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THE STATE

OF WYOMING

WATER DEVELOPMENT
COMMISSION

KEMMERER CITY RESERVOIR REHABILITATION PROJECT

LEVEL II FEASIBILITY STUDY

NOVEMBER 1986

"EXECUTIVE SUMMARY"



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GREENHORNE & O'MARA, INC
Consulting Engineers
Denver, Colorado

EXECUTIVE SUMMARY

AUTHORIZATION

This study was authorized and contracted by the Wyoming Water Development Commission (WWDC) in an agreement with Greenhorne & O'Mara, Inc., consulting engineers of Denver, Colorado. This study was completed under the terms of the State of Wyoming Contract No. RU060286/F, dated June 25, 1986.

PURPOSE AND SCOPE

The U.S. Army Corps of Engineers (COE) completed a Phase I Inspection Report for the Kemmerer City Dam and Reservoir as part of their National Dam Safety Program. This inspection was completed in July 1978 and concluded that the Kemmerer Dam shall be classified as an intermediate size dam having a high potential for damage or loss of life in the event of a failure. Based on this classification, the existing Kemmerer Dam was determined to be hydrologically inadequate in that the existing emergency spillway is limited to passing an event equal to less than 20 percent of the Probable Maximum Flood (PMF) without overtopping the embankment.

The Wyoming State Engineers office has determined that the existing Kemmerer City Reservoir does not meet established state criteria under its classification of "high hazard" dams.

Therefore, the purpose of this study is to evaluate the feasibility of rehabilitating the Kemmerer Dam embankment and emergency spillway in order to increase the safety of the dam for handling larger flood events. This study addresses the existing operation, hydrologic, and geologic conditions of the Kemmerer City Dam and Reservoir and evaluates several rehabilitation alternative scenarios. In addition, the feasibility of hydropower and additional water storage is evaluated in this report.

The following is a summary of the proposed scope of work for this study:

Hydrologic Investigation - A detailed hydrologic evaluation was completed to determine an appropriate Inflow Design Flood (IDF) at the Kemmerer Dam to be used for preliminary design of improvement alternatives for rehabilitation. Items which were evaluated included:

- a) Determine outflows from the existing Viva Naughton Reservoir (located two miles upstream of Kemmerer Dam) for various flood events.
- b) Flood events evaluated include the PMF, 50 percent of the PMF and the 100-year storm event at Viva Naughton Reservoir and determine the storm event which will operate the existing emergency spillway at full capacity.
- c) Determine runoff from the intervening drainage basin between Viva Naughton Reservoir and Kemmerer Dam and combine with the outflows from the Viva Naughton Spillway to develop an inflow hydrograph at the Kemmerer Dam.

Hydropower Evaluation - A feasibility evaluation was completed for hydropower potential at the Kemmerer Dam. Study items included the following:

- a) Develop flow duration curves.

- b) Develop preliminary design and cost estimates.
- c) Examine and evaluate the economics of a proposed hydropower plant.

Surveying - An actual field survey was completed at the Kemmerer Dam to determine the following items:

- a) Cross-sections along existing dam embankment.
- b) Profile the existing dam crest.
- c) Determine the extent of sedimentation in the reservoir and measure the existing available water storage up to the spillway crest level.
- d) Locate all geologic test holes and test pits.

Geotechnical Investigation - A geotechnical study was completed to evaluate the existing dam and site conditions. The items which were completed include:

- a) Preparation of geologic map of project site.
- b) Complete a subsurface investigation to evaluate soil conditions.
- c) Evaluate test pits for determining possible borrow sites.
- d) Evaluate existing dam stability.
- e) Evaluate and map the areas where "slippage" is occurring.
- f) Prepare final geotechnical report as an appendix to this study.

Preliminary Design - Preliminary designs were completed for proposed modifications to the Kemmerer Dam and Reservoir including a review of the existing facility, preliminary spillway and outlet works extension design, stability evaluation, and preliminary embankment design. Six different alternatives were analyzed to determine the most economical and advantageous improvements. Cost estimates for each alternative were prepared.

ACKNOWLEDGEMENTS

This report was prepared by Greenhorne & O'Mara, Inc., Consulting Engineers of Denver, Colorado. Ground survey and topographic mapping of the reservoir storage capacity was completed by Crank Companies, Inc., of Kemmerer, Wyoming. Geotechnical investigations were completed by ESA Geotechnical Consultants of Fort Collins, Colorado. Individuals involved with the project who supplied useful assistance included Ms. Rebecca Mathisen, P.E. of the WWDC and Mr. Kent Smith and Mr. David Johnson from the Town of Kemmerer, and Mr. Carly Burton from Utah Power and Light.

RELATED STUDIES

Several previous studies and reports have been completed for the Hams Fork Basin and for the Kemmerer and Viva Naughton Reservoirs. Information, data and results

from three of these studies were used in the evaluation and preparation of this study.

A Phase I Inspection Report for the Viva Naughton Dam was completed by the U.S. Army Corps of Engineers (COE) in July of 1978. This report included a hydrologic analysis for the Hams Fork drainage basin above the dam. Stage versus storage and stage versus discharge curves for Viva Naughton Reservoir were presented in this report. The results of this study showed that approximately 70 percent of the PMF could pass through the existing spillway without overtopping the dam. The peak discharge and total runoff volume for the inflow PMF to Viva Naughton Dam determined in the COE Report were 63,600 cfs and 44,700 acre feet respectively for a 24-hour storm duration. Maximum spillway discharge capacity was estimated to be 14,800 cfs with the reservoir at the dam crest elevation. Based on these data, the hydrologic capability of Viva Naughton Dam and Reservoir was not considered to be seriously inadequate, although it is less than desirable for a high hazard structure.

At the same time, the COE completed a Phase I Inspection Report for the Kemmerer City Dam and Reservoir. This report utilized the results of the Phase I Report for Viva Naughton Dam and also analyzed the 36 square mile basin between Viva Naughton Reservoir and Kemmerer Reservoir. According to this report, the Kemmerer Dam is capable of passing an event less than 20 percent of the PMF without overtopping the crest. In addition, an event equal to 50 percent of the PMF would overtop the Kemmerer Dam crest by about 2.9 feet. Based on this report, the Kemmerer Dam was deemed to be hydrologically inadequate and susceptible to failure by overtopping from extreme flood events.

In November 1984, Greenhorne & O'Mara, Inc., completed a Hams Fork Basin Level II Investigation for the Wyoming Water Development Commission. As a part of this study, an analysis of Viva Naughton Dam was completed to determine alternative embankment and spillway sizes in view of the economical expansion of the facility in terms of water storage for hydropower. This study determined that based on current power and irrigation demands, expansion of the Viva Naughton Reservoir is not warranted.

HYDROLOGIC MODELING

Since a major portion of the basin drains to Viva Naughton Reservoir, an analysis was required to evaluate several hydrologic scenarios of Viva Naughton Dam to determine the routed outflows from the dam. A list of the flood events evaluated at Viva Naughton Dam is shown below:

- 1) The Probable Maximum Flood (PMF) utilizing the existing emergency spillway.
- 2) 50 percent of the PMF utilizing the existing emergency spillway.
- 3) The storm event which will operate the emergency spillway at full capacity.
- 4) The PMF utilizing an enlarged spillway configuration sized to safely pass this event.
- 5) The 100-year storm event utilizing the existing spillway.

Once these outflows were determined, the resulting hydrographs were combined with the hydrographs generated from the intervening area below Viva Naughton Dam. This developed the inflow hydrographs at Kemmerer Dam for the above scenarios.

Hydrologic reservoir routing was utilized to evaluate the operation and storage capacity of each structure. Reservoir flood routing was completed by the Modified Puls Method as utilized in the HEC-1 flood hydrograph package. Several assumptions were made in modeling the flood operation of each reservoir. These assumptions are listed below:

Viva Naughton Reservoir Modeling Assumptions

- 1) Assumed reservoir full to the "normal operating level" before flood routing.
- 2) Assumed low level outlets and spillway gates to be open for the PMF events.
- 3) Assumed storage capacity based on design data provided by Utah Power and Light (owners of the dam).
- 4) Assumed spillway and outlet works hydraulic capacity were based on design data supplied by Utah Power and Light.

Kemmerer Reservoir Modeling Assumptions

- 1) Assumed reservoir full to emergency spillway crest before flood routing.
- 2) Assumed all outlet gates closed.
- 3) Assumed storage capacity as determined by actual field measurements (to spillway crest).
- 4) Assumed storage capacity above spillway crest based on data presented in the COE study.

Based on these assumptions, the results of the hydrologic analysis for the PMF storm events are summarized below:

<u>Event</u>	<u>Inflow to Viva Naughton Dam</u>	<u>Outflow from Viva Naughton Dam</u>	<u>Inflow to Kemmerer Dam</u>
PMF w/existing spillway	61,105 cfs	53,090 cfs*	59,839 cfs
50% PMF w/existing spillway	30,553 cfs	16,174 cfs	18,524 cfs
Maximize existing spillway capacity	30,553 cfs	16,174 cfs	18,524 cfs
PMF w/enlarged spillway	61,105 cfs	31,252 cfs	34,234 cfs

* - dam overtops

- Notes:
- 1) References to spillway configurations refer to Viva Naughton Dam.
 - 2) Since the Viva Naughton Reservoir outlets and spillway gates are assumed open this represents the worst case scenario for impacting Kemmerer Reservoir but would not necessarily be the recommended assumptions for others in evaluating the adequacy of the Viva Naughton Reservoir emergency spillway.

As shown above, the 50 percent PMF approximates the storm event required to operate the emergency spillway at full capacity at the Viva Naughton Dam. This shows that the existing dam and spillway will overtop for a storm event greater than 50 percent of the PFM. This is consistent with the results presented in the Ham's Fork Study.

Based on recommendations from the COE Study and evaluation for improvements to the Viva Naughton Dam and Spillway, it was determined that the storm event which maximizes the existing emergency spillway at Viva Naughton Dam shall be used for the Inflow Design Flood at Kemmerer Dam. Therefore, the peak inflow design discharge to Kemmerer Dam is 18,524 cfs with a storm volume of 67,661 acre-feet for a 72-hour storm duration.

In addition to determining the PMF events, the 100-year storm event was also evaluated.

<u>Location</u>	<u>100-Year Flood Peaks</u>	<u>Peak Discharge</u>
Inflow to Viva Naughton Dam		10,649 cfs
Outflow from Viva Naughton Dam		734 cfs
Inflow to Kemmerer Dam		2,971 cfs
Outflow from Kemmerer Dam		1,950 cfs

Note: All routed flows for Viva Naughton Dam and Kemmerer Dam are with existing spillway configurations.

ALTERNATIVES DESCRIPTION

GENERAL

For this study, six improvement alternatives for rehabilitation of the Kemmerer Dam were evaluated. As discussed previously, improvements to the dam and spillway are required because the COE deemed the dam to be hydrologically inadequate. Based on the dam safety evaluation and report, the following were recommended.

- a. Enlarge or lower the emergency spillway or raise the dam embankment.
- b. Tree growth and thick vegetation should be removed from the embankment and downstream toe.
- c. The stability of the downstream slope should be evaluated.

The improvement alternatives for rehabilitating the dam were based on the Inflow Design Flood of 18,524 cfs. This is the storm event which will operate the Viva Naughton spillway to full capacity. This storm is approximately equal to 50 percent of PMF. The alternatives evaluated are as follows:

Alternative #1 - Raise the dam embankment by 7 feet and extend the existing concrete spillway to meet the dam crest.

- Alternative #2 -** Construct an additional spillway adjacent to the west dam abutment.
- Alternative #3 -** Raise the dam embankment 5 feet and extend the concrete spillway to meet the dam crest. Armor the crest and downstream slope of the dam for protection against overtopping.
- Alternative #4 -** Enlarge the existing concrete emergency spillway by 265 feet.
- Alternative #5 -** Lower the concrete emergency spillway crest by 4.3 feet and enlarge by 58 feet.
- Alternative #6 -** Breach the existing dam.

ESTIMATED CONSTRUCTION COSTS

The estimated costs of these improvement alternatives are based on typical contractor construction prices, including overhead and profit. These prices are an aggregate unit price which includes the cost for complete installation of these materials.

Unit prices were obtained from cost data and construction bids completed for similar projects. A summary of unit costs used for estimating project costs are shown below:

Unit Costs	Unit Price
Common Excavation	\$3.00/cubic yard
Fill for Dam Embankment	\$4.00/cubic yard
Stripping Existing Dam Embankment	\$3.50/cubic yard
Seeding	\$2,000.00/acre
Rock Riprap	\$55.00/cubic yard
Structural Concrete for Spillway	\$450.00/cubic yard
Non-structural Concrete	\$250.00/cubic yard
Roller Compacted Concrete for Dam Embankment	\$28.00/cubic yard
24-inch Steel Sleeving for Outlet Pipes	\$100.00/LF

Estimated construction costs were calculated using the above unit prices and the material quantities calculated for each improvement alternative. Unit costs were estimated using common materials and construction techniques envisioned to construct the facilities described for each alternative. The use of alternate materials and construction methods could result in a savings over what is presented here.

A summary of the costs estimated for each alternative is presented below:

Cost Summary

	<u>Alt. #1</u>	<u>Alt. #2</u>	<u>Alt. #3A</u>	<u>Alt. #3B</u>	<u>Alt. #4</u>	<u>Alt. #5</u>	<u>Alt. #6</u>
			(Riprap)	(Roller Compacted Concrete)			
Construction Cost	491,430	1,248,570	1,122,850	1,156,354	672,702	495,274	484,005
Contingency (15%)	73,715	187,286	168,428	173,453	100,905	74,291	72,601
Total Estimated Cost	565,145	1,435,856	1,291,278	1,329,807	773,607	569,565	556,606
Engineering (10%)	56,515	143,586	129,128	132,981	77,361	56,957	55,661
Total Project Cost*	621,660	1,579,442	1,420,406	1,462,788	805,968	626,522	612,267

*Costs for Alternatives #1 through #5 do not include revenue lost from fishing if the reservoir has to be drained for refurbishing the outlet gates. Costs for Alternative #6 do not include revenue lost from fishing by eliminating the reservoir.

The cost information presented for each alternative is based on conceptual and preliminary design of improvements. These costs are provided for comparison purposes only and should not be used for final design or construction purposes.

HYDROPOWER FEASIBILITY

Feasibility of installing a hydropower facility at the Kemmerer Dam site is based on the ability to provide power with a money value greater than the cost to construct and maintain the facility. The amount of power which can be produced is dependent on a number of variables including the volume of water, the available hydraulic head, and the efficiency of the equipment.

Inflow to a hydropower facility is usually variable and it is not possible to take advantage of all of the water available unless the reservoir can be operated as a storage reservoir. Due to the manner of operation of Kemmerer Reservoir, i.e., typically a full reservoir with overtopping of the spillway, a plant at this site would be considered to be a run-of-the-river plant. Power can be generated only from the natural flow in the stream that is within the operating range of the plant. During extremely low flow periods the plant is shut down. During high flows the power generated is limited by the maximum capacity of the plant.

Typically for a run-of-the-river plant, the optimum design flow is a flow rate which is exceeded in the range of 15 to 25 percent of the time. Such flow rates will normally harness the most energy (i.e., have the best plant capacity factor). At Kemmerer Reservoir another factor limiting the design flow is the capacity of the anticipated power plant penstock. It is not deemed economical to install a new penstock through the lower reaches of the existing dam embankment. Such an installation would involve excavating a trench with fairly flat side slopes through the core of the dam, which would require essentially rebuilding a major portion of the dam. As a consequence of the high construction costs, it is anticipated that the most advantageous arrangement would entail use of the two existing outlet pipes to house the penstock. The hydropower study therefore assumes using the largest diameter lining pipes practical through the existing 36-inch outlet pipes. It is estimated that the maximum available gross head is 30 feet.

Using established cost data for construction of plants of a 200 kW size, the estimated total project cost (exclusive of structural improvements to the dam and improvements to the spillway) would be on the order of \$600,000 in 1986 dollars. The annual debt service on a \$600,000 capital cost amortized over a 40 year period with interest at 7-1/2 percent is \$47,640. Annual operation and maintenance costs are estimated to be about \$20,000 per year. These two costs combined yield a total estimated annual cost of \$67,640.

Conversations with the Utah Power and Light Company, which owns the small hydroplant at Viva Naughton Dam, indicates that the energy potentially produced at the proposed Kemmerer Dam Plant may have a present value of about 55 mils per kWh. Accordingly, the annual revenue generated at the plant is 984,000 kWh/year X 0.055 = \$54,120. Recent information from the Wyoming Public Utilities Commission indicates that the value of the energy may be as low as 22 to 26 mils per kWh. If energy were valued on these lower figures, the annual revenue from the Kemmerer Dam plant would be about \$23,600.

At the first year, the project is therefore estimated to yield annual revenues somewhere between \$13,500 and \$44,000 less than the annual cost. In our opinion the project is not economically feasible at present interest rates and energy value.

SUMMARY AND RECOMMENDATIONS

- o A hydrologic evaluation of Kemmerer Dam was completed in 1978 by the COE for their National Dam Safety Program. Results from their study indicated that the Kemmerer Dam could not pass a flood event of 20% of the Probable Maximum Flood (PMF) without overtopping. The dam was therefore determined to be hydrologically inadequate since any significant overtopping would probably cause a failure. Improvements to the emergency spillway and/or dam embankment were recommended.
- o The purpose of this study was to evaluate several different hydrologic scenarios in order to determine a reasonable Inflow Design Flood (IDF) hydrograph at Kemmerer Dam. This hydrograph was used to evaluate improvement alternatives for rehabilitating the dam and emergency spillway to improve its hydrologic adequacy according to state and federal guidelines.
- o A geotechnical evaluation of the existing Kemmerer Dam was completed to evaluate the site specific geology of the reservoir area and to determine different rock formations, characteristics, faults, and folds. Areas where slippage is present were evaluated and documented. Subsurface testing was completed along the dam crest to determine the composition of the embankment. Using this information an analysis was completed which determined the stability of the existing embankment with respect to factors of safety and various seismic considerations. The existing dam embankment was considered to have an acceptable static conditions factor of safety. Under earthquake conditions, the stability of the existing dam is not acceptable. Field and laboratory investigations were completed for evaluating sites for borrow material. It was determined that on-site material is available and adequate for use in embankment modifications.

- o A field survey was completed to accurately define critical locations and elevations for the dam and reservoir area. Field measurements were taken to profile and cross-section the dam embankment. All test holes and borrow pits were located. Survey data collected also included a determination of the sedimentation of the reservoir and the present-day storage capacity. The reservoir was found to have approximately 1650 acre-feet of storage at the existing emergency spillway crest. This is approximately 650 acre-feet more than was originally calculated for the reservoir design.
- o The Inflow Design Flood (IDF) to Kemmerer Dam was determined as the largest storm event which could safely pass through the combined existing emergency spillway and outlets for Viva Naughton Reservoir (located two miles upstream). This storm event approximately equals 50 percent of the Probable Maximum Flood. The peak discharge for the Inflow Design Flood entering Kemmerer Dam is 18,524 cfs with a storm volume of 67,661 acre-feet for a 72-hour storm duration.
- o Six different improvement alternatives for rehabilitation of the dam were considered. These alternatives included raising the dam embankment, increasing the size of the emergency spillway, lowering the emergency spillway, armoring the embankment, and breaching the dam. Figures 6 through 10 present sketches of these alternatives along with a summary of the required modifications. Costs for each alternative were evaluated and presented in the section "Estimated Construction Costs".
- o The feasibility of hydropower was evaluated for the Kemmerer Dam. Average annual flow and duration curves were determined based on daily flow records. The maximum design flow for the hydropower plant was assumed to be 100 cfs based on use of the existing outlet works as the plant penstock. The maximum available gross head was assumed to be 30 feet. The power plant selected would be capable of producing 200 kW design capacity, which would generate 984,000 kWh per year. Estimated costs for constructing, operating, and maintaining this power plant versus the revenue generated indicates the project is not economically feasible.
- o Based on the cost information provided for the six alternatives, economics would indicate that alternatives #1, #5, and #6 are the most feasible.

Alternative #1 provides additional flood storage by increasing the height of the dam embankment and extending the emergency spillway. This is desirable due to the fact that the existing dam embankment would be extended to provide a more stable cross-section which would meet general dam construction criteria. No additional right-of-way is required to complete the improvements. In addition, the existing storage capacity of the reservoir would not be affected, therefore, wildlife and fish habitat would be preserved. Construction for this alternative would cause little disruption to the area. Loss of revenue from fishing would occur if the reservoir had to be drained for completing rehabilitation to the outlet gates.

The Wyoming Game and Fish Department presently utilizes the reservoir for maintaining a stock of wild rainbow trout brood fish. If the reservoir were to be drained, the Game and Fish Department would require a two-year lead

time to relocate the stock, since it is a valuable resource. However, the Game and Fish Department would pay for restocking the reservoir once it has been refilled.

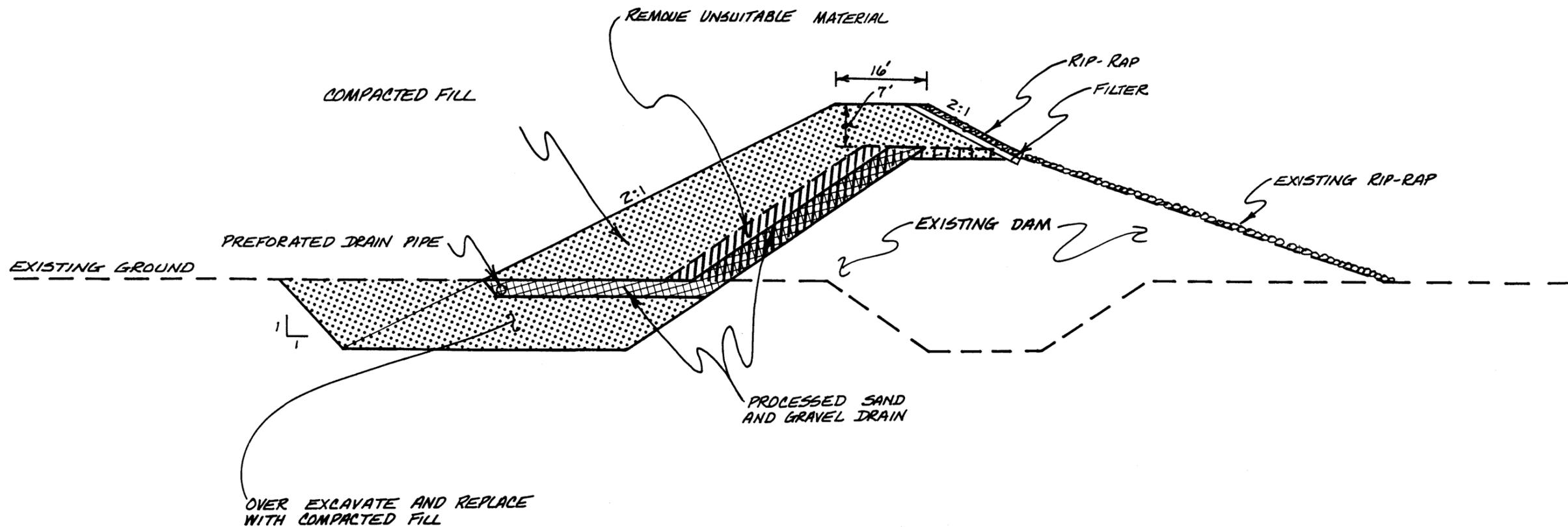
Alternative #5 includes lowering and widening the existing emergency spillway. The spillway crest would be lowered to an elevation which meets the existing water rights allocation for the reservoir. This alternative does not appear to be as desirable as Alternative #1 in that current water storage would be lost by lowering the spillway crest (even though current water allocation would be met). Lowering the reservoir pool by over four feet may impact the fish and wildlife habitat in the upstream reaches. The Wyoming Game and Fish Department estimates that approximately \$34,000 would be lost annually from fishing revenue if the pool is lowered. Additionally, since no improvements are planned for the dam embankment, factors of safety remain lower for earthquake loadings than would be if the embankment section were improved.

Alternative #6 considers breaching the dam instead of rehabilitating the existing structure. The major advantage of breaching is that the city entirely removes itself from the liability associated with a possible dam failure. However, there are many "subjective" factors which should be considered for this alternative. These include the loss of potential water storage for future city use, loss of recreation facilities, adverse affect on fish and wildlife habitat, and the increase in potential maintenance problems for rehabilitating the Ham's Fork Creek through the reservoir area. The Wyoming Game and Fish Department estimates that approximately \$114,000 would be lost annually from fishing revenue if the reservoir were eliminated.

It is worthy to note that Alternative #3 presents improvements which could also protect against failure due to floods greater than the IDF. These alternatives provide armorment of the dam embankment for protection from overtopping. Therefore, if Viva Naughton Dam and spillway were expanded in the future, this alternative could provide the additional protection from larger outflows.

Alternatives #1 through #5 address the landslide area along the east abutment of the existing dam near State Highway 233. Costs for repairing this area have been included for Alternatives #1 through #5. Costs for Alternative #6 do not include repair for the slide area since the dam would be breached. However, this slide area still remains a hazard to the highway stability and should be repaired as part of highway maintenance.

Although there are many factors involved in selecting the "best solution" for the City of Kemmerer, we recommend Alternative #1 based on the discussions presented in this report. Alternative #1 provides a safe and economic solution to increasing the hydrologic capacity of the Kemmerer Dam. In addition, if improvements were completed at Viva Naughton Dam in the future, armorment of the Kemmerer dam embankment should be considered.



RECOMMENDED SECTION FOR
 RAISING DAM EMBANKMENT
 NOT TO SCALE | FIGURE 12