SAN LUIS VALLEY CONFINED AQUIFER STUDY
(PHASE I)
INTERIM TASK 1 REPORT
WATER DEMANDS/ECONOMIC ANALYSES

Prepared for
Colorado Water Resources and Power Development Authority
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1580 Logan Street
Denver, Colorado 80203

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Project No. 4332 August 19, 1986

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JOHN C. HALEPASKA & ASSOCIATES, INC.,
ROBERT E. MORAN AND ROBERT A. YOUNG
August 22, 1986

Mr. Ralph L. Kerr  
Project Manager  
Colorado Water Resources  
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Subject: San Luis Valley Confined Aquifer Study, South-Central Colorado: Submittal of Final Interim Task 1 Report. Project No. 4332, Task 1

Dear Skip:

As requested, we are pleased to submit one camera-ready copy of our final Interim Task 1 Report entitled "Water Demands/Economic Analyses". To the extent possible, we have incorporated your final review comments received orally on August 18, 1986.

Yours truly,

Timothy D. Steele, Ph.D.  
Water Resources Manager  
and Associate

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ACRONYMS AND ABBREVIATIONS

af   acre-feet
af/a acre-feet/acre
af/a/y acre-feet/acre/year
af/y acre-feet/year
bu   bushel
cwt   one-hundred weight
gpm   gallons per minute
gpd/ft gallons per day per foot
kWh   kilowatt-hour
mgd   million gallons per day
ton   ton
USBR  The United States Bureau of Reclamation
USGS  The United States Geological Survey
1.0 INTRODUCTION

The purpose of this task of the San Luis Valley Confined Aquifer Study is to: (1) evaluate existing and future demands for water obtained from the deep confined aquifer; (2) estimate unit annual costs to develop various annual water withdrawals; and (3) assess the current and future range of market values for various types of water use associated with the deep confined aquifer in the San Luis Valley of south-central Colorado. The information on water demand and market prices is compared with estimated annualized construction, operation and maintenance costs. From this comparison, the preliminary assessment of the ability of a development project involving the deep confined aquifer to pay for itself is made. Estimates of water demands, unit annual costs and market prices were done parametrically so that a large number of combinations are available for evaluation.

A brief literature review is included to summarize the documents available relating to water demands, water values and potential project costs. Water demands and water use in the San Luis Valley have been summarized by Siebenthal (1910), the U.S. Soil Conservation Service (1969), Huntley (1976), the U.S. Bureau of Reclamation (1979), Radosevich and Rutz (1979), Simpson and others (1980), the U.S. Army Corps of Engineers (1983), Steffen, Robertson and Kirsten (Colorado) Inc. (1985), and Salazar (1986). Economic analyses of water use and water market values also appear in several of the above reports as well as in Johnson (1975) and Skaggs (1985). Because of the everchanging water demand and economic variables in the San Luis Valley, the above references were used with certain qualifications in making the estimates presented in this report.
2.0 CURRENT WATER DEMANDS

Water demands in the San Luis Valley currently involve agriculture, domestic municipal and non-municipal use and Rio Grande Compact delivery demands. No current water demands are known to exist in the Valley for industrial use or hydroelectric power.

2.1 MUNICIPAL DEMANDS

Municipal water demands in the San Luis Valley are based upon population estimates available from the U.S. Census Bureau for the counties of Alamosa, Conejos, Costilla, Mineral, Rio Grande and Saguache (Table 2.1). Since 1900, population in the Valley has increased, reaching a maximum in 1940 and decreasing through 1970. Population trends since 1980 indicate a slight increase in population, with the estimated 1985 population for the Valley of 40,000, which is approximately the same as the Valley's population in 1930 (Table 2.1). These erratic population time trends are consistent with the agricultural nature of the Valley and the general pattern of young-adult migration from the Valley over recent periods in search of employment.

Table 2.1 estimates municipal water demands based upon population for the period 1900 through 1985, assuming a per-capita water demand of 250 gallons per day. It is understood that not all the Valley population derives its water supply through a municipal water system. However, basing municipal water demand on population appears to be a good estimator. As will be seen later, the total municipal water demand based upon population estimates is small compared to the aggregate agricultural water demand. Estimated 1985 municipal water demand was approximately 11,200 acre feet per year (af/y), if all the population of the Valley were to derive its domestic water supply from a municipal system.
<table>
<thead>
<tr>
<th>Year</th>
<th>Population&lt;sup&gt;(1)&lt;/sup&gt;</th>
<th>Municipal Water Demand&lt;sup&gt;(3)&lt;/sup&gt; (af/y)</th>
<th>Percent Change&lt;sup&gt;(2)&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>1900</td>
<td>23,272</td>
<td>6,517</td>
<td>--</td>
</tr>
<tr>
<td>1910</td>
<td>28,745</td>
<td>8,050</td>
<td>23.5</td>
</tr>
<tr>
<td>1920</td>
<td>31,868</td>
<td>8,925</td>
<td>10.9</td>
</tr>
<tr>
<td>1930</td>
<td>41,037</td>
<td>11,493</td>
<td>28.8</td>
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<td>1940</td>
<td>49,217</td>
<td>13,783</td>
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</tr>
<tr>
<td>1950</td>
<td>45,963</td>
<td>12,872</td>
<td>-6.61</td>
</tr>
<tr>
<td>1960</td>
<td>38,704</td>
<td>10,839</td>
<td>-15.8</td>
</tr>
<tr>
<td>1970</td>
<td>37,466</td>
<td>10,493</td>
<td>-3.19</td>
</tr>
<tr>
<td>1980&lt;sup&gt;(6)&lt;/sup&gt;</td>
<td>37,914</td>
<td>10,618</td>
<td>1.19</td>
</tr>
<tr>
<td>1985&lt;sup&gt;(4)&lt;/sup&gt;</td>
<td>40,107</td>
<td>11,232</td>
<td>5.78</td>
</tr>
</tbody>
</table>


(2) Percent change from previous number.

(3) Assuming a demand of 250 gallons per person (equivalent) per day.

(4) July 1985 estimates by the State of Colorado.

(5) For Alamosa, Conejos, Costilla, Mineral, Rio Grande and Saquache Counties.

(6) San Luis Valley Regional Planning and Development Commission.
2.2 AGRICULTURAL DEMANDS

Current agricultural water demands in the San Luis Valley were based upon inventories of current irrigated cropland totaling approximately 638,000 acres. This assessment of agricultural water demands and associated irrigated acreages has been derived from a detailed inventory by Salazar (1986). The total irrigated acreage is composed of approximately 39 percent irrigated pasture, 32 percent alfalfa and other hay, 17 percent barley, with the remaining 12 percent in grain oats, potatoes, spring wheat and vegetables. Agricultural statistics for 1960 through 1984 indicate that the total crop acreage during the period has increased from a low of about 305,000 acres in 1962 to nearly 420,000 acres in 1984, exclusive of irrigated pasture. Potato, spring wheat and barley acreages have substantially increased since 1960 at the expense of grain oats, alfalfa and other hay. Since 1974, spring wheat and potato acreages have more than doubled in the San Luis Valley.

Table 2.2 shows estimated water demands for the typical cropping patterns in the San Luis Valley. Estimated water demands were based upon consumptive-use estimates, reported irrigation efficiencies, and effective precipitation. It should be kept in mind that the agricultural water demands as considered in this study do not reflect on the water users' ability or willingness to pay for the resource. The unit water demands associated with irrigated agriculture were calculated by dividing estimated annual demand by the number of acres of irrigated crop. On the average, approximately 3.2 acre feet of water per acre of land (af/a) are needed to produce crops in the San Luis Valley. Of this amount, approximately 1.6 af/a is consumptively used by the plants, with the remaining 1.6 af/a going to other losses and return flows. The largest uncertainty in the volumes shown in Table 2.2 is associated with irrigated pasture. Estimates of total irrigated pasture acreage in the San Luis Valley range from 189,400 acres to over 247,000 acres. The actual irrigated pasture acreage is probably somewhere within this range. Also, estimates of evapotranspiration and irrigation efficiency for irrigated pasture assume that the pasture has received an adequate water supply. In some cases, farmers forego irrigation of pasture grasses, or these grasses receive only one irrigation per season because of limited water supplies in some years. The estimated unit water demands for irrigated crops in the San Luis Valley (Table...
### TABLE 2.2

Summary of Current Irrigated Cropland and Agricultural Water Demands in the San Luis Valley

<table>
<thead>
<tr>
<th>Crop</th>
<th>Acres</th>
<th>Percent of Total</th>
<th>Estimated Water Demand (af/y)</th>
<th>(af/a/y)</th>
</tr>
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<tbody>
<tr>
<td>Alfalfa Hay</td>
<td>111,800</td>
<td>18</td>
<td>402,500</td>
<td>3.6</td>
</tr>
<tr>
<td>Other Hay</td>
<td>88,900</td>
<td>14</td>
<td>337,800</td>
<td>3.8</td>
</tr>
<tr>
<td>Barley</td>
<td>105,500</td>
<td>17</td>
<td>211,000</td>
<td>2.0</td>
</tr>
<tr>
<td>Grain Oats</td>
<td>10,700</td>
<td>2</td>
<td>23,500</td>
<td>2.2</td>
</tr>
<tr>
<td>Potatoes</td>
<td>40,600</td>
<td>6</td>
<td>73,100</td>
<td>1.8</td>
</tr>
<tr>
<td>Spring Wheat</td>
<td>28,400</td>
<td>4</td>
<td>59,600</td>
<td>2.1</td>
</tr>
<tr>
<td>Vegetables</td>
<td>4,900</td>
<td>&lt;1</td>
<td>14,200</td>
<td>2.9</td>
</tr>
<tr>
<td>Irrigated Pasture</td>
<td>247,200</td>
<td>39</td>
<td>939,000</td>
<td>3.8</td>
</tr>
<tr>
<td><strong>TOTALS</strong></td>
<td>638,100</td>
<td>100</td>
<td><strong>2,060,700</strong></td>
<td><strong>3.2</strong></td>
</tr>
</tbody>
</table>

Consumptive Use 1.6  
Losses & Return Flows 1.6

---

(1) Adapted from Salazar (1986).
(2) Consumptive use divided by irrigation efficiency minus effective precipitation.
(3) Total demand divided by acres of irrigated crop land.
(4) All acreages rounded to nearest 100 acres; hence, total does not equal sum of individual crop acreages.
2.2) range from 1.8 acre feet per acre per year (af/a/y) for potatoes to 3.8 af/a/y for irrigated pasture and hay. The total estimated irrigation water demands in the San Luis Valley may be over 2 million af/y, based upon the estimate of about 638,000 irrigated acres. In years of below-normal water availability, probably as few as 500,000 acres are irrigated in the Valley, implying an estimated water demand of 1.6 million af/y under these conditions. If irrigated pasture were not considered in the estimates in Table 2.2, the annual estimated water demands are about 1,120,000 af/y, with a unit water demand averaging about 2.9 af/a/y.

2.3 RIO GRANDE COMPACT DEMANDS

The Rio Grande Compact of 1937 was signed by representatives of the States of Colorado, New Mexico and Texas on March 18, 1938. Minor changes have been made to the Compact in 1948 and 1966. Although the Compact was not strictly administered until 1968, it is very much in effect in recent times and essentially provides a downstream delivery obligation by the State of Colorado to the States of New Mexico and Texas. Due to large debits that were accrued by the mid-1960s, a stipulation was entered into by the three signatory states in 1968 in which the State of Colorado agreed to deliver each year's Compact commitment without building any further debt of water. Since 1968, the Colorado State Engineer has had the duty to curtail Colorado's water use in the Valley as necessary in order to meet the delivery requirements for each particular year. The Compact was intended to allocate surplus water and was not suppose to affect pre-Compact (pre-1937) water rights. However, since 1968, a severe curtailment of pre-Compact water rights has occurred in most years (however, not in 1986) in order to meet the Compact delivery requirements. One of the reasons for this curtailment has been the extensive water-well development that occurred in the San Luis Valley during the 1950s and 1960s. These ground-water rights have been more difficult to administer than surface-water diversions. This development, therefore, contributed largely to a situation whereby junior water rights (the wells) were being allowed to use water; whereas, senior water rights (some with priority dates as early as 1855) were curtailed in order to meet the provisions of the 1937 Compact (Steffen, Robertson and Kirsten (Colorado), Inc., 1985).
Two Rio Grande Compact administration tables exist for the State of Colorado: one for the Rio Grande mainstem and another for the Conejos River. The courts have ruled that these tables must be applied separately, requiring a separate delivery obligation from each sub-basin. Therefore, water demands used in this study show the Compact deliveries from the Conejos River and Rio Grande separately. Table 2.3 shows the historical annual deliveries to the Rio Grande Compact from the Conejos River and Rio Grande sub-basins. Since 1968, the historical Compact deliveries have averaged about 305,000 af/y, of which about 39 percent is from the Conejos River sub-basin with the remaining 61 percent from the Rio Grande sub-basin. A critical time of the year for agricultural water users occurs during the April-through-October irrigation season. Table 2.4 summarizes the historical April-through-October deliveries from both the Conejos River and Rio Grande sub-basins. Annual deliveries since 1968 for the April-through-October irrigation season average about 211,000 af, of which about 44 percent came from the Conejos River sub-basin, with the remaining 56 percent from the Rio Grande sub-basin. As indicated in Table 2.4 about, 61 percent of the total annual Compact delivery occurs during the April-through-October irrigation season.

For purposes of this study, it was assumed that the historical Compact deliveries were a measure of Compact demand (hence, the term "deliveries" is analogous to "demand"). Even though the 1985 delivery under the Compact terms was zero and no anticipated delivery should occur in 1986, average historical deliveries are considered to be an indicator of potential future compact-related deliveries. Therefore, an average Rio Grande Compact demand of between 211,000 af (April-through-October) and 305,000 af (annual) does not appear unreasonable.

2.4 SUMMARY

As indicated by the above review of available information, existing water demands for municipal water use in the San Luis Valley are small compared to agricultural use. Municipal water demands may average about 11,200 af/y. Agricultural water demands may be near 2,000,000 af/y, based upon 638,000 acres of irrigated acres with an average demand of 3.2 af/a/y of irrigated land.
### TABLE 2.3

Historical Annual Deliveries to Rio Grande Compact (1)

<table>
<thead>
<tr>
<th>Year</th>
<th>Conejos River (1000 af)</th>
<th>Rio Grande (1000 af)</th>
<th>Total (1000 af)</th>
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</thead>
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<tr>
<td>1968</td>
<td>116.7</td>
<td>214.1</td>
<td>330.8</td>
</tr>
<tr>
<td>1969</td>
<td>168.7</td>
<td>246.4</td>
<td>415.1</td>
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<tr>
<td>1970</td>
<td>109.4</td>
<td>214.1</td>
<td>323.5</td>
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<td>1971</td>
<td>50.1</td>
<td>156.7</td>
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<td>1973</td>
<td>188.9</td>
<td>331.8</td>
<td>520.7</td>
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<td>1974</td>
<td>32.7</td>
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<td>1975</td>
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<td>1985</td>
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<tr>
<td>1986(2)</td>
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</tbody>
</table>

Mean: 118.0 186.7 304.6
Std. Dev.: 80.4 98.8 173.8
Maximum: 231.3 394.5 625.8
Minimum: 0 0 0

(1) Source: Rio Grande Compact Commission reports.

(2) Estimated by Division 3 Engineer (not included in statistical summaries).
<table>
<thead>
<tr>
<th>Year</th>
<th>Conejos River (1000 af)</th>
<th>Rio Grande (1000 af)</th>
<th>Total (1000 af)</th>
<th>Percent of Annual Delivery(3)</th>
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<td>1968</td>
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<td>347.5</td>
<td>562.8</td>
<td>89.9</td>
</tr>
<tr>
<td>1980</td>
<td>195.0</td>
<td>172.1</td>
<td>367.1</td>
<td>81.3</td>
</tr>
<tr>
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<td>14.5</td>
<td>36.7</td>
<td>51.2</td>
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<tr>
<td>1982</td>
<td>205.6</td>
<td>132.6</td>
<td>338.2</td>
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<td>1983</td>
<td>148.8</td>
<td>136.0</td>
<td>284.8</td>
<td>73.4</td>
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<tr>
<td>1984</td>
<td>142.3</td>
<td>153.3</td>
<td>295.6</td>
<td>71.2</td>
</tr>
<tr>
<td>1985</td>
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<td>1986(2)</td>
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</tr>
</tbody>
</table>

Mean 92.9 118.2 211.2 60.8
Std. Dev. 76.8 88.9 160.0 20.2
Maximum 215.3 347.5 562.8 89.9
Minimum 0 0 0 26.8

(1) Source: Rio Grande Compact Commission reports.
(2) Estimated by Division 3 Engineer (not included in statistical summaries).
(3) Annual delivery shown in Table 2.3.
During dry years (below-normal precipitation), the demand may decrease to 1,600,000 af/y. Historical Rio Grande Compact deliveries have averaged 305,000 af/y with 211,000 af/y being provided, on the average, during the April-through-October irrigation season.
3.0 FUTURE WATER DEMANDS

3.1 MUNICIPAL DEMANDS

For purposes of this report, municipal water demands as indicated by Valley population are expected to increase, but with total demand remaining substantially less than agricultural demand (less than 1 percent). Therefore, we have estimated future municipal water demands to be similar or only slightly larger than existing municipal water demands, or approximately 14,000 af/y as a maximum. Hence, new municipal demands might be on the order of 3000 af/y.

3.2 AGRICULTURAL DEMANDS

Estimates of future agricultural water demands in the San Luis Valley were derived predominately from existing lands under irrigation whose water supply would either be curtailed by Compact deliveries or from a general reduction in surface-water supplies during drought years. Additionally, new lands are available which could be placed under irrigation if agricultural-product market prices were favorable.

Estimates have been made of presently irrigated lands in the San Luis Valley that are in need of supplemental irrigation supplies. Several estimates have been made, including those by the Rio Grande Water Conservation District (Ralph Curtis, personal communication, June 9, 1986) and HRS Water Consultants, Inc. (1984). The estimates of presently irrigated lands in need of supplemental irrigation ranges from 30,000 to 50,000 acres per year, although probably none of this land is irrigated pasture but rather is crop land growing hay, barley, grain oats, potatoes, spring wheat or vegetables. There may be over a 100,000 acres of irrigated pasture which does not receive an adequate water supply and would be available to receive supplemental irrigation water from a deep confined aquifer project. Exclusive of irrigated pasture, the annual unit water demand for the typical crop mix shown in Table 2.2 would be
about 2.9 af/a/y. If one-half of this unit irrigation demand (about 1.5 af/a/y came from a supplemental supply from deep confined aquifer wells, then the annual demand might range from 45,000 to 75,000 af/y for the 30,000 to 50,000 acres requiring such supplemental irrigation.

There appears to be no shortage of potential agricultural land in the San Luis Valley. However, development of new land requires large expenditures for land preparation (typically $40,000 to $50,000 for a 130-acre center pivot irrigation system) (LeRoy Salazar, personal communication, June 9, 1986). During the past several years, lower farm commodity prices have reduced the willingness of agriculturalists to expand their acreages under irrigation in the San Luis Valley. Estimates by the Rio Grande Water Conservation District (Ralph Curtis, personal communication, June 9, 1986) and HRS Water Consultants, Inc. (1984) indicate that between 40,000 and 75,000 acres of new land could be brought under irrigation with only minor favorable price adjustments in the farm-commodities picture. Assuming that these lands were used for irrigated crops other than irrigated pasture, at an annual unit demand of 2.9 af/a/y, the demand for water to irrigate these new lands would range from 116,000 to 218,000 af/y.

3.3 RIO GRANDE COMPACT DEMANDS

Future demands to deliver water under the Rio Grande Compact are based on historical deliveries to the Compact as summarized in Tables 2.3 and 2.4. Historical deliveries ranged from 0 af in 1985 to over 625,000 af in 1979, and averaged approximately 305,000 af/y for the period 1968 through 1985. Annual April-through-October deliveries were somewhat less, with a minimum of 0 af in 1985 and a maximum of nearly 563,000 af in 1979, averaging about 211,000 af/y for the 1968-through-1985 period of record. For purposes of this analysis, the historical Compact deliveries were assumed to be representative of those occurring over longer-term hydrologic conditions and to repeat themselves in the future. Therefore, annual deliveries are expected to average approximately 300,000 af/y and may range from a maximum of nearly double the average to zero for any given year.
In order to estimate future likely Compact demands, a log-normal probability distribution was fit to the annual and April-through-October deliveries (Tables 2.3 and 2.4) to estimate a likely delivery which would have to be met most of the time. The annual delivery occurring 90 percent of the time, based upon data in Table 2.3, is about 130,000 af/y. The April-through-October delivery occurring 90 percent of the time, based upon Table 2.4, is about 70,000 af/y.

3.4 CLOSED BASIN PROJECT

The U.S. Bureau of Reclamation's (1975; 1984) Closed Basin Project is undergoing completion of its final planned stages and may affect future-related Compact demands as well as in-Valley water uses. This is designed as a water-salvage project by lowering water levels in the shallow, unconfined aquifer through pumping, thereby reducing the evapotranspiration losses in the Project area. According to a USBR spokesman (Larry Parsons, personal communication, March 26, 1986), the expected maximum Closed Basin annual pumpage rates are allocated as follows:

1. 60,000 af/y to meet Colorado's commitment under the Rio Grande Compact

2. 5,300 af/y for wildlife mitigation

3. 35,300 af/y used to pay off any carryover Compact debts, or available for in-Valley use if the Compact debt has been reduced to zero (as is the case as of 1986)

Upon project completion, the first water amount (item 1) presumably could be conveyed to the Rio Grande, thereby reducing the previously described Rio Grande Compact demand reflected in historical (1968-1985) deliveries. The third water amount (item 3) would be available for in-Valley uses (predominately for irrigated agriculture) during those years when no Compact debt exists. Given the recent years' high flows in the Rio Grande, this debt is now zero, and up to 35,300 af/y pumped from the Project area would be available to meet future water demands.
3.5 SUMMARY

Based on the above assessment, potential future water demands used as a basis for the economic analyses and future project demands are summarized as follows:

1. Municipal demand: 3,000 af/y (new demand)

2. Agricultural demand: 45,000 to 75,000 af/y (supplemental)
   116,000 to 218,000 af/y (new lands)

3. Rio Grande Compact demand: 70,000 to 130,000 af/y (90 percent probability)

4. Water salvaged through the USBR's Closed Basin Project potentially could reduce projected demands given in the above items

Combinations of these future water demands could result in a maximum annual water demand of 437,000 af/y and a maximum April-through-October water demand of 377,000 af/y. In this study task, the proposed deep confined aquifer water-development project and associated economic analyses used a range of annual deep confined aquifer withdrawals of between 50,000 and 300,000 af/y. The maximum withdrawal of 300,000 af/y is judged to be an upper limit based upon professional judgments on aquifer hydraulic characteristics, as well as realistic well spacing and well yields in the Valley. For the parametric cases examined in this study-task report, the considered range of future water demands were assumed to be uniformly distributed throughout the year (see Cost-Sensitivity Analyses below).
Development of the San Luis Valley deep confined aquifer system would entail pumpage of the water from a wellfield located somewhere in the Valley. For purposes of this preliminary analysis, it was assumed that the wellfield would be centered at Hooper (Figure 4.1), although a typical wellfield could be located nearly anywhere in the Valley. To assess the economic impacts of pumping the wellfield, several assumptions regarding the depth and spacing of wells and the hydraulic characteristics of the deep confined aquifer system were made. The sensitivity of the assumptions are discussed in the following sections.

4.1 GENERAL CHARACTERISTICS

The costs of obtaining water from the deep confined aquifer system are sensitive to pumping lift, which is a function of annual water withdrawals as well as the estimated aquifer hydraulic properties. To estimate pumping lift, a preliminary analysis of the expected maximum wellfield drawdowns for various values of annual withdrawals, aquifer transmissivity, well spacing and individual well pumping rates was done. Figure 4.2 shows the number of pumping wells in a typical wellfield for annual withdrawals from the deep confined aquifer ranging from zero to 300,000 af/y, and for individual wells pumping 1000, 1500 and 2000 gallons per minute (gpm). For a typical annual withdrawal of 200,000 af/y, 124 wells pumping 1000 gpm would be needed. If the individual well pumping rate were increased to 1500 gpm, the same 124 wells would produce about 300,000 af/y. This 300,000 af/y also could be produced by 93 wells pumping at an average rate of 2000 gpm. Previous estimates from wells producing 3000 gpm (HRS Water Consultants, Inc., 1984) indicated that 62 wells would be needed to pump 300,000 af/y under their study assumptions.

Aquifer hydraulic characteristics of the deep confined system in the San Luis Valley are largely unknown. For purposes of our analysis, we have assumed that the transmissivity of the deep confined aquifer below 3000 feet would average 25,000 gallons per day per foot (gpd/ft), and above 3000 feet would average 250,000 gpd/ft. The higher transmissivity at shallower depths is in
general conformance with an areal map of transmissivities of the upper 1500 feet of the confined aquifer by Emery, Snipes, Dumeyer, and Klein (1973, Plate 7), which was based upon 36 Theis-recovery tests and flow-meter data, the latter being adjusted for the perforated intervals of the tested wells. The USGS analog-model study assumed a uniform transmissivity of approximately 300,000 gpd/ft for its "lower" (that is, approximately 1620 to 3120 feet below land surface) confined aquifer layer. The lower transmissivity at greater depths was based primarily upon professional judgment, with the consensus that transmissivities may well be an order of magnitude less at the depths considered in this analysis. Also, earlier artesian-well transmissivities values ranged about the smaller assumed value (Powell, 1958). The storativity was assumed to be on the order of 0.0001 (or 10^-4). This represents an average value for confined aquifers reported by Driscoll (1986) and is compared to a 0.008 storativity value assumed by Emery, Patten, and Moore (1975) in the USGS analog-model study.

We have estimated the drawdown in typical wellfields for wells having pumping rates of 1000, 1500 and 2000 gpm for the above assumed transmissivities as well as for well spacings of 5 miles and 2 miles. Results of our analyses for the 5-mile well spacing is shown on Figure 4.3 for wells having pumping rates of 1000 and 2000 gpm, transmissivities of 25,000 and 250,000 gpd/ft, and annual withdrawals ranging from 50,000 to 300,000 af/y. In all cases of the drawdown estimates, we assumed that the deep confined aquifer was infinite in areal extent and that the initial water surface was coincidental with the land surface. Therefore, the maximum wellfield drawdowns shown on Figure 4.3 represent depths below ground surface.

Drawdowns for the deep confined aquifer in the San Luis Valley having a transmissivity of 25,000 gpd/ft ranges from about 700 feet (ft) to over 3,000 ft, depending on the pumping rate of the individual wells. For an assumed transmissivity of 250,000 gpd/ft, drawdowns ranged from about 100 to slightly over 500 ft, depending on the pumping rates of individual wells. The above drawdowns assume continuous pumping for a period of ten years. It was judged reasonable that if the project life was 30 years, then maximum drawdowns at the 10-year time period would be representative of average wellfield drawdowns over the assumed 30-year lifetime of the project. When the well spacing was decreased from 5 miles to 2 miles with aquifer characteristics as pre-
viously assumed, drawdowns generally doubled for the larger annual withdrawal rates at the end of one year and were about 50 percent greater at the end of 10 years of pumping (Figure 4.3).

The assumption that the deep confined aquifer is infinite in areal extent will tend to produce a best-case scenario in terms of pumping lift. Physically, it is realized that the deep confined aquifer is bounded, and therefore expected pumping lifts could be greater than those predicted by the assumption of infinite areal extent. Because there are no data on aquifer hydraulic characteristics for the deep confined system, it was judged that a more complete analysis using boundary conditions on the aquifer was not warranted.

For the economic analyses performed below, we used the drawdowns calculated at the end of ten years of continuous pumping for a wellfield having a 5-mile well spacing, well pumping rates of 2000 gpm, and a transmissivity of 25,000 gpd/ft. The drawdowns for these assumptions for various annual withdrawals ranging from 50,000 to 300,000 af/y are shown as the uppermost curve on Figure 4.3. These drawdowns range from about 900 ft for an annual withdrawal rate of 50,000 af/y to over 3,000 ft for an annual withdrawal rate of about 300,000 af/y. Our economic analyses also assumed that pumping would be year-round. The above assumptions generally conform to a reasonable but quite severe case involving water withdrawals from the deep confined aquifer system in the San Luis Valley. The consequences of these assumptions are examined below in the sensitivity analyses.

4.2 POTENTIAL WATER-DEVELOPMENT PROJECTS

Two potential water-development projects (Base Cases 1 and 2) have been identified for purposes of this study, based upon the above-described future water demands in the San Luis Valley. These projects have been analyzed at selected levels of annual withdrawal from the deep confined aquifer ranging from 50,000 to 300,000 af/y. Both of the potential projects would have a wellfield ranging from 16 to 124 wells (excluding standby wells) completed at average depths of either 3000 or 5000 ft below ground surface. The first project
(Base Case 1) would have 5000-ft deep wells and discharge its water to existing facilities for transport from the wellfield to its point of use. Because the exact location of the wellfield is unknown as well as the exact points of use, existing ditches and canals were assumed for transport to in-Valley use locations. The second project (Base Case 2) is similar to Base Case 1 except the wells are 3000 ft in depth.

An additional separate cost analysis was made whereby differing quantities of San Luis Valley deep confined aquifer water would be transported into the Arkansas River. The intent of the water-export addition to the base cases was to assess the feasibility of sale of a part of the San Luis Valley developed water to help defray the costs of project development for in-Valley use. Realistically, the water transported out of the Valley would be sold at prices substantially higher than the value of that same amount of water if used in the Valley, and such export could help to subsidize in-Valley water use.

Because the exact location of the proposed wellfield, points of use and quantities of use are not known with any degree of certainty, the in-Valley project consists of a generic wellfield, which for cost estimating purposes was assumed to be centered in the vicinity of Hooper (Figure 4.1). Changes in the location of the wellfield, while effecting costs slightly, would not in our opinion change the overall cost structure of a typical potential Valley project.

Because of the relative uncertainty as to the actual water demands in the San Luis Valley coupled with the anticipated value of water used for agriculture (the largest potential demand), it was assumed that part of the water pumped from the deep confined aquifer wellfield would be transported out of the Valley into the Arkansas River for subsequent transport and sale at prevailing Colorado Front Range municipal prices. This addition to the base-case projects has two alternative pipeline routes from the wellfield centered at Hooper (Figure 4.1). The first pipeline route is north along State Route 17 to U.S. 285 to the top of Poncha Pass and ends at the Arkansas River at Poncha Springs, comprising a distance of about 56 miles and an elevation change of approximate-
ly 1460 feet. At Poncha Pass, the pipeline would flow by gravity to confluence with the Arkansas River near Poncha Springs. An alternate pipeline route of 49 miles also would follow State Route 17 to U.S. 285 as far as Villa Grove, and then proceed east over the Sangre de Cristo Mountains through Hayden Pass (Figure 4.1). The pipeline then would flow by gravity into the Arkansas River near Coaldale. The elevation change of this alternative route is 3350 feet.

4.3 FINANCIAL ANALYSES

The economic analyses presented below examine the costs of pumping deep confined aquifer water from the wellfield in the San Luis Valley without delivering the water to any specific location within the Valley, and transport of all or any of the water outside the Valley. The average annual withdrawals from the deep confined aquifer system were assumed to range from 50,000 to 300,000 af/y. In-Valley costs were estimated for project construction, including the cost of wells, pumps and interwell pipe. For transport outside the basin, costs for booster stations and a transportation pipeline were estimated. Also included were interest during construction, start-up costs, working capital, owners' general expense, and land costs. Annual operation and maintenance costs including labor, supplies and materials, along with electric power costs were estimated. These costs were annualized with the total annual costs including annual operation and maintenance (O&M), annual depreciation and non-depreciation capital costs. Unit annual costs were obtained by dividing the total annual cost ($) by the annual water withdrawal (af). These unit annual costs ($/af) thus formed the basis for comparison of different project alternatives. The cost estimates were made using the computer-program COST as described in Appendices A and D. The detailed cost estimates for Base Case 1 and Base Case 2 are shown in Appendix B, along with the detailed cost estimates for the transport to the Arkansas River by two alternative routes.

Certain cost factors were assumed to be constant for each base case and transport additions, although they were allowed to vary during the sensitivity analyses. These cost factors include the following assumed values: $0.065/kilowatt-hour (kWh) for electricity, 70 percent pumping efficiency, pipe-
friction coefficient of 135, land costs of $1000 per acre, annual interest rate of 7 percent, annual insurance rate of 1 percent, and an annual tax rate of 0.25 percent. The unit power cost was judged to be representative of electricity made available to irrigators in the Valley (Ralph Curtis, personal communication, June 9, 1986). The assumed pumping-efficiency level incorporates a number of physical and time-dependent factors and is judged to represent a realistic average value. The pipe-friction coefficient was based upon professional engineering judgment. The economic-based cost factors were judged to represent reasonable average values. The 7 percent annual interest rate represents a non-inflationary rate judged depicting the average cost of obtaining capital for water-development projects by private-sector interests. Annualized costs were amortized over an assumed 30-year project life. Figure 4.4 shows the results of the water-development cost estimates in terms of unit annual costs in both dollars per acre-foot ($/af) and cents per thousand gallons versus annual withdrawals from the deep confined aquifer.

Base Case 1 consists of 5000-ft deep wells pumping 2000 gpm, a transmissivity of 25,000 gpd/ft, storativity of $10^{-4}$ and a 5-mile well spacing. Annual unit costs of water for annual withdrawals ranging from 50,000 to 300,000 af/y vary from $123/af to $318/af to bring the water to the surface without transport (Figure 4.4). Base Case 2 consists of 3000-ft deep wells pumping 2000 gpm, a transmissivity of 250,000 gpd/ft, storativity of $10^{-4}$ and a 5-mile well spacing. Annual unit costs of water for annual withdrawals ranging from 50,000 to 300,000 af/y vary from $42/af to $79/af to bring the water to the surface without transport (Figure 4.4). If all or a part of the annual withdrawals was transported to the Arkansas River, additional annual unit costs would be incurred. These additional annual unit costs would range from $314/af to $526/af for transport via Poncha Pass, depending on the annual quantities transported (Figure 4.5). Via Hayden Pass, the annual unit costs would range from $468/af to $653/af, depending on the annual quantities transported (Figure 4.5).

To estimate the cost of both in-Valley use and transport, both Figures 4.4 and 4.5 are needed. An example calculation for an annual withdrawal of 200,000 af/y follows. Assume that 100,000 af/y of the total 200,000 af/y is used in the Valley, and that 100,000 af/y is transported to the Arkansas River via
Poncha Pass. If the 200,000 af/y is from Base Case 1, then the cost of getting this water to in-Valley use is about $255/af (Figure 4.4). To transport 100,000 af/y to the Arkansas River would cost an additional $410/af (Figure 4.5). Therefore, the cost of the initial 200,000 af of water would be $255/af, while the cost to transport 100,000 of the 200,000 to the Arkansas River would cost about $665/af.

4.4 COST-SENSITIVITY ANALYSES

Cost-sensitivity analyses were performed on each of the two base cases to test the magnitude of the changes in the unit annual costs which would result from altering the assumptions concerning the values of several of the independent variables which are particularly subject to uncertainty. Those variables are:

1. Annual interest rate
2. Deep confined aquifer transmissivity
3. Well spacing
4. Well pumping rate
5. Well depth
6. Demand time period

In each case, alternative values of these independent variables, usually representing probable low, probable medium and probable high values, were chosen and unit annual costs (similar to the base-case costs shown in Appendix B) computed. Table 4.1 is a summary table showing the sensitivity of unit annual cost of project water for the Base Case 1, assuming that the only variable which changed was the one of interest. Table 4.2 is a similar analysis for Base Case 2.

A decrease in the assumed annual interest rate from 7 to 5 percent would reduce unit annual costs by about 3.5 to 11.9 percent (averaging 7.6 percent); whereas, an annual interest rate increase from 7 to 9 percent would increase unit annual costs by about 3.8 to 14.3 percent (averaging 9.0 percent). The
percentage increase or decrease would become less with increasing annual withdrawal of deep confined aquifer water (Table 4.1 and 4.2).

An increase in aquifer transmissivity (Base Case 1) by a factor of 10 would result in a decrease in unit annual costs by up to 71 percent for large annual withdrawals (Table 4.1). A decrease in aquifer transmissivity (Base Case 2) by a factor of 10 would result in an increase in unit annual costs of up to 268 percent for large annual withdrawals (Table 4.2). This is because drawdowns would be substantially reduced with a larger transmissivity value. As expected, a 2-mile well spacing would cause larger drawdowns than a 5-mile well spacing because of well interference, resulting in higher unit annual costs (up to 30 percent higher).

Average well pumping rates (1000, 1500 or 2000 gpm) did not affect unit annual rates to a large extent, except that, if the pumping rate were reduced to 1000 gpm, not all the wells could be located in the Valley at a 5-mile spacing to produce the maximum desired level of water development of 300,000 af/y. This assessment assumes throughout the analysis that the wells are regularly spaced in a grid-pattern.

Construction costs are affected by well depths. If the average well depths were reduced from 5000 to 3000 ft, nearly a 13 percent construction cost savings would be realized (Tables 4.1 and 4.2). However, the unit annual cost savings would be relatively small (about 6 percent), because operation and maintenance costs would not dramatically decline for this assumed reduction in average well depth. In fact, an annual yield of 300,000 af/y could not be obtained with the 3000-ft wells and a transmissivity of 25,000 gpd/ft, because the expected maximum wellfield drawdown based upon our analysis would be greater than 3000 ft (approximately 3100 ft) at this annual withdrawal.

Cost of the project would be affected if the project water were not delivered only during some months of the year such as would be the case for the Valley's irrigation season. Costs were estimated for projects having a large
### TABLE 4.1

Sensitivity of Base-Case 1 Annual Unit Costs to Changing Assumptions ($/af)

<table>
<thead>
<tr>
<th>Annual Withdrawal (af/y)</th>
<th>Assumed Interest Rate</th>
<th>Assumed Transmissivity</th>
<th>Assumed Well Spacing</th>
</tr>
</thead>
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<tr>
<td></td>
<td>Low 5%</td>
<td>Medium (1) 7%</td>
<td>High 9%</td>
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<td>50,000</td>
<td>115</td>
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<tr>
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<td>255</td>
<td>267</td>
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<tr>
<td>300,000</td>
<td>307</td>
<td>318</td>
<td>330</td>
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</table>

<table>
<thead>
<tr>
<th>Annual Withdrawal (af/y)</th>
<th>Assumed Pumping Rate</th>
<th>Assumed Well Depth</th>
<th>Assumed Demand Time</th>
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<tbody>
<tr>
<td></td>
<td>Low 1000 gpm</td>
<td>Low 3000 ft</td>
<td>Low 4 mo</td>
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<tr>
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<td>318</td>
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<td>-- (2)</td>
<td>-- (2)</td>
<td>-- (2)</td>
</tr>
</tbody>
</table>

(1) Base Case 1 assumes the following: Transmissivity = 25,000 gpd/ft, Storativity = 0.0001, Time = 10 years, Interest Rate = 0.07, Well Spacing = 5 mi, Pumping Rate = 2000 gpm and Well Depth = 5000 ft.

(2) -- Indicates no sensitivity analyses because of physical constraints on system.
TABLE 4.2
Sensitivity of Base-Case 2 Annual Unit Costs to Changing Assumptions ($/af)

<table>
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<tr>
<th>Annual Withdrawal (af/y)</th>
<th>Assumed Interest Rate Low 5%</th>
<th>Medium 7%</th>
<th>High 9%</th>
<th>Assumed Transmissivity Low 25,000 gpd/ft</th>
<th>Medium 250,000 gpd/ft</th>
<th>Assumed Well Spacing Low 2-mile</th>
<th>Medium 5-mile</th>
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<td>50,000</td>
<td>37</td>
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<tr>
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<th>Annual Withdrawal (af/y)</th>
<th>Assumed Pumping Rate Low 1000 gpm</th>
<th>Medium 1500 gpm</th>
<th>High 2000 gpm</th>
<th>Assumed Well Depth Low 3000 ft</th>
<th>Medium 5000 ft</th>
<th>Assumed Demand Low 4 mo</th>
<th>Medium 8 mo</th>
<th>Time High 12 mo</th>
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<td>50</td>
<td>51</td>
<td>51</td>
<td>63</td>
<td>79</td>
<td>61</td>
<td>51</td>
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<tr>
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<td>65</td>
<td>66</td>
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<td>79</td>
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<td>--(2)</td>
<td>77</td>
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<td>79</td>
<td>92</td>
<td>--</td>
<td>--</td>
<td>79</td>
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</table>

(1) Base Case 2 assumes the following: Transmissivity = 250,000 gpd/ft, Storativity = 0.0001, Time = 10 years, Interest Rate = 0.07, Well Spacing = 5 mi, Pumping Rate = 2000 gpm and Well Depth = 3000 ft.

(2) -- Indicates no sensitivity analyses because of physical constraints on system.
part of an annual withdrawal and delivery occurring in a 4-month or 8-month period.

The results (Tables 4.1 and 4.2) indicate that, for typical annual withdrawals (50,000 to 100,000 af/y), the unit annual costs could increase up to 46 percent due to limited seasonal production of the water. The physical system would probably limit the 4-month demand project to about 100,000 af/y of withdrawal, and the 8-month demand project to 200,000 af/y because of limitations on numbers of wells, well pumping rates and drawdowns.

In summary, cost sensitivity analyses are performed to identify a realistic range of possible costs for a project. For this project, the variables having by far the greatest sensitivity to cost are aquifer transmissivity and the annual rates of water withdrawal from the aquifer. Within the range of values used for these two variables, unit costs can change from 250 to 350 percent.

4.5 WATER-VALUATION OVERVIEW

The value of project water has been assessed in a preliminary manner for comparison to project costs. The rationale and methodology used in estimating the value of project-developed water, with due consideration to the dominant agricultural economic base in the San Luis Valley, are detailed in Appendix C.

Tables 4.3 and 4.4 show calculations for the residual value of water. Table 4.3 adopts a "realistic" scenario, which represents the best estimate of the likely returns. This assumes what is believed to be the most likely scenario for crop yields and proportions of acreages, and a fairly high charge for clearing, leveling, and reclaiming the salinized soils most likely to be available for new development. Acreage is allocated to crops as follows: 50 percent alfalfa, 40 percent small grains (spring wheat or feed barley), and 10 percent potatoes.
### TABLE 4.3
Summary of Projected Costs, Returns and Residual Return to Water, San Luis Valley, Realistic Scenario (1)(3)

<table>
<thead>
<tr>
<th>Item</th>
<th>Alfalfa Hay Per Acre</th>
<th>Spring Wheat Per Acre</th>
<th>Potatoes Per Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Revenues</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Projected Yields/Acre</td>
<td>4 t</td>
<td>90 bu</td>
<td>300 cwt</td>
</tr>
<tr>
<td>Projected Price/Unit</td>
<td>$70/t</td>
<td>$2.70/bu</td>
<td>$4.50/cwt</td>
</tr>
<tr>
<td>Project Gross Revenues</td>
<td>$280/t</td>
<td>$243/a</td>
<td>$1350/a</td>
</tr>
<tr>
<td><strong>Costs</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land Preparation and Plant(2)</td>
<td>62</td>
<td>49</td>
<td>167</td>
</tr>
<tr>
<td>Other Pre-Harvest Machinery Operations</td>
<td>8</td>
<td>-</td>
<td>30</td>
</tr>
<tr>
<td>Fertilizer, Pesticides</td>
<td>10</td>
<td>46</td>
<td>586</td>
</tr>
<tr>
<td>Irrigation System Operating Costs</td>
<td>29</td>
<td>15</td>
<td>33</td>
</tr>
<tr>
<td>Harvest and Haul</td>
<td>80</td>
<td>28</td>
<td>33</td>
</tr>
<tr>
<td>Land, Land Development and Sprinkler System (Annualized)</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>General Overhead, Taxes, Etc.</td>
<td>29</td>
<td>26</td>
<td>90</td>
</tr>
<tr>
<td>Management</td>
<td>13</td>
<td>12</td>
<td>135</td>
</tr>
<tr>
<td><strong>TOTAL COSTS</strong></td>
<td>281</td>
<td>226</td>
<td>1124</td>
</tr>
<tr>
<td>Net Return to Water ($/a)</td>
<td>-1</td>
<td>17</td>
<td>226</td>
</tr>
<tr>
<td>Annual Water Applied (af/a)(4)</td>
<td>3.6</td>
<td>2.1</td>
<td>1.8</td>
</tr>
<tr>
<td>Return Per Acre Foot ($)</td>
<td>-0.3</td>
<td>8.1</td>
<td>126</td>
</tr>
<tr>
<td>Weighted Average Return Per Acre Foot ($/af)</td>
<td></td>
<td></td>
<td>16</td>
</tr>
</tbody>
</table>

(1) Realistic scenario assumes:

a) $200 land-development costs amortized @ 7 percent.

b) "normal" acreage in high-return crops (10 percent potatoes, 40 percent spring wheat, 50 percent alfalfa.

(2) Alfalfa planting costs represent cost of initial stand established amortized over four-year life.

(3) Adapted from Appendix C (Table C.1).

(4) Based on Salazar (1986); see Table 2.2.
TABLE 4.4
Summary of Projected Costs, Returns and Residual Return to Water, San Luis Valley, Optimistic Scenario\(^{(1)}\)(\(^{3}\))

<table>
<thead>
<tr>
<th>Item</th>
<th>Alfalfa Hay Per Acre</th>
<th>Malt Barley Per Acre</th>
<th>Potatoes Per Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revenues</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Projected Yields/Acre</td>
<td>4 t</td>
<td>40 cwt</td>
<td>300 cwt</td>
</tr>
<tr>
<td>Projected Price/Unit</td>
<td>$70/t</td>
<td>$7.00/cwt</td>
<td>$4.50/cwt</td>
</tr>
<tr>
<td>Project Gross Revenues</td>
<td>$280/a</td>
<td>$280/a</td>
<td>$1350/a</td>
</tr>
<tr>
<td>Costs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land Preparation and Plant(^{(2)})</td>
<td>62</td>
<td>49</td>
<td>167</td>
</tr>
<tr>
<td>Other Pre-Harvest Machinery Operations</td>
<td>8</td>
<td>-</td>
<td>30</td>
</tr>
<tr>
<td>Fertilizer, Pesticides</td>
<td>10</td>
<td>46</td>
<td>586</td>
</tr>
<tr>
<td>Irrigation System Operating Costs</td>
<td>29</td>
<td>15</td>
<td>33</td>
</tr>
<tr>
<td>Harvest and Haul</td>
<td>80</td>
<td>28</td>
<td>33</td>
</tr>
<tr>
<td>Land, Land Development and Sprinkler System (Annualized)</td>
<td>36</td>
<td>36</td>
<td>36</td>
</tr>
<tr>
<td>General Overhead, Taxes, Etc.</td>
<td>29</td>
<td>26</td>
<td>90</td>
</tr>
<tr>
<td>Management</td>
<td>13</td>
<td>14</td>
<td>135</td>
</tr>
<tr>
<td><strong>TOTAL COSTS</strong></td>
<td>267</td>
<td>214</td>
<td>1110</td>
</tr>
<tr>
<td>Net Return to Water ($/a)</td>
<td>13</td>
<td>66</td>
<td>226</td>
</tr>
<tr>
<td>Annual Water Applied (af/a)(^{(4)})</td>
<td>3.6</td>
<td>2.0</td>
<td>1.8</td>
</tr>
<tr>
<td>Return Per Acre Foot ($)</td>
<td>3.6</td>
<td>33</td>
<td>133</td>
</tr>
<tr>
<td>Weighted Average Return Per Acre Foot ($/af)</td>
<td></td>
<td></td>
<td>56</td>
</tr>
</tbody>
</table>

(1) Optimistic scenario assumes:
   a) low land-development costs.
   b) maximum acreage in high-return crops (1/3 potatoes, 1/3 malt barley, 1/3 alfalfa).

(2) Alfalfa planting costs represent cost of initial stand established amortized over four-year life.

(3) Adapted from Appendix C (Table C.2).

(4) Based on Salazar (1986); see Table 2.2.
The optimistic scenario (Table 4.4) is based on a high proportion of high return crops (potatoes and malt barley 1/3 each, together with 1/3 alfalfa) and lower land reclamation costs. This can be regarded as an upper limit on ability to pay for new water supplies.

For both of the above scenarios, land, land development and sprinkler system costs have been included in the costs used to calculate the return per acre-foot of water. Based upon these assumptions for new land development, the realistic scenario give an average weighted return of $16/af of water, while the optimistic scenario gives an average weighted return of $56/af of water.

If the analyses were for supplemental water only, i.e., land and development costs were not included, then the weighted average return would be higher. If the farmer needed additional water to increase yield or save the crop, then the $56/af value becomes more realistic as the farmer's willingness to pay.

Cropping pattern also influences the results of the value of water. In the realistic scenario, alfalfa and spring wheat accounted for 90 percent of the irrigated land; whereas, in the optimistic scenario, the crops were split as 33 percent for each crop. Historical cropping patterns shown in Table 2.2 indicate a typical cropping pattern consists of 32 percent alfalfa and other hay, 17 percent barley, 6 percent potatoes, 4 percent spring wheat, 2 percent oats and vegetables, and 39 percent irrigated pasture. Therefore, the historical cropping pattern is close to the assumed realistic scenario. If the analyses shown in Tables 4.3 and 4.4 was applied to the cropping pattern in Table 2.2, the average weighted value of water would be $15/af, if new land had to be developed. Without land-development costs, the value would be $18/af.

4.6 SUMMARY

Two potential base cases were identified for purposes of developing annual withdrawals of between 50,000 and 300,000 af/y from the deep confined-aquifer system of the San Luis Valley. Base Case 1 depicted a wellfield developing
water from the lower confined-aquifer system, assuming average well depths of 5000 ft and a transmissivity of 25,000 gpd/ft. Costs under these Base Case 1 assumptions to develop water ranged from $123/af to $318/af. Base Case 2 depicted a wellfield developing water from a shallower zone of the deep average confined system. Under this alternative scenario, well depths were assumed to 3000 ft with an average transmissivity of 250,000 gpd/ft. Costs under the Base Case 2 assumptions ranged from $42/af to $79/af. Incremental costs to transport developed water to the Arkansas River ranged from $314 to $526/af via Poncha Pass and $468 to $653/af via Hayden Pass. To contrast these anticipated water-development costs, a farmer's in-Valley ability to pay for water was estimated to range from $16/af (realistic economic assessment) to $56/af (optimistic and unrealistic economic assessment).
COLORADO WATER RESOURCES
AND POWER DEVELOPMENT AUTHORITY
SAN LUIS VALLEY CONFINED AQUIFER STUDY
POTENTIAL WATER-TRANSPORT PIPELINE
ROUTES TO THE ARKANSAS RIVER
IN-SITU, INC.
HRS Water Consultants, Inc., John C. Halepeska & Assoc., Inc.,
Robert E. Moran and Robert A. Young, Study Team
DATE: 8/21/86  FIGURE 4.1
COLORADO WATER RESOURCES
AND POWER DEVELOPMENT AUTHORITY
SAN LUIS VALLEY CONFINED AQUIFER STUDY

NUMBER OF WELLS vs.
ANNUAL WITHDRAWAL
SAN LUIS VALLEY DEEP CONFINED AQUIFER

IN-SITU, INC.

MRS Water Consultants, Inc., John C. Holagosa & Assoc., Inc.,
Robert E. Moran and Robert A. Young Study Team
DATE: 8/21/86  FIGURE 4.2
MAXIMUM WELL FIELD DRAWDOWN - FEET

ANNUAL WITHDRAWAL - 1000 AF/YR

TRANSMISSIVITY = 250,000 GPD/FT
STORATIVITY = 10^{-4}
TIME = 10 YEARS
5-MILE WELL SPACING

TRANSMISSIVITY = 25,000 GPD/FT
STORATIVITY = 10^{-4}
TIME = 10 YEARS
5-MILE WELL SPACING

NOTE: Assumes the aquifer is infinite in areal extent.

COLORADO WATER RESOURCES AND POWER DEVELOPMENT AUTHORITY
SAN LUIS VALLEY CONFINED AQUIFER STUDY
MAXIMUM PIEZOMETRIC SURFACE DECLINE FROM A WELL FIELD FOR SELECTED ANNUAL WITHDRAWALS
SAN LUIS VALLEY DEEP CONFINED AQUIFER

IN-SITU, INC.
HRS Water Consultants, Inc., John C. Haltiopoulos & Assoc., Inc., Robert E. Moran and Robert A. Young Study Team
DATE: 8/21/86 FIGURE 4.3
COLORADO WATER RESOURCES
AND POWER DEVELOPMENT AUTHORITY
SAN LUIS VALLEY CONFINED AQUIFER STUDY
ANNUAL UNIT COST OF SAN LUIS VALLEY DEEP CONFINED AQUIFER WATER FOR BASE CASES 1 AND 2
IN-SITU, INC.
HRS Water Consultants, Inc., John C. Holepaska & Assoc., Inc.,
Robert E. Moran and Robert A. Young Study Team
DATE: 8/21/86 Figure 4.4
ANNUAL UNIT COST OF TRANSPORT OF SAN LUIS VALLEY WATER TO THE ARKANSAS RIVER BASIN

IN-SITU, INC.

COLORADO WATER RESOURCES AND POWER DEVELOPMENT AUTHORITY
SAN LUIS VALLEY CONFINED AQUIFER STUDY

DATE: 8/21/86  FIGURE 4.5
5.0 ACKNOWLEDGMENTS

Analyses presented in this report were prepared under the general supervision of Dr. Timothy D. Steele, Water Resources Manager and Associate of In-Situ, Inc. The analyses were done by Dr. James R. Kunkel, Senior Project Engineer of In-Situ, Inc. and Dr. Robert A. Young, Agricultural Economist with Colorado State University. Dr. Kunkel prepared the draft of this report with assistance from Drs. Young and Steele.
6.0 REFERENCES


SAN LUIS VALLEY CONFINED AQUIFER STUDY
(PHASE I)
INTERIM TASK 1 REPORT
WATER DEMAND/ECONOMIC ANALYSES

Prepared for

Colorado Water Resources and Power Development Authority

DRAFT - SUBJECT TO REVISION

IN-SITU, INC.
and ROBERT A. YOUNG
Project No. 4332 June 20, 1986

IN-SITU, INC. STUDY TEAM, WITH HRS WATER CONSULTANTS, INC.,
JOHN C. HALEPASKA & ASSOCIATES
ROBERT E. MORAN AND ROBERT A. YOUNG
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INTERIM TASK 1 REPORT
WATER DEMAND/ECONOMIC ANALYSES

INTRODUCTION

The purpose of this task is to: (1) evaluate existing and future demands for water obtained from the deep confined aquifer; (2) estimate unit annual costs to develop various annual water withdrawals; and (3) to assess the current and future range of market values for with various types of water use associated with the deep confined aquifer in the San Luis Valley of South-central Colorado. The information on water demand and market prices is compared with estimated annualized construction, operation and maintenance costs. From this comparison, the preliminary assessment of the ability of a deep confined aquifer development project to pay for itself is made. Estimates of water demands, unit annual costs and market prices were done parametrically so that a large number of combinations would be available for analyses if desired.

A brief literature review is included to summarize the documents available relating to water demands, water values and potential project costs. Water demands and water use in the San Luis Valley have been summarized by Siebenthal (1910), U.S. Soil Conservation Service (1969), Huntley (1976), U.S. Bureau of Reclamation (1979), Radosevich and Rutz (1979), Simpson, et al (1980), U.S. Army Corps of Engineers (1983), Steffen, Robertson and Kirsten (Colorado) Inc. (1985), and Salazar (1986). Economic analyses of water use and water market values also appear in some of the above reports and in Johnson (1975) and Skaggs (1985). Because of the everchanging water demand and economic variables in the San Luis Valley, the above references were used with caution in making the estimates presented in this report.
CURRENT WATER DEMANDS

Water demands in the San Luis Valley currently involve agriculture, municipal and Rio Grande Compact delivery demands. No current water demands are known to exist in the Valley for industrial use or hydroelectric power.

Municipal and Industrial Demands

Municipal and industrial water demands in the San Luis Valley are based upon population estimates available from the U.S. Census Bureau for the counties of Alamosa, Conejos, Costilla, Mineral, Rio Grande and Saguache (Table 1). Since 1900, population in the Valley has increased, reaching a maximum in 1940 and decreasing through 1970. Population trends since 1980 indicate a slight increase in population with estimated 1985 population for the Valley approximately the same as the population in 1930. These erratic population time trends are consistent with the agricultural nature of the Valley and the general pattern of young-adult migration from the Valley over recent periods in search of employment.

Table 1 estimates domestic water demands based upon population for the period 1900 through 1985, assuming a per-capita water demand of 250 gallons per day. It is understood that not all the Valley population derives its water supply through a municipal water system. However, basing municipal water demand on population appears to be a good estimator. As will be seen later, the municipal water demand based upon population estimates is small compared to the agricultural water demand. Estimated 1985 municipal water demand would have been approximately 11,200 acre-feet per year (ac-ft/yr), if all the population of the Valley derived its domestic water supply from a municipal system.

Industrial demands were not estimated because the industrial base of the Valley (exclusive of agriculture) is extremely small. Therefore, the combined existing municipal and industrial water demand for the San Luis Valley was assumed to be approximately 11,200 ac-ft/yr.
Agricultural Demands

Current agricultural water demands in the San Luis Valley were based upon current irrigated cropland totaling approximately 638,000 acres (Salazar, 1986). This total irrigated acreage is composed of approximately 39 percent irrigated pasture, 32 percent alfalfa and other hay, 17 percent barley, with the remaining 12 percent in grain oats, potatoes, spring wheat and vegetables. Agricultural statistics for 1960 through 1984 (Salazar, 1986) indicate that the total crop acreage during the period has increased from a low of about 305,000 acres in 1962 to nearly 420,000 acres in 1984, exclusive of irrigated pasture. Potato, spring wheat and barley acreages have substantially increased since 1960 at the expense of grain oats, alfalfa and other hay. Since 1974, spring wheat and potato acreages have more than doubled in the San Luis Valley.

Table 2 shows estimated water demands for the typical cropping patterns in the San Luis Valley as reported by Salazar (1986). Estimated water demands were based upon consumptive-use estimates, reported irrigation efficiencies, and effective precipitation (Salazar, 1986). The unit water demands were calculated by dividing estimated annual demand by the number of acres of irrigated crop. On the average, approximately 3.2 ac-ft of water per acre of land (ac-ft/ac) are needed to produce crops in the San Luis Valley. Of this 3.2 ac-ft/ac, approximately 1.6 is consumptively used by the plants, with the remaining 1.6 ac-ft/ac going to losses and return flows. The largest uncertainty in the numbers shown in Table 2 is associated with irrigated pasture. Estimates of total irrigated pasture acreage in the San Luis Valley range from 189,400 acres to over 247,000 acres (Salazar, 1986). The actual irrigated pasture acreage is probably somewhere within this range. Also, estimates of evapotranspiration and irrigation efficiency for irrigated pasture assume that the pasture has received an adequate water supply. In some cases, farmers forego irrigation of pasture grasses or these grasses receive only one irrigation per season because of limited water supplies in some years. The estimated unit water demands for irrigated crops in the San Luis Valley (Table 2) range from 1.8 ac-ft/ac per year for potatoes to 3.8 ac-ft/ac per year for irrigated pasture and hay. Total estimated water demands in the San Luis Valley may be over 2,000,000 ac-ft/yr based upon the over 638,000 irrigated acres. In below-normal water years, probably as few as 500,000 acres are
irrigated in the Valley, implying an estimated water demand of 1.6 million ac-ft/yr under these conditions. If irrigated pasture is not considered in the estimates in Table 2, the annual estimated water demands are about 1,120,000 ac-ft/yr, with a unit demand of about 2.9 ac-ft/ac per year.

**Rio Grande Compact Demands**

The Rio Grande Compact was signed by representatives of the States of Colorado, New Mexico and Texas on March 18, 1938. Minor changes have been made to the Compact in 1948 and 1966. Although the Compact was not strictly administered until 1968, it is very much in effect today, and essentially provides a downstream delivery obligation from the State of Colorado to the States of New Mexico and Texas. Due to large debits that were accrued by the mid-1960s, a stipulation was entered into by the three states in 1968 in which the State of Colorado agreed to deliver each year's Compact commitment without building any further debt of water. Since 1968, the Colorado State Engineer has had the duty to curtail Colorado water use in the Valley as necessary in order to meet the delivery requirements for each particular year. The Compact was intended to allocate surplus water, and was not suppose to effect existing (pre-1937) water rights. However, since 1968, there has been a severe curtailment of pre-Compact water rights in order to meet the Compact delivery requirements. One of the reasons for this is the extensive water-well development that occurred in the San Luis Valley during the 1950s and 1960s. These ground-water rights are more difficult to administer that surface-water diversions. This development, therefore, contributed largely to a situation whereby junior water rights (the wells) were being allowed to use water; whereas, senior water rights (some with priority dates as early as 1855) were curtailed in order to meet the provisions of the 1937 Compact.

Two Compact administration tables exist for the State of Colorado: one for the Rio Grande mainstem and one for the Conejos River. The courts has ruled that these tables must be applied separately, requiring a separate delivery obligation from each basin. Therefore, water demands used in this study show the Compact deliveries from the Conejos River and Rio Grande separately. Table 3 shows the historical annual deliveries to the Rio Grande.
Compact from the Conejos River and Rio Grande basins. Since 1968, the historical deliveries have averaged about 305,000 ac-ft/yr, of which about 39 percent is from the Conejos River basin with the remaining 61 percent from the Rio Grande basin. A critical time of the year for agricultural water users is the April through October irrigation season. Table 4 summarizes the historical April-through-October deliveries from both the Conejos River and Rio Grande basins. Average annual deliveries since 1968 for the April-through-October irrigation season were about 211,000 ac-ft, of which about 44 percent came from the Conejos River basin with the remaining 56 percent from the Rio Grande basin. As indicated in Table 4 about 61 percent of the total annual Compact delivery occurs during the April-through-October irrigation season.

For purposes of this study, it was assumed that the historical deliveries were a measure of demand for water which could have been used for other purposes such as agriculture. Even though the 1985 delivery under the Compact was zero and no anticipated delivery should occur in 1986, historical deliveries are an indicator of potential future compact-related deliveries. Therefore, a Rio Grande Compact demand of between 211,000 and 305,000 ac-ft/yr does not appear unreasonable.

Summary

As indicated by the above analysis, existing water demands for municipal and industrial use in the San Luis Valley are small compared to agricultural use. Municipal and industrial demands may average about 11,200 ac-ft/yr. Agricultural water demands may be near 2,000,000 ac-ft/yr, based upon 638,000 acres of irrigated acres with an average demand of 3.2 ac-ft/yr of irrigated land. During dry years (below-normal precipitation), the demand may decrease to 1,600,000 ac-ft/yr. Historical Rio Grande Compact deliveries have averaged 305,000 ac-ft/yr with 211,000 ac-ft being provided, on the average, during the April-through-October irrigation season.
FUTURE WATER DEMANDS

Municipal and Industrial Demands

For purposes of this report, municipal and industrial water demands as indicated by Valley population is expected to increase, but with total demand remaining substantially less than agricultural demand (less than 1 percent). Therefore, we have estimated future municipal and industrial water demands to be similar or only slightly larger than existing municipal and industrial water demands, or approximately 14,000 ac-ft/yr as a maximum. Therefore, new municipal and industrial demands might be on the order of 3000 ac-ft/yr.

Agricultural Demands

Future agricultural water demands in the San Luis Valley were derived predominately from existing lands under irrigation whose water supply would either by curtailed by Compact deliveries or from a general reduction in surface-water supplies during drought years. Additionally, there are new lands which could be placed under irrigation if agricultural-product markets were favorable.

There are estimates of presently irrigated land in the San Luis Valley that is in need of supplemental irrigation supplies. Several estimates have been made, including those by the Rio Grande Water Conservation District (Ralph Curtis, personal communication, June 9, 1986) and HRS Water Consultants, Inc. (1984). The estimates of presently irrigated land in need of supplemental irrigation ranges from 30,000 to 50,000 acres per year, although probably none of this land is irrigated pasture but rather crop land growing hay, barley, grain oats, potatoes, spring wheat or vegetables. There may be over a 100,000 acres of irrigated pasture which does not receive an adequate water supply and would be available to receive supplemental irrigation water from the deep confined aquifer project. Exclusive of irrigated pasture, the annual unit water demand for the typical crop mix shown in Table 2 would be about
2.9 ac-ft/ac per year. If one-half of this unit irrigation demand (about 1.5 ac-ft/ac per year) came from a supplemental supply from deep confined aquifer wells, then the annual demand might range from 45,000 to 75,000 ac-ft/yr for the 30,000 to 50,000 acres in need of such supplemental irrigation.

There appears to be no shortage of potential agricultural land in the San Luis Valley. However, development of new land requires large expenditures for land preparation (typically $40,000 to $50,000 for a 130-acre center pivot irrigation system) (LeRoy Salazar, personal communication, June 9, 1986). During the past several years, lower farm commodity prices have reduced the willingness of agriculturalists to expand the acreage under irrigation in the San Luis Valley. Estimates by the Rio Grande Water Conservation District (Ralph Curtis, personal communication, June 9, 1986) and HRS Water Consultants, Inc. (1984) indicate that between 40,000 and 75,000 acres of new land could be brought under irrigation with only minor adjustments in the farm-commodities picture. Assuming that these lands were used for irrigated crops other than irrigated pasture, at an annual unit demand of 2.9 ac-ft/acre, the demand for water to irrigate these new lands would range from 116,000 to 218,000 ac-ft/yr.

**Rio Grande Compact Demands**

Future demands to deliver water under the Rio Grande Compact are based on historical deliveries to the Compact as summarized in Table 3 and 4. Historical deliveries ranged from 0 ac-ft in 1985 to over 625,000 ac-ft in 1979, and averaged approximately 305,000 ac-ft per year for the period 1968 through 1985. Annual April-through-October deliveries were somewhat less, with a minimum of 0 ac-ft/yr in 1985 and a maximum of nearly 563,000 ac-ft in 1979, averaging about 211,000 ac-ft for the 1968 through 1985 period of record. For purposes of this analysis, the historical Compact deliveries were assumed to repeat themselves in the future. Therefore, annual deliveries are expected to average approximately 300,000 ac-ft/yr and may range from a maximum of nearly double the average to zero for any given year.
A log-normal probability distribution was fit to the annual and April-through-October deliveries (Tables 3 and 4) to estimate a likely delivery which would have to be met most of the time. The annual delivery occurring 90 percent of the time, based upon data in Table 3, is about 130,000 ac-ft. The standard error of estimate is about 14 percent. The April-through-October delivery occurring 90 percent of the time, based upon Table 4, is about 70,000 ac-ft, with a standard error of about 19 percent.

Summary

Based on the above assessment, future (new) water demands used as a basis for the economic analyses and future project demands are summarized as follows:

1. Municipal and domestic demand: 3,000 ac-ft/yr (new demand)

2. Agricultural demand: 45,000 to 75,000 ac-ft/yr (supplemental)
   116,000 to 218,000 ac-ft/yr (new lands)

3. Rio Grande Compact: 70,000 to 130,000 ac-ft/yr (90 percent probability)

Combinations of the above demands could result in a maximum annual demand of 437,000 ac-ft/yr and a maximum April-through-October demand of 377,000 ac-ft/yr. The proposed deep confined aquifer water-development project and associated economic analyses used a range of annual deep confined aquifer withdrawals of between 10,000 and 300,000 ac-ft/yr. The maximum withdrawal of 300,000 ac-ft/yr is judged to be an upper limit based upon professional judgments on aquifer hydraulic characteristics, well spacing and well yields. For the parametric cases examined in this report the demands were assumed uniformly distributed over the year (see Sensitivity Analyses below).
Development of the San Luis Valley deep confined aquifer would entail pumpage of the water via a wellfield located somewhere in the Valley. For purposes of this preliminary analysis, it was assumed that the wellfield would be centered at Alamosa, although a typical wellfield could be located nearly anywhere in the Valley. In order to assess the economic impacts of pumping the wellfield, several assumptions regarding the depth and spacing of wells and the hydraulic characteristics of the deep confined aquifer system were made. The sensitivity of the assumptions are discussed in the following report sections.

General Characteristics

Because the costs of obtaining water from the deep confined aquifer system are sensitive to pumping depth, which is a function of annual water withdrawals as well as aquifer hydraulic properties, a preliminary analysis of the expected maximum wellfield drawdowns for various values of annual withdrawals, aquifer transmissivity, well spacing and individual well pumping rates was done. Figure 1 shows the number of pumping wells in a typical wellfield for annual withdrawals from the deep confined aquifer ranging from zero to 300,000 ac-ft/yr, and for individual wells pumping 1000, 1500 and 2000 gallons per minute (gpm). For a typical annual withdrawal of 200,000 ac-ft/yr, 124 wells pumping 1000 gpm would be needed. If the individual well pumping rate were increased to 1500 gpm the same 124 wells would produce about 300,000 ac-ft/yr. This 300,000 ac-ft/yr also could be produced by 93 wells pumping at an average rate of 2000 gpm.

Aquifer hydraulic characteristics of the deep confined system in the San Luis Valley are largely unknown. For purposes of our analysis we have assumed that the transmissivity of the deep confined aquifer would range from 25,000 to 250,000 gallons per day per ft (gpd/ft), and the storativity would be on the order of 0.0001 (or $10^{-4}$). We have estimated the drawdown in typical wellfields for wells having pumping rates of 1000, 1500 and 2000 gpm for both the above transmissivities and for well spacings of 5 miles and 2 miles. Results of our analyses for the 5-mile well spacing is shown on Figure 2 for
wells having pumping rates of 1000 and 2000 gpm, transmissivities of 25,000 and 250,000 gpd/ft, and annual withdrawals ranging from 10,000 to 300,000 ac-ft/yr. In all the drawdown estimates we assumed that the deep confined aquifer was infinite in areal extent and that the initial water surface was coincidental with the land surface. Therefore, the maximum wellfield drawdowns shown on Figure 2 represent depths below ground surface. Drawdowns for the deep confined aquifer in the San Luis Valley having a transmissivity of 25,000 gpd/ft ranges from a few hundred to over 3,000 feet (ft) depending on the pumping rate of the individual wells. For a transmissivity of 250,000 gpd/ft, drawdowns ranged from about 50 to slightly over 500 ft depending on the pumping rates of individual wells. The above drawdowns are for continuous pumping at the end of ten years. It was judged reasonable that if the project life was 30 years, then maximum drawdowns at the 10-year time period would be representative of average wellfield drawdowns over the 30-year lifetime of the project. When the well spacing was decreased from 5 miles to 2 miles with aquifer characteristics as previously assumed, drawdowns generally doubled for the larger annual withdrawal rates at the end of one year and were about 50 percent greater at the end of 10 years of pumping.

For the economic analyses performed below, we used the drawdowns calculated for a wellfield having a 5-mile well spacing, well pumping rates of 2000 gpm, a transmissivity of 25,000 gpd/ft, and a time associated with continuous pumping for ten years. The drawdowns for these assumptions for various annual withdrawals ranging from 10,000 to 300,000 ac-ft/yr are shown as the uppermost curve on Figure 2. These drawdowns range from about 450 ft for an annual withdrawal rate of 10,000 ac-ft/yr to over 3,000 ft for an annual withdrawal rate of about 300,000 ac-ft/yr. Our economic analyses also assumed that pumping would be year-round. The above assumptions generally conform to a reasonable but quite severe case involving water withdrawals from the deep confined aquifer in the San Luis Valley. The consequences of these assumptions are examined below in the sensitivity analyses.
Potential Water-Development Projects

Two potential water-development projects have been identified for purposes of this study, based upon the above-described future water demands in the San Luis Valley. These projects have been analyzed at selected levels of annual withdrawal from the deep confined aquifer ranging from 10,000 to 300,000 ac-ft/yr. Both of the potential projects would have a wellfield ranging from 5 to 124 wells (excluding standby wells) completed at an average depth of 5000 ft below ground surface. Each of the potential projects also would have an optional pipeline to transport the water from the wellfield to its point of use. Because the exact location of the wellfield is unknown as well as the exact points of use, a 10-mile transmission pipeline was assumed for in-Valley use locations. In addition to a project supplying water for use within the Valley, a variation on the in-Valley alternative was made whereby differing quantities of San Luis Valley deep confined aquifer water would be transported into the Arkansas River basin. The intent of the water-export variation was to assess the feasibility of sale of a part of the additional San Luis Valley developed water to help defray the costs of project development for in-Valley use. Ideally the water transported out of the Valley would be sold at prices substantially higher than the value of that same amount of water if used in the Valley.

Because the exact location of the proposed wellfield, points of use and quantities of use are not known with any degree of certainty, the in-Valley project consists of a generic wellfield, which for cost estimating purposes was assumed to be centered in the vicinity of Alamosa. Changes in the location of the wellfield, while effecting costs slightly, would not in our opinion, change the overall cost structure of a typical potential Valley project.

Because of the relative uncertainty as to the actual water demands in the San Luis Valley coupled with the anticipated value of water used for agriculture (the largest potential demand), a second potential project was assumed which would transport a part of the water pumped from the deep confined aquifer wellfield out of the Valley into the Arkansas River basin for sale at prevailing Colorado Front Range municipal prices. This project has two
alternative pipeline routes from the wellfield centered at Alamosa (Figure 4). The first pipeline route is north along State Route 17 to U.S. 285 to the top of Poncha Pass, comprising a distance of about 69 miles and an elevation change of approximately 1460 feet. At Poncha Pass, the water would be discharged to flow by gravity to confluence with the Arkansas River near Salida. An alternate pipeline route of 61 miles also would follow State Route 17 to U.S. 285 as far as Villa Grove, and then proceed east over the Sangre de Cristo Mountains through Hayden Pass (Figure 4). The water would then discharge by gravity into the Arkansas River near Coaldale. The elevation change of the alternative route is 3350 feet.

**Economic Analyses**

The economic analyses presented below examine the costs of pumping deep confined aquifer water from the wellfield in the San Luis Valley and delivering the water to a location within the Valley or, in part, outside the Valley. The average annual withdrawals from the deep confined aquifer system were assumed to range from 10,000 to 300,000 ac-ft/yr. Costs were estimated for project construction, including the cost of wells, pumps and interwell pipe, booster stations and transportation pipeline. Also included were interest during construction, startup costs, working capital, owners' general expense, and land costs. Annual operation and maintenance costs including labor, supplies and materials, along with electric power costs were estimated. These costs were annualized with the total annual costs including annual operation and maintenance (O&M), annual depreciation and non-depreciation capital costs. Unit annual costs were obtained by dividing the total annual cost by the annual water withdrawal. These unit annual costs formed the basis for comparison of different project alternatives. The cost estimates were made using the FORTRAN program COST as described in Appendices A and B. The base case detailed cost estimates are shown in Appendix C.

Certain cost factors are constant (base case) for each project alternative, although they were allowed to vary during the sensitivity analyses. These cost factors include: $0.065/kilowatt-hour for electricity, 70 percent pumping efficiency, pipe friction coefficient of 135, land costs of
$1000 per acre, annual interest rate of 7 percent, annual insurance rate of 1 percent, and an annual tax rate of 0.25 percent. Annualized costs were amortized over an assumed 30-year project life. Figure 3 shows the results of the cost estimates in terms of unit annual costs in both dollars per acre-foot and cents per thousand gallons versus annual withdrawals from the deep confined aquifer. For in-Valley use, unit annual costs range from about $110 to $334/ac-ft if the 10-mile transmission pipeline were not constructed and from $210 to $366/ac-ft with inclusion of a 10-mile transmission pipeline. Transport of deep confined aquifer water to the Arkansas River basin via Poncha Pass would have unit annual costs ranging from $620 to over $900/ac-ft. Transport to the Arkansas basin via Hayden Pass would result in annual unit costs of between $762 and over $1000/ac-ft. It appears from the analysis of transportation to the Arkansas (Figure 3) that annual transport out of the basin to the Arkansas River would have to be at least 100,000 ac-ft/yr in order to minimize the unit annual costs. The following analysis seeks to estimate the annual unit price of water based on selected uses and compare this unit price to the annual unit cost of the project.

Add Bob Young's section on unit prices of water.

Sensitivity Analyses

Sensitivity analyses were performed to test the magnitude of the changes in the unit annual costs which would result from altering the assumptions concerning the values of several of the independent variables which are particularly subject to uncertainty. Those variables are:

1. Annual interest rate
2. Deep confined aquifer transmissivity
3. Well spacing
4. Well pumping rate
5. Well depth
6. Demand window.
In each case, alternative values of these independent variables, usually representing probable low, probable medium and probable high values, were chosen and unit annual costs (similar to the base case costs shown in Appendix C) computed. Table 5 is a summary table showing the sensitivity of unit annual cost of project water for the base case assuming that the only variable which changed was the one of interest.

An annual interest rate decrease from 7 to 5 percent reduced unit annual costs by about 9 percent, while an annual interest rate increase from 7 to 9 percent increased unit annual costs by about 9 percent on the average. The percentage increase or decrease was less with increasing annual withdrawal of deep confined aquifer water (Table 5).

An increase in aquifer transmissivity by a factor of 10 resulted in a decrease in unit annual costs by up to 60 percent for large annual withdrawals. This is because drawdowns would be substantially reduced with a larger transmissivity value. As expected, a closer well spacing will cause larger drawdowns because of well interference, resulting in higher unit annual costs (up to 38 percent higher).

Average well pumping rates (1000, 1500 or 2000 gpm) did not affect unit annual rates to a large extent except that if the pumping rate was reduced to 1000 gpm, not enough wells could be located in the Valley at a 5-mile spacing to produce 300,000 af/yr. This assessment assumes that the wells are regularly spaced in a grid.

Construction costs are affected by well depths. If the average well depths were reduced from 5000 to 3000 ft, nearly a 13 percent construction cost savings is realized. However, the unit annual cost savings is small (about 6 percent) because operation and maintenance costs do not dramatically decline. In fact, an annual yield of 300,000 af/yr could not be obtained with 3000-ft deep wells because the maximum wellfield drawdown is greater than 3000-ft (approximately 3100 ft) at this annual withdrawal.
Sensitivity of the project would be impacted if the project water were not delivered equally distributed over the year, but rather during some part of the year such as the irrigation season. The sensitivity of a large part of the annual withdrawal and delivery occurring in a 4-month or 8-month period was assessed.

The results (Table 5) indicate that, for small annual withdrawals (10,000 af/yr), the unit annual costs increase about 2 percent. For larger annual withdrawals the unit costs increase up to 16 percent. As with the 1000 gpm pumping rates and the 3000-ft deep wells, the physical system would probably limit the 4-month demand window to about 100,000 af/yr of withdrawal, and the 8-month demand window to 200,000 af/yr because of limitations on numbers of wells, well pumping rates and drawdowns.

In summary, the number of wells is a dominant factor in the unit annual costs. The variables which impact the number of wells (annual withdrawal, pumping rate and aquifer transmissivity) are the most sensitive where pipeline lengths are about 10 miles or less. Obviously, a project having relatively shallow, high production wells with little or no transport and with a uniform demand window is the ideal project.

Summary

GENERAL INFORMATION

Professional judgments presented in this report are based partly on the evaluation of technical information and data gathered by others, partly on In-Situ, Inc.'s professional knowledge of conditions in the San Luis Valley, and on our experience with similar projects. Our engineering and scientific work and judgments meet the standard of care of our profession.
CREDITS

Analyses presented in this report were prepared under the general supervision of Dr. Timothy D. Steele, Water Resources Manager and Associate of In-Situ, Inc. The analyses were done by Dr. James R. Kunkel, Senior Project Engineer of In-Situ, Inc. and Dr. Robert A. Young, Agricultural Economist with Colorado State University. Drs. Kunkel and Young prepared the draft of this report.

REFERENCES


### TABLE 1
SAN LUIS VALLEY POPULATION AND DOMESTIC WATER DEMAND TRENDS

<table>
<thead>
<tr>
<th>Year</th>
<th>Population(^1)</th>
<th>Domestic Water Demand(^3) (af/yr)</th>
<th>Percent Change(^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1900</td>
<td>23,272</td>
<td>6,517</td>
<td>--</td>
</tr>
<tr>
<td>1910</td>
<td>28,745</td>
<td>8,050</td>
<td>23.5</td>
</tr>
<tr>
<td>1920</td>
<td>31,868</td>
<td>8,925</td>
<td>10.9</td>
</tr>
<tr>
<td>1930</td>
<td>41,037</td>
<td>11,493</td>
<td>28.8</td>
</tr>
<tr>
<td>1940</td>
<td>49,217</td>
<td>13,783</td>
<td>19.9</td>
</tr>
<tr>
<td>1950</td>
<td>45,963</td>
<td>12,872</td>
<td>-6.61</td>
</tr>
<tr>
<td>1960</td>
<td>38,704</td>
<td>10,839</td>
<td>-15.8</td>
</tr>
<tr>
<td>1970</td>
<td>37,466</td>
<td>10,493</td>
<td>-3.19</td>
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<tr>
<td>1980(^6)</td>
<td>37,914</td>
<td>10,618</td>
<td>1.19</td>
</tr>
<tr>
<td>1985(^4)</td>
<td>40,107</td>
<td>11,232</td>
<td>5.78</td>
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---


2) Percent change from previous number.

3) Assuming a demand of 250 gallons per person per day.


5) For Alamosa, Conejos, Costilla, Mineral, Rio Grande and Saquache Counties.

6) San Luis Valley Regional Planning and Development Commission.
**TABLE 2**

**SUMMARY OF CURRENT IRRIGATED CROPLAND AND AGRICULTURAL WATER DEMANDS IN THE SAN LUIS VALLEY**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Acres</th>
<th>Percent of Total</th>
<th>Estimated Water Demand (af/yr)</th>
<th>(af/ac/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa Hay</td>
<td>111,800</td>
<td>18</td>
<td>402,500</td>
<td>3.6</td>
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<tr>
<td>Other Hay</td>
<td>88,900</td>
<td>14</td>
<td>337,800</td>
<td>3.8</td>
</tr>
<tr>
<td>Barley</td>
<td>105,500</td>
<td>17</td>
<td>211,000</td>
<td>2.0</td>
</tr>
<tr>
<td>Grain Oats</td>
<td>10,700</td>
<td>2</td>
<td>23,500</td>
<td>2.2</td>
</tr>
<tr>
<td>Potatoes</td>
<td>40,600</td>
<td>6</td>
<td>73,100</td>
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<tr>
<td>Spring Wheat</td>
<td>28,400</td>
<td>4</td>
<td>59,600</td>
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<tr>
<td>Vegetables</td>
<td>4,900</td>
<td>&lt;1</td>
<td>14,200</td>
<td>2.9</td>
</tr>
<tr>
<td>Irrigated Pasture</td>
<td>247,100</td>
<td>39</td>
<td>939,000</td>
<td>3.8</td>
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<tr>
<td><strong>TOTALS</strong></td>
<td>638,100</td>
<td>100</td>
<td>2,060,700</td>
<td>3.2</td>
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</tbody>
</table>

Consumptive Use 1.6
Losses & Return Flows 1.6

---

1) Adapted from Salazar (1986).
2) Consumptive use divided by irrigation efficiency minus effective precipitation.
3) Total demand divided by acres of irrigated crop land.
**TABLE 3**

HISTORICAL ANNUAL DELIVERIES TO RIO GRANDE COMPACT

<table>
<thead>
<tr>
<th>Year</th>
<th>Conejos River (1000 af)</th>
<th>Rio Grande (1000 af)</th>
<th>Total (1000 af)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1968</td>
<td>116.7</td>
<td>214.1</td>
<td>330.8</td>
</tr>
<tr>
<td>1969</td>
<td>168.7</td>
<td>246.4</td>
<td>415.1</td>
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<tr>
<td>1970</td>
<td>109.4</td>
<td>214.1</td>
<td>323.5</td>
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<td>1971</td>
<td>50.1</td>
<td>156.7</td>
<td>206.8</td>
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<td>1972</td>
<td>32.7</td>
<td>129.6</td>
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<tr>
<td>1973</td>
<td>188.9</td>
<td>331.8</td>
<td>520.7</td>
</tr>
<tr>
<td>1974</td>
<td>32.7</td>
<td>88.8</td>
<td>121.5</td>
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<td>1975</td>
<td>193.0</td>
<td>273.7</td>
<td>466.7</td>
</tr>
<tr>
<td>1976</td>
<td>89.9</td>
<td>159.1</td>
<td>249.0</td>
</tr>
<tr>
<td>1977</td>
<td>11.3</td>
<td>49.9</td>
<td>61.2</td>
</tr>
<tr>
<td>1978</td>
<td>69.4</td>
<td>105.1</td>
<td>174.5</td>
</tr>
<tr>
<td>1979</td>
<td>231.3</td>
<td>394.5</td>
<td>625.8</td>
</tr>
<tr>
<td>1980</td>
<td>212.1</td>
<td>239.6</td>
<td>451.7</td>
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<tr>
<td>1981</td>
<td>32.5</td>
<td>99.0</td>
<td>131.5</td>
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<td>1982</td>
<td>232.5</td>
<td>207.2</td>
<td>439.7</td>
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<tr>
<td>1983</td>
<td>179.8</td>
<td>207.9</td>
<td>387.7</td>
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<tr>
<td>1984</td>
<td>172.7</td>
<td>242.4</td>
<td>415.1</td>
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<tr>
<td>1985</td>
<td>0</td>
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<td>0</td>
</tr>
<tr>
<td>1986</td>
<td>0</td>
<td>0</td>
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</table>

Mean: 118.0  186.7  304.6
Std. Dev.: 80.4  98.8  173.8
Maximum: 231.3  394.5  625.8
Minimum: 0  0  0

1) Source: Rio Grande Compact Commission reports.
2) Estimated by Division 3 Engineer (not included in statistical summaries).
<table>
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<tr>
<th>Year</th>
<th>Conejos River (1000 af)</th>
<th>Rio Grande (1000 af)</th>
<th>Total (1000 af)</th>
<th>Percent of Annual Delivery</th>
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<tr>
<td>1968</td>
<td>81.9</td>
<td>148.7</td>
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<td>1969</td>
<td>128.8</td>
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<td>38.9</td>
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<td>150.8</td>
<td>198.0</td>
<td>348.8</td>
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<td>69.4</td>
<td>97.0</td>
<td>166.4</td>
<td>66.8</td>
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<td>1977</td>
<td>0.7</td>
<td>15.7</td>
<td>16.4</td>
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<td>59.7</td>
<td>55.4</td>
<td>115.1</td>
<td>66.0</td>
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<td>347.5</td>
<td>562.8</td>
<td>89.9</td>
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<td>172.1</td>
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<td>36.7</td>
<td>51.2</td>
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<td>205.6</td>
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<td>338.2</td>
<td>76.9</td>
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<td>1986</td>
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Mean 92.9 118.2 211.2 60.8
Std. Dev. 76.8 88.9 160.0 20.2
Maximum 215.3 347.5 562.8 89.9
Minimum 0 0 0 26.8

1) Source: Rio Grande Compact Commission reports.
2) Estimated by Division 3 Engineer (not included in statistical summaries).
3) Annual delivery shown in Table 3.
### TABLE 5
SENSITIVITY OF ANNUAL UNIT COSTS TO CHANGING ASSUMPTIONS ($/af)

<table>
<thead>
<tr>
<th>Annual Withdrawal (af/yr)</th>
<th>Assumed Interest Rate</th>
<th>Assumed Transmissivity 25,000 gpd/ft</th>
<th>Assumed Transmissivity 250,000 gpd/ft</th>
<th>Assumed Well Spacing 2-mile</th>
<th>Assumed Pumping Rate 1000 gpm</th>
<th>Assumed Pumping Rate 1500 gpm</th>
<th>Assumed Pumping Rate 2000 gpm</th>
<th>Assumed Well Depth Low</th>
<th>Assumed Demand Window 4 mo</th>
<th>Assumed Demand Window 8 mo</th>
<th>Assumed Demand Window 12 mo</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Low 5%</td>
<td>Medium 7%</td>
<td>High 9%</td>
<td>Low 2-mile</td>
<td>1000 gpm</td>
<td>1500 gpm</td>
<td>2000 gpm</td>
<td>Low 3000 ft</td>
<td>Low 4 mo</td>
<td>Low 8 mo</td>
<td>Low 12 mo</td>
</tr>
<tr>
<td>10,000</td>
<td>187</td>
<td>216</td>
<td>247</td>
<td>216</td>
<td>182</td>
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<td>216</td>
<td>216</td>
<td>199</td>
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<tr>
<td>20,000</td>
<td>192</td>
<td>221</td>
<td>253</td>
<td>221</td>
<td>180</td>
<td>229</td>
<td>221</td>
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<td>210</td>
<td>234</td>
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<td>232</td>
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<tr>
<td>100,000</td>
<td>220</td>
<td>238</td>
<td>259</td>
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<td>129</td>
<td>281</td>
<td>238</td>
<td>238</td>
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<tr>
<td>200,000</td>
<td>291</td>
<td>308</td>
<td>328</td>
<td>308</td>
<td>132</td>
<td>396</td>
<td>308</td>
<td>308</td>
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<tr>
<td>300,000</td>
<td>349</td>
<td>366</td>
<td>386</td>
<td>366</td>
<td>141</td>
<td>504</td>
<td>366</td>
<td>366</td>
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</tbody>
</table>

1) Base Case is for 10-mile transmission pipeline, Transmissivity = 25,000 gpd/ft, Storativity = 0.0001, Time = 10 years, Interest Rate = 0.07, Well Spacing = 5 mi, Pumping Rate = 2000 gpm and Well Depth = 5000 ft.
2) -- Indicates no sensitivity analyses because of physical constraints on system.
1000 GPM WELLS

1500 GPM WELLS

2000 GPM WELLS

NUMBER OF WELLS VS ANNUAL WITHDRAWAL
SAN LUIS VALLEY DEEP
CONFINED AQUIFER

FIGURE 1
--- Transmissivity = 250,000 gpd/ft²
Storativity = 10⁻⁴
Time = 10 years
5-mile well spacing

--- Transmissivity = 25,000 gpd/ft²
Storativity = 10⁻⁴
Time = 10 years
5-mile well spacing

Note: Assumes the aquifer is INFINITE in annual extent.

Maximum piezometric surface decline from a wellfield for selected annual withdrawals.
San Luis Valley Deep Confined Aquifer.

Figure 2 SHT. of

Project ________ Calc. ________ Figure 2 SHT. of

By ______ Date ______ Chkd. ______ Date ______ Project No. ________
APPENDIX A

DESCRIPTION OF COST CALCULATION FACTORS
APPENDIX A
DESCRIPTION OF COST CALCULATION FACTORS

The following sections describe the calculations involved in the FORTRAN program COST (Appendix B) and its subroutines. The program uses functional relationships to calculate facility sizes, quantities and costs. Not all the features of the COST routine were used in this particular application (such as terminal water storage facilities).

WELLS, PUMPS AND INTERWELL PIPE (Subroutine WELL)

Number of Wells

The number of wells is equal to the peak flow rate divided by the yield per well rounded up, plus a standby capacity of 10 percent of the total number of wells, but the standby capacity, however, cannot be less than one or greater than 10 wells.

\[
\text{NWA} = \text{peak flow rate/yield per well (rounded up)}
\]

\[
\text{Number of wells} = \text{NWA} + 10 \text{ percent NWA}
\]  \hspace{1cm} (A-1)

where:

\[
1 \leq 10 \text{ percent NWA} \leq 10
\]

Cost of Pumps

The cost of the pumps is calculated from the following equation:

\[
\text{Cost per pump} = (30 \times \text{yield per well}) + 20,000
\]  \hspace{1cm} (A-2)
Cost of Well Construction

The cost of well construction is calculated from the following equation.

\[
\text{Cost per well} = (150. \times \text{depth of well}) - 2200 \tag{A-3}
\]

Cost of Interwell Pipe

The cost of interwell pipe is related to peak flow rate and number of wells by the following equation:

\[
\text{Cost of interwell pipe} = 27,000. \times (\text{peak flow rate} \times \text{number of wells})^{0.65} \tag{A-4}
\]

Total Cost of Wells

The total cost of the wells equals cost of pumps + cost of interwell pipe + cost of well construction. If the water source is surface water, the number of wells equals 0 and the total cost of wells equals 0.

COST OF TRANSMISSION PIPE

Size of Pipe (Subroutine SIZE)

The diameter is derived from this pipe size optimization formula (Streeter, 1973). As pipe is available only in certain diameters, the size was rounded up to the next six inch interval for \( d_{\text{in.}} \leq 48 \text{ in.} \) and rounded up the next 12 in. interval for \( d_{\text{in.}} > 48 \text{ in.} \).

\[
d_{\text{in.}} = 33.4 \times \frac{P^{0.163} \times Q^{0.463}}{E^{0.163} \times C^{0.301}} \tag{A-5}
\]
where:

\[ P = \text{cost of electricity, } \$/\text{kwh}; \quad Q = \text{peak flow rate, mgd}; \]
\[ E = \text{pumping plant efficiency}; \quad C = \text{Hazen-Williams coefficient of pipe}. \]

**Length of Pipeline (Subroutine PIPE)**

The length of pipeline is equal to the measured miles times a factor \( \geq 1 \) to allow for terrain corrections.

**Cost of Pipe (Subroutine PIPE)**

The cost per foot of pipe is derived from the transmission pipe cost data in recent edition of the F.W. Dodge Manual, and from recent issues of Engineering News Record for steel pipe.

\[
\text{Cost/ft} = 5.21 \times \text{diam. in.} - 13.36, \text{diam.} \leq 36 \text{ in.} \\
\text{Cost/ft} = 7.65 \times \text{diam. in.} - 95.26, \text{diam.} > 36 \text{ in.} \tag{A-6}
\]

**COST OF TERMINAL STORAGE (SUBROUTINE TERM)**

**Number of Storage Tanks**

There must be at least two tanks, and no tank may hold more than 25 mgd. The total storage capacity must be at least equal to two days design usage. The number of tanks is related to design usage in mgd by the following formula:

\[
\text{No. of tanks} = 2, \text{for} \quad \text{ave. mgd} \leq 25 \text{ mgd} \\
\text{No. of tanks} = [2 \times (\text{avg. mgd}/25)]\text{rounded up}, \text{for} \quad \text{avg. mgd} > 25 \text{ mgd} \tag{A-7}
\]
Size of Tanks

Arbitrarily, the height = radius of the tanks

Cost of Tanks

The cost of tanks is derived from the cost data for terminal storage tanks by Ramamurthy and Chicoine (1984). The cost is calculated by the following equation:

\[
\text{Cost per tank} = \left[0.0867 \text{ (ave. gpd/10}^6\text{)} + 0.0532\right] \times 10^6 \tag{A-8}
\]

COST OF BOOSTER STATIONS (SUBROUTINE BOOST)

Total Head

Friction Head - The friction head is obtained from the Hazen-Williams formula as given in Davis and Sorensen (1969).

\[
Q = 0.432 C_w d^{2.63} S^{0.54}, \text{ or}
\]

\[
S = \left(Q/(0.432 C_w d^{2.63})\right)^{1/0.54} \tag{A-9}
\]

where:

\[S = \text{head loss, ft/ft}; \quad Q = \text{peak flow rate in cfs};\]
\[C_w = \text{Hazen-Williams Coef.}; \quad d = \text{pipe diameter in ft}.\]

Total Head - Total booster station pumping head is equal to the friction loss over the length of the pipeline plus the elevation head plus the height of
the terminal storage tanks less the discharge head at the well pumps \([230 \text{ ft} = 100 \text{ psi} \text{ (Streeter, 1973)}]\). If the water source is surface water, the discharge head at the well pumps is equal to 0.

Number of Booster Stations

The number of booster stations is equal to the following:

\[
\text{No. of large stations} = \left(\frac{\text{Total head}}{240 \text{ ft}}\right) \text{ rounded down} \quad (A-10)
\]

If the remainder, \(R\), is greater than .2, there will be one small booster station pumping at \(R \times \text{horsepower}\); if \(R \leq .2\), then \(R = 0\), and additional stages are added to well pumps.

Cost of Booster Stations

Horsepower - The horsepower of each booster station is given by the following from Singh (1971).

\[
\text{Horsepower (H)} = (0.1756) \times (\text{peak flow in mgd}) \times (\text{head per station}) \times (J)/(\text{pump efficiency}) \quad (A-11)
\]

where:

\[
\begin{align*}
\text{Head per Station} &= 240 \text{ ft}.
\text{J is given by the following:} \\
(X = \text{design capacity in mgd})
\end{align*}
\]

\[
\begin{align*}
X \leq 2.0 & \quad J = 2.08 - 0.18X \\
2.0 < X \leq 5.0 & \quad J = 1.9666 - 0.1233X \\
5.0 < X \leq 10.0 & \quad J = 1.42 - 0.14X \\
10.0 < X \leq 20.0 & \quad J = 1.30 - 0.002X \\
20.0 < X \leq 30.0 & \quad J = 1.28 - 0.001X \\
30.0 < X & \quad J = 1.25
\end{align*}
\]
Cost of Booster Stations

Cost per station is given by the following formula from Singh (1971).

\[
\text{Cost of booster stations} = [17000. + (135. \times (\text{Horsepower}^{1.01}))] \times \text{number of stations} + (17000. + [135. \times (R \times \text{Horsepower}^{1.01})])
\]  
(A-12)

CONSTRUCTION COSTS (COST)

Construction Costs = Cost of wells + booster stations + terminal storage + pipeline.  
(A-13)

INTEREST DURING CONSTRUCTION (SUBROUTINE INTR)

Months for Construction

The construction period is determined using the following formula and applied to the design capacity in mgd.

\[
\text{No. of Months (M)} = \left\lceil \frac{8.}{\left(\frac{1.}{\text{mgd}}\right)^{32}} \right\rceil \text{ rounded up}
\]  
(A-14)

Cost of Interest During Construction

The cost is given by the following formula.

\[
\text{Interest} = \left(\frac{\text{annual interest rate}}{12}\right) \times M \times \text{(Construction Costs)}
\]  
(A-15)
ELECTRIC POWER COSTS (SUBROUTINE ELEC)

It takes .004 kwh to lift 1000 gallons of water one foot (Streeter, 1973). The annual cost of electric power is given by the following formula:

\[
\text{Electric power costs} = \left[ .004 \times \frac{\text{design capacity}}{1000} \times \text{head} \right] \quad (A-16)
\]

Head = friction head + elevation head + height of tank + pumping lift \((A-17)\)
+ pump discharge head

O & M LABOR, SUPPLIES AND MATERIALS (SUBROUTINE OM)

The cost of O&M (operation and maintenance) labor, supplies and materials is related to peak flow rate, number of wells and miles of transmission line by the following formula:

\[
\text{Cost of O & M labor} = 3262. \left( \text{peak flow in mgd} \times \text{no. of wells} \times \text{miles of transmission pipe} \right)^{0.49} \quad (A-18)
\]

TOTAL O & M (COST)

\[
\text{Total O & M} = \text{Electric power costs} + \text{O & M labor, supplies and materials}. \quad (A-19)
\]

START-UP COSTS (SUBROUTINE WCSU)

The formula for start-up costs is:

\[
\text{Start-up Costs} = .0833 \times (\text{Total O & M}) \quad (A-20)
\]

Note: .0833 represents one month.
WORKING CAPITAL (SUBROUTINE WCSU)

The formula for working capital cost is:

\[
\text{Working Capital} = 0.1667 \times (\text{Total O & M})
\]  
\text{Note: } .1667 \text{ represents two months.}  

OWNERS GENERAL EXPENSE (SUBROUTINE OGE)

Cost Factor

This cost factor is derived from the scaling factors given on page 145 of Streeter (1973), which vary with total construction cost (C), by the following formula:

\[
\text{Factor} = (0.12/(1,000,000/C)^{-1.25}) \text{ for } C \leq 10,000,000 \\
\text{Factor} = (0.09/(10,000,000/C)^{-1.09}) \text{ for } C > 10,000,000
\]  

Owners' General Expense

\[
\text{Owners' general expense} = C \times \text{factor}
\]  

LAND COSTS (SUBROUTINE LAND)

The land requirements for pumping and transmission of water are as follows: .5 acre/well site, 0.25 acre/booster station, 30 ft. right-of-way for pipeline, and 100 ft. clearance around terminal storage tanks. The total land cost is the total acreage of land times the price of land per acre.
ANNUAL DEPRECIABLE CAPITAL COSTS (COST)

Depreciable Capital Rate

Depreciable capital rate (DCR) is equal to the amortization factor + interest rate + tax rate + insurance rate (Streeter, 1973, page 178). The amortization factor + interest rate = the Capital Rate Factor CRF which is derived from the formula given on page 11 of Singh et al (1972).

\[
CRF = \text{interest rate} \frac{(1 + \text{interest rate})^N}{((1 - \text{interest rate})^N - 1)}
\]  

where:

- \( N \) = amortization period, years.
- \( DCR = CRF + \text{tax rate} + \text{insurance rate} \).

Annual Depreciable Capital Costs

The depreciable capital cost equal the total construction cost + interest during construction + start-up cost + owners' general expense. Annual depreciable capital costs = depreciable capital costs x DCR.  

(A-25)

ANNUAL NON-DEPRECIABLE CAPITAL COSTS (COST)

Non-depreciable capital costs = the land costs + working capital. The annual non-depreciable capital costs = non-depreciable capital costs x interest rate.  

(A-26)

TOTAL ANNUAL COSTS (COST)

Total Annual Costs = total annual O & M + total annual depreciable capital cost + total annual non-depreciable capital cost (Streeter, 1973).  

(A-27)
INFLATION FACTOR

The following costs are multiplies by the inflation factor: total well costs, terminal storage, booster stations, O & M labor, supplies and materials.
REFERENCES


APPENDIX B

FORTRAN PROGRAM COST
PROGRAM COST

THIS PROGRAM COMPUTES COSTS FOR PUMPING AND TRANSMITTING WATER FROM A WELL FIELD OR OTHER SOURCE. THE PROGRAM IS APPLICABLE FOR FLOW RATES GREATER THAN ONE MILLION GALLONS PER DAY (1 MQD).

PROGRAM ORIGINALLY WRITTEN BY JAMES Q. NALVEN, JUNE 1975.

UPDATES AND ADDITIONS BY JAMES R. KUNKEL, MAY 1986.

SUBROUTINES REQUIRED FOR THE PROGRAM: BOOST, ELEC, INTR, LAND, OGE, OM, PIPE, SIZE, TERM, THOU, WELL, WCSU

INPUTS P: COST OF ELECTRICITY, $/KWH  E: PUMP EFFICIENCY, DECIMAL
C: HAZEN-WILLIAMS COEF. FOR PIPE BEING USED
EF: COST OF ESCALATION FACTOR, REAL NUMBER
PLI: LENGTH OF PIPELINE, AIR MILES  RF: MAXIMUM RATE FACTOR
GAF: AVERAGE FLOW, AF/yr  GPM: YIELD PER WELL, GPM
PP: PUMPING LIFT, FT  PA: PRICE PER ACRE FOR LAND, $
XINT: ANNUAL INTEREST RATE, DECIMAL  TX: TAX RATE, DECIMAL
WD: WELL DEPTH, FEET  XINS: INSURANCE RATE, DECIMAL
YR: AMORTIZATION PERIOD, YEARS  PF: PIPE LENGTH FACTOR
HE: ELEVATION HEAD, FEET  XX: IF XX.EQ.0 NO TERM STORAGE
X: IF X.EQ.0 THE COST OF WELLS WILL NOT BE INCLUDED
PLANT: PLANT DESIGNATION, ALPHA  PLOC: PLANT LOCATION, ALPHA
FORM: WITHDRAWAL AGUIFIER, ALPHA  WLOC: WELL LOCATION, ALPHA

OUTPUTS CP: TRANSMISSION PIPELINE COST  CT: TERMINAL STORAGE COST
CW: WELL AND INTERWELL PIPELINE COST
CB: BOOSTER STATION COST  CL: LAND COST
CE: ELECTRIC POWER COST  CWC: WORKING CAPITAL
COM: OPERATION AND MAINT. COST  CS: START-UP COST
CI: INTEREST DURING CONSTRUCTION COST
COG: OWNERS GENERAL EXPENSE  TC: TOTAL CONSTRUCTION COST
TDC: DEPRECIABLE CAPITAL COST  TOM: TOTAL ANNUAL O & M COST
TNDC: NONDEPRECIABLE CAPITAL COST
DCF: DEPRECIABLE CAPITAL RATE  ATDC: ANNUAL TDC
ATNDC: ANNUAL TNDC  TAC: TOTAL ANNUAL COST
DAF: ANNUAL UNIT COST $/AF OF WATER

ALL COSTS ROUNDED TO THE NEAREST THOUSAND AND OUTPUT AS INTEGERS

INPUT IS ON UNIT 5  OUTPUT IS ON UNIT 6
OUTPUT OF SUMMARY DATA IS TEMPORARILY STORED ON UNIT 10

CHARACTER*15 FILEIN, FILEOUT
CHARACTER*20 PLANT, FORM
CHARACTER*16 PLOC, WLOC
COMMON/A/ CI
COMMON PL, NBT, RNB, CL, CB, TH, CE, COM, CS, IT, COG, CWC, CT, HE, ICOM, ICE,
+ QMD, GGP, GMD2, GPM2, GCFS2, HT, NT, P, E, C, EF, PLI, GPM, PP, PA,
+ XINT, D, PF, CP, CW, NW, WD
WRITE(*, 3000)
3000 FORMAT(' INPUT FILE NAME: /')
READ(*, 1600) FILEIN
WRITE(*, 3005)
3005 FORMAT(' OUTPUT FILE NAME: /')
READ(*, 1600) FILEOUT
OPEN(5, FILE=FILEIN, STATUS='OLD')
OPEN(6, FILE=FILEOUT, STATUS='NEW')
OPEN(10, STATUS='SCRATCH')

INPUT DATA

NC = 0
DO 999 IBIQ = 1, 1000
READ(5, 1600, END=1001) PLANT
READ(5, 1600) PLOC
READ(5, 1600) WLOC
READ(5, 1600) FORM
READ(5, 100) P, E, C, EF, PLI, PF, QAF, RF, X, QPM, PP, WD, HE, PA,
+ XINT, XINS, TAX, YR, XX

CONVERSION OF AF/YR TO MGD AND GPM

GGPD = (QAF*325850./365.)
GMGD = GGPD/10. **6

MAXIMUM RATE FOR QPM, MGD AND CFS

GGPM2 = (GGPD/1440.)*RF
GMGD2 = GMGD * RF
GCFS2 = GGPM2/448.8

CALCULATE SIZE OF TRANSMISSION PIPE

IF (PLI.EQ.0.) GO TO 40
CALL SIZE

CALCULATE COST OF PIPE

40 IF (PLI.EQ.0.) D = 1.
CALL PIPE
CALL THOU(CP, ICP)

IF (XX.LT.1) GO TO 10

CALCULATE COST OF WELLS AND INTERWELL PIPE

CALL WELL
CALL THOU(CW, ICW)

CALCULATE COST OF TERMINAL STORAGE

GO TO 20

10 ICW = 0
NW = 0
20 HT = 0.
ICT = 0
IF (XX.LT.1) GO TO 30
CALL TERM
CALL THOU(CT, ICT)

CALCULATE COST OF BOOSTER STATIONS

30 CALL BOOST
CALL THOU(CB, ICD)
CALCULATE LAND COSTS
CALL LAND
CALL THOU(CL, ICL)

CALCULATE COST ELECTRICAL POWER
CALL ELEC
CALL THOU(CE, ICE)

CALCULATE OPERATION AND MAINTENANCE COSTS
CALL OM
CALL THOU(COM, ICOM)

CALCULATE WORKING CAPITAL AND START-UP COSTS
CALL WCSU
ICWC = CWC + .5
ICS = CS + .5

CALCULATE TOTAL CONSTRUCTION COSTS, TC
ITC = ICP + ICW + ICT + ICB

CALCULATE INTEREST DURING CONSTRUCTION COST
CALL INTR
ICI = CI + .5

CALCULATE OWNERS GENERAL EXPENSE
CALL OGE
CALL THOU(COG, ICOG)

CALCULATE DEPRECIABLE AND NONDEPRECIABLE CAPITAL COSTS
ITDC = ITC + ICI + ICS + ICOG
ITNDC = ICL + ICWC
ITTDC = ITNDC + ITDC

CALCULATE TOTAL ANNUAL OPERATION AND MAINTENANCE
ITOM = ICOM + ICE

CALCULATE TOTAL ANNUAL COSTS, ANNUAL DEPRECIABLE CAPITAL
COSTS, DEPRECIABLE CAPITAL COST RATE, AND ANNUAL NON-
DEPRECIABLE CAPITAL COST

DCR = ((XINT*(1. + XINT)**YR)/(((1. + XINT)**YR)-1))
+ XINS + TAX
ISTDC = ITDC * DCR + .5
ISTNDC = ITNDC * XINT + .5

CALCULATE UNIT COST

ITAC = ISTNDC + ISTDC + ITOM
IDAF = ITAC / 1000. / GAF
YINT = XINT * 100.
YDCR = DCR * 100.
IQAF = GAF + 0.5
ID = D + 0.5

WRITE COST SUMMARY

WRITE(6, 2300)
WRITE(6, 1800)
WRITE(6, 1900)
WRITE(6, 2000) PLANT, PLOC, WLOC, FORM, IQAF
WRITE(6, 300)
WRITE(6, 400)
WRITE(6, 500)
WRITE(6, 600) NW, ICW, ID, ICP, ICB, ICT
WRITE(6, 700)
WRITE(6, 800) ITC, ICI, ICS, ICOQ
WRITE(6, 700)
WRITE(6, 900) ITDC, ISTDC, YDCR, ICL, ICWC
WRITE(6, 700)
WRITE(6, 1000) ITNDC, ISTNDC, YINT
WRITE(6, 1700)
WRITE(6, 1100) ICOM, ICE
WRITE(6, 700)
WRITE(6, 1200) ITOM, ITOM
WRITE(6, 1300)
WRITE(6, 1400) ITAC, IDAF
WRITE(6, 1500) PLANT, FORM, IQAF, ITTDC, ITOM, ITAC, IDAF

NC = NC + 1
999 CONTINUE
1001 WRITE(6, 2300)
WRITE(6, 1800)
WRITE(6, 2000)
REWIND 10
1010 WRITE(6, 2100)
DO 99 ISML = 1, NC
READ(10, 1500, END=2001) PLANT, FORM, IQAF, ITTDC, ITOM, ITAC, IDAF
WRITE(6, 2200) PLANT, FORM, IQAF, ITTDC, ITOM, ITAC, IDAF
99 CONTINUE
2001 CALL EXIT

FORMATS

100 FORMAT(10F8.0)
200 FORMAT(' DETAILED COST ANALYSIS'/
+ ' PLANT DESIGNATION: ', A20, ' PLANT LOCATION: ', A16/
+ ' WATER SOURCE LOCATION: ', A16, ' FORMATION: ', A20/
+ ' DESIGN USAGE', I8, ' ACRE- FEET/ YEAR'/1X, 73('-')/1T14,
+ 'COST ITEM', T42, 'ESTIMATED COST', T64, 'ANNUAL COST'/
+ T31.2(14X, '* X 1000'))
300 FORMAT(1X,1T14,9(''-'), T42,14(''-'), T64,11(''-'))
400 FORMAT(' ' CAPITAL COSTS')
500 FORMAT(1X,13(''-'))
600 FORMAT(T6, 'WELLS, PUMPS, INTERWELL PIPE('', I4, ' WELLS)'
+ 'I6/T6,
+ 'TRANSMISSION PIPE ('', I3, ' IN.)', T50, I6/T6, 'BOOSTER ',
+ 'STATIONS', T50, I6/T6, 'TERMINAL STORAGE', T50, I6)
700 FORMAT(1X,1T4B,8(''-'))
800 FORMAT( '/T6, 'SUBTOTAL - CONSTRUCTION COSTS', T4B, '* ', I6//T6,
+ 'INTEREST DURING CONSTRUCTION', T50, I6/T6, 'START- UP COSTS',
+ T50, I6/T6, 'OWNERS GENERAL EXPENSE', T50, I6)
SUBROUTINE BOOST

C THIS SUBROUTINE CALCULATES HEAD IN PIPES AND COST OF BOOSTER PUMPING STATIONS

REAL J
COMMON PL, NBT, RNBl, CL, CB, TH, CE, COM, CS, ITC, CQ, CW, CT, HE, ICOM, ICE, + QMGD, GPPD, QMGD2, GCPM2, GCPM3, HT, NT, P, E, EF, PLI, GPM, PP, PA, + XINT, D, PF, CP, CW, NW, WD

C HL IS THE FRICTION HEAD IN PIPES

HL = 5280. * PL * (QCF2 / (0.432 * C * (D / 12.) ** 2.63)) ** (1. / 54)

C CALCULATE TOTAL HEAD

TH = HL + HT + HE - 230.
IF(NW.EQ.O) TH = TH + 230.
IF(TH.LE.0.) TH = 0.

C CALCULATE COST OF BOOSTER STATIONS

NBT IS THE NUMBER OF STATIONS, 1/240 FT HEAD + ONE LOW HEAD STA.

XNB = TH/240.
RNBl = XNB - IFIX(XNB)
NBT = XNB

C CALCULATE FIRMING FACTOR, J

C
IF(GMD.D.LE.2.) GO TO 30
IF(GMD.D.LE.5.) GO TO 40
IF(GMD.D.LE.10.) GO TO 50
IF(GMD.D.LE.20.) GO TO 60
IF(GMD.D.LE.30.) GO TO 70
J = 1.25
GO TO 80
30 J = 2.08 - (.18*GMD)
GO TO 80
40 J = 1.9666 - (.1233*GMD)
GO TO 80
50 J = 1.42 - (.014*GMD)
GO TO 80
60 J = 1.3 - (.002*GMD)
GO TO 80
70 J = 1.28 - (.001*GMD)

CALCULATE REQUIRED HORSEPOWER, HORS AND HORSR

80 HORS = .176 * GMD2 * 240. * J/E
IF(RNB.LT. .2) GO TO 90
HORSR = (HORS) * RNB

CALCULATE COST OF BOOSTER STATIONS

CB = ((17000. +((135.*HORS)**1.01))*NBT+(17000. +((135.*HORSR)**1.01) +))*EF
GO TO 100
90 CB = ((17000. +((135.*HORS)**1.01))*NBT)*EF
RNB = 0.
100 RETURN
END

SUBROUTINE WELL

THIS SUBROUTINE CALCULATES THE COST OF WELLS AND INTERWELL PIPE

COMMON PL,NBT,RNB,CL,CB,TH,CE,COM,CS,ITC,COG,CWC,CT,HE,ICOM,ICE, + GMD,GGPD,GMMD2,GQPM2,GCFS2,HT,NT,P,E,C,EF,PLI,QPM,PP,PA, + XINT, D, PF, CP, CW, NW, WD

NW IS THE NUMBER OF WELLS: MAX. TOTAL GPM/GPM PER WELL, ROUNDED UP

NW = (GQPM2/GPM) + 1
NWA = (NW *. .1) + 1
IF(NWA.GT.10) NWA = 10
NW = NW + NWA

COST OF WELLS

CW2 = (150. * WD) * NW

COST OF PUMPS

CW = NW * ((30. * QPM) + 20000.)

COST OF INTERWELL PIPE

CIW = 27000. * ((GMD2 * NW)**.65)
CW = (CIW + CW + CW2) * EF
SUBROUTINE LAND

THIS SUBROUTINE CALCULATES THE LAND COST

COMMON PL, NBT, RNB, CL, CB, TH, CE, COM, CS, ITC, COG, CWC, CT, HE, ICOM, ICE,
+ QMD, QGP, QMD2, QMPM2, QCFS2, HT, NT, P, E, C, EF, PLI, QPM, PP, PA,
+ XINT, D, PF, CP, CW, NW, WD

N1 = RNB * 2
CLL = PA * (1.5 * NW) + (.25 * (NBT + N1)) + (((2 * HT) + 100.) ** 2) / 43560.
CLP = PA * (PF * PLI ** 30. * 5280. / 43560.)
CL = CLL + CLP
RETURN
END

SUBROUTINE OM

THIS SUBROUTINE CALCULATES OPERATION AND MAINTENANCE COSTS

COMMON PL, NBT, RNB, CL, CB, TH, CE, COM, CS, ITC, COG, CWC, CT, HE, ICOM, ICE,
+ QMD, QGP, QMD2, QMPM2, QCFS2, HT, NT, P, E, C, EF, PLI, QPM, PP, PA,
+ XINT, D, PF, CP, CW, NW, WD

NWZ = NW
IF (PL .EQ. 0.) PL = 1.
IF (NW .EQ. 0.) NWZ = 1
COM = (3262. * (QMD2 * NWZ * PL) ** .49) * EF
RETURN
END

SUBROUTINE OGE

THIS SUBROUTINE CALCULATES OWNERS GENERAL EXPENSE COSTS

COMMON PL, NBT, RNB, CL, CB, TH, CE, COM, CS, ITC, COG, CWC, CT, HE, ICOM, ICE,
+ QMD, QGP, QMD2, QMPM2, QCFS2, HT, NT, P, E, C, EF, PLI, QPM, PP, PA,
+ XINT, D, PF, CP, CW, NW, WD

TC = ITC * 1000.
IF (TC .LE. 10000000.) GO TO 10
COG = TC * (.09 / ((10000000. / TC) ** (-.109)))
GO TO 20
10 COG = TC * (.12 / ((1000000. / TC) ** (-.125)))
20 RETURN
END

SUBROUTINE THOU(X, I)

THIS SUBROUTINE ROUNDS COSTS TO THE NEAREST THOUSAND AND
CONVERTS TO INTEGER

I = (X / 1000.) + .5
RETURN
END

SUBROUTINE ELEC
SUBROUTINE CALCULATES ELECTRIC POWER COST

COMMON PL, NBT, RNB, CL, CB, TH, CE, COM, CS, ITC, COQ, CWC, CT, HE, ICOM, ICE,
+ GMD, GPD, GM32, GPM2, GCFS2, HT, NT, P, E, C, EF, PLI, QPM, PP, PA,
+ XINT, D, PF, CP, CW, NW, WD

THX = TH + PP + 230.
IF (NW.EQ.0) THX = TH
CE = P * (0.004*GPQD*(365./1000.)*THX)
RETURN
END

SUBROUTINE SIZE

THIS SUBROUTINE CALCULATES THE SIZE OF TRANSMISSION PIPE

COMMON PL, NBT, RNB, CL, CB, TH, CE, COM, CS, ITC, COQ, CWC, CT, HE, ICOM, ICE,
+ GM3D, GPQD, GM32, GPM2, GCFS2, HT, NT, P, E, C, EF, PLI, QPM, PP, PA,
+ XINT, D, PF, CP, CW, NW, WD

D IS THE PIPE DIAMETER IN INCHES

DA = 83.4*(P**1.63)*(GM3D2**.463)/(E**1.63)*(C**3.01)
IF (DA.LE.48.) GO TO 10
D = 12 * (IFIX(DA)/12) + 12
GO TO 20
10 D = 6 * (IFIX(DA)/6) + 6
20 RETURN
END

SUBROUTINE TERM

THIS SUBROUTINE CALCULATES THE NUMBER OF STORAGE TANKS
THE MAX. TANK SIZE IS 25 MILLION GALLONS, AND MINIMUM
STORAGE MUST BE .GE. 2*GM3D. THE COST OF THE STORAGE TANKS
ALSO IS CALCULATED.

COMMON PL, NBT, RNB, CL, CB, TH, CE, COM, CS, ITC, COQ, CWC, CT, HE, ICOM, ICE,
+ GM3D, GPQD, GM32, GPM2, GCFS2, HT, NT, P, E, C, EF, PLI, QPM, PP, PA,
+ XINT, D, PF, CP, CW, NW, WD

IF (GM3D.LT.25.) GO TO 10
NT = 1 + (2*(GM3D/25.))
X = 25.
GO TO 20
10 NT = 2
X = GM3D
20 CT = ((NT**(.0867*X) + .0932))*10.**6)*EF
HT = ((X*10.**6)/(7.48*3.14159)**(1./3.))
RETURN
END

SUBROUTINE PIPE

THIS SUBROUTINE CALCULATES THE COST OF TRANSMISSION PIPE

COMMON PL, NBT, RNB, CL, CB, TH, CE, COM, CS, ITC, COQ, CWC, CT, HE, ICOM, ICE,
+ GM3D, GPQD, GM32, GPM2, GCFS2, HT, NT, P, E, C, EF, PLI, QPM, PP, PA,
+ XINT, D, PF, CP, CW, NW, WD
PL IS THE TERRAIN-CORRECTED PIPELINE LENGTH

PL = PLI * PF
IF(D. LE. 36.) GO TO 10
CP = PL * 5280. * ((7.65*D) - 95.26)
GO TO 20
10 CP = PL * 5280. * ((5.21*D) - 13.36)
20 RETURN
END

SUBROUTINE WCSU
THIS SUBROUTINE CALCULATES WORKING CAPITAL

COMMON PL, NBT, RNB, CL, CB, TH, CE, COM, CS, ITC, CQG, CWC, CT, HE, ICOM, ICE,
+ GMGD, GQPD, GMGD2, GGPM2, GCFS2, HT, NT, P, E, C, EF, PLI, GPM, PP, PA,
+ XINT, D, PF, CP, CW, NW, WD

WORKING CAPITAL

CWC = .1667 * (ICOM + ICE)

START-UP COSTS

CS = .0833 * (ICOM + ICE)
RETURN
END

SUBROUTINE INTR
THIS SUBROUTINE CALCULATES THE INTEREST DURING CONSTRUCTION

COMMON/A/ CI
COMMON PL, NBT, RNB, CL, CB, TH, CE, COM, CS, ITC, CQG, CWC, CT, HE, ICOM, ICE,
+ GMGD, GQPD, GMGD2, GGPM2, GCFS2, HT, NT, P, E, C, EF, PLI, GPM, PP, PA,
+ XINT, D, PF, CP, CW, NW, WD

NUMBER OF MONTHS FOR CONSTRUCTION

MC = (8. /((1./GMGD)**.32)) + 1

INTEREST DURING CONSTRUCTION

CI = ((MC*(XINT/12.)) * ITC)
RETURN
END
APPENDIX C

BASE CASE COST ANALYSES
DETAILED COST ANALYSIS

PLANT DESIGNATION: SAN LUIS 1
WATER SOURCE LOCATION: VALLEY
DESIGN USAGE: 10000 ACRE-FEET/ YEAR

PLANT LOCATION: SAN LUIS VALLEY
FORMATION: DEEP CONFINED

<table>
<thead>
<tr>
<th>COST ITEM</th>
<th>ESTIMATED COST ( \times 1000 )</th>
<th>ANNUAL COST ( \times 1000 )</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CAPITAL COSTS</strong></td>
<td></td>
<td></td>
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<tr>
<td>WELLS, PUMPS, INTERWELL PIPE (5 WELLS)</td>
<td>$4469</td>
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<tr>
<td>TRANSMISSION PIPE (36 IN.)</td>
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<tr>
<td>BOOSTER STATIONS</td>
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<tr>
<td>TERMINAL STORAGE</td>
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<td><strong>SUBTOTAL - CONSTRUCTION COSTS</strong></td>
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<td>INTEREST DURING CONSTRUCTION</td>
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<td>OWNERS GENERAL EXPENSE</td>
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<td><strong>TOTAL - DEPRECIABLE CAPITAL COSTS</strong> (FIXED CHARGE RATE - 9.31%)</td>
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<td>$1514</td>
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<tr>
<td>LAND COSTS</td>
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<td>WORKING CAPITAL</td>
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<td><strong>TOTAL - NONDEPRECIABLE CAPITAL COSTS</strong> (INTEREST RATE - 7.00%)</td>
<td>$145</td>
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<td><strong>ANNUAL O &amp; M EXPENSE</strong></td>
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<tr>
<td>O &amp; M LABOR, SUPPLIES AND MATERIALS</td>
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<tr>
<td>ELECTRIC POWER COSTS</td>
<td>572</td>
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<td><strong>TOTAL - ANNUAL O &amp; M EXPENSE</strong></td>
<td>$637</td>
<td>637</td>
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<tr>
<td>* TOTAL ANNUAL COSTS</td>
<td>$2161</td>
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UNIT COST $216 / ACRE- FEET
### DETAILED COST ANALYSIS

**PLANT DESIGNATION:** SAN LUIS 2  
**WATER SOURCE LOCATION:** VALLEY  
**DESIGN USAGE:** 20000 ACRE-FEET/YEAR

<table>
<thead>
<tr>
<th>COST ITEM</th>
<th>ESTIMATED COST $ x 1000</th>
<th>ANNUAL COST $ x 1000</th>
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</thead>
<tbody>
<tr>
<td><strong>CAPITAL COSTS</strong></td>
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<td></td>
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<tr>
<td>WELLS, PUMPS, INTERWELL PIPE (8 WELLS)</td>
<td>$ 7319</td>
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<tr>
<td>TRANSMISSION PIPE (60 IN.)</td>
<td>$ 19205</td>
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<tr>
<td>BOOSTER STATIONS</td>
<td>$ 0</td>
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<tr>
<td>TERMINAL STORAGE</td>
<td>$ 0</td>
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<tr>
<td><strong>SUBTOTAL - CONSTRUCTION COSTS</strong></td>
<td>$ 26524</td>
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<tr>
<td>INTEREST DURING CONSTRUCTION</td>
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<td>START-UP COSTS</td>
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<tr>
<td>OWNERS GENERAL EXPENSE</td>
<td>$ 2146</td>
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<tr>
<td><strong>TOTAL - DEPRECIABLE CAPITAL COSTS</strong></td>
<td>$ 32037</td>
<td>$ 2982</td>
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<tr>
<td>(FIXED CHARGE RATE - 9.31%)</td>
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<tr>
<td>LAND COSTS</td>
<td>$ 41</td>
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<td>WORKING CAPITAL</td>
<td>$ 237</td>
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<td><strong>TOTAL - NONDEPRECIABLE CAPITAL COSTS</strong></td>
<td>$ 278</td>
<td>19</td>
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<tr>
<td>(INTEREST RATE - 7.00%)</td>
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<tr>
<td><strong>ANNUAL O &amp; H EXPENSE</strong></td>
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<td></td>
</tr>
<tr>
<td>O &amp; H LABOR, SUPPLIES AND MATERIALS</td>
<td>$ 115</td>
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</tr>
<tr>
<td>ELECTRIC POWER COSTS</td>
<td>$ 1306</td>
<td></td>
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<tr>
<td><strong>TOTAL - ANNUAL O &amp; H EXPENSE</strong></td>
<td>$ 1421</td>
<td>1421</td>
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</tbody>
</table>

* **TOTAL ANNUAL COSTS**                       | $ 4422                   |

**UNIT COST** $ 221/ACRE-FEET
DETAILED COST ANALYSIS

PLANT DESIGNATION: SAN LUIS 3
WATER SOURCE LOCATION: VALLEY
DESIGN USAGE: 50,000 ACRE-FEET/YEAR

PLANT LOCATION: SAN LUIS VALLEY
FORMATION: DEEP CONFINED

<table>
<thead>
<tr>
<th>COST ITEM</th>
<th>ESTIMATED COST $ X 1000</th>
<th>ANNUAL COST $ X 1000</th>
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<tbody>
<tr>
<td>CAPITAL COSTS</td>
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<tr>
<td>WELLS, PUMPS, INTERWELL PIPE (18 WELLS)</td>
<td>$17027</td>
<td>$17027</td>
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<tr>
<td>TRANSMISSION PIPE (8 IN.)</td>
<td>$28900</td>
<td>$28900</td>
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<tr>
<td>BOOSTER STATIONS</td>
<td>$0</td>
<td>$0</td>
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<tr>
<td>TERMINAL STORAGE</td>
<td>$0</td>
<td>$0</td>
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<tr>
<td>SUBTOTAL - CONSTRUCTION COSTS</td>
<td>$45927</td>
<td>$45927</td>
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<tr>
<td>INTEREST DURING CONSTRUCTION</td>
<td>$7234</td>
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<tr>
<td>START-UP COSTS</td>
<td>$430</td>
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<td>OWNERS GENERAL EXPENSE</td>
<td>$3501</td>
<td>$3501</td>
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<td>TOTAL - DEPRECIABLE CAPITAL COSTS (FIXED CHARGE RATE - 9.31%)</td>
<td>$57092</td>
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<tr>
<td>LAND COSTS</td>
<td>$46</td>
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<td>WORKING CAPITAL</td>
<td>$860</td>
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<td>TOTAL - NONDEPRECIEABLE CAPITAL COSTS (INTEREST RATE - 7.00%)</td>
<td>$906</td>
<td>$906</td>
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<tr>
<td>ANNUAL O &amp; M EXPENSE</td>
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<td></td>
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<tr>
<td>O &amp; M LABOR, SUPPLIES AND MATERIALS</td>
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<td>$267</td>
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<td>ELECTRIC POWER COSTS</td>
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<td>TOTAL - ANNUAL O &amp; M EXPENSE</td>
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<td>TOTAL ANNUAL COSTS</td>
<td>$10537</td>
<td>$10537</td>
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</table>

UNIT COST $210 / ACRE-FEET
## Detailed Cost Analysis

**Plant Designation:** San Luis 4  
**Water Source Location:** Valley  
**Plant Location:** San Luis Valley  
**Formation:** Deep Confined  
**Design Usage:** 100,000 Acre-Feet/Year

<table>
<thead>
<tr>
<th>Cost Item</th>
<th>Estimated Cost $ \times 1000</th>
<th>Annual Cost $ \times 1000</th>
</tr>
</thead>
</table>

### Capital Costs

- **Wells, Pumps, Interwell Pipe (35 Wells):** $34,096
- **Transmission Pipe (100 in.):** $38,594
- **Booster Stations:** $0
- **Terminal Storage:** $0

**Subtotal - Construction Costs:** $72,690

- **Interest During Construction:** $14,417
- **Start-Up Costs:** $1,246
- **Owners General Expense:** $5,270

**Total - Depreciable Capital Costs** (Fixed Charge Rate - 9.31%): $93,623  
**Total - Nondepreciable Capital Costs** (Interest Rate - 7.00%): $2,547

### Annual O & M Expense

- **O & M Labor, Supplies and Materials:** $520
- **Electric Power Costs:** $1,443

**Total - Annual O & M Expense:** $1,4956

**Total - Annual Costs:** $23,849

**Unit Cost:** $230 /Acre-Feet
DETAILED COST ANALYSIS

PLANT DESIGNATION: SAN LUIS 5
WATER SOURCE LOCATION: VALLEY
DESIGN USAGE: 200000 ACRE-FEET/YEAR

PLANT LOCATION: SAN LUIS VALLEY
FORMATION: DEEP CONFINED

<table>
<thead>
<tr>
<th>COST ITEM</th>
<th>ESTIMATED COST $ x 1000</th>
<th>ANNUAL COST $ x 1000</th>
</tr>
</thead>
</table>

**CAPITAL COSTS**

- WELLS, PUMPS, INTERWELL PIPE (69 WELLS): $69,580
- TRANSMISSION PIPE (144 IN.): $53,135
- BOOSTER STATIONS: 0
- TERMINAL STORAGE: 0

**SUBTOTAL - CONSTRUCTION COSTS**: $122,715

- INTEREST DURING CONSTRUCTION: $30,781
- START-UP COSTS: $3,817
- OWNERS GENERAL EXPENSE: $8,403

**TOTAL - DEPRECIABLE CAPITAL COSTS** (FIXED CHARGE RATE: 9.31%): $163,716

<table>
<thead>
<tr>
<th>LAND COSTS</th>
<th>WORKING CAPITAL</th>
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<tbody>
<tr>
<td>$71</td>
<td>$7,638</td>
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</table>

**TOTAL - NONDEPRECIABLE CAPITAL COSTS** (INTEREST RATE: 7.00%): $7,709

**ANNUAL O & M EXPENSE**

- O & M LABOR, SUPPLIES AND MATERIALS: $1,018
- ELECTRIC POWER COSTS: $4,480

**TOTAL - ANNUAL O & M EXPENSE**: $4,581

* TOTAL ANNUAL COSTS: $61,784

UNIT COST: $308/ACRE-FOOT
## DETAILED COST ANALYSIS

**PLANT DESIGNATION:** SAN LUIS 6  
**WATER SOURCE LOCATION:** VALLEY  
**DESIGN USAGE:** 300,000 ACRE-FEET/YEAR  
**PLANT LOCATION:** SAN LUIS VALLEY  
**FORMATION:** DEEP Confined

---

<table>
<thead>
<tr>
<th>COST ITEM</th>
<th>ESTIMATED COST $ x 1000</th>
<th>ANNUAL COST $ x 1000</th>
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</thead>
<tbody>
<tr>
<td><strong>CAPITAL COSTS</strong></td>
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<tr>
<td>Wells, Pumps, Interwell Pipe (103 Wells)</td>
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<td>Transmission Pipe (180 in.)</td>
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<td>Booster Stations</td>
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<tr>
<td>Terminal Storage</td>
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<td>Interest During Construction</td>
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<td>Start-Up Costs</td>
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<td>Owners General Expense</td>
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<td>Working Capital</td>
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<td><strong>TOTAL - NON DEPRECIABLE CAPITAL COSTS</strong></td>
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<td>(Interest Rate - 7.00%)</td>
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<td><strong>ANNUAL O &amp; M EXPENSE</strong></td>
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<td>O &amp; M Labor, Supplies and Materials</td>
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<td>Electric Power Costs</td>
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<td><strong>TOTAL ANNUAL COSTS</strong></td>
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<td><strong>UNIT COST</strong></td>
<td>$366/ACRE-FEET</td>
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# Summary of Costs

**Ground-Water Withdrawal and Transmission**

<table>
<thead>
<tr>
<th>Plant Designation</th>
<th>Formation</th>
<th>Design Usage AC-FT/YR</th>
<th>Deprec + Nondeprec Capital Costs $ X 1000</th>
<th>Annual O&amp;M Expenses $ X 1000</th>
<th>Total Annual Costs $ X 1000</th>
<th>Unit Cost $/AC-FT</th>
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</thead>
<tbody>
<tr>
<td>San Luis 1</td>
<td>Deep Confined</td>
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<td>16409</td>
<td>637</td>
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<td>216</td>
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<td>366</td>
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APPENDIX A

DESCRIPTION OF CALCULATION FACTORS
FOR THE COMPUTER-PROGRAM "COST"
APPENDIX A

DESCRIPTION OF CALCULATION FACTORS
FOR THE COMPUTER-PROGRAM "COST"

The following sections describe the calculations involved in the FORTRAN computer-program COST (Appendix D) and its subroutines. The program uses functional relationships to calculate facility sizes, quantities and costs. Not all the features of the COST routine were used in this particular application (such as terminal water storage facilities).

WELLS, PUMPS AND INTERWELL PIPE (Subroutine WELL)

Number of Wells

The number of wells is equal to the peak flow rate divided by the yield per well rounded up, plus a standby capacity of 10 percent of the total number of wells, but the standby capacity, however, cannot be less than one or greater than 10 wells.

\[
NWA = \text{peak flow rate/yield per well (rounded up)}
\]

Number of wells = NWA + 10 percent NWA  \hspace{1cm} (A-1)

where:

\[1 \leq 10 \text{ percent } NWA \leq 10\]

Cost of Pumps

The cost of the pumps is calculated from the following equation:

\[
\text{Cost per pump} = (30. \times \text{yield per well}) + 20,000 \hspace{1cm} (A-2)
\]
Cost of Well Construction

The cost of well construction is calculated from the following equation.

\[
\text{Cost per well} = (150 \times \text{depth of well}) - 2200 \quad (A-3)
\]

Cost of Interwell Pipe

The cost of interwell pipe is related to peak flow rate and number of wells by the following equation:

\[
\text{Cost of interwell pipe} = 27,000 \times (\text{peak flow rate} \times \text{number of wells})^{0.65} \quad (A-4)
\]

Total Cost of Wells

The total cost of the wells equals cost of pumps + cost of interwell pipe + cost of well construction.

COST OF TRANSMISSION PIPE

Size of Pipe (Subroutine SIZE)

The diameter is derived from this pipe size optimization formula (Streeter, 1973). As pipe is available only in certain diameters, the size was rounded up to the next six inch interval for \(d_{\text{in.}} \leq 48\) in. and rounded up the next 12 in. interval for \(d_{\text{in.}} > 48\) in.

\[
d_{\text{in.}} = 83.4 \times \frac{P^{0.163} 	imes Q^{0.463}}{E^{0.163} \times C^{0.301}}
\quad (A-5)
\]
where:

\[ P = \text{cost of electricity, } \$/\text{kWh}; \quad Q = \text{peak flow rate, mgd}; \]
\[ E = \text{pumping plant efficiency}; \quad C = \text{Hazen-Williams coefficient of pipe}. \]

**Length of Pipeline (Subroutine PIPE)**

The length of pipeline is equal to the measured miles times a factor > 1 to allow for terrain corrections.

**Cost of Pipe (Subroutine PIPE)**

The cost per foot of pipe is derived from the transmission pipe cost data in recent edition of the F.W. Dodge Manual, and from recent issues of Engineering News Record for steel pipe.

\[
\text{Cost/ft} = \begin{cases} 
5.21 \times \text{diam.} & -13.36, \text{diam. } \leq 36 \text{ in.} \\
7.65 \times \text{diam.} & -95.26, \text{diam. } > 36 \text{ in.} 
\end{cases}
\]

\[(A-6)\]

**COST OF TERMINAL STORAGE (SUBROUTINE TERM)**

**Number of Storage Tanks**

There must be at least two tanks, and no tank may hold more than 25 mgd. The total storage capacity must be at least equal to two days design usage. The number of tanks is related to design usage in mgd by the following formula:

\[
\text{No. of tanks} = \begin{cases} 
2, & \text{for avg. mgd } \leq 25 \text{ mgd} \\
2 \times (\text{avg. mgd}/25) \text{ rounded up}, & \text{for avg. mgd } > 25 \text{ mgd} 
\end{cases}
\]

\[(A-7)\]
Size of Tanks

Arbitrarily, the height = radius of the tanks

Cost of Tanks

The cost of tanks is derived from the cost data for terminal storage tanks by Ramamurthy and Chicoine (1984). The cost is calculated by the following equation:

\[
\text{Cost per tank} = [0.0867 \text{ (avg. gpd/10}^6\text{)} + 0.0532] \times 10^6
\]

COST OF BOOSTER STATIONS (SUBROUTINE BOOST)

Total Head

Friction Head - The friction head is obtained from the Hazen-Williams formula as given in Davis and Sorensen (1969).

\[
Q = 0.432C_wd^{2.63}S^{0.54}, \text{ or}
\]

\[
S = [\frac{Q}{0.432C_wd^{2.63}}]^{1/0.54}
\]

where:

\( S = \text{head loss, ft/ft}; \ Q = \text{peak flow rate in cfs}; \ C_w = \text{Hazen-Williams coefficient.}; \ d = \text{pipe diameter in ft.} \)

Total Head - Total booster station pumping head is equal to the friction loss over the length of the pipeline plus the elevation head plus the height of
the terminal storage tanks less the discharge head at the well pumps (Streeter, 1973). If the water source is surface water, the discharge head at the well pumps is equal to 0.

Number of Booster Stations

The number of booster stations is equal to the following:

\[ \text{No. of large stations} = \frac{\text{Total head}}{240 \text{ ft}}, \text{ rounded down} \]  \hspace{1cm} (A-10)

If the remainder, R, is greater than .2, there will be one small booster station pumping at \( R \times \text{horsepower} \); if \( R \leq .2 \), then \( R = 0 \), and additional stages are added to well pumps.

Cost of Booster Stations

**Horsepower** - The horsepower of each booster station is given by the following from Singh (1971).

\[ \text{Horsepower } (H) = (0.1756) \times \text{(peak flow in mgd)} \times \text{(head per station)} \times \frac{(J)}{(\text{pump efficiency})}. \]  \hspace{1cm} (A-11)

where:

- Head per Station = 240 ft.
- J is given by the following:

\[ X \leq 2.0 \quad J = 2.08 - 0.18X \]
\[ 2.0 < X \leq 5.0 \quad J = 1.9666 - 0.1233X \]
\[ 5.0 < X \leq 10.0 \quad J = 1.42 - 0.14X \]
\[ 10.0 < X \leq 20.0 \quad J = 1.30 - 0.002X \]
\[ 20.0 < X \leq 30.0 \quad J = 1.28 - 0.001X \]
\[ X > 30.0 \quad J = 1.25 \]
Cost of Booster Stations

Cost per station is given by the following formula from Singh (1971).

\[
\text{Cost of booster stations} = [17000. + (135. \times \text{(Horsepower)}^{1.01})] \times \text{number of stations} + (17000. + [135. \times (R \times \text{Horsepower})^{1.01}])
\]

CONSTRUCTION COSTS (COST)

Construction Costs = Cost of wells + booster stations + terminal storage
+ pipeline.

INTEREST DURING CONSTRUCTION (SUBROUTINE INTR)

Months for Construction

The construction period is determined using the following formula and applied to the design capacity in mgd.

\[
\text{No. of Months (M)} = \left[8./((1./\text{mgd})^{.32})\right], \text{rounded up}
\]

Cost of Interest During Construction

The cost is given by the following formula.

\[
\text{Interest} = \left[(\text{annual interest rate}/12) \times M\right] \times \text{(Construction Costs)}
\]
ELECTRIC POWER COSTS (SUBROUTINE ELEC)

It takes .004 kWh to lift 1000 gallons of water one foot (Streeter, 1973). The annual cost of electric power is given by the following formula:

\[
\text{Electric power costs} = \text{unit cost factor} \times \left( .004 \times \frac{\text{design capacity}}{1000} \times \text{head} \right)
\]

\(\text{Head} = \text{friction head} + \text{elevation head} + \text{height of tank} + \text{pumping lift} + \text{pump discharge head}\)

O & M LABOR, SUPPLIES AND MATERIALS (SUBROUTINE OM)

The cost of O&M (operation and maintenance) labor, supplies and materials is related to peak flow rate, number of wells and miles of transmission line by the following formula:

\[
\text{Cost of O & M labor} = 3262 \times (\text{peak flow in mgd} \times \text{no. of wells} \times \text{miles of transmission pipe})^{0.49}
\]

TOTAL O & M (COST)

\[
\text{Total O & M} = \text{electric power costs} + \text{O & M labor, supplies and materials}
\]

START-UP COSTS (SUBROUTINE WCSU)

The formula for start-up costs is:

\[
\text{Start-up Costs} = .0833 \times \text{Total O & M}
\]

Note: .0833 represents one month.
WORKING CAPITAL (SUBROUTINE WCSU)

The formula for working capital cost is:

\[ \text{Working Capital} = 0.1667 \times (\text{Total O & M}) \]  
\[ \text{Note:} \quad 0.1667 \text{ represents two months.} \]  

OWNERS GENERAL EXPENSE (SUBROUTINE OGE)

Cost Factor

This cost factor is derived from the scaling factors given by Streeter (1973, p. 145), which vary with total construction cost (C), by the following formula:

\[ \text{Factor} = \frac{0.12}{(1,000,000/C)^{0.125}} \text{ for } C \leq 10,000,000 \]
\[ \text{Factor} = \frac{0.09}{(10,000,000/C)^{0.109}} \text{ for } C > 10,000,000 \]  

(A-22)

Owners' General Expense

\[ \text{Owners' general expense} = C \times \text{factor} \]  

(A-23)

LAND COSTS (SUBROUTINE LAND)

The land requirements for pumping and transmission of water are as follows: .5 acre/well site, 0.25 acre/booster station, 30 ft. right-of-way for pipeline, and 100 ft. clearance around terminal storage tanks. The total land cost is the total acreage of land times the price of land per acre.
ANNUAL DEPRECIABLE CAPITAL COSTS (COST)

Depreciable Capital Rate

Depreciable capital rate (DCR) is equal to the amortization factor + interest rate + tax rate + insurance rate (Streeter, 1973, p. 178). The amortization factor + interest rate = the Capital Recovery Factor (CRF) which is derived from the formula given by of Singh and others (1972, p. 11).

\[
\text{CRF} = \text{interest rate } \frac{(1 + \text{interest rate})^N}{[(1 + \text{interest rate})^N - 1]} \tag{A-24}
\]

where:

\( N = \) amortization period, years.

\( \text{DCR} = \text{CRF} + \text{tax rate} + \text{insurance rate.} \)

Annual Depreciable Capital Costs

The depreciable capital cost equal the total construction cost + interest during construction + start-up cost + owners' general expense. Annual depreciable capital costs = depreciable capital costs \( \times \) DCR. \( \tag{A-25} \)

ANNUAL NON-DEPRECIABLE CAPITAL COSTS (COST)

Non-depreciable capital costs = the land costs + working capital. The annual non-depreciable capital costs = non-depreciable capital costs \( \times \) interest rate. \( \tag{A-26} \)

TOTAL ANNUAL COSTS (COST)

Total Annual Costs = total annual O & M + total annual depreciable capital cost + total annual non-depreciable capital cost (Streeter, 1973). \( \tag{A-27} \)
INFLATION FACTOR

The following costs are multiplied by the inflation factor: total well costs, terminal storage, booster stations, O & M labor, supplies and materials. For this study, the inflation factor is set equal to 1.
REFERENCES


BASE CASE 1

5000-FT DEEP WELLS
DETAILED COST ANALYSIS

PLANT DESIGNATION: SAN LUIS 3
WATER SOURCE LOCATION: VALLEY
DESIGN USAGE: 50000 ACRE-FEET/YEAR

PLANT LOCATION: SAN LUIS VALLEY
FORMATION: DEEP CONFINED

<table>
<thead>
<tr>
<th>COST ITEM</th>
<th>ESTIMATED COST $ X 1000</th>
<th>ANNUAL COST $ X 1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>WELLS, PUMPS, INTERWELL PIPE (18 WELLS)</td>
<td>$ 17027</td>
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<tr>
<td>TRANSMISSION PIPE (1 IN.)</td>
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<tr>
<td>TERMINAL STORAGE</td>
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<tr>
<td>SUBTOTAL - CONSTRUCTION COSTS</td>
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<td>O &amp; M LABOR, SUPPLIES AND MATERIALS</td>
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<td>UNIT COST</td>
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B-1
DETAILED COST ANALYSIS

PLANT DESIGNATION: SAN LUIS 4
WATER SOURCE LOCATION: VALLEY
DESIGN USAGE 100000 ACRE-FEET/YEAR

PLANT LOCATION: SAN LUIS VALLEY
FORMATION: DEEP CONFINED

<table>
<thead>
<tr>
<th>COST ITEM</th>
<th>ESTIMATED COST $ X 1000</th>
<th>ANNUAL COST $ X 1000</th>
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<tr>
<td><strong>COST ITEM</strong></td>
<td><strong>ESTIMATED COST</strong> $ X 1000</td>
<td><strong>ANNUAL COST</strong> $ X 1000</td>
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<tr>
<td><strong>CAPITAL COSTS</strong></td>
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<tr>
<td>WELLS, PUMPS, INTERWELL PIPE (35 WELLS)</td>
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<td>TRANSMISSION PIPE (1 IN.)</td>
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<td>TERMINAL STORAGE</td>
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<td><strong>SUBTOTAL - CONSTRUCTION COSTS</strong></td>
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<td>INTEREST DURING CONSTRUCTION</td>
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<td>START-UP COSTS</td>
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<td>OWNERS GENERAL EXPENSE</td>
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<td><strong>TOTAL - DEPRECIABLE CAPITAL COSTS</strong></td>
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<td>LAND COSTS</td>
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<td><strong>TOTAL - NONDEPRECIABLE CAPITAL COSTS</strong></td>
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<tr>
<td><strong>ANNUAL O &amp; M EXPENSE</strong></td>
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<tr>
<td>O &amp; M LABOR, SUPPLIES AND MATERIALS</td>
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<td>ELECTRIC POWER COSTS</td>
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<td><strong>TOTAL - ANNUAL O &amp; M EXPENSE</strong></td>
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<td>12944</td>
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<tr>
<td>* <strong>TOTAL ANNUAL COSTS</strong></td>
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<td>$ 17250</td>
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<tr>
<td><strong>UNIT COST</strong></td>
<td>$ 172 /ACRE-FEET</td>
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### Detailed Cost Analysis

**Plant Designation:** San Luis 5  
**Water Source Location:** Valley  
**Design Usage:** 200,000 Acre-Feet/Year  
**Plant Location:** San Luis Valley  
**Formation:** Deep Confined

<table>
<thead>
<tr>
<th>Cost Item</th>
<th>Estimated Cost (X 1000)</th>
<th>Annual Cost (X 1000)</th>
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</thead>
<tbody>
<tr>
<td><strong>Capital Costs</strong></td>
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<td></td>
</tr>
<tr>
<td>Wells, pumps, interwell pipe (69 wells)</td>
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<td>Transmission pipe (1 in.)</td>
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<td>Booster stations</td>
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<td>Terminal storage</td>
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<tr>
<td>Interest during construction</td>
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<td>Start-up costs</td>
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<td>Owners general expense</td>
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<td><strong>Total Annual Costs</strong></td>
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**Unit Cost:** $255 / Acre-Feet
DETAILED COST ANALYSIS

PLANT DESIGNATION: SAN LUIS 6
WATER SOURCE LOCATION: VALLEY
DESIGN USAGE 300000 ACRE-FEET/YEAR

PLANT LOCATION: SAN LUIS VALLEY
FORMATION: DEEP CONFINED

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<th>COST ITEM</th>
<th>ESTIMATED COST</th>
<th>ANNUAL COST</th>
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<tbody>
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<td>WELLS, PUMPS, INTERWELL PIPE (103 WELLS)</td>
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<td>BOOSTER STATIONS</td>
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<td>TERMINAL STORAGE</td>
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<td><strong>UNIT COST</strong> $318 / ACRE-FEET**</td>
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<td>PLANT DESIGNATION</td>
<td>FORMATION</td>
<td>DESIGN USAGE af/yr</td>
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<td>SAN LUIS 3</td>
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# Detailed Cost Analysis

**Plant Designation:** San Luis 3  
**Water Source Location:** Valley  
**Design Usage:** 50,000 Acre-Feet/year

---

<table>
<thead>
<tr>
<th>Cost Item</th>
<th>Estimated Cost ($ x 1000)</th>
<th>Annual Cost ($ x 1000)</th>
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<tbody>
<tr>
<td><strong>Capital Costs</strong></td>
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<tr>
<td>Wells, Pumps, Interwell Pipe (18 Wells)</td>
<td>$11,627</td>
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</tr>
<tr>
<td>Transmission Pipe (1 in.)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Booster Stations</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Terminal Storage</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td><strong>Subtotal - Construction Costs</strong></td>
<td>$11,627</td>
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<tr>
<td>Interest During Construction</td>
<td>1,831</td>
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<tr>
<td>Start-Up Costs</td>
<td>64</td>
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<tr>
<td>Owners General Expense</td>
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<tr>
<td><strong>Total - Depreciable Capital Costs</strong></td>
<td>$14,551</td>
<td>$1,354</td>
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<tr>
<td>(Fixed Charge Rate - 9.31%)</td>
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<tr>
<td>Land Costs</td>
<td>9</td>
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<tr>
<td>Working Capital</td>
<td>127</td>
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<tr>
<td><strong>Total - Nondepreciable Capital Costs</strong></td>
<td>$136</td>
<td>10</td>
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<tr>
<td>(Interest Rate - 7.00%)</td>
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<tr>
<td><strong>Annual O &amp; M Expense</strong></td>
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<tr>
<td>O &amp; M Labor, Supplies and Materials</td>
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<td>Electric Power Costs</td>
<td>678</td>
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<tr>
<td><strong>Total - Annual O &amp; M Expense</strong></td>
<td>$764</td>
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*Total Annual Costs*  
$2,128

**Unit Cost:** $42/acre-feet
### Detailed Cost Analysis

**Plant Designation:** San Luis 4  
**Plant Location:** San Luis Valley  
**Water Source Location:** Valley  
**Formation:** Deep Confined  
**Design Usage:** 100,000 Acre-Feet/Year

<table>
<thead>
<tr>
<th>Cost Item</th>
<th>Estimated Cost $ x 1000</th>
<th>Annual Cost $ x 1000</th>
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</thead>
<tbody>
<tr>
<td><strong>Capital Costs</strong></td>
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<td></td>
</tr>
<tr>
<td>Wells, Pumps, Interwell Pipe (35 Wells)</td>
<td>$23,596</td>
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<tr>
<td>Transmission Pipe (1 in.)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Booster Stations</td>
<td>0</td>
<td></td>
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<tr>
<td>Terminal Storage</td>
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<tr>
<td><strong>Subtotal - Construction Costs</strong></td>
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<td>Start-Up Costs</td>
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<td>Owners General Expense</td>
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<td><strong>Total - Nondepreciable Capital Costs (Interest Rate - 7.00%)</strong></td>
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<td><strong>Annual O &amp; M Expense</strong></td>
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<td>O &amp; M Labor, Supplies and Materials</td>
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<td>Electric Power Costs</td>
<td>$2,093</td>
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<td><strong>Total - Annual O &amp; M Expense</strong></td>
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<td><strong>Total Annual Costs</strong></td>
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<td>$5,119</td>
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**Unit Cost:** $51 / Acre-Feet
DETAILED COST ANALYSIS

PLANT DESIGNATION: SAN LUIS 5
WATER SOURCE LOCATION: VALLEY
DESIGN USAGE 200000 ACRE-FEET/YEAR

PLANT LOCATION: SAN LUIS VALLEY
FORMATION: DEEP CONFINED

<table>
<thead>
<tr>
<th>COST ITEM</th>
<th>ESTIMATED COST</th>
<th>ANNUAL COST</th>
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<tbody>
<tr>
<td></td>
<td>$ X 1000</td>
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CAPITAL COSTS

<table>
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<tr>
<td>WELLS, PUMPS, INTERWELL PIPE (69 WELLS)</td>
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<td>TRANSMISSION PIPE (1 IN.)</td>
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<tr>
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<td>TERMINAL STORAGE</td>
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<td>SUBTOTAL - CONSTRUCTION COSTS</td>
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<td>INTEREST DURING CONSTRUCTION</td>
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<td>START-UP COSTS</td>
<td>12261</td>
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<td>OWNERS GENERAL EXPENSE</td>
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<td>TOTAL - DEPRECIABLE CAPITAL COSTS</td>
<td>$ 65442</td>
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<tr>
<td>(FIXED CHARGE RATE = 9.31%)</td>
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<td>LAND COSTS</td>
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<td>WORKING CAPITAL</td>
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<td>(INTEREST RATE = 7.00%)</td>
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ANNUAL O & M EXPENSE

<table>
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<th>COST ITEM</th>
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<tbody>
<tr>
<td>O &amp; M LABOR, SUPPLIES AND MATERIALS</td>
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<td>ELECTRIC POWER COSTS</td>
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<td>TOTAL - ANNUAL O &amp; M EXPENSE</td>
<td>$ 7209</td>
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<td>* TOTAL ANNUAL COSTS</td>
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UNIT COST $ 66 /ACRE-FEET
DETAILED COST ANALYSIS

PLANT DESIGNATION: SAN LUIS 6
WATER SOURCE LOCATION: VALLEY
DESIGN USAGE 300000 ACRE-FEET/YEAR

PLANT LOCATION: SAN LUIS VALLEY
FORMATION: DEEP CONFINED

<table>
<thead>
<tr>
<th>COST ITEM</th>
<th>ESTIMATED COST $ X 1000</th>
<th>ANNUAL COST $ X 1000</th>
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<tbody>
<tr>
<td>WELL S, PUMPS, INTERWELL PIPE (103 WELLS)</td>
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<tr>
<td>TRANSMISSION PIPE (1 IN.)</td>
<td>0</td>
<td></td>
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<td>BOOSTER STATIONS</td>
<td>0</td>
<td></td>
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<tr>
<td>TERMINAL STORAGE</td>
<td>0</td>
<td></td>
</tr>
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<td></td>
<td></td>
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<tr>
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<td>INTEREST DURING CONSTRUCTION</td>
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<td>START-UP COSTS</td>
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<td>OWNERS GENERAL EXPENSE</td>
<td>5443</td>
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<td>TOTAL - DEPRECIABLE CAPITAL COSTS (FIXED CHARGE RATE - 9.31%)</td>
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<td>$9598</td>
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<tr>
<td>TOTAL - NONDEPRECIABLE CAPITAL COSTS (INTEREST RATE - 7.00%)</td>
<td>$2421</td>
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<tr>
<td>ANNUAL O &amp; M EXPENSE</td>
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<td>O &amp; M LABOR, SUPPLIES AND MATERIALS</td>
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<td>ELECTRIC POWER COSTS</td>
<td>13725</td>
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<td>TOTAL - ANNUAL O &amp; M EXPENSE</td>
<td>$14214</td>
<td>14214</td>
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<tr>
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<tr>
<td>* TOTAL ANNUAL COSTS</td>
<td></td>
<td>$23981</td>
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<tr>
<td>UNIT COST</td>
<td>$79/ACRE-FEET</td>
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<td>PLANT DESIGNATION</td>
<td>FORMATION</td>
<td>DESIGN USAGE af/y</td>
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<tr>
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<tr>
<td>SAN LUIS 3</td>
<td>DEEP CONFINED</td>
<td>50000</td>
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<tr>
<td>SAN LUIS 4</td>
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<tr>
<td>SAN LUIS 6</td>
<td>DEEP CONFINED</td>
<td>300000</td>
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TRANSPORT TO THE ARKANSAS RIVER
VIA
PONCHA PASS
## DETAILED COST ANALYSIS

### PLANT DESIGNATION: SAN LUIS 3
### WATER SOURCE LOCATION: VALLEY
### DESIGN USAGE: 50000 ACRE-FEET/YEAR

### PLANT LOCATION: SAN LUIS VALLEY
### FORMATION: DEEP CONFINED

<table>
<thead>
<tr>
<th>COST ITEM</th>
<th>ESTIMATED COST $ X 1000</th>
<th>ANNUAL COST $ X 1000</th>
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<tbody>
<tr>
<td><strong>CAPITAL COSTS</strong></td>
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</tr>
<tr>
<td>Wells, pumps, interwell pipe (60 wells)</td>
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<td>Transmission pipe (84 in.)</td>
<td>161838</td>
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<tr>
<td>Booster stations</td>
<td>3743</td>
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<tr>
<td>Terminal storage</td>
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<tr>
<td><strong>SUBTOTAL - CONSTRUCTION COSTS</strong></td>
<td>$ 165581</td>
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<tr>
<td>Interest during construction</td>
<td>26079</td>
<td></td>
</tr>
<tr>
<td>Start-up costs</td>
<td>609</td>
<td></td>
</tr>
<tr>
<td>Owners general expense</td>
<td>10974</td>
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<tr>
<td><strong>TOTAL - DEPRECIABLE CAPITAL COSTS</strong></td>
<td>$ 203243</td>
<td>$ 18919</td>
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<tr>
<td>(Fixed charge rate - 9.31%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land costs</td>
<td>$ 206</td>
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<tr>
<td>Working capital</td>
<td>1219</td>
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<tr>
<td><strong>TOTAL - NONDEPRECIABLE CAPITAL COSTS</strong></td>
<td>$ 1425</td>
<td>100</td>
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<tr>
<td>(Interest rate - 7.00%)</td>
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<td><strong>ANNUAL O &amp; M EXPENSE</strong></td>
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<tr>
<td>O &amp; M labor, supplies and materials</td>
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<td>Electric power costs</td>
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<td><strong>TOTAL - ANNUAL O &amp; M EXPENSE</strong></td>
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<td>7310</td>
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<td><strong>TOTAL ANNUAL COSTS</strong></td>
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<td>$ 26329</td>
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</table>

*Total Annual Costs*

**UNIT COST $ 526 /ACRE-FEET**
# Detailed Cost Analysis

**Plant Designation:** San Luis 4  
**Water Source Location:** Valley  
**Design Usage:** 100,000 Acre-Feet/Year  
**Plant Location:** San Luis Valley  
**Formation:** Deep Confined

<table>
<thead>
<tr>
<th>COST ITEM</th>
<th>ESTIMATED COST $ X 1000</th>
<th>ANNUAL COST $ X 1000</th>
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</thead>
<tbody>
<tr>
<td><strong>Capital Costs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wells, Pumps, Interwell Pipe (0 Wells)</td>
<td>$ 0</td>
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</tr>
<tr>
<td>Transmission Pipe (108 In.)</td>
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<td>Booster Stations</td>
<td>7,418</td>
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<tr>
<td>Terminal Storage</td>
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<tr>
<td><strong>Subtotal - Construction Costs</strong></td>
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<tr>
<td>Interest During Construction</td>
<td>44,336</td>
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<td>Start-Up Costs</td>
<td>12,100</td>
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<td>Owners General Expense</td>
<td>14,339</td>
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<tr>
<td><strong>Total - Depreciable Capital Costs</strong> (Fixed Charge Rate - 9.31%)</td>
<td>$ 283,427</td>
<td>$ 26,383</td>
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<td>Land Costs</td>
<td>$ 206</td>
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<td>Working Capital</td>
<td>2,422</td>
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<td><strong>Total - Nondepreciable Capital Costs</strong> (Interest Rate - 7.00%)</td>
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<td><strong>Annual O &amp; M Expense</strong></td>
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<td>O &amp; M Labor, Supplies and Materials</td>
<td>$ 212</td>
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<td>Electric Power Costs</td>
<td>14,318</td>
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<td><strong>Total - Annual O &amp; M Expense</strong></td>
<td>$ 14,530</td>
<td>14,530</td>
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<td>* Total Annual Costs</td>
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**Unit Cost** $ 410 /Acre-Feet
### Detailed Cost Analysis

**Plant Designation:** San Luis 5  
**Water Source Location:** Valley  
**Design Usage:** 200,000 Acre-Feet/Year

<table>
<thead>
<tr>
<th>Cost Item</th>
<th>Estimated Cost $ x 1000</th>
<th>Annual Cost $ x 1000</th>
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<tbody>
<tr>
<td><strong>Capital Costs</strong></td>
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<tr>
<td>Wells, Pumps, Interwell Pipe (0 Wells)</td>
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<tr>
<td>Transmission Pipe (144 in.)</td>
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<td>Booster Stations</td>
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<td>Terminal Storage</td>
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<td><strong>Subtotal - Construction Costs</strong></td>
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<td>Owners General Expense</td>
<td>19,320</td>
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<td><strong>Total - Depreciable Capital Costs</strong></td>
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<td>(Fixed Charge Rate - 9.31%)</td>
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<td>Working Capital</td>
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<td><strong>Total - Nondepreciable Capital Costs</strong></td>
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<td>(Interest Rate - 7.00%)</td>
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<td><strong>Annual O &amp; M Expense</strong></td>
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<td>O &amp; M Labor, Supplies and Materials</td>
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<td>Electric Power Costs</td>
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<td>$28,933 28,933</td>
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**Unit Cost:** $338/Acre-Feet
DETAILED COST ANALYSIS

PLANT DESIGNATION: SAN LUIS 6
WATER SOURCE LOCATION: VALLEY
DESIGN USAGE 300000 ACRE-FeET/YEAR

<table>
<thead>
<tr>
<th>COST ITEM</th>
<th>ESTIMATED COST $ X 1000</th>
<th>ANNUAL COST $ X 1000</th>
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<tbody>
<tr>
<td>CAPITAL COSTS</td>
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<tr>
<td>WELLS, PUMPS, INTERWELL PIPE(0 WELLS)</td>
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<td>TRANSMISSION PIPE (180 IN.)</td>
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<td>BOOSTER STATIONS</td>
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<td>TERMINAL STORAGE</td>
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<td>SUBTOTAL - CONSTRUCTION COSTS</td>
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<td>INTEREST DURING CONSTRUCTION</td>
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<td>TOTAL - DEPRECIABLE CAPITAL COSTS (FIXED CHARGE RATE - 9.31 %)</td>
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<td>$ 50392</td>
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<td>TOTAL - NONDEPRECIABLE CAPITAL COSTS (INTEREST RATE - 7.00 %)</td>
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<td>ANNUAL O&amp;M EXPENSE</td>
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<td>O&amp;M LABOR, SUPPLIES AND MATERIALS</td>
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<td>ELECTRIC POWER COSTS</td>
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<td>TOTAL - ANNUAL O&amp;M EXPENSE</td>
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UNIT COST $ 314 /ACRE-FeET
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<th>FORMATION</th>
<th>DESIGN USAGE (af/y)</th>
<th>DEPREC + NONDEPREC CAPITAL COSTS ($ x 1000)</th>
<th>ANNUAL D&amp;M EXPENSES ($ x 1000)</th>
<th>TOTAL ANNUAL COSTS ($ x 1000)</th>
<th>UNIT COST ($/af)</th>
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<td>SAN LUIS 3</td>
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<td>94229</td>
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TRANSPORT TO THE ARKANSAS RIVER
VIA
HAYDEN PASS
DETAILED COST ANALYSIS

PLANT DESIGNATION: SAN LOUIS 3
WATER SOURCE LOCATION: VALLEY
DESIGN USAGE 50000 ACRE-FEET/YEAR

PLANT LOCATION: SAN LOUIS VALLEY
FORMATION: DEEP CONFINED

<table>
<thead>
<tr>
<th>COST ITEM</th>
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<th>ANNUAL COST $ X 1000</th>
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<tr>
<td><strong>CAPITAL COSTS</strong></td>
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<td>TERMINAL STORAGE</td>
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<td><strong>SUBTOTAL - CONSTRUCTION COSTS</strong></td>
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<td>LAND COSTS</td>
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<td>WORKING CAPITAL</td>
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<td><strong>TOTAL - NONDEPRECIABLE CAPITAL COSTS</strong> (INTEREST RATE - 7.00 %)</td>
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</table>

ANNUAL O & M EXPENSE

| O & M LABOR, SUPPLIES AND MATERIALS            | $141                      |                       |
| ELECTRIC POWER COSTS                          | $15165                    |                       |
| **TOTAL - ANNUAL O & M EXPENSE**              | $15306                    | 15306                 |

* TOTAL ANNUAL COSTS

| UNIT COST                                    | $653 /ACRE-FEET           |

B-16
**DETAILED COST ANALYSIS**

**PLANT DESIGNATION:** SAN LUIS 4  
**WATER SOURCE LOCATION:** VALLEY  
**DESIGN USAGE:** 100000 ACRE- FEET/YEAR  

**PLANT LOCATION:** SAN LUIS VALLEY  
**FORMATION:** DEEP CONFINED

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<th>ANNUAL COST</th>
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</thead>
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<td><strong>TOTAL - ANNUAL O &amp; M EXPENSE</strong></td>
<td>$30528</td>
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* **TOTAL ANNUAL COSTS** $55227

**UNIT COST** $552 / ACRE- FEET
# Detailed Cost Analysis

**Plant Designation:** San Luis 5  
**Water Source Location:** Valley  
**Design Usage:** 200,000 Acre-Feet/Year  
**Plant Location:** San Luis Valley  
**Formation:** Deep Confined

<table>
<thead>
<tr>
<th>Cost Item</th>
<th>Estimated Cost ($ x 1000)</th>
<th>Annual Cost ($ x 1000)</th>
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<tbody>
<tr>
<td><strong>Capital Costs</strong></td>
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<tr>
<td>Wells, Pumps, Interwell Pipe (0 Wells)</td>
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<tr>
<td>Transmission Pipe (144 in.)</td>
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<tr>
<td>Booster Stations</td>
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<td>Terminal Storage</td>
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<td><strong>Subtotal - Construction Costs</strong></td>
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<td>Interest During Construction</td>
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<td>Start-Up Costs</td>
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<td>Owners General Expense</td>
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<td><strong>Total - Depreciable Capital Costs</strong></td>
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<td>(Fixed Charge Rate - 9.31%)</td>
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<tr>
<td>Working Capital</td>
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<td>Electric Power Costs</td>
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<td><strong>Total Annual Costs</strong></td>
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</table>

**Unit Cost:** $489 / Acre-Feet
### Detailed Cost Analysis

**Plant Designation:** SAN LUIS 6  
**Water Source Location:** VALLEY  
**Design Usage:** 300,000 ACRE-FEET/YEAR  
**Plant Location:** SAN LUIS VALLEY  
**Formation:** DEEP CONFINED

<table>
<thead>
<tr>
<th>COST ITEM</th>
<th>ESTIMATED COST</th>
<th>ANNUAL COST</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Capital Costs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wells, Pumps, Interwell Pipe (0 Wells)</td>
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<tr>
<td>Transmission Pipe (180 in.)</td>
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<td>Start-Up Costs</td>
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**Unit Cost:** $468/ACRE-FEET
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<th>DESIGN USAGE af/y</th>
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<th>ANNUAL O&amp;M EXPENSES $X1000</th>
<th>TOTAL ANNUAL COSTS $X1000</th>
<th>UNIT COST $/af</th>
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APPENDIX C

WATER VALUATION FOR AGRICULTURE
IN THE SAN LUIS VALLEY

by

Robert A. Young, Consulting Economist

C.0 INTRODUCTION

This appendix contains the rationale and methodology for estimating the value of project water, considering the dominant agriculture economic base in the San Luis Valley. Comparison of the market value of water can be made with the water-development cost, presented in the main report, for obtaining the water from the deep confined aquifer system.
C.1 FRAMEWORK FOR INVESTMENT APPRAISAL

C.1.1 General

Benefit-cost analysis arose from concern that there be some public counterpart to the financial tests performed by private investors prior to undertaking long-term capital investments. The idea is to assure that proposed public investment programs would, in fact, result in positive economic returns.

For public sector investments, a number of considerations justify special treatment of costs, returns and interest rates. These considerations are based on the fact that markets may not exist to properly price outputs of the project, or that public intervention into markets distort such prices as may be observed. "Shadow" or "accounting" prices are developed to substitute for observed prices in such instances. In the case of water supply projects, markets for the outputs exist in only a limited fashion, if at all, so accounting prices are usually required.

C.1.2 Formulas for Assessing Economic Feasibility

Benefits are measured in terms of willingness to pay for goods and services produced. Costs of resources are measured in terms of benefit in the best foregone alternative use (the "opportunity cost" theory). This concept of costs can also be understood in willingness to pay terms, i.e. the willingness of users to pay to avoid being without the resource. An investment is said to be feasible if anticipated benefits exceed anticipated costs.

Most water resource investments generate returns over a long period. A key issue is how to make benefits and costs over the investment's life commensurate in time. This is achieved by application of an interest rate
(usually called a "discount rate"), which reflects the investor's alternative return on capital or the time value of money.

An investment is said to be economically feasible if the present value of benefits exceed the present value of costs. In symbols:

\[
\sum_{t=0}^{T} \frac{B_t}{(1+r)^t} > \sum_{t=0}^{T} \frac{C_t}{(1+r)^t}
\]

where:
- \( B_t \): benefits in year \( t \)
- \( C_t \): costs in year \( t \)
- \( r \): discount or interest rate
- \( T \): end of planning period

Expression (1) can be rearranged so that feasibility is defined as:

a) Present Value of Net Benefits exceed zero.

\[
\sum_{t=0}^{T} \frac{B_t}{(1+r)^t} - \sum_{t=0}^{T} \frac{C_t}{(1+r)^t} > 0
\]  

b) The ratio of benefits to costs exceeds 1.0.

\[
\frac{\sum_{t=0}^{T} \frac{B_t}{(1+r)^t}}{\sum_{t=0}^{T} \frac{C_t}{(1+r)^t}} > 1.0
\]

C.1.3 "Associated Costs" and the Definition of Producer's Benefits

The costs of an investment usually include construction and operating and maintenance costs for the project plus the producer's costs of utilizing the water in his production process. These latter costs, called "associated costs", in the literature dealing with irrigation, include the cost of owning and operating an irrigation system, developing the land, plus the usual production costs—labor, fertilizer, machinery, etc.
In practice, irrigation benefits are usually defined as producers' revenues less producer's cost of production. In this interpretation, benefits are producers' return to water, net of associated costs. Benefits thus defined, and expressed on a per unit volume basis (i.e., $/acre foot), are often termed the "value" of water.

C.1.4 Simplifying Assumptions

When a project involves a long life and many individual producers, the analysis must be simplified to make it manageable.

One simplification is to select a "representative farm" situation for which to calculate net returns to water. The area and quality of land, the productivity of soils, the machinery and equipment inventory available for production and the acreage to be devoted to each potential alternative crop must be identified. If the situation warrants, more than one representative farm type may be needed, (such as large vs. small farms, or different types according to product specialization).

The other common simplification is to select a representative year on which to perform the analysis, rather than calculating benefits for each year. The midpoint year of the selected project life is the usual choice. Assumptions (forecasts) regarding prices, costs, productivity and technology are made for that year.

C.1.5 Special Problems

Inflation - One issue in forecasting future prices of both costs and benefits is how to represent price inflation. Accurately predicting price changes into the distant future is likely to be a futile exercise. Therefore, the usual convention is to express the price forecasts in real (constant
dollar) terms. If product and input prices are in constant dollars, interest rates should be in constant dollars also.

**Interest rates** - The most contentious and complicated issue in benefit-cost analysis centers around selecting the appropriate interest rate. Market interest rates are not determined in an unfettered market context, but are influenced heavily by government control of monetary (money supply) and fiscal (tax) policies. Hence, accounting prices are usually recommended in place of market interest rates.

The proper interest rate for long term public planning is the rate on long term government bonds (15 years or longer to maturity). Accounting interest rates are usually estimated by adjusting for the effect of inflation on the market interest rate. (Lenders are assumed to raise their rates of interest on bonds or loans by the amount of anticipated inflation.)

**Costs, Prices and Technological Change** - The joint forecasting of future crop prices and technological improvements creates a particular problem. From historical experience, we expect productivity (yield per acre) to improve. Historically, prices (in constant dollars) have tended to fluctuate around a declining trend, since productivity growth has outstepped demand growth. To avoid the bias introduced by simultaneously forecasting improved productivity but not using lower constant dollar prices, a reasonable and simple solution is to use current prices (smoothed by taking a three year average) and current productivity. This is equivalent to assuming the effects exactly offset each other on net returns.

The selection of a representative year forces the analysis of costs to be commensurate in annual terms. This is readily accomplished by converting capital costs to an Equivalent Uniform Annual Cost, by the use of the capital recovery factor (James and Lee). The capital recovery factor converts a fixed
initial investment into an equivalent constant annual cost, which reflects the selected interest rate and planning period.

The feasibility formula for the case of annualized costs and benefits becomes:

\[
\text{Annual Net Benefit} > \text{Annual Capital and Operating Cost (per unit water)} \quad (\text{per unit water})
\]

**c.2 APPROACHES TO ESTIMATING VALUE OF WATER**

In the case at hand, three different techniques are applicable to estimating project benefits. They are (1) observed market values, (2) change in net income, and (3) least cost alternative method (also called "alternative cost").

**c.2.1 Observed Transactions Prices**

If markets for water were everywhere available, the need for separate analysis of ability to pay would be lessened, if not avoided altogether. Under Colorado law, markets for both seasonal rentals and permanent sales are frequently found, and the prices observed these provide useful evidence on the value of water.

The rental price is an approximation to the annual equivalent net benefit discussed above, since it represents actual willingness to pay for incremental water supplies. Rental rates fluctuate depending on current water supply and on short run crop price outlook. However, an average of observed prices over time (corrected for inflation) could be a usable measure of the value of water.

Sale prices of water rights are another alternative. The specific portion paid for the water rights may have to be isolated from payments for other resources (such as land, buildings) involved in the sale. Sale price of water rights can be directly compared with total investment costs or converted to an annual equivalent by the formula:
$S_1 = R$  \hspace{1cm} (4)

where:  
\begin{align*}
S &= \text{sale price per acre foot} \\
1 &= \text{interest rate} \\
R &= \text{annual rental value (per acre foot)}
\end{align*}

The formula (4) is an approximation for the case in which the interest rate (1) and the rental rate (R) both remain unchanged over a long ($T \rightarrow \infty$) planning period.

Market prices for water can be used most appropriately where the climate, production conditions and location with respect to markets is similar to that which will prevail for the investment being analyzed. Because the cost of transporting water can rapidly exceed its value in use, using market prices must also be tempered by adjustment for necessary pumping and transmission expenses.

C.2.2 The "Residual" Approach

Valuation is, in essence, a problem of assigning a price to a resource or a commodity in the absence of a market (or a properly functioning market) to perform the function. The residual approach calculates the remaining ability to pay for one resource by a producer, given the productivity of the resource, the payments required for other production inputs and the price of the products:

A formula used to measure benefits in agricultural production is:

$$B = \frac{\sum Y_i P_y - \sum X_j P_x}{W}$$  \hspace{1cm} (3)

where:  
\begin{align*}
B &= \text{net benefit (ability to pay) per unit water} \\
W &= \text{quantity of water employed} \\
Y_i &= \text{production (yield) of } i\text{th crop} \\
X_j &= \text{quantity required of } j\text{th productive resource}
\end{align*}
\[ P_{y_i}, P_{x_j} = \text{prices of products, inputs} \]

The physical units \( Y_i, X_j \), and \( W \) must refer to a specified production unit, such as an acre of land or more typically, a representative farm situation. The products might include, for example, alfalfa, potatoes, barley, etc. The inputs would include labor, land, machinery, chemicals, overhead, etc. If a charge for any input is omitted, its value will be credited to the residual factor, overstating the latter's importance. Hence, care must be taken in specifying inputs. The second major concern is with commodity prices. Crop prices are likely to vary widely during the life of an investment, and choosing a representative point in the commodity cycle and within the inflationary trend is often a difficult and challenging task and one subject to high probability of error.

C.2.3 "Least-Cost Alternative" Method

The final method discussed here requires that the investment being appraised be the least-cost source of accomplishing the project purpose. If the water is to be developed, for example, for some prospective municipal or industrial demand, the benefits will be limited to the cost of the most likely alternative source, such as by developing an alternative supply of surface water or by purchase of agricultural water rights.

The alternative cost computations are normally expressed in terms of unit cost (per acre foot) of the alternative supply source.

C.3 MARKET AND PRODUCTION CONSIDERATIONS

C.3.1 Production Considerations

Climate - The San Luis Valley lies at elevations mostly exceeding 7,500
feet. Frost-free growing periods are relatively short, and very late spring frosts and very early fall frosts occur with some frequency.

Soils and Topography - The area which might be newly-irrigated ranges from sandy/gravelly to very heavy soils with good water-holding capacity. The terrain is generally relatively level, but much of the potential area's soils have become salinized and overgrown with brush.

Feasible Crops - The soil and growing season considerations noted above indicate the most feasible crops from the production viewpoint are forages (alfalfa, pasture grasses), edible dry beans (pintos), small grains (wheat, barley), potatoes and fresh vegetables.

C.3.2 Market Considerations

Producers in southern Colorado shared in the general agricultural prosperity of the 1970s. However, the 1980s has been a period of precipitously declining real crop prices. The writer sees little prospect for return to strong profitability in the next decade or so, although some minor improvement from present disastrous prices is possible. Three factors will govern commodity price outlook for producers.

First, the international market for food commodities is characterized at present by a large over-supply relative to effective demand. The high prices of the 70s, in a fashion similar to such cyclical peaks in the past, called forth a large increase in production capacity. Further, the trend to encourage market-like institutions in formerly centrally planned and/or highly regulated nations (China, India) plus continuing technological advances will persist in adding to productive capability, and a closer balance between supply and demand will likely be some time in appearing.

Second, policies at the national level are moving in the direction of lower prices and are redirecting crop production capacity. Prices for feed
grains (corn, barley, oats) and their close substitutes (hay, forages) are likely to continue to experience downward pressures. Federal policies aimed at reducing food and feed grain output threaten to shift making the outlook for those crops' prices even more unfavorable.

Third, local market conditions in southwest Colorado show little promise for a brighter outlook. The remoteness from markets and lack of capital, expertise and managerial capability limit prospects for higher income specialty crops (e.g., fresh vegetables) other than potatoes.
VALUE OF IRRIGATION WATER IN THE SAN LUIS VALLEY BY THE RESIDUAL APPROACH

Tables 1 and 2 show calculations for the residual value of water. Table 1 adopts a "realistic" scenario, which represents the best estimate of the likely returns. This assumes what the writer believes to be the most likely scenario for crop yields and proportions of acreages, and a fairly high charge for clearing, leveling, and reclaiming the salinized soils most likely to be available for new development. Acreage is allocated to crops as follows: 50 percent alfalfa, 40 percent small grains (wheat, feed barley), and 10 percent potatoes.

The optimistic scenario is based on a high proportion of high return crops (potatoes and malt barley 1/3 each, together with 1/3 alfalfa) and lower land reclamation costs. This can be regarded as an upper limit on ability to pay for new water supplies.

CONCLUSION

Given the difficult conditions for developing new agricultural lands in the San Luis Valley, plus the short growing season and limited markets, the farmers' ability to pay for water is likely to be no more than the neighborhood of $13.00 per acre foot for a supply of good quality water delivered to the farm. If market conditions encouraged potato production, the amount might approach $49.00 per acre foot, but that is not too likely a prospect.
Table c.1 Summary of Projected Costs, Returns and Residual Return to Water, San Luis Valley, Realistic Scenario^a

<table>
<thead>
<tr>
<th>Item</th>
<th>Alfalfa Hay</th>
<th>Spring Wheat</th>
<th>Potatoes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Per Acre</td>
<td>Per Acre</td>
<td>Per Acre</td>
</tr>
<tr>
<td>Revenues</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Projected Yields/Acre</td>
<td>4 T</td>
<td>90 bu</td>
<td>300 cwt</td>
</tr>
<tr>
<td>Projected Price/Unit</td>
<td>$70/T</td>
<td>$2.70/bu</td>
<td>$4.50/cwt</td>
</tr>
<tr>
<td>Project Gross Revenues</td>
<td>$280/A</td>
<td>243/A</td>
<td>$1350/A</td>
</tr>
<tr>
<td>Costs</td>
<td>$</td>
<td>$</td>
<td>$</td>
</tr>
<tr>
<td>Land Preparation and Plant^b</td>
<td>62</td>
<td>49</td>
<td>167</td>
</tr>
<tr>
<td>Other Pre-Harvest Machinery Operations</td>
<td>8</td>
<td>-</td>
<td>30</td>
</tr>
<tr>
<td>Fertilizer, Pesticides</td>
<td>10</td>
<td>46</td>
<td>586</td>
</tr>
<tr>
<td>Irrigation System Operating Costs</td>
<td>29</td>
<td>15</td>
<td>33</td>
</tr>
<tr>
<td>Harvest and Haul</td>
<td>80</td>
<td>28</td>
<td>33</td>
</tr>
<tr>
<td>Land, Land Development and Sprinkler System (Annualized)</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>General Overhead, Taxes, Etc.</td>
<td>29</td>
<td>26</td>
<td>90</td>
</tr>
<tr>
<td>Management</td>
<td>12</td>
<td>12</td>
<td>135</td>
</tr>
<tr>
<td>TOTAL COSTS</td>
<td>281</td>
<td>226</td>
<td>1124</td>
</tr>
<tr>
<td>Net Return to Water ($/acre)</td>
<td>-1</td>
<td>17</td>
<td>226</td>
</tr>
<tr>
<td>Annual Water Applied (AF/acre)</td>
<td>2.0</td>
<td>1.67</td>
<td>2.33</td>
</tr>
<tr>
<td>Return Per Acre Foot ($)</td>
<td>-0.5</td>
<td>10</td>
<td>97</td>
</tr>
<tr>
<td>Weighted Average Return Per Acre Foot</td>
<td></td>
<td></td>
<td>$13</td>
</tr>
</tbody>
</table>

^aRealistic scenario assumes:
1) $200 land development costs amortized @ 7%.
2) "normal" acreage in high return crops (10% potatoes, 40% spring wheat, 50% alfalfa).

^bAlfalfa planting costs represent cost of initial stand established amortized over four year life.
<table>
<thead>
<tr>
<th>Item</th>
<th>Alfalfa Hay</th>
<th>Malt Barley</th>
<th>Potatoes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Per Acre</td>
<td>Per Acre</td>
<td>Per Acre</td>
</tr>
<tr>
<td><strong>Revenues</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Projected Yields/Acre</td>
<td>4 T</td>
<td>40 cwt</td>
<td>300 cwt</td>
</tr>
<tr>
<td>Projected Price/Unit</td>
<td>$70/T</td>
<td>$7.00/cwt</td>
<td>$4.50/cwt</td>
</tr>
<tr>
<td>Project Gross Revenues</td>
<td>$280/A</td>
<td>$280/A</td>
<td>$1350/A</td>
</tr>
<tr>
<td><strong>Costs</strong></td>
<td>$</td>
<td>$</td>
<td>$</td>
</tr>
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<td>Land Preparation and Plant^b</td>
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<td>167</td>
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<td>Other Pre-Harvest Machinery Operations</td>
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<td></td>
<td>30</td>
</tr>
<tr>
<td>Fertilizer, Pesticides</td>
<td>10</td>
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<td>586</td>
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<td>15</td>
<td>33</td>
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<tr>
<td>Harvest and Haul</td>
<td>80</td>
<td>28</td>
<td>33</td>
</tr>
<tr>
<td>Land, Land Development and Sprinkler System (Annualized)</td>
<td>36</td>
<td>36</td>
<td>36</td>
</tr>
<tr>
<td>General Overhead, Taxes, Etc.</td>
<td>29</td>
<td>26</td>
<td>90</td>
</tr>
<tr>
<td>Management</td>
<td>14</td>
<td>14</td>
<td>135</td>
</tr>
<tr>
<td>TOTAL COSTS</td>
<td>268</td>
<td>214</td>
<td>1110</td>
</tr>
<tr>
<td><strong>Net Return to Water ($)</strong></td>
<td>12</td>
<td>66</td>
<td>240</td>
</tr>
<tr>
<td><strong>Annual Water Applied (AF)</strong></td>
<td>2.0</td>
<td>1.67</td>
<td>2.33</td>
</tr>
<tr>
<td><strong>Return Per Acre Foot ($)</strong></td>
<td>6.00</td>
<td>39.50</td>
<td>103</td>
</tr>
<tr>
<td><strong>Weighted Average Return Per Acre Foot (1/3 of acreage to each crop)</strong></td>
<td>$49</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

^Optimistic scenario assumes:
1) low land development costs
2) maximum acreage in high return crops (1/3 potatoes, 1/3 malt barley, 1/3 alfalfa).

^Alfalfa planting costs represent cost of initial stand established amortized over four year life.
APPENDIX D

COMPUTER-PROGRAM "COST"
PROGRAM COST

THIS PROGRAM COMPUTES COSTS FOR PUMPING AND TRANSMITTING WATER FROM A WELL FIELD OR OTHER SOURCE. THE PROGRAM IS APPLICABLE FOR FLOW RATES GREATER THAN ONE MILLION GALLONS PER DAY (1 MGD).

PROGRAM ORIGINALLY WRITTEN BY JAMES G. NALVEN, JUNE 1975.

UPDATES AND ADDITIONS BY JAMES R. KUNKEL, MAY 1986.

SUBROUTINES REQUIRED FOR THE PROGRAM: BOOST, ELEC, INTR, LAND, OGE, OM, PIPE, SIZE, TERM, THOU, WELL, WCSU

INPUTS
- P: COST OF ELECTRICITY, $/KWH
- E: PUMP EFFICIENCY, DECIMAL
- C: HAZEN-WILLIAMS COEF. FOR PIPE BEING USED
- EF: COST OF ESCALATION FACTOR, REAL NUMBER
- PLI: LENGTH OF PIPELINE, AIR MILES
- RF: MAXIMUM RATE FACTOR
- QAF: AVERAGE FLOW, AF/YR
- QGPM: YIELD PER WELL, GPM
- PP: PUMPING LIFT, FT
- PA: PRICE PER ACRE FOR LAND, $
- XINT: ANNUAL INTEREST RATE, DECIMAL
- TAX: TAX RATE, REAL NUMBER
- PL: LENGTH OF PIPELINE, AIR MILES
- WD: WELD DEPTH, FEET
- XINS: INSURANCE RATE, DECIMAL
- YR: AMORTIZATION PERIOD, YEARS
- PP: PIPE LENGTH FACTOR
- HE: ELEVATION HEAD, FEET
- XX: IF XX.EQ.0 NO TERM STORAGE
- X: IF X.EQ.0 THE COST OF WELLS WILL NOT BE INCLUDED
- PLANT: PLANT DESIGNATION, ALPHA
- FORM: WITHDRAWAL AQUIFER, ALPHA
- PLOC: PLANT LOCATION, ALPHA
- WLOC: WELL LOCATION, ALPHA
- HP: DISCHARGE HEAD AT WELL PUMPS

OUTPUTS
- CP: TRANSMISSION PIPELINE COST
- CT: TERMINAL STORAGE COST
- CW: WELL AND INTERWELL PIPELINE COST
- CB: BOOSTER STATION COST
- CL: LAND COST
- CE: ELECTRIC POWER COST
- CWC: WORKING CAPITAL
- COM: OPERATION AND MAINT. COST
- CS: START-UP COST
- CI: INTEREST DURING CONSTRUCTION COST
- COG: OWNERS GENERAL EXPENSE
- TC: TOTAL CONSTRUCTION COST
- TDC: DEPRECIABLE CAPITAL COST
- TOM: TOTAL ANNUAL O & M COST
- TNDC: NONDEPRECIABLE CAPITAL COST
- TDCR: DEPRECIABLE CAPITAL RATE
- ATDC: ANNUAL TDC
- ATNDC: ANNUAL TNDC
- TAC: TOTAL ANNUAL COST
- DAF: ANNUAL UNIT COST $/AF OF WATER

ALL COSTS ROUNDED TO THE NEAREST THOUSAND AND OUTPUT AS INTEGERS

INPUT IS ON UNIT 5
OUTPUT IS ON UNIT 6
OUTPUT OF SUMMARY DATA IS TEMPORARILY STORED ON UNIT 10

CHARACTER*15 FILEIN, FILEOUT
CHARACTER*20 PLANT, FORM
CHARACTER*16 PLOC, WLOC
COMMON/A/ CI
COMMON PL, NBT, RNB, CL, CB, TH, CE, COM, CS, ITC, COG, CWC, CT, HE, ICOM, ICE,
+ QMGD, QGPD, QMGD2, QGPM2, QGPM2, QGPM2, HT, NT, P, E, C, EF, PLI, GPM, PP, PA,
+ XINT, D, FF, CP, CW, NW, WD, HP

D-1
WRITE(*,3000)
3000 FORMAT(' INPUT FILE NAME: '/)
READ(*,1600) FILEIN
WRITE(*,3005)
3005 FORMAT(' OUTPUT FILE NAME: '/)
READ(*,1600) FILEOUT
OPEN(5,FILE=FILEIN,STATUS='OLD')
OPEN(6,FILE=FILEOUT,STATUS='NEW')
OPEN(10,STATUS='SCRATCH')

C INPUT DATA
NC = 0
DO 999 IBIG = 1,1000
READ(5,1600,END=1001) PLANT
READ(5,1600) PLOC
READ(5,1600) WLOC
READ(5,1600) FORM
READ(5,100) P,E,C,EF,PLI,PQAF,RF,X,GPM,PP,WD,HE,HP,
+ PA,XINT,XINS,TAX,YR,XX

C CONVERSION OF AF/YR TO MGD AND GPM
QGPD = (QAF*325850./365.)
QMGD = QGPD/10.**6

C MAXIMUM RATE FOR GPM, MGD AND CFS
QGPM2 = (QGPD/1440.)*RF
QMGD2 = QMGD * RF
QCFS2 = QGPM2/448.8

C CALCULATE SIZE OF TRANSMISSION PIPE
IF(PLI.EQ.0.) GO TO 40
CALL SIZE

C CALCULATE COST OF PIPE
40 IF(PLI.EQ.0.) D = 1.
CALL PIPE
CALL THOU(CP,ICP)

C IF X.EQ.0 COST OF WELLS WILL NOT BE CALCULATED
IF(X.LT.1) GO TO 10

C CALCULATE COST OF WELLS AND INTERWELL PIPE
CALL WELL
CALL THOU(CW,ICW)

C CALCULATE COST OF TERMINAL STORAGE
GO TO 20
10 ICW = 0
   NW = 0
20 HT = 0,
   ICT = 0
   IF(XX.LT.1) GO TO 30
   CALL TERM
   CALL THOU(CT,ICT)

C CALCULATE COST OF BOOSTER STATIONS

30 CALL BOOST
   CALL THOU(CB,ICB)
C CALCULATE LAND COSTS
   CALL LAND
   CALL THOU(CL,ICL)
C CALCULATE COST ELECTRICAL POWER
   CALL ELEC
   CALL THOU(CE,ICE)
C CALCULATE OPERATION AND MAINTENANCE COSTS
   CALL OM
   CALL THOU(COM,ICOM)
C CALCULATE WORKING CAPITAL AND START-UP COSTS
   CALL WCSU
   ICWC = CWC + .5
   ICS = CS + .5
C CALCULATE TOTAL CONSTRUCTION COSTS, TC
   ITC = ICP + ICW + ICT + ICB
C CALCULATE INTEREST DURING CONSTRUCTION COST
   CALL INTR
   ICI = CI + .5
C CALCULATE OWNERS GENERAL EXPENSE
   CALL OGE
   CALL THOU(COG,ICOG)
C CALCULATE DEPRECIABLE AND NONDEPRECIABLE CAPITAL COSTS
   ITDC = ITC + ICI + ICS + ICOG
   ITNDC = ICL + ICWC
   ITTDC = ITNDC + ITDC
CALCULATE TOTAL ANNUAL OPERATION AND MAINTENANCE

ITOM = ICOM + ICE

CALCULATE TOTAL ANNUAL COSTS, ANNUAL DEPRECIABLE CAPITAL COSTS, DEPRECIABLE CAPITAL COST RATE, AND ANNUAL NON-DEPRECIABLE CAPITAL COST

DCR = ((XINT*(1. + XINT)**YR)/((1. + XINT)**YR)-1)) + XINS + TAX
ISTDC = ITDC * DCR + .5
ISTNDC = ITNDC * XINT + .5

CALCULATE UNIT COST

ITAC = ISTNDC + ISTDC + ITOM
IDAF = ITAC * 1000./QAF
YINT = XINT * 100.
YDCR = DCR * 100.
IQAF = QAF + .5
ID = D + .5

WRITE COST SUMMARY

WRITE(6,2300)
WRITE(6,1800)
WRITE(6,1900)
WRITE(6,2000) PLANT,PLOC,WLOC,FORM,IQAF
WRITE(6,3000)
WRITE(6,4000)
WRITE(6,5000)
WRITE(6,6000) NW,ICW,ID,ICP,ICB,ICT
WRITE(6,7000)
WRITE(6,8000) ITC,ICI,ICS,ICOG
WRITE(6,9000) ITDC,ISTDC,YDCR,ICL,ICWC
WRITE(6,7000)
WRITE(6,10000) ITNDC,ISTNDC,YINT
WRITE(6,1700)
WRITE(6,11000) ICOM,ICE
WRITE(6,700)
WRITE(6,12000) ITOM,ITOM
WRITE(6,1300)
WRITE(6,14000) ITAC,IDAF
WRITE(10,1500) PLANT,FORM,IQAF,ITNDC,ITOM,ITAC,ITAF

NC = NC + 1
999 CONTINUE
1001 WRITE(6,2300)
WRITE(6,1800)
WRITE(6,2000)
REMINDS 10
1010 WRITE(6,2100)
DO 99 ISML = 1, NC
READ(10, 1500, END=2001) PLANT, FORM, IQAF, ITIDIC, ITOM, ITAC, IDAF
WRITE(6, 2200) PLANT, FORM, IQAF, ITIDIC, ITOM, ITAC, IDAF
99 CONTINUE
2001 CALL EXIT

FORMATS

100 FORMAT(10FB.0)
200 FORMAT("DETAILED COST ANALYSIS"/
+ "PLANT DESIGNATION: "A20, ", "PLANT LOCATION: "A16/
+ "WATER SOURCE LOCATION: "A16, "FORMATION: "A20/
+ "DESIGN USAGE", I8, "ACRE-FEET/YEAR"/1X,73('-')/T14,
+ "COST ITEM", 'T42', "ESTIMATED COST", 'T64', "ANNUAL COST"/
+ 'T31,2(14X, "$ X 1000")
300 FORMAT('T6, 'SUBTOTAL - CONSTRUCTION COSTS', 'T48, "$ '', I6//T6,
+ 'INTEREST DURING CONSTRUCTION', 'T50, I6/T6, 'START-UP COSTS',
+ 'T50, I6/T6, 'OWNERS GENERAL EXPENSE', 'T50, I6)
700 FORMAT('T6, 'TRANSITION PIPES', 'I6/T6, 'BOOSTER',
+ 'STATIONS', 'T50, I6/T6, 'TERMINAL STORAGE', 'T50, I6)
800 FORMAT('T6, 'SUBTOTAL', 'T48, "$ '', I6//T6,
+ 'INTEREST DURING CONSTRUCTION', 'T50, I6/T6, 'START-UP COSTS',
+ 'T50, I6/T6, 'OWNERS GENERAL EXPENSE', 'T50, I6)
900 FORMAT('T6, 'TOTAL - DEPRECIABLE CAPITAL COSTS', 'T48, "$ '', I6, T67,
+ 'fixed charge rate - ', F5.2, '%')/T6,
+ 'LAND COSTS', 'T48, "I6/T6, 'WORKING CAPITAL', 'T50, I6)
1000 FORMAT('T6, 'TOTAL - NONDEPRECIABLE CAPITAL COSTS', 'T48, "$ '', I6,
+ 'T69, I6/T12, 'INTEREST RATE - ', F5.2, '%' '/" ANNUAL ',
+ 'O & M EXPENSE')
1100 FORMAT('T6, 'O & M LABOR, SUPPLIES AND MATERIALS', 'T48, "$ '', I6/
+ 'T6, 'ELECTRIC POWER COSTS', 'T50, I6)
1200 FORMAT('T6, 'TOTAL ANNUAL O & M EXPENSE', 'T48, "$ '', I6, T69, I6)
1300 FORMAT('T6, 'TOTAL ANNUAL O & M EXPENSE', 'T48, "$ '', I6, T69, I6)
1400 FORMAT('T6, 'TOTAL ANNUAL COSTS', 'T67, "$ '', I6//1X, 73('-')//'T6,
+ 'UNIT COST ''I6, "AC-FT/ACRE-FT"
2000 FORMAT('T43, 'SUMMARY OF COSTS', 'T32, 'GROWTH-WATER WITHDRAWAL AND ',
+ 'TRANSMISSION')
2100 FORMAT('T9, 'PLANT', 'T23, 'FORMATION', 'T45, 'DESIGN DEPRECIATION + NONDEPRECIATION',
+ 'ANNUAL O & M TOTAL ANNUAL UNIT', 'T6, 'DESIGNATION',
+ 'USAGE CAPITAL COSTS EXPENSES', 'T87, 'COSTS',
+ 'T97, 'COST/T44, 'AC-FT/YR X 1000', 'T73, "$ X 1000',
+ 'T85, "$ X 1000 "AC-FT"/
+ 'T6, 'T20, 'I8('-'), 'T44, 'B('-'), 'T57, '8('-'),
+ (T73, '8('-'), 'T85, 'B('-'), 'T95, '8('-'))/
2200 FORMAT('T43, 'SUMMARY OF COSTS')
1500 FORMAT('T43, 'SUMMARY OF COSTS')
1600 FORMAT('A')
1700 FORMAT('A')
1800 FORMAT('A')
1900 FORMAT('A')
2300 FORMAT('A')
END

SUBROUTINE BOOST

THIS SUBROUTINE CALCULATES HEAD IN PIPES AND COST OF BOOSTER PUMPING STATIONS

REAL J
COMMON PL, NBT, RNB, CL, CB, TH, CE, COM, CS, ITC, COG, CWC, CT, HE, ICOM, ICE,
+ QMGR, QGPD, QMG2, QGPM2, QCPS2, NT, NT, P, E, C, EF, PLI, GPM, FF, PA,
+ XINT, D, PF, CP, CW, NW, WD, HP

HL IS THE FRICTION HEAD IN PIPES

HL = 5280.*PL*(QCFS2/((.432*C*((D/12.)**2.*.63)**(.54))**(1./.54))

CALCULATE TOTAL HEAD

TH = HL + HT + HE - HP
IF(NW.EQ.0) TH = TH + HP
IF(TH.LE.0.) TH = 0.

CALCULATE COST OF BOOSTER STATIONS

NBT IS THE NUMBER OF STATIONS; 1/240 FT HEAD + ONE LOW HEAD STA.

XNB = TH/240.,
RNB = XNB - IFIX(XNB)
NBT = XNB

CALCULATE FIRMING FACTOR, J

IF(QMGR.LE.2.) GO TO 30
IF(QMGR.LE.5.) GO TO 40
IF(QMGR.LE.10.) GO TO 50
IF(QMGR.LE.20.) GO TO 60
IF(QMGR.LE.30.) GO TO 70
J = 1.25
GO TO 80
30 J = 2.08 - (.18*QMGR)
GO TO 80
40 J = 1.9666 - (.1233*QMGR)
GO TO 80
50 J = 1.42 - (.014*QMGR)
GO TO 80
60 J = 1.3 - (.002*QMGR)
GO TO 80
70 J = 1.28 - (.001*QMGR)

CALCULATE REQUIRED HORSEPOWER; HORS AND HORSR

80 HORS = .176 * QMG2 * 240. * J/E
IF(RNB.LT.2) GO TO 90
HORSR = (HORS) * RNB
CALCULATE COST OF BOOSTER STATIONS

\[
CB = ((17000.+((135.*HORS)**1.01))*NBT+(17000.+((135.*HORSR)**1.01 +)))*EF
\]

GO TO 100

\[
90 \ CB = ((17000.+((135.*HORS)**1.01))*NBT)*EF
\]

RNB = 0.

100 RETURN

END

SUBROUTINE WELL

THIS SUBROUTINE CALCULATES THE COST OF WELLS AND INTERWELL PIPE

COMMON PL,NBT,RNB,CL,CB,TH,CE,COM,CS,ITC,COG,CWC,CT,HE,ICOM,ICE,
+ QMGD,QGPD,QMGD2,QGPM2,QCFCS2,HT,NT,P,E,C,EF,PLI,GPM,PP,PA,
+ XINT,D,PF,CP,CW,NW,WD,HP

NW IS THE NUMBER OF WELLS: MAX. TOTAL GPM/GPM PER WELL, ROUNDED UP

\[
NW = \lceil \frac{QGPM2}{GPM} \rceil + 1
\]

NWA = (NW * ,1) + 1

IF(NWA,GT,10) NWA = 10

NW = NW + NWA

COST OF WELLS

\[
CW2 = (150. * WD) * NW
\]

COST OF PUMPS

\[
CW = NW * ((30. * GPM) + 20000.)
\]

COST OF INTERWELL PIPE

\[
CIW = 27000. * ((QMGD2 * NW)**.65)
\]

\[
CW = (CIW + CW + CW2) * EF
\]

RETURN

END

SUBROUTINE LAND

THIS SUBROUTINE CALCULATES THE LAND COST

COMMON PL,NBT,RNB,CL,CB,TH,CE,COM,CS,ITC,COG,CWC,CT,HE,ICOM,ICE,
+ QMGD,QGPD,QMGD2,QGPM2,QCFCS2,HT,NT,P,E,C,EF,PLI,GPM,PP,PA,
+ XINT,D,PF,CP,CW,NW,WD,HP

\[
N1 = RNB * 2
\]

\[
CLL = PA*(.5*NW)+(25*(NBT+N1))+(((2*HT)+100.)**2)/43560.)
\]

\[
CLP = PA * (PF * PLI * 30, * 5280./43560.)
\]

CL = CLL + CLP

RETURN
END

SUBROUTINE OM
C
THIS SUBROUTINE CALCULATES OPERATION AND MAINTENANCE COSTS
C
COMMON PL,NBT,RNB,CL,CB,TH,CE,COM,CS,ITC,COG,CWC,CT,HE,ICOM,ICE,
 + QMGD,QGPD,QMGD2,QGPM2,QCFS2,HT,NT,P,E,C,EF,PLI,GPM,PP,PA,
 + XINT,D,PF,CP,CW,NW,WD,HP
C
NWZ = NW
IF(PL.EQ.0) PL = 1,
IF(NW.EQ.0) NWZ = 1
COM = (3262. * (QMGD2*NWZ*PL)**.49) * EF
RETURN
END

SUBROUTINE OGE
C
THIS SUBROUTINE CALCULATES OWNERS GENERAL EXPENSE COSTS
C
COMMON PL,NBT,RNB,CL,CB,TH,CE,COM,CS,ITC,COG,CWC,CT,HE,ICOM,ICE,
 + QMGD,QGPD,QMGD2,QGPM2,QCFS2,HT,NT,P,E,C,EF,PLI,GPM,PP,PA,
 + XINT,D,PF,CP,CW,NW,WD,HP
C
TC = ITC * 1000.
IF(TC.LE.1000000.) GO TO 10
COG = TC * (.09/((1000000./TC)**(-.109)))
GO TO 20
10 COG = TC * (.12/((1000000./TC)**(-.125)))
20 RETURN
END

SUBROUTINE THOU(X,I)
C
THIS SUBROUTINE ROUNDS COSTS TO THE NEAREST THOUSAND AND
CONVERTS TO INTEGER
C
I = (X/1000.) + .5
RETURN
END

SUBROUTINE ELEC
C
THIS SUBROUTINE CALCULATES ELECTRIC POWER COST
C
COMMON PL,NBT,RNB,CL,CB,TH,CE,COM,CS,ITC,COG,CWC,CT,HE,ICOM,ICE,
 + QMGD,QGPD,QMGD2,QGPM2,QCFS2,HT,NT,P,E,C,EF,PLI,GPM,PP,PA,
 + XINT,D,PF,CP,CW,NW,WD,HP
C
THX = TH + PP + HP
IF(NW.EQ.0) THX = TH
CE = P * (.004*QGPD*(365./1000.)*THX)
RETURN

D-8
SUBROUTINE SIZE

THIS SUBROUTINE CALCULATES THE SIZE OF TRANSMISSION PIPE

COMMON PL,NBT,RNB,CL,SB,TH,CE,COM,CS,ITC,COG,CWC,CT,HE,ICOM,ICE,
  QMGD,QGPD,QMGD2,QGPM2,QCFS2,HT,NT,P,E,C,EF,PLI,GPM,PP,PA,
  XINT,D,PF,CP,CW,NW,WHP

D IS THE PIPE DIAMETER IN INCHES

DA = 83.4*(P**1.63)*(QMGD2**0.463)/(E**1.63*(C**3.01))
IF(DA.LE.48.) GO TO 10
D = 12 * (IFIX(DA)/12) + 12
GO TO 20
10 D = 6 * (IFIX(DA)/6) + 6
20 RETURN
END

SUBROUTINE TERM

THIS SUBROUTINE CALCULATES THE NUMBER OF STORAGE TANKS
THE MAX. TANK SIZE IS 25 MILLION GALLONS, AND MINIMUM
STORAGE MUST BE .GE. 2*QMGD. THE COST OF THE STORAGE TANKS
ALSO IS CALCULATED.

COMMON PL,NBT,RNB,CL,SB,TH,CE,COM,CS,ITC,COG,CWC,CT,HE,ICOM,ICE,
  QMGD,QGPD,QMGD2,QGPM2,QCFS2,HT,NT,P,E,C,EF,PLI,GPM,PP,PA,
  XINT,D,PF,CP,CW,NW,WHP

IF(QMGD.LT.25.) GO TO 10
NT = 1 + (2*(QMGD/25.))
X = 25.
GO TO 20
10 NT = 2
X = QMGD
20 CT = ((NT**(.0867*X) + .0532))**(10.**6))**EF
   HT = ((X*10.**6)/(7.48*3.14159))**(1./3.)
RETURN
END

SUBROUTINE PIPE

THIS SUBROUTINE CALCULATES THE COST OF TRANSMISSION PIPE

COMMON PL,NBT,RNB,CL,SB,TH,CE,COM,CS,ITC,COG,CWC,CT,HE,ICOM,ICE,
  QMGD,QGPD,QMGD2,QGPM2,QCFS2,HT,NT,P,E,C,EF,PLI,GPM,PP,PA,
  XINT,D,PF,CP,CW,NW,WHP

PL IS THE TERRAIN-CORRECTED PIPELINE LENGTH

PL = PLI * PF
IF(D,I.E.36.) GO TO 10
CP = PL * 5280. * ((7.65*D) - 95.26)
GO TO 20
10 CP = PL * 5280. * ((5.21*D) - 13.36)
20 RETURN

SUBROUTINE WCSU

THIS SUBROUTINE CALCUALTES WORKING CAPITAL

COMMON PL,NBT,RNB,CL,CB,TH,CE,COM,CS,ITC,COG,CWC,CT,HE,ICOM,ICE,
+ QMGD,QGPD, QMGD2,QGPM2,QCFS2,HT,NT,P,E,C,EF,PLI,GPM,PP,PA,
+ XINT,D,PF,CP,CW,NW,WD,HP

WORKING CAPITAL

CWC = .1667 * (ICOM + ICE)

START-UP COSTS

CS = .0833 * (ICOM + ICE)
RETURN
END

SUBROUTINE INTR

THIS SUBROUTINE CALCUALTES THE INTEREST DURING CONSTRUCTION

COMMON/A/ CI

COMMON PL,NBT,RNB,CL,CB,TH,CE,COM,CS,ITC,COG,CWC,CT,HE,ICOM,ICE,
+ QMGD,QGPD, QMGD2,QGPM2,QCFS2,HT,NT,P,E,C,EF,PLI,GPM,PP,PA,
+ XINT,D,PF,CP,CW,NW,WD,HP

NUMBER OF MONTHS FOR CONSTRUCTION

MC = (8./((1./QMGD)**.32)) + 1

INTEREST DURING CONSTRUCTION

CI = ((MC*(XINT/12.)) * ITC)
RETURN
END