assessment of potential economic impact of dam construction could be made by producing an educated but more subjective area-wide analysis. For this purpose, discussions with farmers were summarized and reports and studies prepared by the Soil Conservation Service have been reviewed.

C. Economic Overview
The economy of the Cokeville area is dominated by its agricultural base. The farms and ranches in the vicinity of the dam site are almost entirely individually owned and operated. A recent survey of southern Lincoln County performed by the Soil Conservation Service ascertained that the largest proportion of the agricultural operations in the area, 41 percent, is devoted to beef production. Approximately 24 percent is in a combination of cattle and sheep production with 9 percent in sheep production exclusively. Four percent of agricultural use is irrigated crop lands for growing barley and oats and 2 percent is in dairy production.

Cattle production provides the economic base of the Cokeville area as it represents a substantial export product. It is important to note that the beef producers are almost entirely dependent upon the local production of hay and grains for winter feed. The climate in the Cokeville area is such that snow covers the ground for 6 to 7 months during the year placing considerable importance upon the ready availability of winter feed at a reasonable cost.

Although hay and grain producers are a relatively small proportion of the total agricultural operations in the area, it is obvious that as a residential industry, feed production provides major support to the cattle producers.

The most common practice among cattle producers is the cow-calf production in which calves are raised to about 300-400 pounds and sold. Many
producers, however, keep their calves over the winter months and finish their growth period in local feed lots. Sheep producers move their stock to the Rock Springs area for the winter where the climate is less severe.

Of the crops raised in the Cokeville area, the highest production is alfalfa hay/grass mix. Relatively little pure alfalfa is produced. The hay/grass is preferred by cattle producers. Some grains, primarily barley and oats, are raised for winter feed, mostly by cattle producers themselves. Most of the hay production, therefore, is by cattle producers for their own use or is raised by farmers for sale to the local cattle producers.

Because of the importance of hay/grass production to the base economy of the area, it is obvious that an adequate supply of water to farms be assured. The supply of water from the Smiths Fork and Bear River drainage areas has generally been steady. A review of past records reveals that there have been periods (most recently 1977-78) during which a drought condition existed and the natural water supply was low. Ground water sources at that time were relied upon more heavily.

The drought condition of stream flow not equalling the stream demand occurs once in twenty years. During the period covered by the data it was found that the stream had adequate water to meet the stream demands on an annual basis. The monthly flows do not peak at the same cycle as the irrigation demand. In the forty-one year period additional water would have been
used as follows.

May - 1 year
June - 4 years
July - 15 years
Aug. - 27 years
Sept. - 30 years

The construction of a dam will develop a reservoir that stores the early high runoff for release during the periods of high irrigation demand.

There are farmers in the area who have drilled wells. The wells are deep however, and pumping the water would be prohibitively costly if it became necessary to rely entirely upon well water.

Many hay and grain producers in the area have installed side roll sprinkler systems. These systems are expensive to acquire and low cost of operation is important. Information received from producers reveals that fuel and lubrication costs to operate the sprinkler systems range from $9.00 to $27.00 per acre per year. Repair and maintenance costs are additional. Sprinklers normally make five trips across the planted area in a growth season. A major cost to this operation is the electric power to operate the system.
Other producers are relying upon traditional flood irrigation. The past two to three years have been "wet" climatically and water supplies have been adequate. The most noticeable problem during the current wet seasons has been occasional flooding by excessive water flow in the Smiths Fork and other streams. Farmers have indicated that several acres are currently out of production because of high water. Others have incurred extra expenses to clear flood debris.

Hay producers can depend upon two crops in a normal growing season. Production ranges between two-and-a-half to three-and-a-half tons per acre. Most producers find a market in the local area but naturally, costs of production are high and an adequate market price is essential. Market value is normally about $45.00 to $50.00 per ton. Some producers have held on to their crop into the winter months to assure a higher price, or have sold outside the area. In those instances, market value can rise to a range of $50.00 to $100.00 per ton. Producers normally add an additional $20.00 per ton if the hay is trucked to the buyer.

Hay producers generally are attempting to achieve an optimum net return of $30.00 per acre. Typically, the net return is closer to $16.00 to $20.00 per acre.

D. Dam Impact
Although the need for a dam on the Smith Forks is not unanimously favored by farmers in the area it is supported by a majority. The presence of a dam for water storage will provide for controlled flow to meet the peak irrigation demands and assure that there is adequate water to support the end of the season plant growth.

The County Agricultural Agent indicates that having sufficient water at the end of the season hay yield per acre could be substantially improved to above the three-and-a half ton per acre normal yield. An increased water supply would allow for faster operation of the sprinkler systems. Greater use of the sprinklers, however, would also increase electric power use. The current cost of electric power is perhaps one of the most critical concerns of hay producers.

Farmers in the area have recently organized opposition to rate increases proposed by the Utah Power and Light Company. It has been estimated that the power cost to operate a sprinkling system is approximately $18.75 per acre per year. The rate increases presently proposed could result in costs of up to $28.00. Producers feel that power costs are already excessively high and they could not absorb a rate increase. Farmers point out that Utah Power and Light Company assured them several years ago that power rates would not increase above the then current level. It was on the strength of that commitment that many farmers in the area invested in costly sprinkler systems.
Flooding has not traditionally been a serious problem to local agriculture. The possibility of the control of excessive water by a dam is considered as a positive contribution, but is not a large factor in a cost/benefit equation.

It has been generally observed that the economy of the Cokeville area is slowing. Several businesses in the city have closed recently. Reports from the Employment Security Commission of Wyoming point out that as of mid-1984, Lincoln county was suffering from the highest unemployment rate (11.9 percent) in the State. The average rate for the entire State is 6.5 percent.

In summary, it can be stated that dam construction could produce generally a positive impact on agricultural operations in the area and to the economy in general. The potential availability of supplemental irrigation water is favorably received by at least 50 percent of the representative agricultural users contacted. The survey also revealed that some users were not interested in participating in purchasing water from the project. Most significantly, the survey failed to identify any potential users willing to place a value on available supplemental water.

A supplemental irrigation supply will increase yield on all of the crop. The type of agriculture in an area is dependent on climate and available moisture. The Cokeville Climate provides a short forty to fifty day
frost free growing season that limits the types of crops that can be economically produced. The uncontrolled flow of Smiths Fork provides an abundance of water in the early part of the growing season when the temperature is low and soil moisture is high. A reservoir will provide for a controlled release of the available water so that irrigation can be scheduled to match the moisture requirements of the crop. The availability of supplemental irrigation water with good farming practices will allow additional types of crops to be produced and increase yields of existing ones. The County Agricultural Agent indicates that the late summer supplemental irrigation will increase hay yield.

As a follow-up to the preliminary draft of the agricultural benefit analysis, the Wyoming Water Development Commission has asked that an additional inquiry be made of landowners in the Smiths Fork Drainage Area. The Commission requested that a representative selection of landowners and producers in the area be contacted and asked if they would be willing to pay a fee for water (as would be required if the dam were constructed) and if so, approximately how much would they be willing to pay.

The questions were presented to landowners in the area by telephone and generally the area ranchers were unwilling to pay for supplemental irrigation water.
CHAPTER IX

DOWNSTREAM WATER QUALITY EFFECTS

The construction of an impoundment within the area, volume and depth proposed for Smiths Fork will affect water quality parameters such as temperature, dissolved oxygen, sediments, dissolved minerals and nutrients in the downstream waters of Smiths Fork, Bear River and Bear Lake. These effects generally tend to improve downstream quality by removing sediment and nutrients which accelerate eutrophication. Those which could have negative effects such as the release of water devoid of dissolved oxygen, or water with temperatures incompatible with the seasonal aquatic activity in the stream, can be mitigated to a great extent by providing the operator of the facility sufficient flexibility in selecting the depth within the impoundment from which discharges are drawn. This will enable the reservoir operator to discharge water of a quality which minimizes downstream impact during the various seasonal changes of flow and other stream requirements.

The conceptual design for the dam intake structures provides for a minimum of three elevations from which reservoir discharges can be made. Computer analysis of the projected seasonal thermal stratification may reveal additional ports need evaluation or placement of the openings should be at elevations other than those initially selected.
In addition to the multiple withdrawal levels, the design of the hydro-
power turbine tail races and energy dissipators at the dam discharge will
provide for mixing and re-aeration of waters which may be low in dissolved
oxygen below the hypolimnion or lower layer during certain times of the
year.

The Bear Lake Regional Commission is currently conducting a detailed
environmental survey to evaluate the effect of the reservoir on Smiths Fork,
Bear River and Bear Lake quality in terms of:

a) nitrogen
b) phosphorus
c) sediments
d) temperature
e) trophic state of the lake

This study will also address cost/benefit factors relative to eutrophica-
tion problems which exist in Bear Lake, the effect of projected flow altera-
tions, and to summarize the potential impact to the Bonneville cutthroat trout
species.

During the course of developing this Level II report, the Consultant
has met with members of Bear Lake Regional Commission team involved with the
impact evaluation to brief them on the scope and general concept of the study
and to appraise them of the general flow release rate parameters with which we
were working, the proposed dam configuration, depths, areas, volumes and proposed intake elevations. Subsequent correspondence has provided copies of the reservoir simulation computer runs and flow/duration curves as used in this study. This information will enable Bear Lake Regional Commission to model thermal stratification and predict discharge quality parameters on the same criteria as used throughout this study.

The Preliminary Draft of the "Environmental Evaluation Smiths Fork Reservoir project prepared for the Utah Division of Water Resources prepared by the Bear Lake Regional Commission" predicts the impact of the reservoir on the Bear River and Bear Lake. The study estimates a phosphorus removal benefit to the Bear Lake of $7,366,000 from the Smiths Fork Dam. An alternate evaluation of the phosporus removal estimates a $900,820 per year value.

The controlled reservoir outflow will have an impact on the wetlands created by spring flooding along the Bear River. The controlled release of the stored waters will reduce the spring flood but will increase the late summer flow which may reduce the overall wetland along the river. The Level II Smiths Fork Study does not address the river water surface profiles or the impact on the wet lands.

The Bear Lake Regional Commission report provides additional information concerning the impact of the reservoir on the Bear Lake below Smiths Fork.
NOTE:
STATIONING IS BASED ON SPILLWAY
STATIONING SEE SHEET 10
SMITHS FORK DAM
INFLOW MASS DIAGRAM