51.1248 (Upper Green River)

A REPORT TO THE
WYOMING
WATER DEVELOPMENT COMMISSION
ON THE
PRE-FEASIBILITY STUDY
OF THE
UPPER GREEN RIVER DRAINAGE
POTENTIAL RESERVOIR SITES

JANUARY 12, 1983

PREPARED BY:
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Suite 1
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307 856 6505
January 12, 1983

Wyoming Water Development Commission
4th Floor, Barrett Building
Cheyenne, Wyoming 82002

Attention Mr. Michael Reese, Administrator

Gentlemen:

Submitted herein, for your consideration, is the report representing the completion of the Pre-Feasibility Phase of the Upper Green River Drainage Area Level II Feasibility Study of seven potential reservoir sites.

The report endeavors to outline for you the procedures by which the ARIX project team gathered and evaluated the critical data pertaining to the feasibility of developing additional water storage reservoirs in the Upper Green. By establishing criteria and quantifying the impact of each site's characteristics on its feasibility potential, the team has arrived at conclusions and recommendations.

These recommendations are presented herein to facilitate your decision as to the direction of the Feasibility Phase with regards to which sites will be selected for further study. It is not the intent of the Project Team to make this decision for you, but rather to present the findings of this first level of investigation and solicit your guidance for further efforts.

We look forward to presenting this information to you in formal session. If you have any questions in the interim, please feel free to contact me.

Respectfully,

ARIX, A Professional Corporation

Dean L. Swartz
Project Manager

DLS:kav
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UPPER GREEN STORAGE DEVELOPMENT RESERVOIR SITES

1. Sixty-Seven Reservoir
2. Sand Hill
3. McNinch Wash
4. Fish Creek
5. Snider Basin
6. South Cottonwood
7. La Barge Meadows
8. North Piney

LEGEND

- Forest Boundary
- County Boundary
- Creek or River
- Paved Road
- Potential Dam Site

WYOMING RANGE POTENTIAL STORAGE SITES
GREEN RIVER BASIN
Wyoming

EXHIBIT 'A'
A Report To The Wyoming Water Development Commission
on the
PRE-FEASIBILITY STUDY
OF THE
UPPER GREEN RIVER DRAINAGE
POTENTIAL RESERVOIR SITES

January 12, 1983

Prepared by:
ARIX, A PROFESSIONAL CORPORATION
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Riverton, Wyoming
I. **EXECUTIVE SUMMARY AND RECOMMENDATIONS**

The objective of the Pre-Feasibility Phase of the Level II Feasibility Study of the seven potential reservoir sites within the Upper Green River Drainage Area was to identify the major advantages and disadvantages for each site. These sites are shown on the location map at Exhibit A.

Major components of this identification process were the studies conducted by Leonard Rice Consulting Water Engineers and the law firm of Kirkland and Ellis to determine the availability of water to these sites, both physically and legally. To complete the picture for each site, ARIX then utilized a preliminary geotechnical reconnaissance study of the sites by Earth Sciences Associates to develop the physical characteristics of each impoundment structure and then assign respective costs to determine the overall cost of each water project.

Environmental constraints for each site were solicited from the affected agencies and organizations and were included in the evaluations. These constraints were not weighted on an equal basis as the other considerations since the level of environmental review in the Pre-Feasibility phase did not substantiate the development of a "critical flaw" that would necessarily eliminate a project site. Comprehensive environmental studies will be completed by the affected agencies during the Feasibility Phase studies of those sites selected for further study.

The criteria for evaluating the project sites has been condensed for review purposes and is presented in Table 1 (Evaluation Criteria Matrix).
Recommendations

The ARIX project team recognizes that the decision for causing a project site to continue on to the Feasibility Phase rests with the Wyoming Water Development Commission and the Big Piney Conservation District. We have therefore, endeavored to identify the major advantages and disadvantages of each proposed site and quantify those into a final cost per acre foot of water developed. It is on the basis of this final line of analysis that the following three project sites are recommended for your consideration.

<table>
<thead>
<tr>
<th>Site No.</th>
<th>Description</th>
<th>Estimated Development Cost Per Acre-Foot</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Sand Hill</td>
<td>$270</td>
</tr>
<tr>
<td>5</td>
<td>Snider Basin</td>
<td>$452</td>
</tr>
<tr>
<td>6</td>
<td>South Cottonwood</td>
<td>$548</td>
</tr>
</tbody>
</table>

The above ranking must be qualified by recognizing that the quantity of water available at the respective sites is a major factor in deriving the final cost per acre-ft. It must also be recognized that these storable flows can be significantly affected by the institution of a basin-wide water management program. Table I-1 on Page I-8 of the Leonard Rice Consulting Water Engineers report at Appendix A shows how the storable flows could be positively increased through such a management plan.

Additionally, the ARIX project team feels that an alternative site on North Piney Creek warrants further study if the commission would desire to expand the scope of the Feasibility Study. The North Piney Creek site
III. INTRODUCTION

Working under contract to the Wyoming Water Development Commission, ARIX, A Professional Corporation, has accomplished the first phase of the study to determine the feasibility of developing potential reservoir sites in the Upper Green River Drainage Area. The ARIX project team consists of four subcontractors in addition to ARIX. These are: Leonard Rice Consulting Water Engineers (LRCWE) - Hydrology and Water Rights; Earth Sciences Associates (ESA) - Geotechnical Consultants; Browne, Bortz and Coddington, (BBC) - Economics; and Kirkland and Ellis, (K & E) - Legal Counsel.

The Pre-Feasibility Phase services were intended to identify the availability of water, both physically and legally and to identify other major considerations for each of the seven sites that would either enhance or detract from the viability of each site's potential for development. Although it was not called for in the contract for services, the ARIX project team has expended considerable efforts to evaluate early in the project, reconnaissance level geotechnical and engineering considerations. These added evaluation processes enabled the team to accomplish a closer examination of the aspects of each site and thus produce recommendations based on broader considerations.
IV. POTENTIAL PROJECT SITES

The potential sites evaluated in this Pre-Feasibility Study are shown on the location map included herein at Exhibit A. These sites and their locations are as follows:

<table>
<thead>
<tr>
<th>Site</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sixty Seven Reservoir</td>
<td>E 1/2 8 &amp; 17-30-112</td>
</tr>
<tr>
<td>Sand Hill</td>
<td>E 1/2 1 &amp; 36-30-113</td>
</tr>
<tr>
<td>McNinch Wash</td>
<td>E 1/2 10-30-113</td>
</tr>
<tr>
<td>Fish Creek</td>
<td>SE 1/4 26-30-115</td>
</tr>
<tr>
<td>Snider Basin</td>
<td>SW 1/4 11-29-115</td>
</tr>
<tr>
<td>South Cottonwood</td>
<td>W 1/2 12-32-115</td>
</tr>
<tr>
<td>LaBarge Meadows</td>
<td>W 1/2 16-29-116</td>
</tr>
<tr>
<td>North Piney Creek</td>
<td>NE 1/4 25-31-115</td>
</tr>
</tbody>
</table>

While on a field tour of the sites on September 10, 1982, the project team endeavored to examine each site physically as well as try to identify other sites that could possibly serve as alternatives if the seven pre-selected sites become untenable. Several such sites were identified and later eliminated due to further preliminary evaluation. One location did remain as a possible alternative site and this is located on North Piney Creek. This site exhibited favorable characteristics and so the team included it in enough of the evaluation processes to be able to determine its relative feasibility with regards to the other seven sites.
V. WATER RIGHTS AND HYDROLOGIC ANALYSIS

This portion of the study was accomplished by Leonard Rice Consulting Water Engineers (LRCWE) and is included with this report at Appendix A. The resulting determinations from that report are reflected in the achievable storage volumes of each site and are tabulated on the Evaluation Criteria Matrix at Table I.

As detailed in the LRCWE report, an essential element to the development of any of the project sites in the Upper Green River Drainage Area is the responsible management of water rights by every user. At critical points in the year, this management scheme for the conservation of resources could guarantee availability at times when those resources have historically not been available.

VI. GEOTECHNICAL ANALYSIS

Earth Science Associates, Geotechnical Consultants performed the reconnaissance level study of the geotechnical characteristics of each site. The results of this study are included herein at Appendix B. These evaluations were instrumental in providing a basis for the engineering analysis by ARIX. The impact of the geotechnical constraints are reflected in the preliminary design considerations for the respective dam embankments and seepage control measures. Additionally, the degree of complexity of each project site's construction requirements was dictated by the results of ESA's preliminary analysis.
VII. ENGINEERING ANALYSIS

7.1 INTRODUCTION

It is the intent of this portion of the pre-feasibility study to establish an engineering basis for narrowing down the number of sites so that study resources may be concentrated on the more promising alternatives.

7.1.1 Depth of Investigation

At this stage, the study is, and has been, based on reconnaissance level information. The study has produced relative rankings of the potential sites without detailed analysis of each construction component and without considering silt storage and permanent pool requirements.

7.1.2 Basis for Evaluation

Evaluation of the sites has considered the following:

- total storable water available at the site
- geological considerations including:
  1. foundation conditions
  2. material availability
  3. seepage potential
- reconnaissance level cost estimates considering the following construction components:
  1. foundation preparation
  2. seepage control
  3. embankment
  4. spillway
  5. riprap and slope protection
  6. outlet works
  7. conveyance works
  8. access roads
  9. road relocation
  10. misc. items (including mobilization)
Table 2, titled "Reconnaissance Level Cost Estimates for Upper Green River Sites," provides a comparison of the reconnaissance level cost for each of 10 construction cost components and an estimate of the relative construction cost per A.F. of stored water at each site studied.

Table 1 titled "Evaluation Criteria Matrix," provides a summary comparison of important features of the alternatives and a overall recommendation for each site.

When the storage capacities have been adjusted (as will be done in the Feasibility Phase), to provide for silt storage and permanent pool requirements the total project costs can be expected to increase. It is not anticipated that any significant changes in relative ranking will occur from changes in storage capacities.

7.1.3 Sources of Information

* For this reconnaissance level study, all rough construction quantity estimates have been based on Standard U.S.G.S. 1:24000 topographic mapping.

* A field tour of all the sites under study was conducted September 10, 1982. Additional visits to selected sites have been made by the Geotechnical Subcontractor to provide additional information. The information gained from the field tour has been very useful in the analysis of the alternates and the preparation of reconnaissance level cost estimates.
<table>
<thead>
<tr>
<th></th>
<th>Sixty-Seven</th>
<th>Sand Hill</th>
<th>McNinch Wash</th>
<th>Fish Creek</th>
<th>Snider Basin</th>
<th>South Cottonwood</th>
<th>La Barge Meadows</th>
<th>North Piney</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Foundation Preparation</td>
<td>229,200</td>
<td>177,200</td>
<td>236,400</td>
<td>88,250</td>
<td>88,550</td>
<td>228,290</td>
<td>160,900</td>
<td>337,850</td>
</tr>
<tr>
<td>2. Seepage Control</td>
<td>412,000</td>
<td>289,400</td>
<td>307,000</td>
<td>13,260</td>
<td>18,700</td>
<td>49,300</td>
<td>142,800</td>
<td>25,500</td>
</tr>
<tr>
<td>3. Embankment (in place)</td>
<td>514,300</td>
<td>612,000</td>
<td>705,600</td>
<td>297,460</td>
<td>335,000</td>
<td>754,000</td>
<td>750,000</td>
<td>882,300</td>
</tr>
<tr>
<td>4. Spillway Construction</td>
<td>65,500</td>
<td>226,700</td>
<td>81,300</td>
<td>112,750</td>
<td>179,650</td>
<td>259,780</td>
<td>133,650</td>
<td>875,150</td>
</tr>
<tr>
<td>5. Riprap and Slope Protection</td>
<td>994,200</td>
<td>511,300</td>
<td>733,800</td>
<td>107,260</td>
<td>194,780</td>
<td>553,600</td>
<td>620,200</td>
<td>395,000</td>
</tr>
<tr>
<td>6. Outlet Works</td>
<td>72,600</td>
<td>124,160</td>
<td>86,800</td>
<td>127,820</td>
<td>146,820</td>
<td>169,120</td>
<td>154,350</td>
<td>237,000</td>
</tr>
<tr>
<td>7. Conveyance Works</td>
<td>52,500</td>
<td>210,000</td>
<td>422,400</td>
<td>65,000</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>8. Access Road</td>
<td>50,000</td>
<td>-</td>
<td>50,000</td>
<td>150,000</td>
<td>25,000</td>
<td>-</td>
<td>-</td>
<td>30,000</td>
</tr>
<tr>
<td>9. Road Relocation</td>
<td>-</td>
<td>400,000</td>
<td>45,000</td>
<td>-</td>
<td>300,000</td>
<td>180,000</td>
<td>270,000</td>
<td>215,000</td>
</tr>
<tr>
<td>10. Misc. Items</td>
<td>50,000</td>
<td>65,000</td>
<td>75,000</td>
<td>75,000</td>
<td>60,000</td>
<td>90,000</td>
<td>100,000</td>
<td>128,200</td>
</tr>
<tr>
<td>SUBTOTAL</td>
<td>2,440,300</td>
<td>2,615,760</td>
<td>2,743,300</td>
<td>1,036,800</td>
<td>1,348,500</td>
<td>2,284,090</td>
<td>2,331,000</td>
<td>3,126,000</td>
</tr>
<tr>
<td>+20% TOTAL EST. CONST.</td>
<td>2,928,400</td>
<td>3,168,900</td>
<td>3,291,960</td>
<td>1,244,160</td>
<td>1,618,200</td>
<td>2,740,900</td>
<td>2,798,280</td>
<td>3,751,200</td>
</tr>
<tr>
<td>+20% TOTAL EST. PROJ. COST</td>
<td>3,514,000</td>
<td>3,802,700</td>
<td>3,950,000</td>
<td>1,493,000</td>
<td>1,941,800</td>
<td>3,289,000</td>
<td>3,358,000</td>
<td>4,501,440</td>
</tr>
<tr>
<td>STORAGE CAPACITY A. F.</td>
<td>5,600</td>
<td>14,100</td>
<td>5,600</td>
<td>1,400</td>
<td>4,300</td>
<td>6,000</td>
<td>4,800</td>
<td>5,600</td>
</tr>
<tr>
<td>EST. COST PER STORAGE A.F.</td>
<td>$628</td>
<td>$270</td>
<td>$705</td>
<td>$1,066</td>
<td>$452</td>
<td>$548</td>
<td>$700</td>
<td>$804</td>
</tr>
</tbody>
</table>
Geotechnical information has been gathered by the Geotechnical Subcontractors, Earth Sciences Associates, and a summary of their reconnaissance level findings is located in Appendix B.

Hydrology and water rights information has been gathered and developed by Leonard Rice Consulting Water Engineers and a summary of their work to date is located in Appendix A.

7.2 SITE DISCUSSIONS

Using the available U.S.G.S mapping, depth-storage capacity curves and depth-embankment volume curves have been developed, and a reservoir water surface outline map prepared for each site. These exhibits are located within the text discussing them and provide the basis for quantities used in preparing the relative cost estimates.

In order to further refine the cost estimates, larger scale mapping will be required and the amount of storage to be provided must be more defined. In the preparation of these estimates, factors have been included to provide for miscellaneous undefined construction items and for contingencies and engineering.

The tour of the sites provided a great amount of input to the evaluation process and observations will be noted in the following discussions of probable engineering consideration at each site.
At the present time, only the Sand Hill Reservoir site is noticeably impacted by the presence of existing oil field installations, however several of the other sites could be similarly impacted before reservoir construction is commenced.
SIXTY SEVEN RESERVOIR SITE
SUBLETTE COUNTY
T.30N., R.112W.

NORMAL W.S. ELEV. = 7087
CAPACITY = 9600 A.F.
MAX. SURFACE AREA = 580 AC.
7.2.1 SIXTY SEVEN RESERVOIR

This the only existing reservoir of the sites under study. The facility consists of a dam structure across Sixty Seven Draw at the southeast end of the reservoir and a variable height dike along a saddle located on the northeast perimeter of the reservoir.

Some seepage was observed below the main dam, and the portion of the dike visited did not appear to be up to current dam standards. It is therefore anticipated that a complete analysis of the existing embankments will be required to determine if it can be incorporated into an enlarged dam or if it needs to be partially or completely reconstructed. If complete reconstruction of the embankments, or if considerable reconstruction of the existing inlet conveyance works is required, the costs shown for the site could increase 20 to 40%. The location of this site on private land could provide some public access problems.

Engineering considerations relative to this site are anticipated to include:

- Foundation preparation - Little clearing of reservoir site is needed. Stripping of the top 3' of the foundation will be required. Provide a key trench with 10' bottom, 1:1 side slopes to a depth equal to one third the height of the dam. Some of this material should be wasted, some may be suitable for incorporation in selected parts of the dam structure.
SIXTY SEVEN RESERVIOR SITE

DEPTH - STORAGE CAPACITY AND EMBANKMENT VOLUME CURVES

FIGURE 1A
• Seepage control - Place a clay blanket 3' thick along the upstream slope of dam and for 300' upstream from the toe of the dam along both the main dam and saddle dike.

• Embankment - Anticipate a soft foundation and provide 3:1 side slopes up to 30' dam height and 3.5:1 above 30' dam height. (Provide at least 5' freeboard for all off-channel reservoirs and 7' for all on-channel sites.)

• Spillway - This is an off channel reservoir so the spillway may be sized for the local drainage area and consist of a relative small service spillway with a larger emergency spillway.

• Riprap and slope protection - For estimation purposes use 3' thick stone riprap with 12" of bedding and filter material. It is anticipated that the riprap will come from off site with perhaps long haul costs.

• Outlet works - Probably relative easy excavation, sized to provide irrigation releases for the existing and enlarged reservoir. Possibly will require only a simple slide gate and lift mechanism.

• Conveyance works - Probably will require some enlargement of existing works consisting of ditches, canals, diversion structures and drainage crossings.

• Access road - The existing road system consists of private ranch roads which use the crest of the existing dam. If improved access from the public road system is required the cost would increase.

• Road relocation - No public road relocation has been considered.

• Miscellaneous - This includes contractor mobilization costs.
The results of the reconnaissance level estimate of cost indicate a relative cost per acre foot for 5600 acre foot of enlarged storage to be $628, if extensive removal and reconstruction of the existing structure is not required.
NORMAL W.S. ELEV. = 7168
CAPACITY = 14,100 A.F.
MAX. SURFACE AREA = 790 AC.
This location appears to be a relatively good storage site. However, there are several existing petroleum pipe lines and a paved highway traversing the reservoir area, and several operating oil wells in the basin. The costs of relocating the oil field related improvements have not been included in this estimate.

Engineering considerations relative to this site are anticipated to include:

* Foundation preparation - Little clearing of the reservoir basin is needed. Strip off the top 3' of the foundation. Excavate a key trench with 10' bottom, 1:1 side slopes to a depth equal to one third the height of the dam. Some of this material should be wasted, some may be suitable for incorporation in selected areas of the dam structure.

* Seepage control - Place a clay blanket 3' thick along the upstream slope of the dam and for 600' upstream from the toe of the dam. Provide a toe drain system at the downstream toe of the dam.

The Geotechnical Consultant does not anticipate the excessively large seepage losses previously estimated at this location. (See Appendix B)

* Spillway Construction - This is an off channel reservoir and the spillway will be required to provide protection only against runoff occurring over the local drainage area, and from the diversion inflow. The area appears to be highly erodible.
EMBANKMENT VOLUME $\times 10^5$ C.Y.

EMBANKMENT VOLUME

7172 TOP OF DAM (72'D)

WS ELEV. 7167 (67'D.)

STORAGE CAPACITY

14100 A.F.

25

SANDHILL RESERVOIR SITE

DEPTH - STORAGE CAPACITY AND EMBANKMENT VOLUME CURVES

FIGURE 2A
Riprap and slope protection - The location and orientation of the dam, as for both the Sixty Seven and McNinch sites, is such as to provide maximum exposure to high down slope winds. Three feet of stone riprap on a 1 foot bedding and filter layer has been estimated.

Outlet works - This reservoir is of larger volume and the embankment is higher so the outlet works will require larger capacity and heavier construction.

Conveyance works - Diversion works are required in both the South and Middle Piney Creeks. The conveyance system may be able to utilize expanded existing ditch works. The system anticipated at this time will probably require up to 2-1/2 times the capacity of the McNinch location.

Access road - It is anticipated that the dam would be located adjacent to the relocated public highway and access requirements would be minimal.

Road relocation - a considerable section of existing paved highway will require relocation, with construction of new drainage structures and road surfacing required.

Misc. Items - Contractor mobilization costs are estimated to be moderate at this location. Relocation costs of oil field improvements have not been evaluated at this time.
The relative cost of $270 per acre foot of storage at this site is based on a storage capacity of 14,100 acre foot and reflects the economy of scale generally true of all locations. That cost does not include costs required to accommodate the existing oil and gas facilities.
McNINCH WASH
RESERVOIR SITE
SUBLETTE COUNTY
T.30N., R.113 W.

NORMAL W.S. ELEV. = 7248
CAPACITY = 5600 A.F.
MAX. SURFACE AREA = 340 AC.
7.2.3 McNINCH WASH RESERVOIR

This site appeared to have good storage potential but requires an extensive conveyance works from North Piney Creek, which increases the costs at this site.

There is at the present time, oil field activity near the reservoir and this may be a factor when more complete information is obtained. The location of this site on private land may provide accessibility problems.

Engineering considerations relative to this site are anticipated to include:

* Foundation preparation - Little clearing of reservoir site is needed. Strip the top 3' of the foundation. Excavate core trench with 10' bottom, 1:1 side slopes to a depth equal to one third the height of the dam. Some of this material should be wasted, some may, if found suitable, be incorporated in selected parts of the dam structure.

* Seepage control - Place a clay blanket 3' thick along the upstream slope of dam and for 300' upstream from the toe of the dam.

* Embankment - The dam height of 58' on the anticipated soft foundation would probably require 3.5:1 slopes.

* Spillway - This is an off channel reservoir so the spillway may be sized for the local drainage area and consist of a relative small service spillway and a larger emergency spillway.
McNinch Wash Reservoir Site

Depth-Storage Capacity and Embankment Volume Curves

Figure 3A
Riprap and slope protection - For estimation purposes use 3' thick stone riprap with 12" of bedding and filter material. It is anticipated that the riprap will come from off site with perhaps a long haul costs.

Outlet works - Probably relatively easy excavation but the required structure height in the anticipated soft foundations will require careful design and construction. The outlet works should be sized to provide for required irrigation releases.

Conveyance works - A completely new diversion and conveyance works, about 8 miles long with stream crossings, is required to fill this reservoir site. The estimated cost for this component alone represents $108 of the estimated cost per acre foot of storage. The ditches or canals should be easy excavation with some potential for seepage but probably will not require lining.

Access road - A completely new access road from the existing McNinch Reservoirs will be needed, and some upgrading of the existing ranch roads may also be required at additional costs.

Road relocation - some relocation of ranch roads has been estimated.

Misc. Items - This includes contractor mobilization costs.

The relative cost of $705 per acre foot of storage at this site is based on a 5600 A.F. of storage capacity.
FISH CREEK RESERVOIR SITE
SUBLETTE COUNTY
T.30N., R.115W.

NORMAL W.S. ELEV. = 8258
CAPACITY = 1400 A.F.
MAX. SURFACE AREA = 50 AC.
7.2.4 FISH CREEK RESERVOIR SITE

This site appears to be a good on-channel storage location except for the limited tributary drainage area.

Engineering considerations relative to this site are anticipated to include:

- **Foundation preparation** - In addition to 3' stripping requirements, a core trench averaging 10' in depth and a single line of grout holes, 10 feet on centers 50' deep has been estimated.
- **Seepage control** - A toe drain system is estimated.
- **Embankment** - To be constructed of earth or earth-rock with a clay core if suitable material is found on-site. A homogenous structure with 3:1 slopes has been estimated.
- **Spillway construction** - A side channel spillway excavated into rock is probable and the cost at this site may be relatively low.
- **Riprap and slope protection** - The dam face is somewhat protected by the narrow site. Rock and bedding sources are estimated to be available on-site.
- **Outlet works** - This on channel location requires sizing relative to stream flows rather than for irrigation releases. The facilities will require heavy duty construction throughout.
- **Conveyance works** - A diversion structure on Indian Creek and diversion ditch into Fish Creek has been estimated.
- **Access road** - The existing 4 wheel drive road into the area will require considerable upgrading and extension to the site - a north side location is desirable to increase the accessible season.
EMBANKMENT VOLUME $\times 10^5$ C.Y.

1400 A.F.

8265 TOP OF DAM (85 D.)

WS ELEV. 8258 (78 D.)

FISH CREEK RESERVOIR SITE

DEPTH - STORAGE CAPACITY AND EMBANKMENT VOLUME CURVES

FIGURE 4A
* Road relocation - None required at this site.

* Misc. Items - Contractor mobilization cost to this site are probably second only to the LaBarge site. No other items are estimated at this time.

The relative cost of $1066 per acre foot is based on a storage capacity of 1400 acre feet and reflects the small amount of water available for storage.

If the storable amount were increased by water management practices the unit cost would be decreased.
SNIDER BASIN RESERVOIR SITE
SUBLETTE COUNTY
T.29N., R.115W.

NORMAL W.S. ELEV. = 7948
CAPACITY = 4300 A.F.
MAX. SURFACE AREA = 180 AC.

FIGURE 5
7.2.5 SNIDER BASIN

This reservoir study area is impacted by the Lander Cutoff of the Oregon Trail and the presence of the marked emigrant grave sites upstream from the stream junction with Porcupine Creek. A dam located upstream from the graves is not, by any engineering criteria, as desirable as an alternative site located downstream below the junction of South Piney Creek with Porcupine Creek and Coal Creek. There the geology is much more favorable (reported to be the best of alternates) and the available water supply potential much greater. This site would be even more favorable as water management practices are put into effect and the required size of the reservoir increased. Movement of graves and erection of suitable markers could enhance the memorial to the pioneers and probably be much more consistent to the spirit they demonstrated. The lower location is an apparently good storage site and in a location that would provide considerable potential for water management practices, high enough on the stream to be effective and low enough to allow control of a considerable volume.

Engineering considerations relative to the site include:

- Foundation preparation - Stripping 3' over the entire foundation and an average 10' depth core trench has been estimated. A grout curtain was not estimated.
- Seepage control - a limited toe drain system has been estimated.
SNIDER BASIN RESERVOIR SITE

DEPTH - STORAGE CAPACITY AND EMBANKMENT VOLUME CURVES

FIGURE 5A
Embankment - A homogeneous dam of earth or earthrock, with 3:1 slopes, has been used. If clays are available a zoned structure should be considered.

Spillway construction - The Geotechnical consultant reports a good side channel spillway site around the right abutment. This is an on channel reservoir with considerable flood flow potential.

Riprap and slope protection - This reservoir will be somewhat more protected from the winds than the plains storage units. Riprap and bedding sources appear on-site.

Outlet works - The same comments apply as for Fish Creek, except that Snider Basin flows will be somewhat larger.

Conveyance works - None required at the lower site.

Access road - The relocated public road will be adjacent to the dam.

Road relocation - A considerable amount of public road relocation will be required.

Misc. Items - Contractor mobilization costs have been estimated. An estimate of costs for moving and memorializing the emigrant grave sites has not been included, however this cost need not be great.

The relative cost of $452 per acre foot is based on a storage capacity of 4300 acre feet. This site has the potential to store considerably more water, at costs competitive with the Sand Hill Site.
7.2.6 SOUTH COTTONWOOD RESERVOIR SITE

The Geotechnical Evaluation of this site warns of possible seepage problems and spillway concerns, and rates it below Snider Basin and Fish Creek and perhaps better than LaBarge and North Piney. A dam location below the confluence with Bare Creek is the studied site.

Engineering considerations relative to this site include:
- Foundation Preparation - The foundation is to be stripped 3' deep and a cutoff trench averaging 20' feet in depth has been estimated to offset anticipated seepage.
- Seepage control - In addition to the cutoff trench provided in foundation preparation a relatively large toe drain system has been estimated.
- Embankment - Some instability in the left abutment is suspected at this stage but no cost has been assigned to corrective measures. A homogeneous dam with 3:1 side slopes is anticipated.
- Spillway construction - Spillway conditions have been assessed as poor and a side channel spillway with extensive lining is suggested.
- Riprap and slope protection - The requirements are similar to Snider Basin with riprap stone, and the material suitable for bedding available on the project.
- Outlet works - To be sized for on-channel discharge requirements. The high dam, together with potential foundation difficulties, requires careful design.
- Conveyance works - None required at this location.
SOUTH COTTONWOOD RESERVOIR SITE

DEPTH - STORAGE CAPACITY AND EMBANKMENT VOLUME CURVES

FIGURE 6A
Access road - The relocated public road will be adjacent to the dam.

Road relocation - Road relocation is required but less than most other sites.

Miscellaneous Items - Contractor mobilization costs at this location have been considered.

The relative cost of $548 per acre foot is based on a 6000 acre foot of storage capacity.
LA BARGE MEADOWS
RESERVOIR SITE
LINCOLN COUNTY
T. 29 N.  R.116 W.

NORMAL W.S. ELEV. = 8458
CAPACITY = 4800 A.F.
MAX. SURFACE AREA = 160 A.C.
7.2.7 LaBARGE MEADOWS RESERVOIR SITE

This is, at first impression, a very attractive site, however the Geotechnical Evaluation lists a number of concerns requiring much more detailed investigations to resolve than the other sites. The evaluation cautions that both design and construction costs could be much higher than can be logically estimated from the information presently available.

Engineering considerations provided for at this location include:

* Foundation preparation - Stripping 3' deep over entire foundation, and undercutting left abutment an average of 10' and providing a grout curtain under the left abutment. Provide 10' average depth of core trench under entire dam.
* Seepage control - Provide 3' clay blanket on dam face and 300' upstream together with a toe drainage system.
* Embankment - A homogeneous structure using 3:1 slopes.
* Spillway construction - Locate a lined spillway over glacial deposits around the right abutment, sized to provide for on channel flows.
* Riprap and slope protection - Riprap bedding may be located on-site but riprap may not be available and may present a problem of availability at this location, due in part to environmental concerns.
EMBANKMENT VOLUME x 10^5 C.Y.

EMBANKMENT VOLUME

8465 TOP OF DAM (105 D.)

WS ELEV. 8458 (98 D.)

STORAGE CAPACITY

LA BARGE MEADOWS RESERVIOR SITE

DEPTH - STORAGE CAPACITY AND EMBANKMENT VOLUME CURVES

FIGURE 7A
• Outlet works - Locate on right side away from the area to be over excavated. Provide for construction through glacial and unconsolidated material. Size adequately to pass on channel stream flow demands.

• Conveyance works - None required at this location.

• Access road - The dam is adjacent to the public road.

• Road relocation - A considerable amount of road relocation is required.

• Miscellaneous Items - Contractor mobilization costs at this site are anticipated to be the second greatest of all the alternates. The relative cost of $700 per acre foot is based on a 4800 acre foot storage capacity. The geotechnical evaluation warns of unknown conditions and the potential for unanticipated costs.
NORMAL W.S. ELEV. = 8118
CAPACITY = 5600 A.F.
MAX. SURFACE AREA = 264 AC.

NORTH PINLEY CREEK RESERVOIR SITE
SUBLETTE COUNTY
T.31N., R.115 W.

FIGURE 8
7.2.8 NORTH PINEY CREEK RESERVOIR SITE

This reservoir site appeared to be a logical alternative to the Sixty Seven Reservoir enlargement or the McNinch Reservoir site.

High costs estimated for spillway and outlet works construction due to the on-channel locations at the North Piney Creek study site combined with greater road relocation cost have shown the North Piney site to be not competitive at the 5600 A.F. storage capacity.

The Geotechnical evaluation at the site studied raises a great many doubts. It then summarizes by saying that construction would be relatively costly and that construction costs estimates based on the limited information used must be considered very weak, with the potential for unpleasant surprises during design and construction very high.

If, under a comprehensive water management program, greater storage capacities are desirable at a higher location, other sites along North Piney Creek should be studied.

Engineering considerations anticipated at this site include:
* Foundation preparation - possible high costs of regrading of the landslide slopes upstream from the dam have not been estimated.
  Removal of 3' strippings over the foundation and a 10' average
EMBANKMENT VOLUME $\times 10^5$ C.Y.

EMBANKMENT VOLUME

STORAGE CAPACITY

8125 TOP OF DAM (115 D.)

WS ELEV. 8118 (108 D.)

5600 A.F.

NORTH PINEY CREEK RESERVIOR SITE

DEPTH - STORAGE CAPACITY AND EMBANKMENT VOLUME CURVES

FIGURE 8A
cutoff trench, except for 20' average depths in the left abutment, has been estimated. A grout curtain of single row, 10' o.c., 50' deep holes have been considered.

- Seepage control - In addition to the core and grouting program covered under foundation preparation, a toe drain system is provided.
- Embankment - A zoned fill of on-site material using 4:1 slopes has been estimated.
- Spillway construction - This is an on channel location, requiring sizing for flood flows. A side channel spillway around the right abutment will require deep excavation.
- Riprap and slope protection - Suitable material should be generated on site.
- Outlet works - Must be located away from the slide debris, and will require heavy duty construction sized for on-stream flows.
- Conveyance works - None required.
- Access Road - Minor access road construction is anticipated.
- Road relocation - Considerable road relocation is anticipated and new bridges may be required.
- Miscellaneous Items - Contractor mobilization costs at this site are estimated to be the highest of all sites.

Estimated relative costs of $804 per acre foot is based on a 5600 acre foot storage capacity.
APPENDIX A

Report by Leonard Rice Consulting Engineers
WYOMING WATER DEVELOPMENT COMMISSION

UPPER GREEN RIVER
STORAGE PROJECT

Prepared for
ARIX

January, 1983

Leonard Rice Consulting Water Engineers, Inc.
ACKNOWLEDGEMENTS

The technical material in this report was prepared by or under the supervision and direction of the undersigned whose seals as a professional engineer and certified consulting engineer are affixed below:

Leonard Rice

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I SUMMARY AND CONCLUSIONS

This report describes the hydrology and water rights investigation made to assist in determination of the pre-feasibility of seven reservoir sites in the Upper Green River Basin. The results of the study are estimates of monthly storable flow at each site for an average runoff year and a 10-year period of record (1972-1981). Results are presented under two assumptions of water rights administration. These estimates will be combined with other aspects of the sites, such as embankment quantities and geotechnical information, to eliminate several reservoir sites from the study before proceeding with the full Level II Feasibility Study.

The Wyoming Water Development Commission and the Big Piney Conservation District have identified seven reservoir sites on tributaries of the Green River for a Level II Feasibility Study. The purpose of the reservoirs would be to supply late season supplemental irrigation supply to ranches in the Big Piney area. Other uses of the water may be identified during the study. Four of the reservoir sites are on Forest Service land high in the basins. The other three sites, Sand Hill, Sixty-Seven and McNinch Wash Reservoirs, are offstream reservoirs located low in the basin near Big Piney.
The storable flows were computed using the Wyoming Integrated River System Operation Study (WIRSOS) program which combines the basin hydrology and water rights to simulate administration of a river system. As part of this study, a hydrology analysis was made to determine the physical supply at the project sites. All U.S. Geological Survey streamflow records in the vicinity were compiled and extended by correlation analyses. This information was used to generate runoff at the necessary ungauged locations. All existing water rights on the study streams were tabulated and input to program WIRSOS. Assumptions for operation of program WIRSOS were made based on the best available information about local irrigation practice. Storable flow for the proposed reservoirs was computed to be all water available after senior water right users had been satisfied. Consideration was given to demands on the mainstem Green River, both for existing conditions and potential future demands.

During the course of this study, several water rights issues have surfaced which could have a significant bearing on the results of the storable flow study. These included administration of surplus water rights for pre-1945 permit holders, forfeiture of unused rights and the status of minimum instream flows in Wyoming. These matters were addressed by Ray Petros at Kirkland and Ellis, and his opinions are included as Appendix B to this report.
In summary, the conclusions are:

1. Surplus water rights are valid rights to which new projects would be subjected and need to be considered under a strict administration assumption.

2. Forfeiture of unused water rights is provided for in the Wyoming statutes, but is not practical from an administrative standpoint.

3. Minimum instream flows are not presently recognized as a beneficial use in Wyoming, but will likely be incorporated into all Wyoming Water Development projects as mandated by legislative directive. Quantification will likely be based on site-specific conditions and negotiations between various project beneficiaries and interested parties.

The results of the study are summarized in Tables I-1 and I-2. Table I-1 shows the storable flow at each reservoir site for an average runoff year and water years 1973 and 1977. Water year 1973 represents a year for which annual runoff would be equaled or exceeded approximately 8 of every 10 years. This is a generally accepted criterion for design of irrigation supply systems. Water year 1977 is generally the driest year of record in the basin and storable flows in this
year are presented to illustrate the effects of a severe drought year. Table I-2 shows the estimated acreage in each basin which could benefit from supplemental supply in an average year. Acreages are given considering both total adjudicated area and actual irrigated area. The three off-stream reservoirs could benefit users on all three Piney streams through exchange. Areas irrigated from any of the Piney streams, in the vicinity of Big Piney, could be served from each of these three sites without extensive new conveyance systems.

It is apparent that water management practices in the basins could significantly improve reservoir yields over those realized under strict water rights administration. At such time as specific project users are identified, options for increasing yield through management of runoff on a subbasin basis may be explored. After narrowing the list of sites for further study, detailed operation studies will be undertaken to help identify project users and opportunities for exchanges.

Instream flow requirements have not been factored in at any of the sites. It is likely that stipulations for each project would include a guarantee of some minimum level of flow below a reservoir which could limit storage at a site. This effect would be most noticeable during winter months when natural
flows are low. Reduction of winter storage could significantly effect yields at these sites. It is also possible that guaranteed release rates could be a project benefit. Instream flow criteria are not yet well-defined in Wyoming and the magnitude of such requirements is unknown at this time. Instream flow requirements would probably have greater impacts on the four sites located on Forest Service land than the three offstream sites.

It is apparently not likely that Wyoming's Colorado River Compact allotment will be depleted in the foreseeable future by projects with permits senior to the proposed reservoirs. The State of Wyoming retains some flexibility in approval and continuance of permit applications and an application for new permits in the basin could provide impetus to the State to reassess pending applications. At any rate, there appears to be a limited risk that projects with pending permits senior to the study projects could deplete Wyoming's Compact share. On the other hand, the study projects could be a more practical alternative for utilization of a portion of Wyoming's Compact share.

The physically and legally available water supply at each site appears to be limited. This is due, in part, to the relatively low winter flows and the late runoff season
combined with the fact that the streams are generally over-appropriated. Approximately 80 percent of the runoff occurs during the irrigation season when the new reservoirs would likely be "called out" in most years. The general practice is to flood fields in the spring with excess runoff water. If this practice could be modified, substantial flows could be made available for storage during May and early June. It is recommended that further study of a basin-wide coordinated management scheme be undertaken for the site(s) selected for the next phase.
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<td>Average Year</td>
<td>80% Chance Yield (1973)</td>
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<tr>
<td>Sixty-Seven</td>
<td>5,200</td>
<td>3,400</td>
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<tr>
<td>Sand Hill&lt;sup&gt;b&lt;/sup&gt;</td>
<td>14,100</td>
<td>13,400</td>
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<tr>
<td>McNinch</td>
<td>5,200</td>
<td>3,400</td>
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<tr>
<td>Fish Creek&lt;sup&gt;c&lt;/sup&gt;</td>
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<td>Snider Basin</td>
<td>4,300</td>
<td>3,300</td>
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<tr>
<td>South Cottonwood</td>
<td>6,000</td>
<td>4,500</td>
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<tr>
<td>La Barge Creek</td>
<td>4,800</td>
<td>4,200</td>
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NOTE: Water years used; annual totals do not match tables in Chapter V which are for calendar years.

<sup>a</sup> No minimum streamflow considered.
<sup>b</sup> Includes yield from both Middle and South Piney Creeks.
<sup>c</sup> Includes additional runoff captured from Indian Creek; estimated to be 200 acre-feet/year.
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<td>22,500</td>
<td>20,400</td>
<td>9,600</td>
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<td>North Piney Creek</td>
<td>25,900</td>
<td>18,600</td>
<td>15,700</td>
<td>8,400</td>
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<td>South and Middle Piney Creeks</td>
<td>28,600</td>
<td>19,100</td>
<td>15,000</td>
<td>5,500</td>
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<td>La Barge Creek</td>
<td>16,200</td>
<td>7,900</td>
<td>4,200</td>
<td>0</td>
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\textsuperscript{a} Area with shortage is assumed to be all rights "called out" during August of average year – based on run from Program WIRSOS.

\textsuperscript{b} Adjudicated and permitted shortage less land not presently irrigated.
Authorization and Scope

Leonard Rice Consulting Water Engineers, Inc. (LRCWE) was authorized to make a water rights and hydrology evaluation for determination of storable water at seven reservoir sites in the Upper Green River Basin in Wyoming. The study is being made for ARIX in conjunction with the Level II Feasibility Study for storage development in the Upper Green River Basin. This report describes Phase I of this study, termed the prefeasibility study, which is being conducted to reduce the number of sites which will be studied in the full Level II Feasibility Phase (Phase II).

The scope of work for Phase I includes two primary work items, as described below:

1. **Water Rights Analysis** - All significant water rights on the study streams will be tabulated and schematic diagrams will be prepared showing the location of these rights. Wyoming's obligation, under the Colorado River Compact, will be reviewed and availability of water for future projects assessed. Major water rights issues which could impact the projects will be identified.
2. **Hydrologic Analysis of Sites** - Available streamflow gauge records will be compiled and used to derive runoff estimates for the project sites on a monthly basis. Virgin flow estimates will be developed which will be combined with water rights information as input to the Wyoming Integrated River Systems Operation Study (WIRSOS) computer model for determination of the available water supply. The results of this analysis will be firm yield estimates at each site to be used in assessing the prefeasibility of each site.

**General Basin and Project Description**

The seven proposed reservoir sites are located on western tributaries to the Green River near Big Piney in the Upper Green River Basin, Water Division No. 4. The purpose of the project is to provide supplemental late season irrigation supply to ranchers in the area. Under current conditions, irrigators often experience late season shortages due to the subsidence of runoff in July and August.

The Green River Basin is located in southwestern Wyoming and incorporates an area of approximately 17,000 square miles. The basin ranges in elevation from 6,050 feet near the state line to 13,785 feet on the Continental Divide. The Green
River drains the Wind River and Gros Ventre Ranges, the Wyoming Range and Uinta Mountains, and the Sierra Madre Mountains and flows south into Utah.

Two reservoirs, Flaming Gorge and Fontenelle Reservoirs, provide storage on the mainstem Green. Flaming Gorge is a Colorado River Storage Project Reservoir with an active capacity of 3,515,700 acre-feet, located in both Utah and Wyoming, and completed in 1962. Fontenelle Reservoir, located south of La Barge, Wyoming, has a total active capacity of 190,250 acre-feet and was completed in 1968 by the U.S. Bureau of Reclamation. The Green River is included in the Colorado River Compact which limits the depletions which Wyoming is entitled to make from the river.

The project sites are located on streams which drain the Wyoming Range on the west side of the Basin in Sublette County (see Figure II-1). Upstream from the study streams, on the Green River, the New Fork River enters the Green from the east. The average annual discharge from the New Fork is 517,000 acre-feet. Above the New Fork, Horse Creek and Beaver Creek enter the Green from the west. A U.S.G.S. streamflow gauge is located at Warren Bridge near Daniel, above the confluence with Beaver Creek. Average annual flow at this gauge is 368,000 acre-feet.
Streams on which potential projects are located include Cottonwood Creek, North, Middle and South Piney Creeks, and La Barge Creek. These streams all enter the Green River in the vicinity of Big Piney above Fontenelle Reservoir. Average annual precipitation in the study area ranges from 9 inches at Big Piney to 50 inches or more in the Wyoming Range.

There is currently limited reservoir storage on the study streams. Offstream storage on North Piney Creek includes Sixty-Seven and McNinch Nos. 1 and 2 Reservoirs which have a combined capacity of approximately 6,700 acre-feet. Middle Piney Reservoir is located in the upper reaches of Middle Piney Creek and has a capacity of approximately 4,200 acre-feet. The project reservoir sites are located on Figure II-1 and summarized below:

1. Sixty-Seven Reservoir - This is a proposed enlargement of the existing reservoir located just off North Piney Creek. Water would most likely be conveyed to the reservoir through enlargement of the existing Hughes Ditch.

2. Sand Hill - This is an offstream reservoir which would receive its supply from both South and Middle Piney Creeks.
3. McNinch Wash - This is an offstream site which would divert its supply from North Piney Creek. The most likely diversion scheme would be an extension and enlargement of the Dewey Ditch.

4. Fish Creek - Fish Creek is a tributary of South Piney Creek. The site is located approximately 9 miles above the confluence with South Piney Creek. Additional runoff could be captured by constructing a diversion ditch to intercept Indian Creek, a tributary of Middle Piney Creek.

5. Snider Basin - This site is located on South Piney Creek. For this study, it was assumed that the site would be below Coal Creek.

6. South Cottonwood - This site is located on South Cottonwood Creek 16 miles above the confluence with North Cottonwood Creek.

7. La Barge Creek - The site is located near the headwaters of La Barge Creek.

It is anticipated that these reservoirs could be used to store runoff during the non-irrigation and peak runoff seasons for late season supplemental supply.
Approximately 66,800 acres on the study streams are presently irrigated for at least part of the season. All irrigated area is used for growing hay and pasture in support of local livestock production. Hay consists primarily of native pasture grass with approximately 12 percent being alfalfa. The irrigated area is located primarily within the stream valleys, with relatively short diversion schemes.

**Study Objectives and Assumptions**

The purpose of the Phase I Prefeasibility Study is to eliminate several sites before completion of a full Level II Feasibility Study. LRCWE has taken the task to determine the amount of water at each of the seven sites which is physically and legally available for storage. This information will assist in determination of prefeasibility of each site. The results of this study are presented as tables of storable flow by month for the 10-year study period, as well as an average year. The study period includes the driest year of record (1977) and a year that approximates a 1-year out of 5 dry year (1973). This is a commonly used criterion for reservoir design and means that this volume would have an 80 percent chance of being exceeded in any year. To arrive at storable flow results, various assumptions were required which are described below:

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1. All adjudicated and permitted water rights on each stream were included in the analysis. Non-use of certain rights was not considered. Storable flows under two basic assumptions were determined; a) strict administration of water rights on which all rights were given their full diversion amount during the season, and allowance was also made for double diversion rights during surplus flow in June; b) improved watershed management in which diversions are called for to match the actual distribution of consumptive use over the season. The effect of this assumption is to decrease diversion requirements during the early part of the irrigation season.

2. For operation of Program WIRSOS, several parameters, such as irrigation efficiency and return flow patterns, had to be estimated without the benefit of adequate data. Assumptions made for the operation of WIRSOS are identified in Chapter V.

3. The new reservoirs studied for this project were assumed to have current 1983 appropriation dates which would place them behind all existing water rights, as well as pending water rights which could eventually be perfected.
4. All reservoirs were considered independently. It was assumed that not more than one reservoir would be constructed on each stream.

5. The storable flow at each site is assumed to be all water available after all existing water rights on the stream are satisfied. The reported volumes are not limited in wet years by reservoir capacity. It was also assumed that all available flow could be conveyed to the offstream reservoirs. This assumption may not be valid in wet years, but should not be critical in less than average years.

6. Instream flow requirements at reservoir sites and diversion points were not considered for this phase. The reported storable flows include all available water without passing minimum winter flows. All sites are being evaluated under the same assumptions so that a relative comparison of the sites should be possible. During Phase II, a detailed analysis of instream flow requirements will be made and applied to each site selected for further study. This could serve to reduce the flow available for storage at each site.

7. Program WIRSOS allocates water to all water right holders in order of priority until all available supply
is used up. Each run produces information on which rights are "called out" and do not receive their supply. It has been assumed that this "call out list" provides information on the amount of irrigated area which would benefit from a supply of supplemental water from the reservoir.

8. It is assumed that there is water available for depletion in Wyoming under the Colorado River Compact with a 1983 water right. A review of pending water right applications indicates that enough projects have been filed on to deplete Wyoming's share of their Compact entitlement if all were to be perfected. However, for all practical purposes, there are no foreseeable plans to develop some of these projects, which would leave Compact water available for other projects. Part of the determination of availability of Compact water is dependent on State policy for handling pending permits. The Compact situation in the Green River Basin is detailed in Chapter III and Appendix A.

9. It was assumed that the water supply availability for McNinch Wash and Sixty-Seven Reservoir would be the same, since both would divert from lower North Piney Creek.
10. The Snider Basin site would have runoff from Coal Creek and Porcupine Creek available for storage.

Acknowledgements and Sources of Data

Various agencies provided assistance and data for this study including ARIX, the staff of the Wyoming Water Development Commission, the State Engineer, Wyoming Game and Fish, the U.S. Soil Conservation Service and the counsel from Kirkland and Ellis.

ARIX, as the prime consultant, provided assistance with initiating contacts, gathering general base data and arranging a site visit. The Commission staff provided maps of irrigated area in the basin and assistance in obtaining general project information. The Wyoming State Engineer's Office provided a list of all water rights to be studied. Two meetings were held with the State Engineer to review water rights administration in Division 4 and obtain information on the Compact situation in the Green River Basin. The local hydrographer, Chuck MacIlvaine, provided assistance with the water rights on the project streams and the schematic diagrams. In addition, the annual diversion summaries for the project streams, compiled by Mr. MacIlvaine, were provided. The Wyoming Department of Game and Fish provided assistance in assessing instream flow needs and environmental impacts of the project sites.

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The U.S. Soil Conservation Service provided reports and information from previous studies of these sites. Kirkland and Ellis have been retained to provide assistance with water rights and other legal issues which might arise. For the Phase I study, they provided legal opinion on several water rights administration questions which were incorporated into the assumptions made for this study.
The project reservoirs would be adjudicated with junior 1983 dates which would place them behind all other adjudicated and permitted water rights in the Green River Basin for storing water. Any water rights investigation must, therefore, give some consideration to all existing and pending rights in the basin. As a practical consideration, since the Green River Basin currently has surplus water, attention should be focused more heavily on the water rights situation on the tributary streams for which the projects are proposed. Historically, calls for water have never been placed up the project streams from the Green River, not even in the dry year of 1977. This is partly due to the fact that the many senior rights on these tributaries generally deplete the runoff during times when calls for irrigation water could come up the Green. Also, the existing rights on the streams are senior to the two large reservoirs on the Green, Flaming Gorge and Fontenelle Reservoirs. These conditions would not apply to the new projects. For this study, general consideration was given to potential future demands on the mainstem Green River, while a detailed water rights analysis was reserved for the project streams.
Water Rights in Local Project Basins

The local project streams include Cottonwood Creek, North, Middle and South Piney Creeks and La Barge Creek. These streams are located in District 10 of Division 4 except for La Barge Creek which is located in District 5. Adjudicated water rights on these streams date back to 1879. The ratio of water rights to runoff is generally very high with late season shortages often occurring. The water rights are primarily direct flow for irrigation and are adjudicated at the ratio of 1 cfs to 70 acres. All adjudicated land is not currently being irrigated, most likely due to the late season shortages. Numerous filings for temporary rights for drilling operations exist, but were not considered for this study.

Table III-1 summarizes the direct flow water rights on each stream. This table shows the adjudicated and permitted acreage as well as the area estimated to be actually irrigated. This information is based on information provided by the Wyoming Water Development Commission based on mapping completed by the Wyoming Water Planning Program prior to 1969. For all basins the overall ratio of irrigated area to adjudicated area is approximately 65 percent. Water rights information was taken from the Wyoming State Engineer's tabulation obtained in August, 1982 from their computer data base. While it is conceded that this information may not be
completely accurate and up to date, it is the best available information. Adjudicated water rights in Division 4 are also tabulated in the "Red Book", a tabulation by the Wyoming State Board of Control dated 1968, with supplements in 1969 and 1972. The two sources of information were frequently cross-checked for consistency.

There are several reservoir rights on these streams as well. Middle Piney Reservoir is located high in the Middle Piney Creek Basin and has a priority date of 1911 and a capacity of 4,200 acre-feet. This reservoir serves users on Yankee and Reardon Ditches, located on South Piney Creek. The water is transported from Middle to South Piney in AA Ditch. Sixty-Seven and McNinch Reservoirs are offstream reservoirs, located approximately 6 miles northwest of Big Piney and take their supply from North Piney Creek, as well as irrigation return flows which drain into the reservoirs. The total decreed capacity is approximately 6,650 acre-feet. Sixty-Seven Reservoir has priority dates ranging from 1904-1941. The McNinch Reservoirs have priority dates ranging from 1941 to 1956. A third McNinch Reservoir is permitted for 405 acre-feet with a 1975 priority date, but is not yet in place. There is no storage adjudicated on La Barge Creek and only 19 acre-feet for Soda Lake on Cottonwood Creek.
A review of the available diversion records for Districts 5 and 10 was made. Annual reports and diversion summaries, compiled by Chuck MacIlvaine, the Hydrographer-Commissioner, are available for Districts 5, 6, 7, 10 and 11 for the years 1974 through 1981. Prior to 1974, no formal records had been maintained by the State Engineer's Office. The diversion records for Districts 5 and 10 consist of spot discharge measurements for various ditches, reports of dates when ditches were regulated and overall summaries of the runoff conditions for each year. Daily diversion records are not available.

The records indicate that diversions for irrigation generally start from the beginning to middle of May each year, depending on weather conditions and the start of the runoff season. Diversions continue as long as the runoff lasts, generally receding by the end of July. It has been reported that some diversions continue on into October, primarily for maintenance of stock. Under normal runoff conditions, water is generally available for surplus irrigation diversions during the latter part of May and part of the month of June. Ditch regulation generally starts in July. In dry years, such as 1977 and 1981, ditch regulation may start at the beginning of the diversion season. Ditch regulation appears to be more prevalent on the Piney Creeks than on La Barge and Cottonwood Creeks.
The water rights on the project streams are tabulated on schematic diagrams which are scaled representations of the streams showing the approximate diversion locations of the water rights. Figure III-1 is an index sheet of the nine schematic diagrams prepared for this study. Figures III-2 through 10a are reduced copies of the diagrams which show water rights including the permit number, amount and priority date. Figures III-8a and III-9a show Green River water rights from Warren Bridge to Fontenelle Reservoir. Figures III-2b through 9b show the location of return flows from the major diversions. A return flow diagram for Dry Piney Creek has not been prepared since all rights are small. Return flow locations were assigned based on inspection of the irrigated parcels on U.S.G.S. quad maps and discussion with the water commissioner. The data as presented on these diagrams were incorporated into program WIRSOS. Muddy Creek and Dry Piney Creek were subsequently deleted from the WIRSOS data base since the water rights on these streams are small and would not effect the analysis.

Water Rights on Mainstem Green River

The detailed water rights study included a tabulation of mainstem Green River rights for the 90-mile reach from Warren Bridge to Fontenelle Reservoir. On this reach, adjudicated and permitted direct flow rights total approximately 780 cfs,
not including the Seedskadee project rights. Approximately 70 percent of these rights are located above the confluence with Cottonwood Creek. For the current level of development on the Green, the project streams would not be effected by demands on the Green.

Fontenelle Reservoir is located 5 miles below the confluence with La Barge Creek on the Green. It is adjudicated for approximately 190,800 acre-feet with a priority date of 1967. There is an application pending for adjudication of an additional 154,600 acre-feet of inactive storage which was not originally adjudicated. This reservoir was constructed by the U.S. Bureau of Reclamation in conjunction with the Seedskadee Project, for power, municipal and industrial supply, recreation, wildlife and, originally, irrigation. The project holds a permit for 1,140 cfs direct flow for irrigation of 79,800 acres with a priority date of 1955. This right has not been used and an application has been made to convert it to municipal and industrial use.

A change of use for a pending application on the Green and Cottonwood Creek has been sought and approved by the State Engineer. Final approval of the requested change is pending a decision by the State Supreme Courts. The change was sought by the Green River Development Company for 9,116 acres of land originally applied for on the Green River Supply Canal
and the Cottonwood Canal which had never been brought under irrigation. They sought to change the point of use to a location near Green River at the Jim Bridger Power Plant and the type of use to steam power plant cooling purposes. It was contended that a change in Federal regulations concerning desert land entries had made irrigation impractical and the change should be allowed on this basis. The State Engineer agreed, but limited the change to 2,003 acres. The order allowed transfer of the potential consumptive use, less 25 percent conveyance charge and limited the transfer to the months of May to July.

Pending water right applications in the Green River Drainage were reviewed for potential impact to the project reservoirs. At such time as pending permits with priority dates senior to the project reservoirs would be adjudicated, impacts on the projects could be twofold. 1) Requests for strict administration of water rights could extend up the tributaries from the mainstem Green as a result of the development of large downstream projects or rebound calls could extend up the tributaries as a result of new depletions in the basin above the tributaries with appropriation dates senior to the projects; and 2) eventually, Wyoming's share of the Colorado River Compact water could be depleted through utilization of pending water rights resulting in curtailment of the use of very junior rights in the basin. The Compact
situation in the Green River Basin will be discussed in the following section. The pending applications which could significantly effect the project reservoirs are summarized below:

1. Fontenelle Reservoir and the Seedskadee Project - It is presently unknown whether the direct flow right for 1,140 cfs will be allowed to be perfected as municipal and industrial supply. The application to permit the 154,600 acre-feet of storage could increase demand on the river at such time as industrial uses are developed in the vicinity of Green River.

2. Applications for increased direct flow rights for industrial use in the vicinity of Green River total approximately 280 cfs with priority dates ranging from 1963 to 1980. These rights are likely to be utilized at some time in the future. The only significant tributary to enter the Green between Fontenelle Reservoir and Green River is the Big Sandy. Therefore, these demands would be met primarily from available flows at Fontenelle Reservoir.

3. Major reservoirs applied for on the Green River include Kendall, New Fork Narrows, Lower Green and Plains
Reservoirs. In conjunction with these projects is a proposed diversion of Green River water to the North Platte system. Utilization of any of these projects could significantly effect available supplies in the entire basin. How the project streams would be administered with one of these projects in place is not presently known. None of these projects appear likely to be constructed in the foreseeable future.

For this study, the effects of implementing both the Seedskadee rights and industrial direct flow rights near Green River were considered, as discussed in Chapter V.

**Colorado River Compact**

The significance of the Colorado River Compact on future water use in the Green River Basin in Wyoming is summarized in Appendix A to this report. The first section is a brief history of the establishment of the Compact and related documents. This is followed by a "Discussion of the Colorado River Situation as It Pertains to Wyoming's Compacted Water Use" prepared by Mr. Lou Allen of the Wyoming State Engineer's Office in July, 1981. This represents the most current assessment of the Compact situation in Wyoming.
For the purposes of this study, it was assumed that due to the small size of the project reservoirs and the uncertainty of the timing of future depletions in the basin, water would be available for depletion under the Compact by the study projects.

Federal Reserved Rights

There are presently no applications or proceedings to adjudicate Federal Reserved Rights in Division 4. Such rights could eventually be claimed for Forest Services lands in the upper reaches of the project streams, but no quantification of such claims can be made at this time.

Salinity Reduction Program

Proposals are currently being evaluated for programs to reduce the salinity of the Green River in Wyoming as part of the overall Colorado River Salinity Program. Plans in Wyoming are concentrated on programs on the Big Sandy River. The only impact to the project reservoirs could result through increased depletions of the Compact allotment. At this time, it is not known how such depletions would be administered in Wyoming, but it is unlikely that other uses would be curtailed to continue depletions solely for salinity programs.
The impacts of the Upper Green River Storage Project on the overall salinity load in the Green River have not been evaluated as part of LRCWE's study.

Summary of Legal Issues for New Reservoirs

Several issues were identified during this study for which additional legal input was obtained.

The following describes the issues and how they relate to the project reservoirs.

1. Imposition of minimum instream flows at new reservoir sites - Storable flow at the proposed reservoirs could be significantly affected by the imposition of instream flow requirements below the sites. This is especially critical since most of the storage would occur during the low streamflow periods of the non-irrigation season.

2. Administration of surplus irrigation water rights - Strict administration of these rights could limit storable flow during the high runoff months of May and June.

3. Forfeiture of unused water rights - Due to the amount of adjudicated land which is not irrigated, there is the
potential that some adjudicated rights are not being used. However, as long as they are on the books they retain their priority and the potential for future use. One alternative for increasing the dependability of the project reservoir yield would be to have inactive rights cancelled or under-utilized rights reduced.

Legal opinions on these three issues are summarized in three memoranda included as Appendix B to this report.

The conclusions, as they relate to this study are:

1. Instream flows of some magnitude will likely be required for the Water Development projects. For the Phase I study, they have not been considered at any sites. Quantification of such requirements will be undertaken for sites selected for Phase II study.

2. Administration of surplus irrigation rights has been included in this study. Assumptions will be described in Chapter V.

3. It was concluded that forfeiture of unused water rights is not practical to assume. All adjudicated water rights were considered as potentially active for this study.

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Table III-1
PERMITTED AND IRRIGATED ACREAGE FOR PROJECT STREAMS

<table>
<thead>
<tr>
<th>Stream</th>
<th>Adjudicated</th>
<th>Permitted</th>
<th>Total</th>
<th>Presently Irrigated</th>
<th>Ratio of Irrigated to Total Adjudicated &amp; Permitted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cottonwood Creek</td>
<td>30,660</td>
<td>2,660</td>
<td>33,320</td>
<td>22,500</td>
<td>.68</td>
</tr>
<tr>
<td>North Piney Creek</td>
<td>23,720</td>
<td>2,180</td>
<td>25,900</td>
<td>18,600</td>
<td>.72</td>
</tr>
<tr>
<td>South and Middle Piney Creeks</td>
<td>26,600</td>
<td>1,980</td>
<td>28,580</td>
<td>19,100</td>
<td>.67</td>
</tr>
<tr>
<td>La Barge Creek</td>
<td>14,770</td>
<td>1,400</td>
<td>16,170</td>
<td>7,900</td>
<td>.49</td>
</tr>
<tr>
<td>Total</td>
<td>95,750</td>
<td>8,220</td>
<td>103,970</td>
<td>68,100</td>
<td>.65</td>
</tr>
</tbody>
</table>

NOTE: Water rights in Wyoming are adjudicated at the ratio of 1 cfs to 70 acres for irrigation.

a Based on irrigated area mapping completed by Wyoming Water Planning Program.
Figure III-1  Index Sheet for Schematic Diagrams
Figure III-2a  Cottonwood Creek Water Rights
Figure III-3b Muddy Creek Return Flows
Figure III-4b  North Piney Creek Return Flows
Figure III-5b  Middle Piney Creek Return Flows
Figure III-6a  South Piney Creek Water Rights
Figure III-7a  La Barge Meadow Water Rights
Figure III-7b  La Barge Meadow Return Flows
Figure III-8a  Upper Green River Water Rights
Figure III-8b  Upper Green River Return Flows
Figure III-9a  Lower Green River Water Rights
Figure III-9b  Lower Green River Return Flows
Figure III-10  Dry Piney Creek Water Rights
Summary of Existing Runoff Records

The Green River Basin above Fontenelle Reservoir has substantial streamflow runoff records available covering the past fifty years. Gauge records are available for some periods of record at approximately 38 stations within the basin above Fontenelle Reservoir. Gauges utilized for this study included those located on the west side of the basin in the proximity of the study streams and the mainstem of the Green River above Fontenelle Reservoir, and are described in Table IV-1. Information shown on this table includes gauge elevation, drainage area, the period of record for each gauge and average annual discharge measured at the gauge for the period of record. Gauge locations are shown on Figure IV-1.

Two gauges were used as index gauges for this study, to which runoff at other sites was adjusted to obtain long-term average runoff. The Green River at Warren Bridge gauge has a period of record dating back to 1932 and is still active. The other site is the Green River near La Barge gauge located above Fontenelle Reservoir. The period of record for this gauge is 1964-present. Prior to this, the gauge was located downstream at a section which was subsequently flooded by the Fontenelle Reservoir pool. This gauge record extended back to 1946. The two sites are close enough together that the record is considered continuous for 1946 to the present at the La Barge gauge. Records at this site have been generated back to 1930 from a correlation derived by the Wyoming Water Planning Program with the Green River at Green River gauge (U.S.G.S. gauge 334)[Ref. 1]. This provides a continuous period of record of 52 years above Fontenelle Reservoir.
Runoff records exist for varying durations for the streams on which the proposed reservoirs would be located. Cottonwood Creek has had three gauges with a total of 23 years of record. Gauge No. 8 provides the longest period of record and was used for correlation analysis in this study. There were approximately 16,000 acres of irrigated area above the gauge which requires a significant adjustment to the gauge flows to provide an estimate of virgin flow.

There has been one gauge on North Piney Creek with 41 consecutive years of record. This gauge was discontinued in 1973. Irrigated area above the gauge totaled approximately 700 acres. This gauge provides a reliable estimate of long-term average runoff on North Piney Creek and the adjustment to obtain virgin flow is relatively minor.

Middle Piney Creek has had three gauges, of which No. 13 provides 15 years of consecutive record. Runoff at this gauge was assumed to be virgin flow since diversions above the gauge for irrigation were insignificant. Flow at the gauge was affected by storage in Middle Piney Reservoir. There have been no gauges on Fish Creek and only one gauge on South Piney Creek with four years of record. Estimates of runoff on South Piney Creek were primarily based on records from the other basins. The State of Wyoming placed a gauge on South Piney Creek in 1981.

On La Barge Creek, there are 31 years of continuous record at the proposed reservoir site at La Barge Meadows. This gauge provides an excellent record of the runoff at the site. The gauge was discontinued in 1981. Two other gauge sites were located near the mouth of La Barge Creek, with the most recent having a continuous record from 1941-1949.
In addition to the above gauges, other gauges in the vicinity provided information used to develop unit runoff curves for use at the reservoir sites. These included Horse Creek at Sherman Ranger Station (No. 4) which provides virgin flow, and Fontenelle Creek near Herschler Ranch (No. 24) which required only a minor adjustment to obtain virgin flow and is still an active gauge.

Due to the amount of gauge data available on the west side of the Green, gauges east of the Green River in the New Fork Basin were not used for this study. A brief search also revealed that no significant gauge records are available west of the Wyoming range in the Snake River Basin.

Table IV-2 shows the range in annual runoff at the North Piney, La Barge and Green River gauges. The driest years of record in the basin were 1977 and 1934. The driest year in the North Piney record was 1934 with a runoff of 42 percent of average. The driest year in the period of record at the Warren Bridge gauge, which included 1934, was 1977 with a runoff of 55 percent of average. Figure IV-2 shows the 10-year running average of annual runoff for the Green River at Warren Bridge.

The distribution of runoff on the project streams is represented by Figures IV-3 to IV-6, which show the average and dry year monthly runoff for the North Piney and La Barge Creek gauge stations. These indicate that approximately 50 percent of the runoff occurs in May and June, with June being generally the peak runoff month. The runoff dramatically drops off in the months of July-September, illustrating the cause of irrigation shortages during those months. Dry years are generally typified by much smaller peak runoffs, with the base flows slightly less than average.
Extension of Gauge Records

From the gauges identified above, several were used to extend the gauged records for the study streams. Correlation analyses were made for streams in the study basins to obtain records for a coincident period of record on all streams. Gauge records were first adjusted to virgin flow by adding average annual consumptive use for irrigated area above the gauges. No other adjustments were made. Correlations were tested for annual runoff at a gauge with several parameters which included annual runoff at adjacent gauges, annual precipitation at nearby climatological stations and April 1 snowpack data. The snowpack and climatological stations considered are shown on Figure IV-1. The best correlation at each gauge was used to extend the record.

Consumptive Use - Average annual potential consumptive use was calculated for three climatological stations within the study area; Big Piney, La Barge and Merna. Crop distribution for the area was determined and long-term average data were used to compute crop irrigation requirements using the Jensen-Haise method. Solar radiation data were taken from the Climatic Atlas of the U.S. (Reference 2) for Lander, Wyoming. Lander is located 74 miles east of the study area.

Irrigation water requirements were computed for pasture grass and alfalfa at each site. Table IV-3 shows the irrigation requirement at each station for both crops, as well as the growing season as determined by temperature data and the effective precipitation. Potential consumptive use ranges from approximately 1.5 feet at Merna to 2.5 feet at La Barge. Figure IV-7 shows the distribution of consumptive use and runoff in the study area. This figure illustrates the cause of late season shortages without reservoir storage to supplement runoff.
Crop distribution was taken from SCS data [Reference 3]. Crop distribution and irrigated area for the study streams are shown in Table IV-4. An average basin distribution of 10 percent alfalfa and 90 percent pasture grass was used to establish a weighted average consumptive use. The crop-weighted irrigation requirement at each station is also shown in Table IV-3.

Table IV-5 shows the results of the correlation analysis for gauges in the study basin. This table includes the station or gauge which provides the best correlation for annual runoff, the correlation coefficient ($r^2$), the derived equation, and the number of years of record used to derive the relationship. Correlations were also made for Beaver Creek near Daniel and Horse Creek near Daniel since gauge records at these stations needed to be extended for input to Program WIRSOS.

The derived correlation coefficients are acceptable for this level of study and range from 0.7 for the La Barge Creek gauge to 0.97 for the correlation between North and South Piney Creeks. The North Piney gauge was extended using the Triple Peak snowpack data. South and Middle Piney and Cottonwood Creeks were then correlated to the North Piney gauge. These gauges could not be correlated with the Triple Peak snowpack since they did not have overlapping records. No extension of the La Barge Meadows gauge record was necessary for this study.

**Study Period**

A ten-year study period was selected for determination of storable flow at the project reservoir sites. The ten years
chosen were 1972-1981, which are the most recent years available. In addition, a long-term average runoff year was generated for each gauge site. The study period included both extremely wet and dry years in the basin, with 1977 being, generally, the driest year of record in the basin. Table IV-6 shows virgin flow at each of the study gauges for this period, as well as the computed long-term average annual runoff. The average year was computed by adjusting the average of the period of record by the ratio of the 52-year average for the Green River at La Barge gauge (gauge No. 22) to the average at gauge No. 22 for the period of record considered.

Table IV-6 also shows the 1972-81 average as a percent of long-term average for each gauge. Also included in this table are the Green River gauge Nos. 2 and 22 for comparative purposes.

Runoff at Project Sites

To estimate runoff at ungauged sites, unit runoff curves were developed for each year of the study period and for long-term average annual runoff using gauged data. Unit runoff in acre-feet/mile$^2$ was plotted against tributary area for each of seven study gauges. A relationship of runoff to tributary area was then derived for each year and used to predict the runoff at ungauged sites. Runoff at gauge No. 4, Horse Creek at Sherman Ranger Station, was consistently above the curve derived from the other gauges and was, therefore, omitted in the final determination of the unit runoff curves. Figure IV-8 shows the unit runoff curve derived for the long-term average annual runoff. The gauges used to derive the relationship had tributary areas ranging from 6.3 mile$^2$ for La Barge Meadows to 202 mile$^2$ for Cottonwood Creek. As noted
in Table IV-6, some runoff values for the South Piney Creek gauge (No. 16) were taken from the unit runoff curves rather than the correlation equation. Since the correlation equation for South Piney Creek was derived from only four years of data, it was not considered to provide a reliable estimate over the complete range of annual runoffs.

Annual runoff at three of the four on-stream reservoir sites was determined using the unit runoff curves. The runoff at La Barge Meadows was already established with the gauge data. The same unit runoff values were used at each of the three other sites; Fish Creek, Snider Basin and South Cottonwood Creek. The gauge sites used to determine unit runoff curves were all located on the mainstem of the tributaries below the branching of the tributaries. Unit runoff for the reservoir sites was determined considering all tributary area in a basin above the elevation of the reservoir site. This required consideration of all branches to the mainstem, not just the branch on which the reservoir site was located. Since the three sites are situated similarly in the basins at approximately the same elevations, unit runoffs corresponding to a tributary area of 50 square miles were used for each site. The unit runoff at each site was multiplied by the tributary area to obtain total annual runoff at each site. Table IV-7 shows the tributary area, the average annual unit runoff and total runoff for each site. The average annual runoff at each site ranges from 7,400 acre-feet at Fish Creek to 23,900 acre-feet at Snider Basin. Annual runoff was apportioned to monthly values using distributions from gauge records on each stream. The North Piney runoff distribution was applied to South Piney Creek and its tributaries due to the small amount of data available for South Piney Creek. The distribution on Middle Piney Creek was adjusted somewhat from
gauge records to account for storage effects in Middle Piney Reservoir. The distribution for La Barge Creek was applied to inflows below the La Barge Meadows gauge.

Runoff at additional locations was needed for program WIRSOS. These values were computed in the same manner as for project sites and the locations are noted in Chapter V under the WIRSOS Data Base.
<table>
<thead>
<tr>
<th>U.S.G.S. Gauge Number</th>
<th>LRCWE Gauge Number</th>
<th>Station</th>
<th>Elevation (ft)</th>
<th>Drainage Area Sq. Mi.</th>
<th>Average Annual Discharge Acre-ft/yr</th>
<th>Period of Record (Water Year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1880</td>
<td>1</td>
<td>Green River near Kendall</td>
<td>7,700</td>
<td>271</td>
<td>368,000</td>
<td>1910, 1920</td>
</tr>
<tr>
<td>1885</td>
<td>2</td>
<td>Green River at Warren Bridge</td>
<td>7,468</td>
<td>468</td>
<td>368,000</td>
<td>1910, 1920</td>
</tr>
<tr>
<td>1890</td>
<td>3</td>
<td>Beaver Creek near Daniel</td>
<td>7,440</td>
<td>141</td>
<td>24,180</td>
<td>1910, 1920</td>
</tr>
<tr>
<td>1895</td>
<td>4</td>
<td>Horse Creek at Sherman Ranger Station</td>
<td>7,771</td>
<td>43</td>
<td>49,480</td>
<td>1910, 1920</td>
</tr>
<tr>
<td>1900</td>
<td>5</td>
<td>Horse Creek near Daniel</td>
<td>7,350</td>
<td>124</td>
<td>46,120</td>
<td>1910, 1920</td>
</tr>
<tr>
<td>1905</td>
<td>6</td>
<td>Horse Creek at Daniel</td>
<td>7,185</td>
<td>173</td>
<td>83,140</td>
<td>1910, 1920</td>
</tr>
<tr>
<td>1910</td>
<td>7</td>
<td>Green River near Daniel</td>
<td>7,040</td>
<td>932</td>
<td>503,200</td>
<td>1910, 1920</td>
</tr>
<tr>
<td>1915</td>
<td>8</td>
<td>Cottonwood Creek near Daniel</td>
<td>7,220</td>
<td>202</td>
<td>50,460</td>
<td>1910, 1920</td>
</tr>
<tr>
<td>1920</td>
<td>9</td>
<td>Cottonwood Creek near Big Piney</td>
<td>7,070</td>
<td>227</td>
<td>55,390</td>
<td>1910, 1920</td>
</tr>
<tr>
<td>1925</td>
<td>10</td>
<td>Cottonwood Creek near mouth</td>
<td>7,000</td>
<td>238</td>
<td>13,430</td>
<td>1910, 1920</td>
</tr>
<tr>
<td>2055</td>
<td>12</td>
<td>North Piney Creek near Mason</td>
<td>7,520</td>
<td>58</td>
<td>41,370</td>
<td>1910, 1920</td>
</tr>
<tr>
<td>2060</td>
<td>13</td>
<td>Middle Piney Creek below So. Fork</td>
<td>7,980</td>
<td>34</td>
<td>20,420</td>
<td>1910, 1920</td>
</tr>
<tr>
<td>2065</td>
<td>14</td>
<td>Middle Piney Creek above Springman Cr.</td>
<td>7,700</td>
<td>42</td>
<td>17,940</td>
<td>1910, 1920</td>
</tr>
<tr>
<td>2070</td>
<td>15</td>
<td>Middle Piney Creek near Big Piney</td>
<td>7,500</td>
<td>46</td>
<td>17,940</td>
<td>1910, 1920</td>
</tr>
<tr>
<td>2075</td>
<td>16</td>
<td>South Piney Creek near Big Piney</td>
<td>7,234</td>
<td>117</td>
<td>29,050</td>
<td>1910, 1920</td>
</tr>
<tr>
<td>2077</td>
<td>17</td>
<td>Dry Piney Creek near Big Piney</td>
<td>7,150</td>
<td>67</td>
<td>2,720</td>
<td>1910, 1920</td>
</tr>
<tr>
<td>2080</td>
<td>18</td>
<td>LaBarge Creek near LaBarge Meadows</td>
<td>8,410</td>
<td>6</td>
<td>10,290</td>
<td>1910, 1920</td>
</tr>
<tr>
<td>2085</td>
<td>19</td>
<td>LaBarge Creek near Viola</td>
<td>6,890</td>
<td>172</td>
<td>65,610</td>
<td>1910, 1920</td>
</tr>
<tr>
<td>2090</td>
<td>20</td>
<td>LaBarge Creek near LaBarge</td>
<td>6,593</td>
<td>193</td>
<td>40,540</td>
<td>1910, 1920</td>
</tr>
<tr>
<td>2094</td>
<td>21</td>
<td>Green River near LaBarge</td>
<td>6,520</td>
<td>3,910</td>
<td>1,185,000</td>
<td>1910, 1920</td>
</tr>
<tr>
<td>2095</td>
<td>22</td>
<td>Green River near Fontenelle</td>
<td>6,490</td>
<td>3,970</td>
<td>1,140,000</td>
<td>1910, 1920</td>
</tr>
<tr>
<td>2100</td>
<td>23</td>
<td>Fontenelle Creek near Fontenelle</td>
<td>7,260</td>
<td>58</td>
<td>17,750</td>
<td>1910, 1920</td>
</tr>
<tr>
<td>2105</td>
<td>24</td>
<td>Fontenelle Creek near Herschler Ranch</td>
<td>6,950</td>
<td>132</td>
<td>52,670</td>
<td>1910, 1920</td>
</tr>
<tr>
<td>2110</td>
<td>25</td>
<td>Fontenelle Creek near Fontenelle</td>
<td>6,580</td>
<td>224</td>
<td>48,000</td>
<td>1910, 1920</td>
</tr>
<tr>
<td>2112</td>
<td>26</td>
<td>Green River below Fontenelle Reservoir</td>
<td>6,378</td>
<td>4,280</td>
<td>1,237,000</td>
<td>1910, 1920</td>
</tr>
<tr>
<td>2050</td>
<td>27</td>
<td>New Fork River near Big Piney</td>
<td>6,800</td>
<td>1,230</td>
<td>523,100</td>
<td>1910, 1920</td>
</tr>
</tbody>
</table>

*a Approximately
<table>
<thead>
<tr>
<th>Station</th>
<th>Wet Year</th>
<th>Dry Year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Year</td>
<td>Amount (AF)</td>
</tr>
<tr>
<td>Green River at Warren</td>
<td>1971</td>
<td>499,500</td>
</tr>
<tr>
<td>Bridge Gauge 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green River at La Barge</td>
<td>1972</td>
<td>1,853,000</td>
</tr>
<tr>
<td>Gauge 22, 21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>La Barge at Meadow</td>
<td>1971</td>
<td>15,100</td>
</tr>
<tr>
<td>Gauge 18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>North Piney Creek</td>
<td>1951</td>
<td>75,300</td>
</tr>
<tr>
<td>Gauge 12</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Table IV-2*

SUMMARY OF LONG-TERM GAUGING STATIONS

<table>
<thead>
<tr>
<th>Station</th>
<th>Wet Year</th>
<th>Dry Year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Year</td>
<td>Amount (AF)</td>
</tr>
<tr>
<td>Green River at Warren</td>
<td>1971</td>
<td>499,500</td>
</tr>
<tr>
<td>Bridge Gauge 2</td>
<td>1972</td>
<td>1,853,000</td>
</tr>
<tr>
<td>Green River at La Barge</td>
<td>1971</td>
<td>15,100</td>
</tr>
<tr>
<td>Gauge 22, 21</td>
<td>1934</td>
<td>395,700</td>
</tr>
<tr>
<td>La Barge at Meadow</td>
<td>1977</td>
<td>4,200</td>
</tr>
<tr>
<td>Gauge 18</td>
<td>1934</td>
<td>17,600</td>
</tr>
<tr>
<td>North Piney Creek</td>
<td>1951</td>
<td>75,300</td>
</tr>
<tr>
<td>Gauge 12</td>
<td>1934</td>
<td>17,600</td>
</tr>
</tbody>
</table>

*See Table IV-1 for period of record.*

*Gauge 22 and 21 are considered equivalent.*

*From correlation with Green River at Green River gauge by Wyoming Water Planning Program.*
<table>
<thead>
<tr>
<th>Climatological Station</th>
<th>Elevation (Ft.M.S.L.)</th>
<th>Growing Season</th>
<th>Effective Precipitation (in)</th>
<th>Irrigation Consumptive Use (in)</th>
<th>Effective Precipitation (in)</th>
<th>Irrigation Consumptive Use (in)</th>
<th>Crop-Weighted Irrigation Consumptive Use (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Merna</td>
<td>7,700</td>
<td>5/14-9/28</td>
<td>5</td>
<td>18</td>
<td>5</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>Big Piney</td>
<td>6,820</td>
<td>4/29-9/29</td>
<td>4</td>
<td>25</td>
<td>4</td>
<td>26</td>
<td>25</td>
</tr>
<tr>
<td>La Barge</td>
<td>6,830</td>
<td>4/22-10/9</td>
<td>4</td>
<td>30</td>
<td>4</td>
<td>32</td>
<td>30</td>
</tr>
</tbody>
</table>

a Computed using Jensen-Haise formula.

b Computed by using an average daily temperature of 40°F for plant growth to start and an average daily temperature of 43°F for plant growth to stop.

c 90% Pasture
  10% Alfalfa
### Table IV-4

**IRRIGATED AREA ON PROJECT STREAMS**

<table>
<thead>
<tr>
<th>Basin</th>
<th>Irrigated Area&lt;sup&gt;a&lt;/sup&gt; Acres</th>
<th>% Improved Hay&lt;sup&gt;b&lt;/sup&gt; (Alfalfa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cottonwood Creek</td>
<td>22,500</td>
<td>10</td>
</tr>
<tr>
<td>North Piney Creek</td>
<td>18,600</td>
<td>8</td>
</tr>
<tr>
<td>Middle and South Piney Creeks</td>
<td>19,100</td>
<td>19</td>
</tr>
<tr>
<td>La Barge Creek</td>
<td>7,900</td>
<td>13</td>
</tr>
</tbody>
</table>

Area weighted distribution = 12% Improved Hay

---

<sup>a</sup> Based on irrigated area mapping completed by Wyoming Water Planning Program.  
<sup>b</sup> From SCS Type IV Study; (Reference 3)
Table IV-5
RESULTS OF CORRELATION ANALYSIS

<table>
<thead>
<tr>
<th>Extended Gauge (Y)</th>
<th>Gauge or Station For Correlation (X)</th>
<th>Correlation Coefficient $r^2$</th>
<th>Equation for Predicting Annual Runoff</th>
<th>Years Overlapping Record</th>
</tr>
</thead>
<tbody>
<tr>
<td>(4) Horse Creek at Sherman Ranger Station</td>
<td>Rowdy Peak Snowpack</td>
<td>.84</td>
<td>$Y = (1881)X + 8778$</td>
<td>14</td>
</tr>
<tr>
<td>(8) Cottonwood Creek near Daniel</td>
<td>(12) North Piney near Mason</td>
<td>.95</td>
<td>$Y = 23,217.84e^{(2.491X10^{-5})}X$</td>
<td>16</td>
</tr>
<tr>
<td>(12) North Piney near Mason</td>
<td>Triple Peak Snowpack</td>
<td>.83</td>
<td>$Y = (1512.33)X + 2508$</td>
<td>16</td>
</tr>
<tr>
<td>(13) Middle Piney below South Fork</td>
<td>(12) North Piney near Mason</td>
<td>.94</td>
<td>$Y = .08718 X^{1.1544}$</td>
<td>15</td>
</tr>
<tr>
<td>(16) South Piney near Big Piney</td>
<td>(12) North Piney near Mason</td>
<td>.97</td>
<td>$Y = (1.7418)X - 16,779$</td>
<td>4</td>
</tr>
<tr>
<td>(19) La Barge near Viola</td>
<td>(21-22) Green River above Fontenelle Reservoir</td>
<td>.70</td>
<td>$Y = (.0776)X - 13,402$</td>
<td>9</td>
</tr>
</tbody>
</table>

(number) indicates reference number of stream gauge.
### Table IV-6
ANNUAL RUNOFF AT STUDY GAUGES FOR STUDY PERIOD

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Green River at Warren Bridge a</td>
<td>486,600</td>
<td>326,600</td>
<td>439,200</td>
<td>376,300</td>
<td>391,700</td>
<td>203,300</td>
<td>398,700</td>
<td>281,600</td>
<td>339,000</td>
<td>257,000</td>
<td>347,000</td>
<td>367,600</td>
<td>94</td>
</tr>
<tr>
<td>4</td>
<td>Horse Creek b</td>
<td>79,300 a</td>
<td>41,900 a</td>
<td>68,400 a</td>
<td>53,900</td>
<td>64,100</td>
<td>24,200</td>
<td>64,500</td>
<td>50,900</td>
<td>50,200</td>
<td>30,800</td>
<td>52,800</td>
<td>108</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Cottonwood Creek b</td>
<td>101,100</td>
<td>50,600</td>
<td>83,100</td>
<td>67,800</td>
<td>90,300</td>
<td>34,200</td>
<td>112,300</td>
<td>62,900</td>
<td>75,400</td>
<td>40,500</td>
<td>71,800</td>
<td>101</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>North Piney Creek b</td>
<td>59,100</td>
<td>31,200</td>
<td>51,200</td>
<td>43,000</td>
<td>54,500</td>
<td>15,500</td>
<td>63,300</td>
<td>40,000</td>
<td>47,300</td>
<td>22,300</td>
<td>42,800</td>
<td>102</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Middle Piney Creek b</td>
<td>28,100</td>
<td>13,500</td>
<td>23,800</td>
<td>19,500</td>
<td>25,600</td>
<td>6,000</td>
<td>30,400</td>
<td>17,900</td>
<td>21,700</td>
<td>9,100</td>
<td>19,600</td>
<td>19,300</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>South Piney Creek b</td>
<td>74,900 c</td>
<td>37,600</td>
<td>58,500 c</td>
<td>51,500 c</td>
<td>64,400 c</td>
<td>19,500 c</td>
<td>77,200 c</td>
<td>46,800 c</td>
<td>65,600</td>
<td>22,100</td>
<td>51,800</td>
<td>49,200</td>
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</tr>
<tr>
<td>18</td>
<td>La Barge Creek a,b</td>
<td>14,200</td>
<td>8,100</td>
<td>11,800</td>
<td>11,500</td>
<td>11,200</td>
<td>4,200</td>
<td>12,900</td>
<td>8,600</td>
<td>10,200</td>
<td>7,200</td>
<td>10,000</td>
<td>9,900</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>La Barge Creek b</td>
<td>130,400</td>
<td>70,400</td>
<td>91,500</td>
<td>87,600</td>
<td>92,700</td>
<td>24,100</td>
<td>98,000</td>
<td>56,000</td>
<td>80,400</td>
<td>40,100</td>
<td>77,100</td>
<td>75,800</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Green River near La Barge a</td>
<td>1,853,000</td>
<td>1,080,000</td>
<td>1,351,000</td>
<td>1,302,000</td>
<td>1,367,000</td>
<td>683,800</td>
<td>1,436,000</td>
<td>894,000</td>
<td>1,209,000</td>
<td>689,000</td>
<td>1,166,500</td>
<td>1,114,000</td>
<td>105</td>
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</table>

a Actual gauge record shown
b Virgin flow
c From unit runoff curves; correlation equation not used
<table>
<thead>
<tr>
<th>Reservoir Site</th>
<th>Tributary Area (sq.mi.)</th>
<th>Approximate Elevation (ft)</th>
<th>Average Year Unit Runoff (af/mi²)</th>
<th>Total Runoff (af)</th>
<th>Dry Year Unit Runoff (af/mi²)</th>
<th>Total Runoff (af)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fish Creek</td>
<td>12.0</td>
<td>7,900</td>
<td>620</td>
<td>7,400</td>
<td>235</td>
<td>2,800</td>
</tr>
<tr>
<td>Snider Basin</td>
<td>38.6</td>
<td>8,100</td>
<td>620</td>
<td>23,900</td>
<td>235</td>
<td>9,100</td>
</tr>
<tr>
<td>South Cottonwood</td>
<td>32.9</td>
<td>8,200</td>
<td>620</td>
<td>20,400</td>
<td>235</td>
<td>7,700</td>
</tr>
<tr>
<td>La Barge Meadow</td>
<td>6.5</td>
<td>8,500</td>
<td>-</td>
<td>9,900ᵃ</td>
<td>-</td>
<td>4,200ᵃ</td>
</tr>
</tbody>
</table>

ᵃ Actual Gauge 18 data.
FIGURE IV-2

TEN YEAR RUNNING AVERAGE

GREEN RIVER AT WARREN BRIDGE (GAGE #2)

TEN YEAR RUNNING AVERAGE
(1,000 Acre-Feet)
FIGURE IV-3

UPPER GREEN RIVER STORAGE

LA BARGE MEADOW

GAGE 18

AVERAGE MONTHLY RUNOFF

Leonard Rice Consulting Water Engineers, Inc.
DECEMBER, 1982

617 WWD 01
FIGURE IV-4

UPPER GREEN RIVER STORAGE
LA BARGE MEADOW
GAGE 18
DRY YEAR (1977) MONTHLY RUNOFF

Leonard Rice Consulting Water Engineers, Inc.

DECEMBER, 1982
FIGURE IV-5

UPPER GREEN RIVER STORAGE
NORTH PINEY CREEK
GAGE 12
AVERAGE MONTHLY RUNOFF

AVERAGE RUNOFF (Acre-Feet)

|||OCT|NOV|DEC|JAN|FEB|MAR|APR|MAY|JUN|JUL|AUG|SEP|
|---|---|---|---|---|---|---|---|---|---|---|---|---|
|0  | 1000 | 2000 | 3000 | 4000 | 5000 | 6000 | 7000 | 8000 | 9000 | 10000 | 11000 | 12000 |

Leonard Rice Consulting Water Engineers, Inc.  DECEMBER, 1982
FIGURE IV-6

UPPER GREEN RIVER STORAGE
NORTH PINEY CREEK
GAGE 12
DRY YEAR (1934) MONTHLY RUNOFF

RUNOFF (Acre-Feet)

OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP

Leonard Rice Consulting Water Engineers, Inc.

DECEMBER, 1982
FIGURE IV-7
UPPER GREEN RIVER STORAGE
DISTRIBUTION OF RUNOFF AND CONSUMPTIVE USE

% OF SEASONAL TOTAL

- % of Potential Irrigation Consumptive Use
- % of May-September Runoff North Piney Creek

MAY JUNE JULY AUGUST SEPTEMBER
FIGURE IV-8
UNIT RUNOFF CURVE

LONG TERM AVERAGE

\[ r^2 = 0.92 \]
\[ y = 3307x^{-0.697} \]

UNIT RUNOFF (AF/m²) vs. AREA (mi²)

USGS GAGE # (see Table IV-1)
This chapter presents the analysis and results utilizing all the information previously developed in the Water Rights and Hydrology chapters. The water supply analysis determined the amount of water available to meet the existing demands and supply project reservoirs in the Upper Green River Basin. The results of the analysis are estimates of monthly storable flow for each site.

Program WIRSOS

An integrated analysis for this study was completed with the use of the Wyoming Integrated River System Operation Study Model (WIRSOS) which was developed by Leonard Rice Consulting Water Engineers, Inc. as part of our engineering responsibilities for the Big Horn River Adjudication. Although the primary application of the model has been to evaluate the impact of Federal claims on state-awarded water rights, it can also be applied to the analysis of various water development alternatives such as those presented for this study, to determine the physical and legal availability of water under various streamflow conditions. Essentially, the program uses a step-by-step procedure to describe the
operation of the stream basin in terms of water supply (virgin flows), depletions (diversions less returns) and return flows by state-awarded water rights under the Wyoming prior appropriation system. The existing WIRSOS program has proven very successful, as applied to the entire Water Division 3, and has been accepted by the Special Master for the Big Horn River Adjudication as providing an accurate representation of historic operations. The program has been designed for maximum flexibility of operations and can be adapted to specific varying water rights operations, administration or other peculiarities within individual water basins, districts or divisions throughout Wyoming.

With the use of the WIRSOS model the existing watershed operations can be simulated and then analyzed with respect to potential future diversions or storage projects that are needed to fulfill the existing shortages within the project drainages. Numerous alternative solutions can be identified and analyzed with the use of the computer simulation and refined as additional administrative and historic practices are investigated and adopted.

The previous success and strengths of the WIRSOS program is due in part to the fact that it represents "real world" conditions and is not intended to be a theoretical
optimization model. To establish actual operations when considering complicated water rights procedures can only be accomplished by working closely with and by having the cooperation of people who actually operate the system and work within its bounds. To assist with the understanding of the various procedures and criteria that were established and utilized within the computer operation, the reader is referred to Figures V-1 and V-2 which describe the basic data, engineering analysis, assumptions and criteria utilized in the modeling effort. These flowcharts, in addition to the subsequent discussions, will help consolidate the various water resource engineering factors used in this water resource investigation.

**Water Demand Schedules** - Water demand schedules within the study drainages are primarily based on the permitted or certificated amounts of water for each water right under analysis. These include water right uses for industrial, domestic, direct flow irrigation and storage waters. Specific demand schedules for each of these uses were developed based on various factors. These include the use of actual diversion records collected and maintained by the Wyoming State Engineer's Office, the review of the previously derived irrigation consumptive use determinations which are representative of the demands required by the crop, a review of the streamflow information to determine the pattern of
water availability and interviews with local water officials. All of these considerations, in addition to our understanding of the various surface water rules and regulations promulgated by the State Engineer's Office for the diversion and storage of surface waters within the State of Wyoming, were used.

The specific diversion schedules developed for domestic and industrial use water rights were for year round diversions at their full permitted or certificated amounts. Since these demands typically represent year-round water usage it is reasonable to assume this diversion pattern for these rights.

For irrigation diversions, two separate diversion schedules were developed with the use of the operation model. Each of these diversion schedules are based on the available sources of information discussed above. The first schedule is reflective of the historic diversion demands placed upon the stream system by irrigators throughout the watershed. Based primarily on the diversion records collected by the Water Commissioner and interviews with him, specific schedule of diversions throughout the full irrigation season of May through September was developed. Although we are aware that many irrigators do not divert throughout this full season due to the lack of water supply, the diversion records indicate
that some irrigation diversions have been made throughout this season. The diversion schedule indicates increased diversions during the early part of the season which are associated with snowmelt runoff in the months of May and June. Runoff in subsequent months reflects a dramatic decrease in streamflows creating a water shortage situation throughout the watershed.

A second irrigation diversion schedule was developed to represent demands under a basin management scenario. This schedule is based not only on diversion records but also considers the irrigation consumptive use distribution. The effect was to reduce demands during the high runoff months of May and June, resulting in a seasonal increase in efficiency. The reduced demands during the high runoff season allow more water to be placed into storage in the project reservoirs. The only incentive for a user to reduce early season diversions would be if late season storage is provided to alleviate shortages. It is assumed that users of the project reservoirs would cooperate in some manner to make more water available for storage where possible. Storable flows have been developed for both demand assumptions.

Storage demand schedules were also established for existing reservoirs on the project streams. These reservoirs are
operated for primary and supplemental irrigation water supply. The offstream reservoirs, Sixty-Seven and McNinch No. 1 and 2, were assumed to fill early in the runoff season when excess water may be available and not required for direct flow irrigators. Evaporation and conveyance losses were estimated and accounted for. Demands from Sixty-Seven Reservoir were distributed over the irrigation season based on consumptive use distribution. Demands from the McNinch and Middle Piney Reservoirs were assumed to be for late season supply after the runoff peak had passed. Once the water is released from the reservoir, it is applied to the irrigated lands, partially consumed, and returned to the creek.

Other Water Resource Data for Model Purposes - In addition to the water demand schedules other factors were estimated and used in the computer simulation of the water rights operations. For the water rights information the permitted priority dates were used for modeling purposes. Based on the discussion in the Administration section of this study, it was determined that the model should operate on a strict prior appropriation basis as provided by the rules and regulations of the State Engineer's Office.

Additionally, a series of water use efficiencies were developed. For this study, the efficiency represents the amount of water that is depleted from the stream system by
the diversion and consumption of water. For the domestic diversions, we assumed a 10 percent efficiency, (10 percent of the water diverted is consumed and 90 percent returns to the stream). An efficiency of 100 percent was assumed for industrial uses which consist primarily of drilling operations. For direct flow irrigation diversions, two different efficiencies were assumed. For the demand pattern reflecting current irrigation practices, a seasonal efficiency of 30 percent was assumed. This is based on estimates used in previous studies (References 4, 5) and reflects the large volumes of water diverted during the early runoff season. Diversion records were not adequate to verify this assumption. For demands with basin water management practices, the efficiency was assumed to be 45 percent. This reflects the decreased early season diversions and subsequent reduction in return flows.

The last significant item required for the computer simulation is the effect of return flows associated with the application of irrigation waters. This is an important consideration since historic irrigation practices indicate significant augmentation to the stream by return flows late in the season. Therefore, the timing and location of returns are important to the overall operation of water rights throughout the drainage basin.
Based initially upon research of other computer simulation operations developed by the U.S. Bureau of Reclamation, as a part of previous responsibilities for the Big Horn River Adjudication, detailed ground water investigations were undertaken to estimate the delaying effects of return flows from irrigation. For this study, all available data on the geology of the Green River Basin in the project vicinity was evaluated and used to establish water conveyance characteristics to be used in a return flow analysis. The patterns developed and used were the result of the analysis of geology in the project drainages, the review of irrigated lands, diversion records, and of the use of ground water theories developed by Glover (Reference 6). With the use of this information a monthly distribution of percentages was developed to account for water returning to the stream in the subsequent months after diversion. These delaying effects have a dramatic impact on the late season streamflows associated with early season diversions.

Upon review of the irrigated area map developed by the S.C.S., the location(s) of return flows from each individual diversion were identified. These locations are shown on Figures III-2b through III-9b. The dashed lines shown on these figures identify the point associated with the return flows from the diversion of individual water rights along the streams. For those water rights where no dashed line is
identified, the return flows are assumed to return to the next downstream accounting point. Each appropriator within the drainage is then assigned a delay pattern, an efficiency and a location(s) of return flow. This information is incorporated into the operation of program WIRSOS.

**Storable Flow at Project Sites**

Program WIRSOS was operated to determine quantities of water which would be available for storage at the reservoir sites under the assumptions previously noted. For the Phase I study, no attempt has been made to identify project users, develop operating criteria for the reservoirs or investigate exchange options to enhance the firm yield of the reservoirs. During Phase II, such analyses will be made for the selected sites.

Estimates were made for the 10-year study period and a long-term average runoff year, as described in Chapter IV. Two assumptions of irrigation diversion demand on the project streams were considered. Consistent with the assumption of neglecting instream flow requirements in this phase, all excess water in the stream is reported as storable flow. These values would be reduced to the extent flows are required to be left in the stream. Each project site is considered separately, assuming not more than one project per
stream would be constructed. Tables V-1a through V-7a show estimated monthly storable flows under strict administration of water rights. Tables V-1b through V-7b show the increased storable flows which could result from reduced diversions during the early runoff season. The results are discussed for each site below:

1. Sixty-Seven Reservoir enlargement/McNinch Wash - The available supply for each of these sites is assumed to be equal. Both would divert from North Piney Creek in the vicinity of the existing Hughes Ditch. The water available for storage was considered to be that remaining after permits for the existing storage facilities, as well as the McNinch No. 3 permit, were satisfied.

2. Sand Hill Reservoir - This site would be supplied from both South and Middle Piney Creeks. Separate tables are included to show the water available from each creek. Approximately 70 percent of the supply would come from South Piney Creek.

3. Fish Creek - Located on a tributary to South Piney Creek, the available physical flow at this site is considerably less than at other sites. For this study, it was assumed that a portion of Indian Creek could be
diverted into Fish Creek during the non-irrigation season. Based on an average annual runoff of 620 acre-feet/mile$^2$ and 18 percent of the runoff occurring in October through April, approximately 200 acre-feet/year additional water could be made available at the Fish Creek site.

4. Snider Basin - The storable flows shown assume that flows from Coal Creek and Porcupine Creek would be available at the reservoir site. Loss of Coal Creek could reduce the storable flows by approximately 20 percent. Without both Porcupine and Coal Creeks, available flows would be 40 to 50 percent of those reported.

5. South Cottonwood Creek - The storable flows are computed assuming the site is below Bare Creek.

6. LaBarge Meadow - The tributary area above this site is small, but the runoff is good. The site is located 13 miles above the upstream irrigation diversions and is less affected by existing water rights than the other sites. Even under strict administration of water rights storage could occur in May and June during most years.
Evaluation and Conclusions

The tables of storable flows show that in most years storage could take place only during the non-irrigation season of October through April. Since only approximately 20 percent of the annual runoff occurs during this period, the storable flows are necessarily quite low. The storable flows under basin management practices illustrate the potential increase in yield which could occur with decreased diversion demands in May and June.

Storable flows for the offstream reservoirs were computed as all available water, assuming ditch capacity would be adequate to handle it. The tables show the peak months for which conveyance ditches would have to be sized to obtain such yields. Operation of conveyance ditches during the hard winter months may not prove to be practical, in which case yields would be less than shown. Approximately 30 to 50 percent of the storable flow is available from December through February.

The storable flows presented were computed without consideration for minimum flows below the reservoirs. To achieve these levels of storage would require drying up the stream during periods when storage occurs. It is likely that
some minimum flows will be required, thereby reducing the storable flows. The magnitude of such flow requirements have not been determined for this phase of the study. During Phase II, site-specific data at selected sites will be used to determine flow rates which would be necessary to maintain the desired stream habitat. Minimum flow requirements may also be applied to offstream reservoirs by requiring minimum flows in the creeks below diversion points.

Program WIRSOS was used to model all the project streams and the mainstem Green from Warren Bridge to Fontenelle Reservoir. Inflows to the Green River were added at Warren Bridge, Beaver Creek, Horse Creek, the New Fork River and Fontenelle Creek. It was verified that under existing development, no calls would go up the tributaries from the mainstem Green. A second run was made assuming greater use of Fontenelle Reservoir, including development of an additional 278 cfs direct flow demands for industry at Green River, and full use of the Seedskadee direct flow right of 1,140 cfs during the months of April through October. This analysis showed that, for the study period, these demands could be met while allowing the project reservoirs to store. However, an analysis was not made for a critical period of years on Fontenelle Reservoir. For the study period, carryover storage provided supply for the dry years and Fontenelle Reservoir was able to fill each year.
Estimates of the amount of lands which could benefit from supplemental water were made from the model runs. It is expected that permit holders which experience late season shortages could benefit from supplemental supply from the reservoirs. It was assumed that all rights "called out" during the month of August in an average year run of the computer model would provide a representative estimate of the quantity of land experiencing shortages. Table I-2 in Chapter I shows the acreage on each stream system. Middle and South Piney Creeks were combined for this analysis since users on the lower end of the creeks can usually obtain water from either source. The first column shown represents all adjudicated and permitted land which could experience shortage. The last column is adjusted downward to show the shortage based on actual irrigated area. This column represents the current irrigated lands which experience late season shortages in an average year. The areas range from 9,600 acres on Cottonwood Creek to zero at La Barge Creek.

This table provides a rough estimate of the comparative level of benefits which could result from each project. It is assumed that a project located on a stream system could provide benefits to any users on that system through direct release or exchange. For example, the Snider Basin Reservoir could benefit users on Fish Creek by allowing Fish Creek users to divert out-of-priority in exchange for releases from
the reservoir to South Piney Creek users. Utilization of one of the three offstream reservoirs would likely involve widespread exchanges for maximum benefit. It is assumed that either of the three offstream reservoirs could be utilized by exchange or direct release on any of North, Middle or South Piney Creeks.

Reservoir evaporation rates have been estimated at the project sites. The annual evaporation loss can be approximated by the net evaporation, which is total evaporation minus precipitation. The net evaporation rates for the project sites are estimated to be 2 feet per year for the three offstream reservoirs and 1 foot per year for the four upper reservoirs.

This phase of the study has identified the storable flow at each of seven reservoir sites so that yields at each site could be compared. It was determined that storage at the reservoir sites would be primarily affected by the water right situation on the local streams and that use on the Green River should not significantly affect availability for foreseeable demands. Ultimate development of pending permit applications on the Green could eventually lead to limitations on storage on the tributaries, but the timing or feasibility of these large Green River projects cannot accurately be predicted at this time.
For the project reservoirs, it has been shown that under strict administration of water rights, accounting for all adjudicated and permitted rights, storage would generally be limited to the non-irrigation season. Assuming a coordinated management scheme in a subbasin would provide increased yields by reducing springtime irrigation diversions and placing additional runoff into storage during this season. This would be a viable assumption to the extent that senior water right holders are made project beneficiaries.

During the next phase of the study, more detailed operation studies will be made for the site(s) selected for further study. The hydrology will be refined and reservoir operating criteria will be defined. Potential project users will be identified and potential exchange schemes will be investigated. Account will be taken for evaporation, conveyance losses and reservoir sedimentation. The result of the Phase II study will be firm yield estimates and recommended operating criteria for the selected site(s).
TABLE V-1a

MONTHLY STORABLE FLOWS IN ACRE-FEET

PROJECT: MCNINCH WASH / 67 RESERVOIR

STRICT ADMINISTRATION ASSUMPTION

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TABLE V-1b

MONTHLY STORABLE FLOWS IN ACRE-FEET

PROJECT: MCNINCH WASH / 67 RESERVOIR

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### TABLE V-2a

**MONTHLY STORABLE FLOWS IN ACRE-FEET**

**PROJECT: SAND HILL - SOUTH PINEY CREEK**

**STRICT ADMINISTRATION ASSUMPTION**

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Leonard Rice Consulting Water Engineers, Inc.
617WWD01
Dec. 1982
Table V-2b

MONTHLY STORABLE FLOWS IN ACRE-FEET
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TABLE V-3a

MONTHLY STORABLE FLOWS IN ACRE-FEET

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**MONTHLY STORABLE FLOWS IN ACRE-FEET**

**PROJECT**: SAND HILL - MIDDLE PINEY CREEK

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**NOTE:** An additional 200 acre-feet/year can be captured from Indian Creek.
### TABLE V-4b

**MONTHLY STORABLE FLOWS IN ACRE-FEET**

**PROJECT: FISH CREEK**

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Leonard Rice Consulting Water Engineers, Inc.

Dec. 1982
TABLE V-6a

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TABLE V-7a

MONTHLY STORABLE FLOWS IN ACRE-FEET

PROJECT: LABARGE MEADOW

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FIGURE V-1
DATA DEVELOPMENT FLOWCHART
WYOMING INTEGRATED RIVER SYSTEM OPERATION STUDY (WIRSOS) MODEL

**BASIC DATA**

- **RUNOFF**
  - U.S.G.S. Records for gauged basins

- **CLIMATIC**
  - Temperature
  - Precipitation
  - Solar Radiation
  - Evaporation
  - Snow Depth/Water Content

- **TOPOGRAPHIC**
  - Elevation
  - Watersheds
  - Irrigated Areas
  - Water Uses
  - Reservoirs

- **AGRICULTURAL**
  - Cropping Patterns
  - Growing Period
  - Diversion & Use Patterns

- **WATER RIGHTS**
  - Certificated Rights
  - Permitted Rights
  - Diversion & Use Patterns
  - Storage Operation

- **GEOLGY/SOILS**
  - Surficial Geology
  - Soil Characteristics
  - Aquifer Information
  - Slopes

---

**WIRSOS MODEL DATA BASE**

Adjust Records at Gauged Basins for Upstream Depletions

- Upstream Depletions
  - Irrigation
  - Municipal/Industrial
  - Reservoir Evaporation

- Consumptive Use of Irrigation Water
  - Penney-Criddle
  - Jensen-Haise
  - Published Studies

- Assess Priorities
  - Administration Criteria
  - Reservoir Operation

- Develop Diversion Schedules
  - Monthly Distribution
  - Amount Called
  - Irrigation Efficiency

- Return Flow Distribution
  - Surface & Ground Water
  - Time
  - Location
  - Amount

---

- Virgin Flow at Gauged Basins

- Correlation of Virgin Flow at gauged basins with Physical & Climatic Parameters
  - Area
  - Elevation
  - Precipitation
  - Snow Pack

- Complete Incomplete Records of Virgin Flow at gauged basins

- Apply Correlation Equations to derive Virgin Flow at ungaged locations (Accounting points)

- PHYSICAL AVAILABILITY
  - Virgin Flow

- LEGAL AVAILABILITY
  - Water Rights Operation

- BENEFICIAL USE
  - Divisions Less Returns

---

Leonard E. Consulting Water Engineers, Inc.
Dec. 1982
FIGURE V-2
MODEL OPERATION AND RESULTS FLOWCHART
WYOMING INTEGRATED RIVER SYSTEM OPERATION STUDY (WIRSO) MODEL

ASSUMED FUTURE DEVELOPMENT
ALTERATIVES AND DEMANDS
*Water Development Projects
*Federal Reserved Rights Claims

WIRSO MODEL DATA BASE

WIRSO MODEL OPERATION

PROCESS WATER RIGHTS
IN ORDER OF PRIORITY
*Irrigation
*Municipal
*Storage
*Power
*Industrial

OPERATE DIVERSIONS, USES
AND RETURN FLOWS
*Consumptive Uses
*Instream Flows
*Trans Basin Diversion
*Storage and Subsequent
Use

RESERVOIR OPERATION
*Storage
*Releases
*Evaporation
*Project Rights

WIRSO MODEL RESULTS

VIRGIN FLOW SUMMARY
*Annual, Monthly
*At All Accounting Points

PHYSICAL SUPPLY IN RIVER
*Annual, Monthly
*At All Accounting Points

LIST OF SHORTED WATER RIGHTS
*Project Number
*Location
*Priority
*% Net Net (Amount Shorted)
*Reason for Shortage

RESERVOIR OPERATION SUMMARY
*Contents
*Releases
*Loses
*Shortage
REFERENCES


APPENDIX A

COLORADO RIVER COMPACT
APPENDIX A

History of Colorado River Compact by Leonard Rice Consulting Water Engineers, Inc. A-1

Discussion of the Colorado River Situation as It Pertains to Wyoming's Compacted Water Use by Lou Allen, Wyoming State Engineer's Office A-5

Table Showing Estimates of Wyoming's Compact Supply A-12
THE COLORADO RIVER

Description

The Colorado River originates in the mountains of Colorado and flows southwesterly for approximately 1,300 miles through Colorado, Utah and Arizona, along the Arizona/Nevada and Arizona/California boundaries, briefly through Mexico and into the Gulf of California. Tributary waters are received from Wyoming, Colorado, Utah, New Mexico, Nevada, California and Arizona. With a drainage basin of approximately 242,000 square miles, the Colorado River basin encompasses practically one-twelfth of the area of the Continental United States, excluding Alaska.

Lee Ferry, in northern Arizona, is the dividing point on the river between the upper and lower Colorado River Basins. The Upper Basin includes, in addition to the natural drainage basins above Lee Ferry, all parts of Arizona, Colorado, New Mexico, Utah and Wyoming located outside of the drainage areas of the Colorado River system which are now or shall in the future be beneficially served by waters diverted from the system above Lee Ferry. These outside areas include the east slope areas of Colorado, the Wasatch front areas of Utah and important areas in New Mexico and Wyoming.

The Law of the River

The law of the Colorado River began with the move for the construction of Hoover Dam initiated by the Lower Basin states to regulate the flow of the river, control salt, generate power and remove the hazard of disastrous floods. The possible construction of a dam with a large storage capacity on the lower Colorado caused apprehension among the states of the Upper Division (Colorado, New
Mexico, Utah and Wyoming), that it would permit rapid expansion of water use in the Lower Basin which would eventually form the basis for claims of appropriated rights that would preclude the availability of water for the more slowly developing needs of the Upper Basin.

California and Arizona, however, were unable to finance the necessary projects and it was generally considered a Federal responsibility. The states in the Upper Basin, where most of the water originated, also had problems of floods and shortages and a much slower rate of population growth as compared to that in the lower reaches of the river. Southern California, particularly, was making an increasing use of the river and was thereby becoming more dependent upon its diversions from the river.

Because of their apprehension relative to the increased uses of water by the Lower Basin states, and because Congress had refused a request for construction of lower Colorado River projects until the seven Colorado River Basin states agreed on a division of waters of the river, an interstate compact was necessary. In 1921, Congress agreed to compact negotiations for the Colorado River, but required that the legislatures of all seven states, and Congress, approve the compact.

**Colorado River Compact**

The Colorado River Compact was signed at Santa Fe, New Mexico on November 24, 1922. Because the states were unable to agree on a seven-state division of water, the Compact did not allocate water to individual states but only divided the water between Upper and Lower Basin states. All of the states, except Arizona, agreed to the Compact and so the requirement that all seven agree had not been met. This impass was finally resolved when agreement was reached that six states could sign, including California, with a self-limiting declaration. The agreement was expressed by Congress in the Boulder
Canyon Project Act of 1928 which approved the Compact and authorized the Secretary of the Interior to construct Hoover, Davis and Imperial Dams, but only when the legislatures of six of the basin states, including California, ratified the Compact.

The Compact has been the subject of much disagreement and debate, and is often referred to as "the law of the river."

A treaty with Mexico apportioning waters of the Colorado River to Mexico had been anticipated in the Colorado River Compact, but was never regarded as a serious threat to the operation of the Colorado River Compact. In fact, however, the treaty has proven to be troublesome to all states of the Colorado River Basin and there is no agreement between the Upper Basin and the Lower Basin concerning the "deficiency" in deliveries to Mexico, as defined in the Compact.

Upper Colorado River Basin Compact

The use of waters apportioned to the Upper Basin under the Colorado River Compact is divided among the Upper Basin states by the Upper Colorado River Basin Compact, approved by Congress on April 6, 1949. This Compact also establishes the obligations of each state of the Upper Division with respect to the deliveries of water required to be made at Lee Ferry by the Colorado River Compact. It was ratified by the legislatures of all five upper Colorado River Basin states including Arizona (which in 1944 had at long last ratified the Colorado River Compact).

Colorado River Storage Project

During the negotiation of the Colorado River Compact in 1922, it was recognized that the flow of the Colorado River was highly erratic. Since records started in 1896, the virgin flow at Lee Ferry had ranged from a high of 24 million acre-feet in 1917 to a low of 5.6
maf in 1934. Without holdover storage above Lee Ferry there have been years in which no water would be available to the Upper Basin if a delivery of 75,000,000 acre-feet in every consecutive ten-year period were made at Lee Ferry in accordance with the Compact. To resolve this problem, and to provide a means for the full development of the water resources of the Colorado River system above Lee Ferry, the Colorado River Storage Project Act (CRSP) was enacted in 1956. The three major provisions of the Act include: 1) construction of the Glen Canyon Dam on the Colorado River in Arizona, Flaming Gorge Dam on the Green River in Utah, the Navajo Dam in New Mexico on the San Juan River, and the Blue Mesa and Morrow Point Dams on the Gunnison River in Colorado; 2) construction of participating projects in the Upper Basin subject to a finding of feasibility; and 3) establishment of the Upper Colorado River Basin fund from apportioned power revenues to assist in the repayment of participating projects.

Arizona vs. California

In 1930, Arizona had sought unsuccessfully to have both the Boulder Canyon Project Act and the Colorado River Compact declared unconstitutional as a means of preventing the building of Hoover Dam. In 1934, Arizona used National Guard troops to delay construction of Parker Dam. Finally, in 1944, Arizona reversed its position and ratified the Colorado River Compact. In 1952, Arizona initiated suit in the Supreme Court of the United States against California and seven public agencies of that State for confirmation of title to 2.8 million acre-feet of water from the Colorado River, as well as to all the water of the tributaries within Arizona and for limitation of use by California to 4.4 maf of water from the Colorado River System. The Supreme Court issued a long and complex decision in 1963 which is a significant factor in the development of the law of the Colorado River, but which has created as many problems as it solved.
DISCUSSION OF THE COLORADO RIVER SITUATION AS IT PERTAINS TO WYOMING'S COMPACTED WATER USE.

The discussion was prepared as a summary of the Colorado River regulatory situation and particularly to examine Wyoming's allotted water use under the Compacts, the Treaty with Mexico, and other constraints. Hopefully, it will provide a concise reference to address many questions that continue to arise. The uncertainties involved in arriving at firm figures for the beneficial consumptive use of water both present and future are noted, as are some of the physical limitations to full use of the compact water.

The Constitution of the State of Wyoming declares the waters of the State are the property of the State, and provides for the administration of those waters by the State. The Wyoming Statutes provide for the use of the State's waters under the appropriation doctrine of law whereby the earliest appropriator of water for beneficial use has the best right to its use. Water appropriation does not convey water ownership, only the ownership of a right to the beneficial use of a specified water flow rate or of a specified volume of stored water, subject to the laws of the State and the physical availability of water to the water right.

The 1922 Colorado River Compact divided the flow of the river between the Upper Basin and the Lower Basin, with the intent to allow 7.5 million acre-feet of annual consumptive use in each portion. A delivery by the Upper Basin of 75 million acre-feet in any consecutive ten-year period at Lee Ferry, Arizona, is required. Hydrologically, the Upper Basin may not be able to consumptively use its allotted 7.5 million acre-feet and still deliver the ten-year 75 million acre-feet required, since the long term average annual flow at Lee Ferry appears to be less than the 15 million acre-feet or more anticipated at the time of the Compact.

The Upper Colorado River Basin Compact of 1948 apportioned the water allocated to the Upper Basin under the 1922 Compact among the States of
the Upper Basin. Wyoming is to receive the consumptive use of 14 percent of the Upper Basin water, after deducting 50,000 acre-feet apportioned to Arizona for its Upper Basin drainage. The apportionment refers to man-made depletions and is restricted to beneficial uses. The Compact also apportions the waters of the Little Snake River between Wyoming and Colorado, and the waters of Henrys Fork between Wyoming and Utah.

A Treaty between the United States and Mexico (1944) includes the Colorado River. This basically requires the annual delivery of a minimum of 1.5 million acre-feet to Mexico. The obligations of the United States under this Treaty are protected in the Upper Colorado River Basin Compact of 1943. Court decisions and Federal legislation add to the constraints of the Colorado River operation.

The question of how much water Wyoming is entitled to consume from the system is not fully answerable at this time. The uncertainties include the long-term average annual flow of the river at Lee Ferry, corrected for depletions. There are uncertainties and estimations in calculating this virgin flow. The average annual flow is apparently less than the 15 million plus acre-feet anticipated when the 1922 Compact was drafted. The 1.5 million acre-feet delivery to Mexico is an obligation of the United States, but if there are less than 16.5 million acre-feet of average annual flow in the system, there may be a shortage to the Upper Basin Compact apportionments. How any shortage will be borne has not been adequately defined, beyond the delivery of 75 million acre-feet to the Lower Basin in any consecutive ten-year period. The unresolved questions of Federal reserved rights, Indian reserved rights, and who is to be charged with water wasted in order to meet salinity reduction demands further complicate the issue. For water available to future uses, there are uncertainties in the estimations of actual depletions, particularly reservoir and stock pond evaporation and irrigation consumptive use.

The Colorado River Storage Project (CRSP) has as one of its purposes the provision of storage in above-average flow years to meet the required delivery to the Lower Basin of 75 million acre-feet in any consecutive 10-year period. The CRSP consists of four units and a total of six reservoirs:
Lake Powell, Flaming Gorge, Navajo, Blue Mesa, Morrow Point, and Crystal. These reservoirs have a combined storage capacity of nearly 34 million acre-feet. Power revenues from the CRSP are shared by the Upper Basin States to help with the development of the water apportioned to the States. CRSP reservoir evaporation is also proportioned among the Upper Basin States as a part of the Upper Basin depletions of the Colorado River.

Davis Dam has been constructed as part of the Parker-Davis Project in the Lower Basin for the purpose of storing water to meet the 1.5 million acre-feet annual delivery required under the Treaty with Mexico. The reservoir, Lake Mohave, has an active capacity of 1,810,000 acre-feet.

With the storage provided by the CRSP for protection of the 1922 Compact delivery to the Lower Basin, and by Lake Mohave for protecting the delivery to Mexico required by the 1944 Treaty with Mexico, the Upper Basin States should not often be restricted in their Compact water uses. The States should, however, consider the long-term average annual virgin flow at Lee Ferry in determining their compacted depletions. Depletions based on this amount should not be curtailed except in times of severe and prolonged droughts.

Estimates of the total depletion of the system apportioned to Wyoming, 14 percent of the Upper Basin apportionment, range from 805,000 acre-feet to 1,043,000 acre-feet, depending upon the definitions, interpretations, and combinations of the above uncertainties. While the larger figure may not be realized due to the hydrologic situation, the State believes the amount may exceed the lower estimate by a significant amount.

There are about 445,400 acre-feet per year of surface water now being consumed in Wyoming from the Colorado River system. This depletion can be broken down as shown in Table I.
TABLE I

1981 Green River Basin Depletions in Wyoming*

<table>
<thead>
<tr>
<th>Use</th>
<th>1981 Depletion (Ac-Ft)</th>
<th>Percent of 1981 Depletion</th>
<th>Percent of 805,000 Acre-Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigation</td>
<td>254,700</td>
<td>57.2</td>
<td>31.6</td>
</tr>
<tr>
<td>Industrial</td>
<td>70,100</td>
<td>15.7</td>
<td>8.7</td>
</tr>
<tr>
<td>Municipal and Domestic, in-basin</td>
<td>4,400</td>
<td>1.0</td>
<td>0.5</td>
</tr>
<tr>
<td>Cheyenne Stage I Diversion</td>
<td>7,200</td>
<td>1.6</td>
<td>0.9</td>
</tr>
<tr>
<td>Livestock and Wildlife</td>
<td>8,500</td>
<td>1.9</td>
<td>1.1</td>
</tr>
<tr>
<td>In-basin Reservoir Evaporation</td>
<td>27,500</td>
<td>6.2</td>
<td>3.4</td>
</tr>
<tr>
<td>Wyo. Share of CRSP Evaporation</td>
<td>73,000</td>
<td>16.4</td>
<td>9.1</td>
</tr>
<tr>
<td></td>
<td>445,400</td>
<td>100.0</td>
<td>55.3</td>
</tr>
</tbody>
</table>

*Based on an analysis by the Wyoming Water Development Commission (WWDC) Staff, April 1981.

The depletions shown in Table I are from all of the Green River drainage - the Green River and tributaries above Flaming Gorge Reservoir; Blacks Fork and its tributaries, including Hams Fork; Henrys Fork and its tributaries; and the Little Snake River and its tributaries.

A summary display of Compact water available to Wyoming and its reduction by present level uses (1981) and committed uses, with remaining water available after each reduction, is given in Table II. Many of the entries in this table are, of necessity, estimates. There is room for disagreement in defining "committed". The "A" section of Table II shows between 161,500 and 399,500 acre-feet of depletion remaining to the State after present and committed basin-wide depletions are accounted for. The "B" section considers only the Little Snake River, with 78,600 acre-feet of potential depletion remaining after accounting for present and committed
TABLE II
Compact Analysis, Green River and Little Snake River Basins*

All units are acre feet

<table>
<thead>
<tr>
<th>Depletions</th>
<th>Little Snake River Water Available</th>
<th>Compact Depletion Allotted to Wyoming</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Low Est.</td>
</tr>
<tr>
<td>A. Available for Wyo. depletion</td>
<td></td>
<td>805,000</td>
</tr>
<tr>
<td>1981 Depletions (from Table I)</td>
<td>445,400</td>
<td></td>
</tr>
<tr>
<td>Remaining depletion for Wyo.</td>
<td></td>
<td>359,600</td>
</tr>
<tr>
<td>Committed uses:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exclusive of Little Snake</td>
<td></td>
<td></td>
</tr>
<tr>
<td>River, estimated</td>
<td>100,000</td>
<td></td>
</tr>
<tr>
<td>Little Snake River (see</td>
<td>98,100</td>
<td></td>
</tr>
<tr>
<td>below), estimated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total committed depletion</td>
<td>198,100</td>
<td></td>
</tr>
<tr>
<td>Remaining depletion for Wyo.</td>
<td></td>
<td>161,500</td>
</tr>
<tr>
<td>B. Little Snake River, remaining flow depletable by Wyo.</td>
<td>176,700</td>
<td></td>
</tr>
<tr>
<td>Committed Little Snake River</td>
<td></td>
<td></td>
</tr>
<tr>
<td>uses:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irrigation, permitted,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>undeveloped</td>
<td>20,100</td>
<td></td>
</tr>
<tr>
<td>Stage II, estimate</td>
<td>20,500</td>
<td></td>
</tr>
<tr>
<td>Stage III, estimate</td>
<td>30,000</td>
<td></td>
</tr>
<tr>
<td>New reservoir yield, estimate</td>
<td>27,500</td>
<td></td>
</tr>
<tr>
<td>Total Little Snake River</td>
<td></td>
<td></td>
</tr>
<tr>
<td>committed depletion</td>
<td>98,100</td>
<td></td>
</tr>
<tr>
<td>Remaining available for Little</td>
<td></td>
<td>78,600</td>
</tr>
<tr>
<td>Snake River depletion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. Remaining for compact depletion from Green River, Blacks Fork, and Henrys Fork, assuming that the remaining Little Snake River compact water (78,600 ac-ft) is developed from the Little Snake River</td>
<td>82,900</td>
<td>320,900</td>
</tr>
</tbody>
</table>

*Adapted from an analysis by the WWDC Staff, April 1981.
depletions. The "C" section shows between 82,900 and 320,900 acre-feet of potential depletion for the rest of the basin if all of the 78,600 acre-feet of depletion remaining to the Little Snake River was developed from the Little Snake River.

The potential depletion remaining for Wyoming use, 161,500 to 399,500 acre-feet, can be developed from any of the streams where sufficient unappropriated water is physically available. The key to how and where it is to be developed lies in the water rights system for appropriation of water for beneficial consumptive use. Apart from a portion of the Green River main stem under the provisions of the 1974 Fontenelle Contract, there are no restrictions upon where water can be diverted from the streams. "First in time is first in right" for appropriation of water. In reality, considering water availability, most of the remaining uncommitted Compact water (Table II, Section C) will probably be developed from the Green River. Much of the remaining 78,600 acre-feet of uncommitted Little Snake River depletion will likely be developed from that basin. If not, it will be lost to Wyoming use and the demand to meet water needs will fall on the remaining streams in the Green River Basin. The depletion of water from a given stream will obviously reduce the remaining Compact water, and the depletion of that amount from the other streams will be foregone.

Only a limited amount of future water needs can be met in the Basin without further storage development. Some storage space in Fontenelle Reservoir is still available for purchase. The reservoir has 190,250 acre-feet of designated active storage, but due to the "as built" rip-rap situation, only about 154,000 acre-feet of the active storage can be utilized. The bulk of the runoff in the basin coincides with the spring snow melt and, except for two or three months, the flows are relatively low for the remainder of the year. Unless storage space is available to capture water during the high flow period, future industrial and other uses requiring a steady supply are precluded. Most of the irrigation potential for large users has been developed, and future developments would require storage to be effective.

Stages I, II, and III of the Cheyenne Project incorporate storage, although it is out of the basin. The Stage III concept has been expanded
to include storage in the Little Snake River basin for in-basin uses. Proposals for major additional storage in the Green River Basin have not been acceptable to the general public. Fontenelle Reservoir, even if all 190,250 acre-feet of active storage space was available, could not have much impact on the roughly one million acre-feet annual flow in the Green River. The uncaptured Green River runoff can only flow out of the State and be lost to Wyoming use, unless storage space can be acquired in Flaming Gorge Reservoir and the water pumped back to its place of use. This approach appears to be uncertain at this time.
Estimates of Wyoming's Colorado River Compact water supply\(^1\),
Green River Basin, Wyoming

<table>
<thead>
<tr>
<th>Acre-Feet per Year</th>
</tr>
</thead>
</table>

### I. State of Wyoming

**A.** Based upon Article III (a) of the Colorado River Compact and the Upper Colorado River Compact:

- **Upper Basin Supply**: 7,500,000
- **Arizona Upper Basin Share**: 50,000
- **Wyoming's 14% share (salvage neglected)**: 1,043,000

**B.** Based upon R. J. Tipton's *Development of Presently Unused Water Supplies of the Green River Basin in Wyoming, October, 1972*, Tipton and Kalmbach (15). Water supply estimate and Article III (d) delivery requirements of 75,000,000 acre-feet each consecutive 10-year period:

- **Upper Basin Supply**: 6,300,000
- **Arizona Upper Basin Share**: 50,000
- **Wyoming's 14% share (salvage neglected)**: 875,000

The Mexican Treaty delivery has not been calculated. The Upper Basin has not agreed with the accounting of Lower Basin uses, losses, and tributary water flows and uses. PL 90-537 (Colorado River Basin Project Act, Section 202, 1968) declares the Mexican Treaty water deliveries to be a national obligation.

### II. U.S.S.R. - Most severe water supply hypothesis

**A.** Based on the assumption that the Upper Basin must deliver 750,000 acre-feet per year to Mexico under Article III (c) plus the delivery required by Article III (d).

- **Upper Basin Supply**: 5,800,000
- **Arizona Upper Basin Share**: 50,000
- **Wyoming's 14% Share**: 805,000
- **Salvage (reduction in channel losses)**: 31,000
- **Relief from Mexican Treaty**: 105,000
- **Total**: 941,000

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\(^1\) Source - Wyoming Water Planning Program
APPENDIX B

MEMORANDA ON WATER RIGHT ISSUES

by

Ray Petros

Kirkland and Ellis

Leonard Rice Consulting Water Engineers, Inc.
APPENDIX B

Minimum Streamflows in Wyoming  B-1
Pre-1945 Surplus Water Rights for Irrigation  B-4
Forfeiture of Wyoming Water Rights  B-8

FROM: Raymond L. Petros 

DATE: November 29, 1982 

RE: Minimum Streamflows in Wyoming 

FILE: Upper Green River Study 

QUESTION: What is the status of instream flow rights under Wyoming law? 

* * * * * 

In Wyoming, there are no express statutes authorizing appropriative rights for minimum streamflows, either by state agencies or by private parties. There is also no legislation which reserves or withdraws a certain percentage of the flows in Wyoming rivers for minimum streamflows. See Comment, "Statutory Recognition of Instream Flow Preservation: A Proposed Solution for Wyoming," 17 Land and Water L. Rev. 139 (1982) [copy attached]. Several instream flow bills have been introduced in the Wyoming Legislature during recent years, but none of them have managed to gain passage. 

The Wyoming Supreme Court has not addressed the issue of whether appropriations can be made for minimum streamflows. It has not, for example, decided whether a diversion from the stream is necessary to an appropriation, or whether an appropriation for instream uses is a beneficial use. As you are probably aware, there has been a split among the western appropriative states over these issues. See, generally, Comment, "Statutory Recognition of Instream Flow Preservation," supra. 

In this regard, I note that W.S. 1977, §41-3-101, which defines the nature of water rights and beneficial use, does not contain an explicit requirement for a diversion. Also, as discussed later, W.S. 1977, §41-2-112(a), appears to recognize instream flows as a beneficial use in connection with water projects developed by the Wyoming Water Development Commission.
In any event, I was informed by Mr. Larry Wolfe, Assistant Wyoming Attorney General for the State Engineer and the Commission, that the pervasive attitude in Wyoming is that specific statutory authorization would be required before the State Engineer would approve a permit for minimum streamflows. The State Engineer, however, has sanctioned incidental reservoir releases for minimum streamflows pursuant to an agreement between the appropriator and the United States Forest Service.

Absent special statutory recognition of minimum streamflows, it is theoretically possible that such flows could be required by the State Engineer as a condition for obtaining a permit to initiate an appropriation for other purposes. The Wyoming Constitution and the relevant statutes permit the State Engineer to deny permits on the basis that the proposed appropriation would be detrimental to the public interest. Wyo. Const. art. 8, §3; and W.S. 1977, §41-4-503. I was informed by the Mr. Wolfe that no minimum streamflows have yet been required by the State Engineer, and that no rules or regulations currently define the situations in which the State Engineer would do so. Mr. Wolfe also stated that, in his opinion, the current State Engineer would never require minimum streamflow releases without an express legislative directive to do so at the permitting stage.

It can also be argued that state agencies, such as the Wyoming Game and Fish Commission, have implied powers to initiate appropriations for minimum streamflows in order to accomplish their statutory mandates. For example, the Game and Fish Commission is "directed and empowered" to "acquire lands and waters in the name of Wyoming" for fish and wildlife purposes. See W.S. 1977, §23-1-302(a)(iii). These powers might be interpreted as authorizing the Game and Fish Commission to make minimum streamflow appropriations, although the cited section, perhaps significantly, does not specifically enumerate minimum streamflow appropriations as a means for acquiring waters for fish and game purposes.

Another source of authority for minimum streamflows might be the enabling legislation for the Wyoming Water Development Program by which the Wyoming Water Development Commission is authorized to identify and select water development projects. W.S. 1977, §41-2-112 (1982 Supp.), states in pertinent part:

"The program shall encourage development of water facilities for irrigation, for reduction of flood damage, for abatement of pollution, for preservation and development of fish and wildlife resources [and] for protection and improvement of public lands and shall help make available the waters of this state for all beneficial uses, including but not limited to municipal, domestic, agricultural, industrial, instream flows, hydroelectric power and recreational purposes, reservation and land
resources and protection of the health, safety and
general welfare of the people of the state of
Wyoming." [Emphasis added.]

Elsewhere, the same statute requires the Commission, when de-vel-
oping financing for development projects, to "emphasize multi-
purpose water projects for maximum benefits and cost allocation"
and also requires financing plans to reimburse expenditures of
state funds, except "as such expenditures may be allocated to a
state benefit, including enhancement of fish and wildlife habitat
for recreation...." Consequently, these statutes may be inter-
preted as imposing a duty upon the Commission to structure water
development projects in order to foster minimum streamflows for
fish, wildlife, and recreational purposes.

The foregoing discussion does not take into account the
role that the federal government may have in requiring minimum
streamflow releases. As you know, the federal government may
claim federal reserve water rights for minimum streamflows or
attempt to appropriate such flows as a matter of federal law.
Also, the federal government may require the minimum streamflows
as a condition for federal right-of-way permits for the construc-
tion of reservoirs on federal land or as a condition of federal
financing.

CONCLUSION

Wyoming statutes do not explicitly authorize appropropia-
tions for minimum streamflows, and, absent such express legislation,
is unclear whether such appropriations can be lawfully made.
However, minimum streamflows could, theoretically, be required by
the State Engineer at the permitting stage if he deems it to be
in the public interest, and instream flow recognition may be
statutorily required of any project sponsored by the Wyoming
Water Development Commission. If federal lands are involved,
minimum streamflows would likely be protected either as a
condition for obtaining right-of-way permits, or financing from
the federal government, or because of federal reserve rights or
federal appropriative rights in the affected streams. Thus, in
studying the various reservoir sites for the Upper Green River
Study, you should probably assume that some type of minimum
streamflow preservation would be required for the development of
a new reservoir, especially if the federal government is somehow
involved.

cc w/encl. Dean L. Swartz, Arix.
QUESTION: How are pre-1945 surplus water rights administered in Wyoming? Should these rights be considered when determining how much water is available for future appropriations on the Upper Green River?

* * * * *

Early Wyoming law established a duty of water for direct-flow rights for irrigation of 1 c.f.s. for 70 acres. See W.S. 1977, §41-4-317. However, when there was water in a stream in excess of the total amount of appropriations, the excess could be divided proportionately among the appropriators in excess of 1 c.f.s. per 70 acres if it could be beneficially used. See W.S. 1977, §41-4-317.

During the 1930's and 1940's, senior appropriators apparently became concerned that the growing number of appropriators would make less and less of this surplus water available for their use. See Comment, "Determining Quantity in Irrigation Appropriations," Land and Water L. Rev. 501 (1969) [copy enclosed for your information]. Consequently, in 1945, the Legislature passed an act (the Wyoming Surplus Water Law) providing that water flowing in a stream in excess of the total amount required by appropriators with rights prior to March 1, 1945 was surplus water and that a right to use this surplus water at a rate of an additional 1 c.f.s. for every 70 acres would attach to all direct flow water rights in being on March 1, 1945. See W.S. 1977, §§41-4-313 through 41-4-324.

All appropriators who qualified to use surplus water have a priority of March 1, 1945 for the surplus, and they are entitled to a priority senior to any water right acquired after March 1, 1945. In cases where there is surplus water available,
but an insufficient quantity to allow each appropriator to get the maximum allowable, then each pre-1945 appropriator is allowed the same proportion of the surplus as his rights to the total quantity appropriated from the stream by other pre-1945 users.

The practical effect is that appropriators with priorities before March 1, 1945 for direct-flow irrigation can, through the Surplus Water Law, get up to 1 c.f.s. per 35 acres—twice as much water as originally adjudicated by the state. Post-1945 appropriators, however, are still subject to the original statutory limitation of 1 c.f.s. for every 70 acres, unless there is excess water available for all appropriators. See W.S. 1977, §41-4-317.

The best statement of how these pre-1945 surplus rights are administered can be found in a Wyoming Attorney General Opinion, a copy of which I have enclosed for your review. See 1964 Op.Wyo.Att'y Gen., No. 29, p. 373 (May 4, 1964). This opinion was paraphrased by the Wyoming Supreme Court in Budd v. Bishop, 543 P.2d 368 (Wyo.S.Ct. 1975), as follows:

The Defendant [the State Engineer and subordinate officials] consistently have interpreted the Wyoming Surplus Water Law to the end that each water right with the priority date of March 1, 1945 or earlier, is entitled to divert water in the volume of two cubic feet per second of time for each 70 acres of land before any water is made available to the holder of a water right with the priority date after March 1, 1945. If there is not sufficient water to furnish two cubic feet per second to each pre-March 1, 1945 water right, but more than enough to furnish one cubic foot per second to each of such rights, then the surplus water is divided among those rights on a pro rata basis. If there is so little water that each pre-March 1, 1945 right cannot receive one cubic foot per second, they are regulated on a strict priority basis. Should there be sufficient water to furnish two cubic feet per second for each 70 acres of land to the pre-March 1, 1945 water rights and to furnish one cubic foot per second for each 70 acres of land for the post-March 1, 1945 water rights, and should there be excess water beyond that, it is allowed to the post-March 1, 1945 appropriators up to the extent of two cubic feet per second of time for each 70 acres. This interpretation, consistently applied by the State Engineer, was supported by an opinion of the Wyoming Attorney General dated May 4, 1964. . . .

543 P.2d at 370. In Budd v. Bishop, a constitutional challenge was made to the surplus water statute on various grounds, including that it abolished the priority system in awarding the surplus water rights, which are administered on a pro rata basis. The
Supreme Court dismissed the lawsuit on the basis that the plaintiffs did not have standing to make these constitutional challenges on the statute, and it therefore, did not address the question of whether the statute is unconstitutional.

Thus, direct-flow, irrigation rights prior to March 1, 1945 are administered in priority up to 1 c.f.s. per 70 acres. If there is surplus water available after such use, then the water is prorated among the pre-1945 users up to 2 c.f.s. per 70 acres if they can beneficially use the water. If there is still water available, then it is distributed in priority to water users with priority dates after March 1, 1945, and in the case of direct-flow irrigation rights, it is limited to an amount equal to 1 c.f.s. per 70 acres. If excess water is still available after satisfying all appropriators on the stream, then such excess water can be divided pro rata among the post-1945 irrigation users up to 2 c.f.s. per 70 acres. Unlike the pre-1945 surplus rights, however, the post-1945 excess rights can be defeated by new appropriations on the stream which can place a demand on the stream for that water.

It has long been Wyoming law that a water right is limited to the amount actually beneficially used, even though a larger amount of water has been adjudicated or established by statute. See Basin Electric Power Cooperative v. State Board of Control, 578 P.2d 557 (Wyo. S. Ct. 1978). Consequently, pre-1945 surplus water right can presumably be forfeited by nonuse just like any other water right. See 1964 Op.Wyo.Att'y Gen. No. 29, p. 373 (May 4, 1964); and Budd v. Bishop, supra.

CONCLUSION

Pre-1945 suprlus water rights are vested rights which you should take into account in your computer program for stream forecasts on the Upper Green. I was told by Mr. Larry Wolfe, Assistant Wyoming Attorney General representing the State Engineer and the Wyoming Water Development Commission, that it is unlikely that the State Engineer would ever bring a concerted action to forfeit these water rights. Consequently, the State must consider them as vested rights which can be used.

Inclusion of pre-1945 surplus water rights within your stream forecasts, however, may result in a finding that no unappropriated water exists in the river for new storage, even though in reality there is such water available. I have mentioned this problem to Mr. Wolfe and he stated that a new permit has never been denied, to his knowledge, in Wyoming because there was no longer any unappropriated water in the stream. He felt, though, that if this should ever become an issue, the State Engineer would consider streamflows based on both the amount of paper water rights and the amount of water that the applicant can actually show was put to use by irrigators along the stream.
It would be my recommendation, therefore, that pre-1945 surplus water rights be factored into your computer runs of stream forecasts, but that also a study be done as to the actual amount of water appropriated from the stream, based on actual irrigated acreage and the water requirements for such acreage. Both of these methods would be useful for determining whether a particular project is feasible and also would be useful at the permitting stage should the issue arise as to whether there is unappropriated water available for a new storage appropriation.

cc w/encl. Dean L. Swartz, Arix.
QUESTION: How are unused water rights forfeited in Wyoming?

* * * * *

W.S. 1977, §§41-3-401 and 41-3-402 (copies attached) provide that when any appropriator has failed, intentionally or unintentionally, to use surface, underground or reservoir water appropriated by him, whether under an adjudicated or unadjudicated right, for a period of five successive years, an action may be brought before the state board of control to declare a forfeiture of the unused water right.

Forfeiture, though, is not automatic after five years of nonuse. Forfeiture is only effective when a formal declaration of forfeiture is obtained from the State Board of Control. Sturgeon v. Brooks, 73 Wyo. 436, 281 P.2d 675 (1955); and Horse Creek Conservation Dist. v. Lincoln Land Co., 54 Wyo. 320, 92 P.2d 572 (1939). If the use of the water is resumed after five years of nonuse but before an action is instituted to forfeit the water rights, the water right cannot be subject to forfeiture. See Sturgeon v. Brooks, supra, and Horse Creek Conservation Dist. v. Lincoln Land Co., supra. See also W.S. 1977, §41-3-402(c) and (f). Consequently, absent a declaration of forfeiture, or until a forfeiture proceeding has been initiated, the owner of the water right still retains title to the water right and is justified in his resumption of the use of the water right. See Sturgeon v. Brooks, supra.

A forfeiture proceeding may be initiated by a "water user who might be affected" by a declaration of forfeiture. In determining which water users might be "affected," the Wyoming Supreme Court has held that an action for forfeiture can only be
initiated by another user who can clearly show that he will be benefited by the forfeiture—in other words by a junior appropriator who can show he would otherwise obtain the water. See Horse Creek Conservation Dist. v. Lincoln Land Co., supra. See also Note, "Forfeiture of Water Rights in Wyoming", 14 Wyo. L.J. 51 (1958).

The state engineer can also initiate forfeiture proceedings, but he only rarely does so because of manpower restrictions and the obvious political fallout. I was informed by Mr. Larry Wolfe, Wyoming Assistant Attorney General, that he was aware of only three or four occasions when the state engineer has ever initiated forfeiture proceedings.

Forfeiture is determined by the Wyoming Board of Control after notice to all interested parties and after a hearing. The burden of proving the nonuse for five years is on the party initiating the forfeiture proceedings. The burden of proving that water was not available, which would excuse the nonuse, is on the water user. See State Board of Control v. Johnson Ranches, Inc., 605 P.2d 367 (Wyo. S.Ct. 1980).


Forfeiture, as set forth in these statutes, should not be confused with the doctrine of abandonment, which depends upon a showing of an intent on the part of the water user to abandon his water right. In abandonment proceedings, no specific period of nonuse is necessary, although lengthy nonuse may be relevant for purposes of establishing the intent to abandon. Also, once abandoned, a water right cannot be resurrected by a resumption of use. Wyoming law is now unclear whether the statutory forfeiture procedures preclude traditional actions for abandonment. There is no statute expressly authorizing the state engineer to initiate abandonment proceedings, other than through forfeiture, or granting jurisdiction to the State Board of Control to determine abandonment. See Parshall v. Cowper, 22 Wyo. 385, 143 P.302 (1914); Note, "Forfeiture of Water Rights in Wyoming," supra.

cc w/encl. Dean R. Swartz, Arix.
Preliminary Geotechnical Evaluation
Upper Green River Project

A preliminary geotechnical evaluation was made of site conditions for eight potential dam sites under consideration in the Upper Green River Project area. This evaluation was based on existing reports on specific dam sites, regional geologic mapping and brief field inspections during September and October 1982. The purpose of this evaluation was to support comparisons of project alternatives and to select the best projects for feasibility analyses. This report is limited to general field conditions since no attempt was made to differentiate rock types or formations in the foundation and reservoir areas or to define specific borrow areas or quarry sites.

In general, three dam sites are situated in rolling plains type terrain and five sites are in mountainious terrain at higher elevations. The three plains sites are underlain by relatively soft rocks of the Wasatch Formation. This indicates that foundations materials will have generally less strength and that the potential for development of high foundation pore pressures is generally greater. In contrast, the higher elevation sites are underlain by hard, relatively strong sedimentary rocks with some exceptions. At the plains sites construction materials appear to be limited primarily to finer grained soils (sands, silts and clays) although terrace gravels may be present in adequate quantities. Potential sources of rip rap for slope protection were not observed at or near the three lower sites. At the higher elevations, glacial deposits and terrace gravels will probably provide good sources of shell or homogeneous fill material and fair to good rock sources are probably available for rock fill and rip rap. Sources of cohesive soils for core zones appear to be generally scarce.

In general, plains sites will probably require embankments with flatter slopes because of the relatively weak foundations and may require carefully designed seepage control measures such as blanketing, to control foundation pore pressures. Reservoir losses from seepage should not be a major problem unless there is a high percentage of soluble minerals that could result in internal erosion. This condition was not observed at any of the three sites,
but gypsiferous units were noticed in the vicinity and could be present. Spillway requirements will be less severe at the plains sites because they are off-stream storage sites. In contrast, the higher elevation embankments can probably be designed with steeper slopes, but larger spillways will be required and excavation and stripping will be more expensive involving at least some rock excavation.

The following is a brief description of each of the eight sites evaluated.

67 Reservoir Site

This existing dam and reservoir is situated in low rolling terrain, probably underlain by Wasatch clay shales interbedded with sands. There are indications of seepage at and below the downstream toe of the main embankment and saddle dike. This suggests that seepage control measures would be required if the embankments are raised or modified to control foundation pore pressures and possible internal erosion. The existing embankment characteristics as well as the foundation need detailed exploration to determine how they can be incorporated in a new embankment. Slope protection will be required against wave action. There was no obvious source of rip rap observed in the vicinity of the site and the nearest source is unknown.

McNinch Site

The foundation at this dam site appears to be primarily soft clay shales probably interbedded with sands that are nearly flat lying. There is also a thin appearing veneer of terrace gravels on the abutment ridges. An embankment 50 to 60 feet high will require detail exploration and testing to determine foundation strengths and permeabilities. Conditions that would indicate significant reservoir losses by seepage were not observed during the brief site visit. Fine
grained soils appear to be readily available for embankment construction. Free draining shell, filters and drain materials may be scarce. However terrace gravels may be thick enough along the western rim of the reservoir to provide a good source of shell material. Spillway requirements may be minimal but will require protection against erosion. Sources of rip rap for slope protection were not observed in the vicinity. The reservoir rim appears to have no major stability problems.

**Sand Hill Site**

Conditions at the Sand Hill site appear to be very similar geologically to the 67 Reservoir and McNinch sites. Test holes drilled in 1950 indicate sands and soft shales with about 30 feet of unconsolidated alluvium beneath the stream channel. A soft friable, sandstone is reported above elevation 7150 feet that is +40 feet thick and reportedly extends around the reservoir rim. The permeability was estimated to be 1000 gpd/ft^2 or 49,000 ft/yr. This is an exceptionally high permeability for the Wasatch Formation and is at least questionable since no permeability tests were reported. A permeability almost an order of magnitude (1/10) lower might be more reasonable and if so, reservoir losses would not be a problem as feared in the existing report. Even if the higher permeability exists, reservoir seepage losses (not including initial seepage losses and bank storage) are estimated to be less than 5 percent of maximum storage. At all of the plains reservoir sites there will be a high initial seepage loss during the first filling to saturate soils beneath and around the reservoir until a relatively stable regional ground water mound is established.

**Snider Basin Site**

At Snider Basin, two sites were visited: one upstream from the confluence of Porcupine Creek near the Pioneer Graves; and one downstream about 2000 feet below the confluence of Coal Creek on South Piney Creek. The upper site has a
The lower dam site has a channel section about 200 feet wide and alluvial fill probably averages about 10 feet deep. The foundation consists of interbedded sandstone siltstone, limestone and claystone dipping about 45° upstream. The right abutment is a broad, hogback spur formed by more resistant rocks. The left abutment consists of the same rocks with more uniform slopes. A good side-channel spillway site exists around the right abutment, across the spur ridge. Surficially, this site appears to be the best in the project area from a geotechnical standpoint. Limestone units are present but no solution cavities were noticed, which will be investigated more closely if this site is selected for feasibility analysis. In general seepage conditions appear to be minimal. No reservoir rim stability problems were observed.

The primary problem with the lower Snider Basin Site is a possible scarcity of impervious core materials. The terrace gravels in the reservoir area would probably be good shell material and probably have enough fines for a homogeneous embankment. Rockfill and rip rap sources appear to be readily available.

Fish Creek Site.

Generally good foundation conditions prevail at this site below the narrow alluvial valley starting from about the middle of the northeast quarter of section 27. Consolidated, strong sedimentary rocks composed of sandstone, limestone, shale and siltstone that dip 35° to 40° upstream compose the foundation. The
alluvial channel fill along the creek is generally 200 feet or less wide and the alluvium is probably less than 15 to 20 feet deep. A side channel spillway around either abutment may require relatively deep rock excavation. Good sources of homogeneous fill material appear to be present in the reservoir area. Rockfill and rip rap sources appear to be available at or downstream from the dam site. Reservoir seepage losses should not be significant and the reservoir rim appears to be stable. Overall, the Fish Creek Site is one of the better sites available from a geotechnical standpoint.

South Cottonwood Site

The foundation rocks beneath the site are complex structurally and are mapped as the Twin Creek Limestone. Rocks generally dip upstream at about 40°, but are deformed into an overturned anticline. Also, a small thrust fault reportedly passes beneath the site. In addition there are gravelly terrace deposits covering most of the broad gently sloping right abutment. The depth of these deposits are unknown and could contain a deep buried channel. The terrace deposits along with the limestone could result in seepage problems that would be difficult and expensive to control. There also appears to be some minor unstable slopes above the left abutment. Spillway conditions may be relatively poor, requiring lining to protect against erosion. Sources of construction materials appear to be similar to the Fish Creek and Snider Basin sites. Overall this site appears poor in comparison to the Snider Basin and Fish Creek sites from a geotechnical standpoint. It appears to be generally better than the La Barge and North Piney Creek sites although subsurface exploration could prove this opinion to be wrong.

La Barge Meadow Site

Foundation conditions at this site are relatively complex and several potential geotechnical problems would require careful investigation to develop adequate design criteria. The left abutment area is formed by a dip slope of thinly bedded Aspen Shales that strike parallel to the stream channel and dip
toward the stream channel parallel to the abutment slope. High foundation pore pressures can potentially develop along bedding planes and seepage control measures will be required. Undercutting of the dip slope during foundation preparation (stripping and excavation of a core trench) can cause severe slope stability problems.

The right abutment consists of deep glacial materials. Surficially, they appear to have a low permeability as evidenced by perennial ponds on the surface of these deposits. However, the glacial deposits may be underlain by highly permeable stream channel deposits that could result in reservoir seepage problems. In addition the Madison Limestone may underlie the western part of the glacial deposits.

Structurally, the immediate vicinity of the dam and reservoir area is very complex. Several major faults including the Absoroka Thrust Fault, intersect in this area. This could enhance the severity of foundation strength and seepage problems. The best spillway site is across the glacial deposits around the right abutment. The spillway would require protection against erosion.

Sources of construction materials are similar to the previously described mountain sites. A possible exception is that rockfill and rip rap sources may be more remote. No potential quarry sites were observed in the immediate vicinity of the dam site.

Overall there are many potential geotechnical problems with this site that are very difficult to quantify without detailed exploration. Relative to other sites and the size of the dam and reservoir, a much more detailed exploration and testing program would be required to develop adequate design criteria. It is obvious that the risk is very high in performing a feasibility analysis of a project incorporating this site, based on surficial work alone. Both design costs and construction costs could be much higher than can be logically estimated at this time.
North Piney Creek Site

An attractive reservoir site on North Piney Creek was inspected as an additional alternative. A massive landslide (or series of slides) forms the left abutment of this site and extends over 2 miles upstream along the left side (northeast side) of Apperson Creek. Immediately upstream from the dam site the landslide blocked the stream which has since breached the slide by erosion. The massive nature of this landslide suggests the possibility of a seismically induced event along with other mechanisms. (This further suggests that seismic design criteria should be analysed carefully for all dams planned in the region.) The landslide material appears quite clayey with a low permeability. The channel and right abutment foundations consist of strong sedimentary rocks that dip upstream at 25° to 30°+ and strike at a small angle to the stream channel. The best location for a spillway is around the right abutment. Slopes at this site are relatively steep and would require a deep excavation. Good sources of construction materials appear to be generally available.

The landslide does not preclude safe dam construction, but it would be relatively costly. In addition to careful stability analyses and foundation preparation, the steep side slopes of the canyon upstream consisting of landslide debris, would have to be extensively regraded to stabilize slopes to prevent blockage of the outlet. Also, part of the northeastern reservoir rim would probably require stabilization to prevent remobilization of slide material, particularly during reservoir drawdown. As at the La Barge Site, construction cost estimates at this site based on surficial information above, must be considered extremely weak.
APPENDIX C
Agency Responses
Dear Mr. Swartz:

In response to your request of November 9, 1982, we are providing the following comments concerning those potential reservoir sites located on the Bridger-Teton National Forest. At the outset I need to make clear that our comments are preliminary in nature, primarily addressing the major management concerns we are able to identify at this time. Should any of these sites be selected for further evaluation we would need more detailed information before any decision could be made.

For ease of reference we have grouped our responses into those applying to all sites and others which are more site specific. For all the sites, the Forest Service concerns can be subdivided by resource categories as follows:

**Recreation - Visual - Cultural - Historic Resources**

- There will be a need for recreation development planning to accompany dam construction planning.

- The drawdown effect on the shoreline scenery will need to be evaluated.

- A cultural resources survey and evaluation conducted by a qualified source will be required. This survey must be cleared by the Forest Service Regional Archeologist as well as the Wyoming State Historic Preservation Officer.

**Range Resource**

- Each proposed reservoir will create access problems for cattle trailing to ranges surrounding or upstream of the sites.

**Transportation System**

- For all sites other than Fish Creek main access routes onto the National Forest would have to be relocated.
- Scarcity of material sources for the dam would create long distance hauling and traffic problems.

Wildlife Resources

- There will be a significant loss of prime riparian habitat for many species including moose and deer.
- Instream flow needs, downstream of the reservoirs, must be taken into account.
- The possible disruption of big game migration routes and loss of key habitat will have to be evaluated.

Watershed Resource

- The geologic stability of shoreline slopes saturated by the reservoirs needs to be thoroughly evaluated.
- The potential for excess shoreline recession will have to be analyzed.
- The construction impact upon water quality must be considered.

Oil and Gas Development

- All the sites have the potential of occurring within existing, such as the Riley Ridge project, or future oil and gas field developments. Coordinated advance planning of any reservoir site with the oil and gas companies as well as the Forest Service is, therefore, essential.

Socio-Economic

- From the standpoint of public safety the type of dam and construction method needs to be evaluated.
- An analysis of the economics in terms of public costs and benefits will be required.

The following comments relate to the individual sites.

South Cottonwood

- Access to a timber sale area may be blocked.
- Some summer range currently under permit to one rancher will be lost.
- Access to an oil and gas test well operated by True Oil near Soda Lake could be blocked.
- The elk migration to the South Horse feedground might be disrupted.
- One segment of the old Indian Trail would be inundated.
- A potential historical site at the mouth of Lander Creek called Sjoberg Cabin #2 could be lost to the reservoir.
- Stability of slope on the north side of the creek immediately above dam site is questionable.

**Fish Creek**

- A landslide has occurred on the north slope in the vicinity of the dam site. This geologic condition may extend upstream from this location.
- Access for livestock to summer grazing above reservoir will be eliminated.
- There will be some loss of grazing to one permittee rancher.
- Access roads to construction area will be difficult to locate and build.

**Snider Basin**

- A portion of the Lander Trail and two grave sites associated with the trail will be inundated.
- A key access road to that portion of the National Forest will have to be relocated through steep and potentially unstable terrain.
- Approximately 70% of the South Piney Cattle Allotment which has five ranchers will be eliminated.
- The elk calving area on Porcupine Creek could be adversely affected.
- Access to the Forest Service work center will have to be provided.
- The fillslope stability on both north and south slopes in the vicinity of the dam site appears marginal.
LaBarge Meadow

- Of all the sites there appears to be more unstable shoreline at this location. The entire north slope above the reservoir has been previously identified as possessing high potential for landsliding due to saturation of the toeslopes. Likewise, there is an existing landslide at the west end of the reservoir. In addition, the same geologic condition which produced this landslide occurs to the southeast on a slope which would make up part of the shoreline. Also the moraine which would serve as the foundation and part of the southern arm of the dam should be carefully investigated for "piping" characteristics.

- The LaBarge road would have to be relocated since it connects to the Greys River and Smith Fork portions of the National Forest. Finding a stable relocation route will be quite difficult.

- The "meadow", which would be inundated by a reservoir, provides excellent range forage for livestock and outstanding wildlife riparian habitat.

- Roughly 60% of the permitted grazing of cattle would be lost to the reservoir.

- As this site is several miles from the National Forest boundary the instream flow needs become important - both Forest Service reserved water rights for watershed protection as well as fishery requirements.

- As presently situated, the meadow area possesses considerable natural beauty which it is doubtful the reservoir would equal - particularly with drawdown.

- A U.S.G.S. gauging station #09208000 would be eliminated.

- Another portion of the Lander Trail will be inundated.

From the foregoing, we can say at this time that the LaBarge Meadows and Snider Basin sites would have the greatest impact upon current uses within the Bridger-Teton National Forest. The South Cottonwood sites would be somewhat less, and the Fish Creek site the least. We would appreciate the courtesy of receiving a copy of your report to the Wyoming Water Development Commission when it is available.

Sincerely,

[Signature]

REID JACKSON
Forest Supervisor
Dear Mr. Swartz:

We have reviewed our records for archeological and historic sites which may be affected by development of the reservoir areas under study. None of the areas has been systematically surveyed for cultural resource sites but several sites are known to exist in the Sixty-Seven, Snyder Basin and LaBarge Meadow areas. The Green River area is known to have a high potential for archeological sites so there is a high probability that there will be some sites in any reservoir area selected for development. We recommend that after the preferred location has been selected, a Class III level (100% ground coverage) cultural resource survey be conducted to locate and evaluate the significance of any sites in the project area. A survey is generally required if there is any Federal involvement (i.e. funding, permits or lands) in the project.

Concerning the proposed Sand Hill Reservoir, it should be recognized that the historically significant Lander Cut-off of the Oregon Trail may be adversely affected depending on the actual shoreline, construction activities and final access routes and recreation areas, if any. Trail remnants will need to be examined in the field during the Class III survey for physical integrity. If original ruts remain, proper mitigative measures must be implemented to protect the trail. (Note: A 0.5 mile buffer zone is recognized by the SHPO.

We can provide you with details on survey methods and a list of qualified archeological consultants at your request. If you have any further questions, feel free to contact me at (307) 777-6292.

Sincerely,

Richard Bryan
Compliance Archeologist

Robert G. Rosenberg
Compliance Historian
Dear Mr. Book:

In response to your request I am submitting my opinion on fisheries mitigation measures desired in the event the reservoirs of the Upper Green River Storage project are constructed. These are tentative recommendations subject to revision as additional information becomes available.

Although a minimum pool is desirable in any reservoir I am unable to provide a recommendation without additional information.

Minimum stream flows (releases) based on the information provided should be one third of the average annual flow until results of more detailed studies concerning habitat availability at various flow levels are obtained. Flow recommendations based on 1/3 average annual flows are:

<table>
<thead>
<tr>
<th>Location</th>
<th>Flow (cfs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LaBarge Creek</td>
<td>4.7</td>
</tr>
<tr>
<td>Fish Creek Res</td>
<td>3.4</td>
</tr>
<tr>
<td>Snyder Basin, Upper</td>
<td>4.4</td>
</tr>
<tr>
<td>Snyder Basin, Lower</td>
<td>10.9</td>
</tr>
<tr>
<td>South Cottonwood Res</td>
<td>9.3</td>
</tr>
<tr>
<td>South Piney Creek</td>
<td>20.9</td>
</tr>
<tr>
<td>Middle Piney Creek</td>
<td>8.9</td>
</tr>
<tr>
<td>North Piney Creek</td>
<td>19.1</td>
</tr>
</tbody>
</table>

These recommendations are somewhat higher than minimum flows you provided on the preliminary hydrology table. However, the flows are significantly lower than flows you indicated for Sept., Oct., Nov., and April when fish are migrating and spawning (some species continue to spawn thru May).

A flush flow of "bank full" for at least 72 hours would also be desirable during the month of June in order to keep the channel clear of silt and trash. The interpretation of "bank full" is
subjective but is not likely to be as great as natural high water flows or would they be expected to last as long. Again, this is the best recommendation that can be made pending a detailed study. For purposes of roughly estimating water available for storage I suggest using the average monthly flow for June times 72 hours for a flushing flow.

In our discussion on October 5, 1982 it was mentioned storage would require almost total storage of all winter water flows to fill the reservoirs by the end of April, therefore I recommend the storage period extend through June which could provide additional benefits for flood control.

Impacts expected as a result of reservoir development would be negative, even with minimum pool and minimum flow considerations, at all sites except possibly Sand Hill, McNinch and 67 Reservoir. Failure to provide adequate minimum flows below diversion points on South Piney and North Piney could result in reduced land values (the presence of a trout stream commonly increases the sale value of property) for landowners in addition to lost public values associated with the fisheries.

The LaBarge Meadows site would flood a complex of stream channels and beaver ponds that are popular with many people. There are no specific figures available concerning use of the area but incidental observations during the summer of 1982 suggest an estimate of 500 to 1000 fisherman days/year would not be out of line. Creel checks indicate a catch rate of about 2 fish/hr. If we accept a conservative fisherman day as 3 hrs. there would be a catch of 1000 to 2000 fish of which almost all would be wild. To sustain similar catch rates in a reservoir would require a fishstocking program, probably using catchable trout since a fluctuating reservoir situation and slow growth rates would limit carry over of fish through the winter. A costly type program.

LaBarge Creek below the meadows and down to the confluence of the South Fork has a somewhat more limited, fishery, ie, fewer fish, but could be severely damaged by insufficient minimum flows. Impacts below that point would still occur but would decrease with each tributary entering LaBarge Creek. There is a good quality fishery below the South Fork confluence.

The Fish Creek site also includes the more popular use area for fishing on this stream. I do not have sufficient information to guess at current use or harvest. It would be safe to say that maintenance of a fishery would require the same consideration as the LaBarge Creek site.
Mr. Dale E. Book  
October 14, 1982  
Page Three

The upper site of the Snyder Basin would need the same consideration as the previous two sites, however, use and production would be considerably less.

The lower Snyder Basin site would flood about a mile of the more popular reach of river for fishing in an area containing wild trout. This area does not produce as many fish to the creel as does the LaBarge site or the Fish Creek site but it is an important nursery area for young fish that eventually contribute to a good fishery located downstream. It should be pointed out that failure to provide adequate minimum flows would severely damage the downstream fishery.

The South Cottonwood site would displace a nursery area for fish and would remove about a mile of moderately good stream fishing. A fish stocking program would be needed to maintain catch rates due to slow growth of fish that would be entering the reservoir from upstream and the loss of fish when the reservoir was drawn down. This is probably the least "damaging" of the four on forest sites. Minimum flow considerations would be necessary to avoid serious damage to downstream fisheries.

The Sand Hill Reservoir site has no fisheries values at present so any minimum pool recommendations, if any, for fisheries will require additional information. A minimum pool for other considerations is desirable and could enhance the existing situation.

There is significant potential to improve the existing fishery in 67 Reservoir. However, no effort to do so has occurred since access is restricted. The adjoining land owner if not the public in general would benefit from a minimum pool requirement.

A adequate minimum flow below the diversion on South Piney, Middle Piney and North Piney Creeks is recommended. Although the fish are owned by the state and should receive consideration accordingly. The potential influence of their exsistance on land values is an important consideration.

Another point for consideration is that Fish Creek, North Piney Creek and South Cottonwood Creek are now included in a management program intended to improve the status of the Colorado cutthroat trout. This fish is the only native trout in the drainage and is listed as a sensitive species by the BLM and as rare with declining populations by the Wyoming Game and Fish.

I hope these comments will be of value in preparing your report. Although the recommendations are general in nature any attempt
Mr. Dale E. Book  
October 14, 1982  
Page Four  

...to be more specific would be hazardous considering the time element and the information available. If I can be of more help please contact me.

Sincerely,

Glen T. Dunning  
Area Fisheries Supervisor  
Wyoming Game and Fish Department  
Pinedale, WY 82941

GTD: vg

CC: Mike Stone
ARIX

Riverton, WY

Gentlemen: The Historical Society met last Tuesday evening. Your proposed idea for the 7 dams was discussed. Some said they were better than another great dam and reservoir such as at Fontanelli. Some locations seemed ok. The two main objections were against the ones at the Barge Meadows and in Snyder Basin. I know it is hard to keep from crossing some of the old trails such as the Lander Cutoff at Barge Meadows is there another near location that wouldn't interfere as much? There are really a few places where the old trails can be identified. The place with the strongest objections was in Bridger Basin. My husband and Ed Caju wanted several graves with concrete markers and a January 1978 - Two men, David Bond and William Dunkin, and a 10 month old child. I'm sure there are another unmarked graves near this place. We had him a location where the pioneers seemed to have stopped to rest awhile, take care of the livestock, etc. about like the location at Pinedale Crossing, which there were many graves.
The reservoir on Alpenny Road seems objectionable to me. How far from Trinity? Would the replacement of the road be of a great inconvenience to anyone travelling in that area? What about the pipelines that would be covered—do any of the oil companies object?

It will take time to get all plans finalized and for any work to start. Don't know if our comments are timely help, but good of you to let the Historical Society know of your proposals. As irritated about you do, it want please everyone!

Sincerely,

Alice Harrison.