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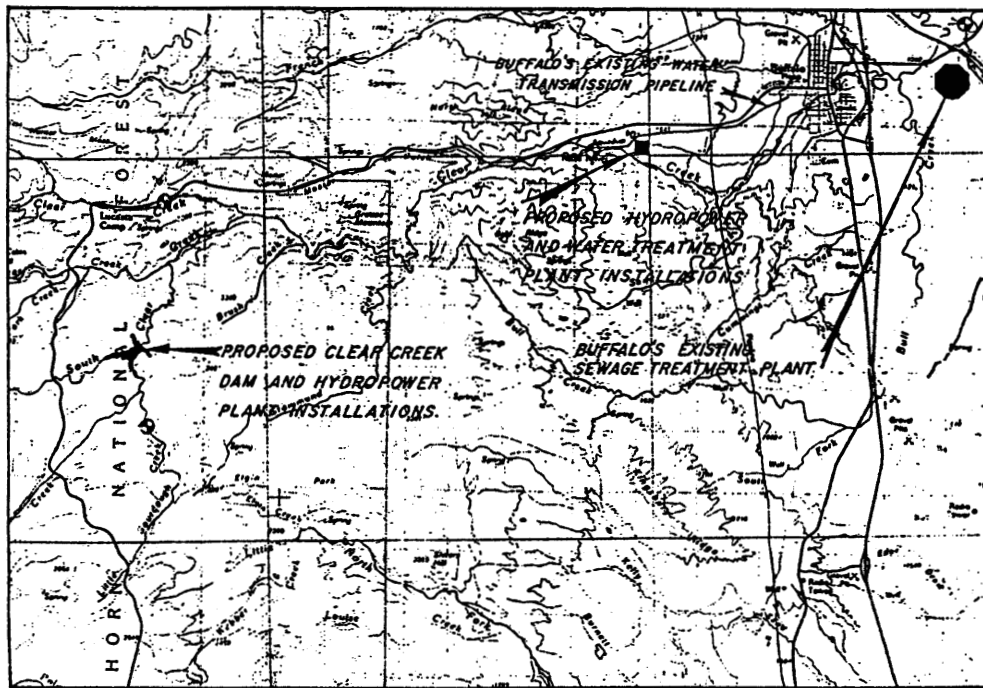
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Interim Report

Buffalo Municipal Reservoir Project



to
Wyoming Water Development Commission

by
States West Water Resources Corporation

October 1, 1988

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Introduction

This report summarizes the status and results of the Phase I activities undertaken on the Buffalo Municipal Reservoir Project. Currently, no changes in either the scope or budget for the proposed Phase II activities are anticipated.

Recommendation of Preferred Site

Evaluation of Alternative Dam Sites

Preliminary evaluations were conducted on two alternative dam sites near the Tie Hack Campground, located approximately fifteen miles west of Buffalo in the Bighorn National Forest. These evaluations used preliminary water supply estimates, feasibility-level cost estimates, reconnaissance-level geotechnical analysis, and preliminary assessment of environmental effects. The preferred-site recommendation resulted from these studies.

Lower Tie Hack Site

Location

The lower Tie Hack site lies on South Clear Creek at the confluence with Sourdough Creek (Figure 1-1). The proposed dam would be approximately 1500 feet downstream of the Tie Hack Campground. The site is on U.S. Forest Service land. The reservoir would impound water in both the South Clear Creek valley and the Sourdough Creek valley.

Capacity

The reservoir site shown in Figure 1-1 can store more than 10,000 acre-feet (Figure 1-2).

Geotechnical Reconnaissance

The purpose of the reconnaissance-level geotechnical analysis was fourfold:

- Detection of possible fatal flaws,
- Determination of suitability for different dam types,
- Study of the availability of construction materials, and
- Evaluation of general acceptability of the site for a dam.

The investigation of the lower Tie Hack site indicates that the site is suitable for several dam sizes and types, as described below. Appendix A summarizes the geotechnical findings.

Alternative Dam Types

Three dam types were analyzed for this site. Large volumes of rock available near the site, as well as a suitable foundation, could allow rockfill construction. Earthfill construction was also studied, though there is a concern that insufficient fill material is available near the dam site, particularly for the larger dam sizes. The stable rock foundation, narrow valley, and adequate material supply could permit roller-compacted concrete (RCC) construction. Appendix A more fully describes the feasibility of the three dam types.

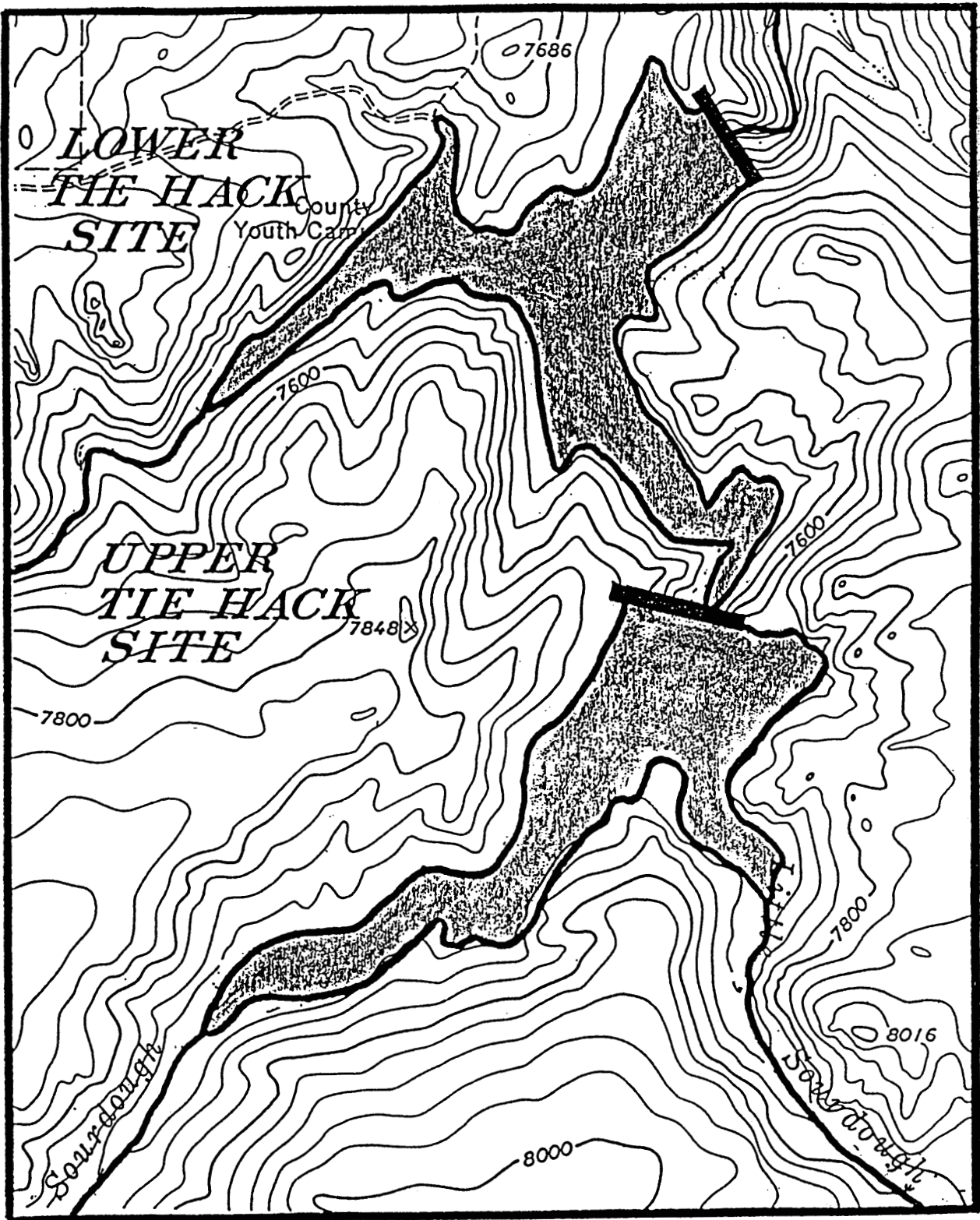


Figure 1: Alternative Dam Sites

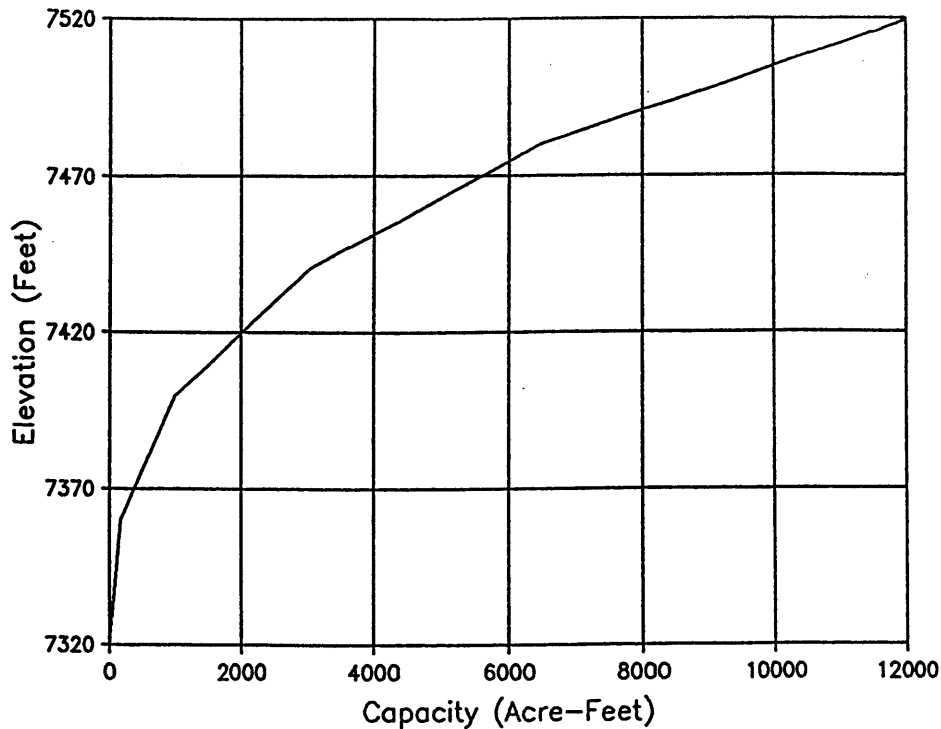


Figure 2: Lower Tie Hack Site Elevation-Capacity Curve

Water Supply

Detailed hydrologic analyses on the site have not been completed. However, an estimated annual average of approximately 19,500 acre-feet of water flow through the site. Prior downstream water rights will reduce the total storable volume.

Flood Flows

Approximate probable maximum flood (PMF) flows were developed for the site in order to size emergency spillways. The estimated PMF peak flow is 130,000 cfs.

Environmental Effects

Depending on its size, the proposed reservoir would inundate from 46 to 176 acres and from 1.0 to 2.2 miles of South Clear Creek and Sourdough Creek. The Tie Hack Campground and possibly the County Youth Camp would be inundated. Terrestrial habitat and wetlands along both creeks would be flooded. Table 1-1 on the following page summarizes project impacts.

Table 1-1

Comparison of Environmental Effects of Alternative Sites

Location and Size (ac-ft)	Inundated Area (acres)	Inundated Stream (miles)	New Roads (miles)	Terrestrial Habitat and Wetlands (acres)	Youth Camp and Campground
Upper Tie Hack Site					
10,000	166	2.1	1.9	23	No effect
5,000	98	1.6	1.9	13	No effect
1,500	43	1.0	1.9	8	No effect
Lower Tie Hack Site					
10,000	176	2.2	1.1	15	Both inundated
5,000	104	1.6	1.1	12	Both inundated
1,500	46	1.0	1.1	8	Campground inundated

Access

The lower Tie Hack site has access from an existing Forest Service road. Access to the proposed dam would require construction of approximately one mile of additional road.

Upper Tie Hack Site

Location

The upper Tie Hack site is located on Sourdough Creek approximately 3500 feet upstream of the Tie Hack Campground (Figure 1-1). and is on Forest Service land. The reservoir would inundate parts of the Little Sourdough Creek valley and Sourdough Creek valley.

Capacity

The site shown in Figure 1-1 can store more than 10,000 acre-feet (Figure 1-3).

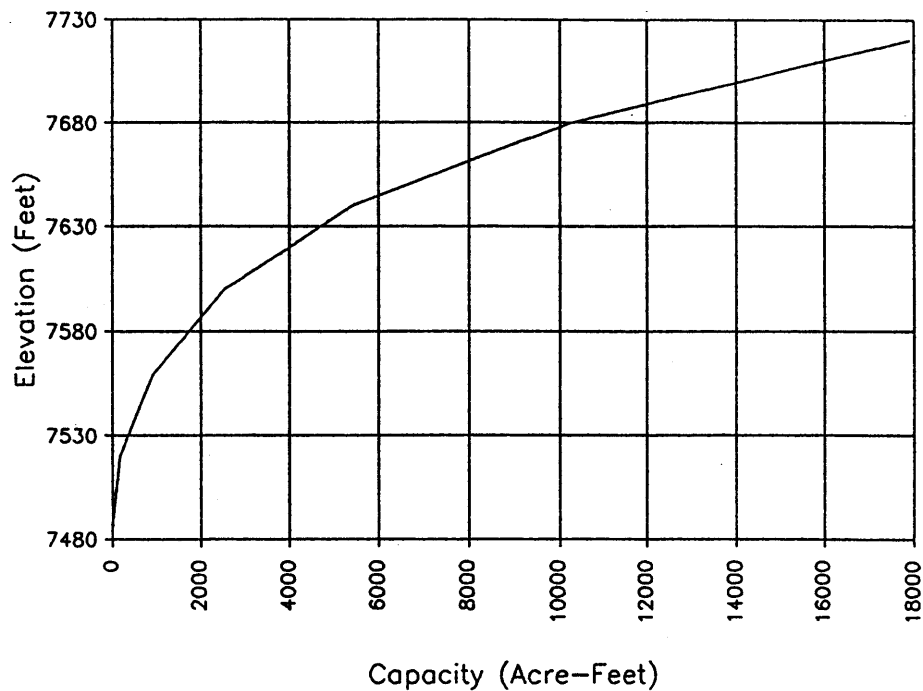


Figure 3: Upper Tie Hack Site Elevation-Capacity Curve

Geotechnical Reconnaissance

The reconnaissance-level geotechnical analysis of the upper Tie Hack site yielded two areas of concern. A large rock slide on the right abutment could indicate abutment instability. In addition, a considerable depth of material, which could require removal, appears to blanket the valley bottom. Appendix A details these findings.

Alternative Dam Types

The three dam types analyzed for the lower site were also reviewed for use at the upper Tie Hack site. The categories are rockfill, earthfill, and RCC dam types.

Water Supply

Preliminary estimates show that an annual average of 5,500 acre-feet of water flow through the site. However, as previously noted, prior downstream rights will reduce the total storable volume.

Flood Flows

The estimated PMF flow is 75,000 cfs at the upper Tie Hack site.

Environmental Effects

Depending on its size, the reservoir would inundate from 43 to 166 acres and from 1.0 to 2.1 miles of Sourdough Creek and Little Sourdough Creek. Terrestrial habitat and wetlands would be inundated along both creeks. Table 1-1 summarizes project impacts.

Access

The upper Tie Hack site currently lacks road access. Site access would necessitate construction of approximately two miles of new road.

Comparison of Alternative Dam Sites

Reservoir Sizes

The alternative reservoir sites were compared for storage volumes of 1,500, 5,000, and 10,000 acre-feet.

Cost Comparisons

Reconnaissance level cost estimates were developed at the two alternative sites for each of the above-described reservoir sizes. Analysis of the three dam types identified the least expensive dam type for each combination of site and size. The cost estimates include dam embankment, spillways, outlet works, and appurtenances. Table 1-2 below shows the cost estimates.

Table 1-2

Cost Summary: Least Expensive Dam Type, By Storage Volume and By Site		
Storage Volume (acre-feet)	Upper Tie Hack Site	Lower Tie Hack Site
1,500	\$ 5,500,000	\$ 3,750,000
5,000	13,300,000	9,050,000
10,000	25,700,000	16,100,000

The cost comparisons show that the lower Tie Hack site is considerably less expensive than the upper Tie Hack site for the entire range of reservoir sizes. The cost estimates at this level of study are insufficiently accurate for final elimination from consideration of any dam type.

Water Supply

The preliminary water supply estimates indicate that there is approximately three times more streamflow at the lower Tie Hack site than at the upper Tie Hack site. Flows at both sites are subject to prior downstream water rights. However, considerably more water is available at the lower Tie Hack site than at the upper Tie Hack site.

Geotechnical Reconnaissance

From a geotechnical standpoint, the lower Tie Hack site is more favorable for dam construction than is the upper Tie Hack site. Rock slides on the upper site, as well as deeper overburden, reduce that site's desirability.

Environmental Effects

The two sites would inundate nearly the same length of stream for each reservoir size, but the fishery impacts will probably be substantially greater for the lower site because of its larger streamflows. Although the two sites flood nearly the same acreage, the impact on terrestrial habitat and wetlands would probably be greater for the upper site because of its smoother terrain. Access to the upper site would require more new road construction than at the lower site. The lower site would inundate the Tie Hack Campground and possibly the County Youth Camp. The overall environmental effects fail to favor one site over the other. Table 1-1 summarizes the effects.

Recommended Site

Examination of preliminary costs, reconnaissance-level geotechnical considerations, preliminary water supply estimates, and preliminary assessment of environmental effects promotes recommendation of the lower Tie Hack site for further study.

Hydrologic Analyses

Streamflow Determination

To determine the size and effects of operating a proposed reservoir, a computer model is typically developed to simulate reservoir operation. The key input to such a model is a long time sequence of streamflows, usually gathered during a multi-year stream gaging program, at the proposed reservoir site. Because there has never been a stream gaging station located at or near the proposed lower Tie Hack site, estimating a streamflow record for the site was necessary. The generated streamflow record will be utilized in the sizing of the proposed reservoir and to assess downstream effects of operation of the proposed reservoir.

Several gaging stations are operated or have been operated in the vicinity of the proposed reservoir. Two of these stations -- one on Little Sourdough Creek, the other on Sourdough Creek -- were installed in 1985 to provide data for the Buffalo project. By relating streamflow to drainage basin characteristics at sites with gages, it is possible to develop relationships between basin characteristics and streamflow.

In addition to the above analyses, a streamflow gaging program was instituted in the summer of 1988 to monitor stream flow at the dam site and several other locations. This program will assist in relating flow at the reservoir site to the several gaged locations, and will provide a check of the above-described statistical analyses. The gaging program will be continued for another month.

Preliminary findings indicate that mean annual streamflow at the lower Tie Hack site is 19,500 acre-feet. This is about 45 percent of the flow that passes the town of Buffalo's diversion. The estimate of streamflow given herein is preliminary; it will be finalized after the stream gaging program and this year's gaging station record become available and can be integrated into the hydrologic analyses.

Irrigated Lands Mapping

As a part of the hydrologic analysis, mapping of all irrigated lands within the Clear Creek drainage basin has been completed. Mapping was accomplished utilizing color infra-red photography on file within the Wyoming Water Development Commission's (WWDC's) office.

Identified irrigated lands were mapped onto U.S. Geological Survey, 7.5 minute, reproducible quadrangles. Draft copies of irrigated lands maps were sent to the State Board of Control's Water Division II office for review and comment. A meeting was held in

Sheridan, Wyoming with the Water Division II superintendent to discuss map accuracy.

A total of 30,098 acres have been mapped as irrigated within the Clear Creek basin. This acreage compares with 29,970 acres mapped in 1970 (Wyoming Water Planning Program, 1972), and 27,000 acres estimated as irrigated in 1965 (Streeter, 1965). The total acreage for permits in good standing within the Clear Creek basin is 85,530 acres. The fact that only 35% of water rights are actually irrigated indicates that the Clear Creek basin is heavily overappropriated.

All final mapping will be submitted to the WWDC's offices along with the final Phase I report on or before February 15, 1989.

Water Rights Analysis

All adjudicated and unadjudicated water rights have been tabulated, by priority, with corresponding diversion points plotted onto the irrigated lands data base. This water right information has also been sent to the Water Division II Superintendent, and his comments incorporated. Temporary filings have also been tabulated.

Meetings with personnel within the Cheyenne and Sheridan offices of the State Board of Control concerned the movement of existing water rights to the proposed lower Tie Hack Reservoir site. Transfer of both the 1600 acre-feet associated with the original Little Sourdough reservoir site and the 1000 acre-feet from Lake DeSmet will require the preparation of petitions to the State Engineer along with all associated mapping. Both petitions will require extensive reservoir mapping and signed consent forms from all intervening water users.

Approval for moving the 1600 acre-foot Little Sourdough temporary filing seems likely, since there are no intervening users. However, transfer of the 1000 acre-feet from Lake DeSmet will require the consent of many intervening users. The Lake DeSmet transfer will also require substantial revision of existing DeSmet reservoir mapping. Until the Clear Creek basin hydrologic modeling has been completed, the real value, if any, of the proposed DeSmet transfer is difficult to ascertain.

Hydrologic Modeling and Water Supply Analysis

Although determination of streamflow at the reservoir site describes how much water is physically available, legal availability of that water will determine how much can actually be stored. Downstream water rights which have senior priorities to those of the Buffalo water supply system will "call out" the project if their water demands cannot be met from inflow to Clear Creek downstream of the project. In order to fully assess the

legal availability of water at the project location, an analysis of water rights and uses on Clear Creek downstream of the project must be made. This analysis must be extended downstream to a point where permitted uses will no longer call out the project.

In addition to the proposed reservoir, the town of Buffalo has several very senior water rights, which for the purpose of this study, are considered part of the Buffalo water supply system. The most beneficial of these rights total 8.95 cfs and have priorities of 1897 or senior. The proposed reservoir could store 1,620 acre-feet of water under a 1933 priority, and through a possible transfer, could store water that is currently stored in Lake DeSmet. A current (1989) permit would be required for a reservoir having a capacity greater than the combined 1933 permit and transfers from Lake DeSmet.

To evaluate the feasibility of the project, a preliminary operation plan has been developed. This plan aids in the assessment of reservoir size requirements and potential impact upon the stream system. Operation of the project (reservoir and current direct flow diversions) will occur as follows:

1. The town will continue to first meet its domestic water requirements by utilizing its direct flow rights when they are in priority.
2. When the town's domestic water requirements are less than the discharge needed for hydropower generation, natural streamflow will be diverted to maintain hydropower requirements. Flow used solely for hydropower generation will be returned to Clear Creek at the generator, west of town. Natural flow will be diverted out of priority as necessary, as long as intervening users do not call out the diversion. Users downstream of the generator will, of course, not be impacted.
3. When the domestic requirement for Buffalo can not be met from natural streamflow, releases will be made from the reservoir.
4. When hydropower requirements cannot be met by the total of the supplied domestic requirement plus natural streamflow diversion as described in item 2 above, reservoir releases will be made to satisfy the hydropower requirement.
5. When all downstream senior demands are met, the project reservoir will store water, within the regulations imposed by the State Engineer. Instream flow bypass requirements may further restrict those periods when the reservoir may store.

This operation plan is being mathematically implemented within the OPSTUDY model developed by the Bureau of Reclamation (August, 1986). Additionally, the model is being utilized to simulate

nearly the entire Clear Creek basin; this simulation is a necessity, since downstream water rights will limit both the town's direct flow diversions and project reservoir storage. Several different scenarios of Clear Creek basin operation are being evaluated for their impact upon project feasibility. The first of these scenarios is modeling the basin as it actually operates today to represent how the reservoir would function during its first few years of operation until other uses within the basin increase.

A second scenario has Lake DeSmet water being utilized to the fullest extent possible. This situation will occur in the future when industrial demands upon the reservoir are about 50,000 acre-feet per year. The third scenario assumes that all the presently permitted rights and temporary filings are utilized to their fullest extent. As explained earlier, the amount of land being irrigated in the Clear Creek basin is less than is permitted. Scenario 3 assumes that all permitted land is irrigated. A more substantial impact, however, will be felt by the development of all reservoirs presently having temporary filings. One of these alone, the proposed Clear Creek Reservoir on the lower Clear Creek, could store up to 231,000 acre-feet. This third scenario will eliminate any project reservoir storage that is dependent upon a 1989 storage right.

As of the time of this interim report, model development is underway. Final development of model data is not expected until all this season's streamflow data have been incorporated into the hydrologic analyses. After these data have been incorporated, reservoir sizing and operation impacts will be assessed.

Water Quality Analysis

Inter-Mountain Laboratories, Inc. of Sheridan, Wyoming will be utilized for analysis of water samples from Lake DeSmet. All samples will be tested according to the 1988 standards established by the Environmental Protection Agency under the Safe Drinking Water Act and applicable amendments. Results of testing shall be completed on or before November 1, 1988.

Hydropower Investigations

Initial hydropower analyses have been completed both for the proposed dam site facility and for the facility associated with the City's existing water supply pipeline. Completion of this task is awaiting hydrologic modeling results and response from Pacific Power and Light Company (PP&L) regarding several key issues associated with each proposed hydropower plant.

Initial investigation indicates that a hydropower plant built in conjunction with a water treatment plant and the City's existing supply pipeline will have positive economic benefits for the Buffalo community. However, a hydropower plant associated with proposed new dam construction does not appear to be economical. The economics related to each proposed plant will be finalized after receipt of PP&L's response.

References

1. Wyoming Water Planning Program, 1972, Water and related land resources of northeastern Wyoming: Wyoming State Engineer's Office, Wyoming Water Planning Program Report No. 10, 209 p.
2. Streeter, R.L., 1965, Water resources inventory for Water Division Number 2, State of Wyoming: Casper, WY, prepared for Wyoming State Engineer's Office, 58 p.

Appendix A

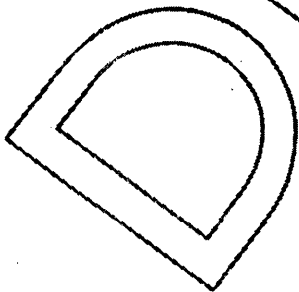
Reconnaissance Grade

Geologic and Geotechnical Dam Site Evaluation

A geologic and geotechnical reconnaissance of potential dam sites identified for the Buffalo Municipal project was conducted on Thursday July 21, 1988, by Messrs. John H. Black, senior geologist, and James R. Obermeyer, senior geotechnical engineer. We also reviewed available aerial photographs of the sites. This work was done in fulfillment of the Task C activities described in Woodward-Clyde Consultants contract with States West Water Resources Corp. dated July 22, 1988.

This report describes the findings of the reconnaissance grade site evaluations and provides input for the decision to select either the Upper or Lower Tie Hack site for a dam and reservoir to serve the City of Buffalo, Wyoming.

The Upper Tie Hack site is located on Sourdough Creek upstream of its confluence with South Clear Creek. A dam at this site would be about 180 ft. high and store 9,000 acre-feet of water. The Lower Tie Hack Site is located about 2,000 feet downstream of the Tie Hack Campground, on South Clear Creek. The Lower Tie Hack Dam would be approximately 180 feet high and store about 10,000 acre-feet of water. Locations of the sites are shown on Figure 1. This report also discusses an alternate Upper Site as shown in the figure.



The Upper Tie Hack site is located on Sourdough Creek upstream of its confluence with South Clear Creek.

At the confluence between the Sourdough Creek and the South Clear Creek, we estimated the water to be flowing in a channel approximately 15 feet wide, 6 inches deep, with a velocity of some 4-5 feet per second (fps), giving an approximate rate of flow of some 35 cubic feet per second (cfs) on the day of our reconnaissance.

Just upstream of the confluence, the valley bottom is relatively flat and about 250-300 feet wide. The valley bottom supports vegetation including grasses and moderately dense pine tree growth. Both valley sideslopes at this location are moderately steep and are also covered with pine trees.

At the location of the axis of the Upper dam site, the right abutment slope is relatively devoid of tree growth, but is grass covered, and has shallow soil cover over the granite bedrock. The left abutment slope is heavily tree covered and the valley bottom, at an elevation of about 7,420 ft mean sea level (msl), is relatively flat and an estimated 200 feet wide. The soil cover on the valley sideslopes ranges from a few inches to a few feet in thickness and we estimate the alluvial or glacial soil depth in the valley bottom to be from 10-30 feet thick.

While the majority of the bedrock outcrops in the vicinity of the dam site consist of granites, some gneissic rock is present. The granitic bedrock is frequently exposed, and has moderately to widely spaced joints. This bedrock is hard, blocky to slabby in form and ranges from fresh to slightly weathered. Upstream of the dam site, on the right side, is a pronounced rock rib with an orientation and boundaries which are parallel to a major joint trend, approximately north 20° east, vertical or very steeply dipping.

A rock slide exists immediately downstream of the dam site on the right abutment. The width of the slide is about 250-300 feet and no trees are growing within the slide area. Most of the slide debris has apparently been eroded away by Sourdough Creek but some remains on the lower portions of the slope. It appears that the base of the slide may be controlled by stress relief jointing dipping at 15-20° and slightly upstream (southwest). This rock slide may be an indication of unfavorable stability on the right abutment of the upper site.

There is a saddle at the top of the right abutment where a spillway could be located. It was apparent that the granitic bedrock here is also shallow.

An alternative location for the Upper Tie Hack dam on Sourdough Creek lies several hundred feet further downstream, upstream of its confluence with the South Clear Creek. At this location, the right abutment is relatively heavily tree covered and the left abutment is tree-covered in the lower 100-150 feet and relatively devoid of trees above that elevation. At this site, a spillway could be located over the saddle that forms the ridge of the right abutment.

While the dam located at the alternative (downstream) site appears favorable, reservoir waters from a dam at this site or at the upstream site would saturate the right abutment slope of the original (upstream) site, and could trigger more slope movement. The potential for this occurrence should be considered in more detail, if the Upper Tie Hack site is selected.

The Lower Tie Hack site is located approximately 2000 feet downstream of the center of the Tie Hack campground, on the mainstem of South Clear Creek. At the confluence between South Clear Creek and Sourdough Creek, South Clear Creek was flowing in a channel approximately 20 feet wide, 1 foot deep, with a velocity of 5-6 fps, giving an estimated flow rate of about 100 cfs. The combined flows of South Clear Creek (above the Sourdough confluence) and Sourdough passing through the Lower Tie Hack site was on the order of 135 cfs on July 21, 1988.

The dam site is located just upstream of a 90° left hand bend in South Clear Creek, with a creek bed elevation approximately 7320 ft msl. The river makes the bend at a location where there is a pronounced rib of granitic/gneissic rock on the left side. This rock rib is deeply incised by open joints that are parallel to the regional set (north 20° east, vertical), and the rib itself is not considered suitable as a left abutment because of the open joints and its narrowness.

A more appropriate damsite location is several hundred feet upstream (southwest) of this rib. Here both the left and right abutments are massive, with the axis of the dam on the right side lying between two massive granitic outcrops. Overburden on the left abutment is shallow at low elevations, and possibly reaches 20-30 ft thickness at higher elevations. In the valley bottom, the floor is approximately 150 ft wide, with overburden likely in the 10-15 ft thickness range. Overburden on the right abutment is likely thinner than on the left.

The left abutment has a pronounced joint set dipping approximately 40-60° to the south, while higher on the right abutment another set dips approximately 60° to the northwest. Both of these sets could be stress relief sets. A saddle, which could serve as a spillway location, is located at

the top of the left abutment. Bedrock in this saddle is likely at a depth of less than 10 feet.

As with the Upper site, bedrock outcrops observed at the lower site are generally hard and fresh to slightly weathered. Based on our reconnaissance grade evaluation, this site appears appropriate for siting a dam of the size contemplated.

If a fill dam were contemplated for the Lower Tie Hack Site, a spillway could be constructed in the left abutment saddle. If a concrete dam were contemplated for this site, water could be spilled over the dam.

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It appears that the relatively wide (300 ft \pm) valley bottom upstream of the confluence of Sourdough Creek and South Clear Creek would be a potential source of borrow materials for dam construction. Materials at this location would probably be granular in nature and contain some cobbles and boulders; however, the majority of the materials would likely be sands and gravels. These materials are expected to be suitable for use in coarser zones of a zoned earthfill dam or as aggregate for a traditional or a roller-compacted concrete dam. Similar materials are also expected in the valley bottom within the Upper Tie Hack reservoir area. It is less likely that all construction materials for a concrete dam at the original Upper site could be produced from within the reservoir area. The actual types and quantities of potential borrow materials must be confirmed with borrow investigations in a future phase of the project.

Construction materials for a concrete dam likely could be produced from within the reservoir area of the Lower Tie Hack site, but would probably require processing (i.e. screening, crushing and washing).

There appears to be extremely limited quantities of fine grained materials available for the construction of a clay core at either site. If a rockfill dam is considered, it probably would require an upstream impervious membrane constructed of either asphalt or concrete. Ample quantities of rockfill should be available from excavations for spillways, access roads, foundation excavations, or a quarry source in the reservoir area. We judge that the lack of clayey borrow materials for a core may make construction of an earth fill dam at either site infeasible.

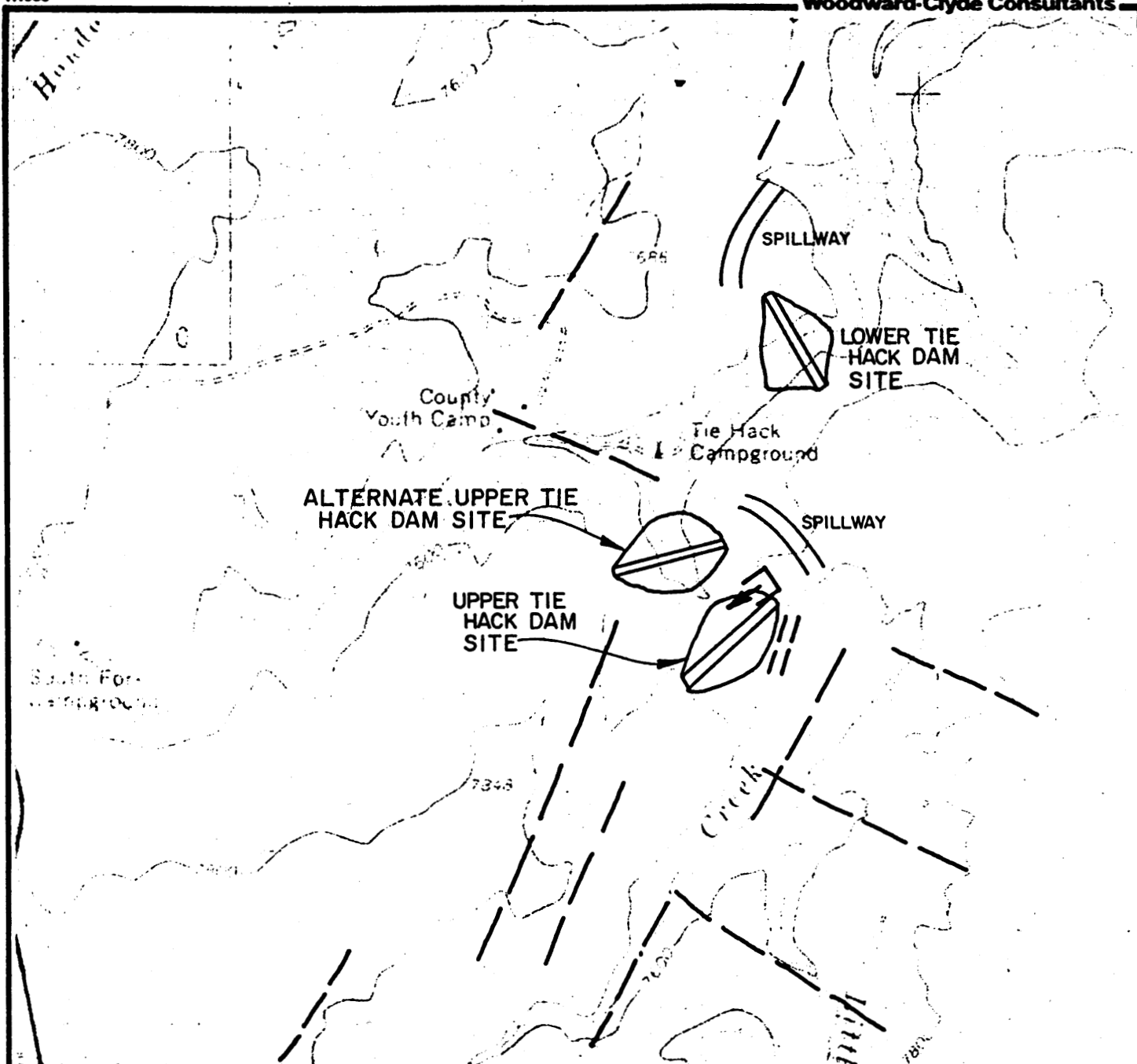
For the Upper site, access to the dam could be achieved using the existing road to the campground and a new road along Sourdough Creek.

For the lower site, access to the dam crest could be along a specially constructed road branching from the present campground road approximately 1000 ft uphill from the County Youth Camp. Access to the downstream toe of the dam would be difficult, but could branch from the access (mentioned above), at the spillway saddle, then wind northwards down to the creek bed. Alternatively, a spur could branch off the campground road some 3000 ft from Highway 16 in a northeasterly then southeasterly direction to reach creek level at the downstream toe.



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LEGEND

-  ROCK SLIDE LOCATION
-  MAJOR JOINT SET ORIENTATION



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SCALE IN FEET

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Interim Report

Job No. : 22166

Prepared by: S.M.B.

Date: 8/3/88

LOCATION MAP
PROPOSED TIE HACK DAM SITES

FIG. 1