Adding the 206,000 acre-feet of direct use diversions to the 77,000 of reservoir discharge, we get 283,000 acre-feet as the average annual gravity supply to the 95,000 acres under the ditches, a headgate average of about 3.0 acre-feet per acre. Delivery losses are heavy.

In the 12 ditches or systems they vary from 10 or 15% to 50% or more under poor conditions in the Riverside and Bijou systems.

Pump discharges from the wells on the 35,000 acres above the ditches vary from less than an acre-foot per acre in the upper tributary valleys to 2 to 3 acre-feet nearer the main valley. Assuming an average of 2 acre-feet would mean 70,000 acre-feet annually. Also, the hundreds of wells supplying supplemental water on lands under the ditches probably utilize an equal amount of ground water in an average season.

Assuming these "guesstimates" as somewhere near right, nearly 450,000 acre-feet are applied annually to the 130,000 total of irrigated land, about 3.5 acre-feet per acre in addition to the rainfall.

However, the consumptive use is only 119,000 acre-feet or 26% of the total applied. Putting it another way, the return flows in the District of 304,000 acre-feet are about 2½ times the consumptive use.

The official records indicate an even lower consumptive use in District Sixty-four.

With an average recorded discharge of 258,000 acre-feet at Balzac and 319,000 at Julesburg, the river actually gains 61,000 acre-feet over and above the diversions.

Diversions for direct use of 188,600 acre-feet and 17,600 for storage (Julesburg Reservoir) total 206,200. Adding this to the Julesburg flow and subtracting the Balzac discharge, we get 267,200 acre-feet as the average return flow in the 75 miles of river, an average of about 5.0 C.F.S. per mile.

This can be partly explained by the occasional flood waters in several tributary streams but from averages computed from records kept by the Water Commissioner, they would not affect the results more than 2 or 3%.

The table below summarizes the operation of the three reservoirs.

<table>
<thead>
<tr>
<th></th>
<th>Capacity</th>
<th>Av. Diverted</th>
<th>Av. Discharge</th>
<th>% Cap.</th>
<th>% Div.</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. Sterling</td>
<td>87,400</td>
<td>89,300</td>
<td>62,880</td>
<td>72</td>
<td>70</td>
</tr>
<tr>
<td>Prewitt</td>
<td>32,300</td>
<td>43,100</td>
<td>11,140</td>
<td>35</td>
<td>25</td>
</tr>
<tr>
<td>Julesburg</td>
<td>28,180</td>
<td>17,490</td>
<td>15,210</td>
<td>54</td>
<td>86</td>
</tr>
<tr>
<td></td>
<td>141,880</td>
<td>149,900</td>
<td>89,230</td>
<td>62</td>
<td>59</td>
</tr>
<tr>
<td>Loss</td>
<td></td>
<td></td>
<td>60,700</td>
<td>38</td>
<td>41</td>
</tr>
</tbody>
</table>
### Reservoir losses

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct</td>
<td>3,950.0 T</td>
</tr>
<tr>
<td>Storage</td>
<td>607.0 T</td>
</tr>
<tr>
<td>Loss</td>
<td>2,002.0 T</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td><strong>5,568.0 T</strong></td>
</tr>
</tbody>
</table>

### Reservoir deliveries

<table>
<thead>
<tr>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>770.1 T</td>
</tr>
<tr>
<td>892.3 T</td>
</tr>
<tr>
<td><strong>1,662.4 T</strong></td>
</tr>
</tbody>
</table>
Adding the total reservoir discharges of 89,230 acre-feet to the
direct diversions of 186,600 we get 276,140 acre-feet as the average
headgate supply for the estimated 105,000 acres of irrigated land; a
duty of about 2.6 acre-feet per acre.

There are about 30 operating ditches in the District; most of them
small ones covering first bottom land.

If we combine the records of both Districts (using 20 year averages)
we can get a clearer understanding of what happens below Kersey.

Deducting the Julesburg discharge of 318,700 acre-feet from the
509,200 at Kersey we get 191,500 acre-feet as the total average con-
sumptive loss in the 140 miles of river which serves about 235,000
acres of irrigated land. The Julesburg flow is 62% of Kersey.

The total average diversions are 393,000 acre-feet for direct use and
368,000 for storage, a total of 761,000 acre-feet.

Adding this to the Julesburg flow of 318,700 we get 1,080,000 acre-
feet or slightly over twice the original Kersey supply.

Subtracting the Kersey figure of 509,200 we get 570,500 acre-feet as
the twenty year average return flow, an average of 5.6 C.F.S. per mile
of river.

The 191,000 acre-feet consumptive loss is just one-fourth of the
total diversion.

Assuming 235,000 acres of irrigated land in the valley, the use would
be 81% of an acre-foot per acre.

These return flow determinations have not considered the effects of
occasional local floods from tributary streams.

The Water Commissioners of both Districts have kept records of the
estimated amount and duration of these floods.

In District One several small floods from Bijou and Wildcat Creek,
totaling an estimated 121,000 acre-feet would, if averaged over the
twenty years, added about 2.0% to the Balzac discharge.

In District Sixty-four several small flows in Pawnee, Lewis,
Lodgepole and other creeks, if they reached the river and were likewise
averaged, would have increased the Julesburg flow perhaps 1.5%.

These flash flows were often unusable.

The Kersey flows varied from a maximum of 1,425,000 acre-feet in
1942 to a minimum of 159,900 in 1954 in the twenty year period, a
spread of almost 9 to 1.

The maximum at Kersey was 350% of average and the minimum 33%.
While the Kersey flow averaged 509,000 acre-feet for the past 20 years,
the mean for the preceding 10 years (the 1930's) was only 329,000
acre-feet.
The following table summarizes the flows at the three stations.

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>Maximum</th>
<th>Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kersey</td>
<td>509,200</td>
<td>1,425,700 (1942)</td>
<td>159,000 (1955)</td>
</tr>
<tr>
<td>Balzac</td>
<td>257,700</td>
<td>1,030,000 (1942)</td>
<td>59,950 (1954)</td>
</tr>
<tr>
<td>Julesburg</td>
<td>318,700</td>
<td>1,092,000 (1942)</td>
<td>55,400 (1956)</td>
</tr>
</tbody>
</table>

There were seven years above the average at Kersey and thirteen below. The four short years of 1953-1956 averaged only 198,000 acre-feet.

The table below is a summary of the flows at the three stations in both "direct use" and "storage" seasons.

<table>
<thead>
<tr>
<th></th>
<th>Kersey %</th>
<th>Balzac %</th>
<th>Julesburg %</th>
</tr>
</thead>
<tbody>
<tr>
<td>April 1 to Oct. 1</td>
<td>328,000-64%</td>
<td>205,000</td>
<td>181,000</td>
</tr>
<tr>
<td>Oct. 1 to April 1</td>
<td>181,000-36%</td>
<td>52,000</td>
<td>138,000</td>
</tr>
</tbody>
</table>

509,000 257,000 319,000

The Balzac winter flow is low due to diversions for North Sterling and Prewitt reservoir.

It may be noted here that during this 20 year period, Conservancy District records show an average supply of "original" water entering the District (at the canyons of the four tributary streams and Ft. Lupton) of about 823,000 acre-feet.

Apparently, after serving nearly 500,000 acres in the upper five Water Districts, 509,000 acre-feet or 62% of the base supply (including some flash surpluses) shows up at Kersey.

On the face of these figures 314,000 acre-feet was consumed in the upper Districts or about 63% of an acre-foot per acre.

During the past six years an average of 211,000 acre-feet of Project water has been delivered into the streams, increasing the base supplies and undoubtedly raising the Kersey discharges.

It should be mentioned also that the longest protracted drought period of "original" supplies on record occurred in this twenty year period. The four years of 1953-1956 averaged less than one-half the long time mean. As reflected at Kersey, the four year average was only 38% of the twenty year period.
The following table summarizes what happens to the river east of Kersey:

<table>
<thead>
<tr>
<th>District No. 1</th>
<th>District No. 64</th>
<th>Both Districts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kersey</td>
<td>509,200</td>
<td>257,700</td>
</tr>
<tr>
<td>+ Return</td>
<td>303,390</td>
<td>+Return</td>
</tr>
<tr>
<td></td>
<td>812,590</td>
<td>524,860</td>
</tr>
<tr>
<td>- Diversions</td>
<td>554,890</td>
<td>- Diversions</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Balzac</td>
<td>257,700</td>
<td>Julesburg</td>
</tr>
</tbody>
</table>

Below is another summary of what happens to the 823,000 acre-feet average "original" water entering the Conservancy District (stream flows only):

"Original" water entering District 823,000
Diversions in Districts 3-4-5-6-12 778,000 45,000 46,000
Return flow in upper Districts +464,000
Kersey 509,000
District One Diversion -555,000 (46,000)
District One Return +303,000
Balzac 259,000
District Sixty-four diversion -206,000 52,000
District Sixty-four returns +267,000
Julesburg 319,000

Average original 823,000
Average total returns +1,034,000 1,857,000
Average Diversions -1,538,000 319,000
Going back to the long-time 58 year period with an average at Kersey of 532,000 acre-feet, we find a maximum of 1,580,000 acre-feet in 1914 and the minimum of 159,000 in 1955.

There were 24 years above the average, due largely to high floods, and 34 years below the mean.

During a thirteen year period (1929-1941) there was only one year that slightly exceeded the average and the average for these thirteen years was only 330,000 acre-feet.

There is no apparent trend or pattern in the return flow records.

While the average of 340,000 acre-feet at Julesburg is 64% of the Kersey flow of 532,000 there were four years in the first decade of the century above this average and five in the last 20 years.

Part of the Julesburg flows derive from surplus basic flows at Kersey, part from occasional flash floods in the valley and the remainder from actual return flows from the reservoirs and irrigated lands.

It seems impossible to make an accurate estimate of the proportion of each source.

If we select the twenty years of the fifty-eight at Kersey with discharges nearest the average and with no recorded flood flows in the valley, we get an average of 523,000 acre-feet at Kersey and 251,000 at Julesburg. Assuming this as the average return flow for all years, we find it to be about 74% of the long-time Julesburg mean of 340,000 acre-feet.

Regarding surplus basic flows, the twenty-four years of record at Kersey which exceeded 500,000 acre-feet per year averaged 810,000 or 260,000 above the full fifty-eight year average.

The following table summarizes the flows at the three recording stations by months and three month periods.
### Twenty Year Discharges (Units 1,000 A-F)

<table>
<thead>
<tr>
<th></th>
<th>1st ½</th>
<th></th>
<th></th>
<th>3rd ¼</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Kersey</td>
<td>24.5</td>
<td>31.9</td>
<td>31.8</td>
<td>31.0</td>
<td>28.8</td>
<td>39.8</td>
<td>49.0</td>
<td>110.0</td>
<td>111.0</td>
</tr>
<tr>
<td>% Year</td>
<td>4.8</td>
<td>6.2</td>
<td>6.2</td>
<td>6.2</td>
<td>5.6</td>
<td>7.8</td>
<td>9.6</td>
<td>21.6</td>
<td>21.6</td>
</tr>
<tr>
<td>% ¼</td>
<td>(..</td>
<td>(..</td>
<td>51.8</td>
<td>(..</td>
<td>64.0</td>
<td>(..</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>%½</td>
<td>(.</td>
<td>.</td>
<td>36.0</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Balzac</td>
<td>5.6</td>
<td>2.1</td>
<td>5.0</td>
<td>7.7</td>
<td>9.2</td>
<td>17.6</td>
<td>23.9</td>
<td>70.1</td>
<td>69.5</td>
</tr>
<tr>
<td>% Year</td>
<td>2.1</td>
<td>.8</td>
<td>2.0</td>
<td>3.0</td>
<td>3.7</td>
<td>6.8</td>
<td>9.0</td>
<td>27.1</td>
<td>26.7</td>
</tr>
<tr>
<td>% ¼</td>
<td>(..</td>
<td>63.8</td>
<td>(..</td>
<td>(..</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% ½</td>
<td>(.</td>
<td>.</td>
<td>20.3</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td></td>
<td>79.6</td>
</tr>
<tr>
<td>Julesburg</td>
<td>6.0</td>
<td>15.6</td>
<td>20.3</td>
<td>24.8</td>
<td>26.1</td>
<td>32.1</td>
<td>29.5</td>
<td>66.8</td>
<td>72.2</td>
</tr>
<tr>
<td>% Year</td>
<td>1.8</td>
<td>5.0</td>
<td>6.3</td>
<td>7.9</td>
<td>8.1</td>
<td>10.0</td>
<td>9.2</td>
<td>20.9</td>
<td>22.5</td>
</tr>
<tr>
<td>% ¼</td>
<td>(..</td>
<td>52.1</td>
<td>(..</td>
<td>(..</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% ½</td>
<td>(.</td>
<td>.</td>
<td>39.0</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td></td>
<td>61.2</td>
</tr>
</tbody>
</table>

This table shows, of course, that nearly all the large flows at Kersey are in the spring months and the deficiencies are in the fourth quarter of the water year.

The fairly steady flows of the first half of the water year go almost entirely into storage.

In the third quarter part of the water is used for direct irrigation and available surpluses to "top out" the reservoirs.

With over one-half of the average annual Kersey discharges occurring in this period, part of the total volume is surplus above the needs in some years and passes out of the State.

There were six such years in the twenty years above the average of 280,000 acre-feet and fourteen below. There were eight years below 100,000 acre-feet.

The records show only about twelve percent of the annual flows in the fourth or critical period of the crop growing season. There were five years above the average of 65,000 at Kersey and fifteen below. There were eleven years below 50,000 acre-feet and one of only 24,000.
<table>
<thead>
<tr>
<th>Month</th>
<th>July</th>
<th>Aug.</th>
<th>Sept.</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st 1/4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2nd 1/4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3rd 1/4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4th 1/4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>28.4</td>
<td>23.9</td>
<td>13.7</td>
<td>509,000</td>
</tr>
<tr>
<td></td>
<td>5.5</td>
<td>4.7</td>
<td>2.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>.</td>
<td>12.2</td>
<td>.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>.</td>
<td>.</td>
<td>.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>16.4</td>
<td>15.1</td>
<td>12.2</td>
<td>258,000</td>
</tr>
<tr>
<td></td>
<td>6.3</td>
<td>5.8</td>
<td>4.7</td>
<td>(50% K)</td>
</tr>
<tr>
<td></td>
<td>.</td>
<td>16.8</td>
<td>.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>.</td>
<td>.</td>
<td>.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>17.1</td>
<td>64</td>
<td>5.8</td>
<td>319,000</td>
</tr>
<tr>
<td></td>
<td>5.3</td>
<td>2.0</td>
<td>1.8</td>
<td>(63% K)</td>
</tr>
<tr>
<td></td>
<td>.</td>
<td>9.1</td>
<td>.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>.</td>
<td>.</td>
<td>.</td>
<td></td>
</tr>
</tbody>
</table>
The above proportions are approximately the same using 58 year figures.

The annual flows from mountain snow packs are largely unpredictable.

Snow course reports are interesting but the season runoff depends mostly on the weather in May and June.

Theoretically at least, an annual flow at Kersey of 400,000 acre-feet or even less would be ample to supply the present acreage in the valley if it could be distributed ideally throughout the year to match the needs.

The writer ventures a few tentative observations:

The main point established by the study is the small amount of water actually consumed by its use and the large amounts of return flows.

These flows increase mile by mile as the river flows toward the Nebraska line although large quantities of water are consumed by cottonwoods, willows and other vegetation in the river bottom.

The basic flows at Kersey circulate through the seven reservoirs and thirty or more ditches serving 235,000 acres of land and, minus the evaporation and consumptive use of the crops, join the underflow back to the river. Much of this residual flow develops too far down the river for use within the State.

Most of the soils of the valley are well drained and are underlaid with vast deposits of water bearing gravel.

Standard irrigation practices often tend to apply more water to the crops than necessary. Much of it percolates below the root zones and eventually back to the river. When available many farmers use too much water.

The enormous water table below the valley floor constitutes reserve storage, which to some extent equalizes the varying annual supplies and, of increasing importance in recent years, supplies the hundreds of irrigation wells in the main valley.

It may be said that the valley supplies are from both the Kersey flow (itself mostly return water) and from returns in the valley and that they supplement each other.

When the ditches and reservoirs are well supplied from basic flows, the water tables rise in elevation, returns increase and the wells in the main portion of the valley operate with lower lifts.

Possibly, future projects designed to help recharge these aquifers, particularly in tributary valleys like Bijou and Kiowa, may be as worthwhile as surface storage.

With the Conservancy District adding at least 30% to the "original" supplies on the upper tributary streams and with prospective increases to the river from the operations of the City of Denver, the Kersey discharges will continue to gain in coming years and, most important, become more uniform and stable. This will reduce the shortages in the valley and by the same token will also add to the surpluses that pass out of the State. These outflows will always continue and may increase.
As the tabulations and charts show, there are large and fairly regular amounts of surplus water in the lower valley and smaller and more intermittent excess flows on the tributaries and at Kersey. Of course, the higher up any water can be conserved, the more value it will have in supplying the several cycles of diversions, application and return flow for re-use before leaving the State.

All the yearly and monthly averages of the supplies do not provide a complete or accurate picture of the situation.

Even with increased supplies at Kersey these will be years of deficient flows.

Also, the hundreds of wells in the valley intercept much of the return flows during the irrigation season and reduce the river flows available to the decreed ditches. Of course, the pumped water is put to beneficial use but it is partly at the expense of users who do not have pumps and depend on gravity supplies.

For example, during recent fairly normal years with from 500 to 600 C.F.S. at Kersey during the winter storage months and with an additional return flow of perhaps 300,000 acre-feet, the six reservoir intakes in District One divert around 1,800 acre-feet daily. Very little water passes Balzac.

In District Sixty-four with only Julesburg Reservoir diverting around 10,000 acre-feet, the return flows in the 75 mile stretch averages around 350 C.F.S. at Julesburg.

During the irrigation season, except in periods of high flows from excess runoff on the upper tributaries, the Kersey discharge drops to as low as 100 C.F.S.

These with many of the junior ditches deprived of water on their decrees the hundreds of pumps in the valley go into operation, intercepting much of the return flows and the supplies of the water users dependent on river appropriation, which in earlier years were considered fairly reliable, are further reduced.

Changing crop rotation programs of recent years require more late season water for the more valuable row crops.

Most of this must come from storage supplies or from the wells.

Reservoir losses from seepage and evaporation in the valley are enormous (as they are also in the upper tributary valleys).

Seepage losses are often reclaimable by users below but the evaporation from the many shallow storage basins is a total loss.

For many years, plans have been discussed for equalizing the variable yearly supplies. As the country grows and the need for more crop production develops the demand for an answer to the difficult problem will increase.

With changing conditions and values, largely due to the transmountain diversions, we need more knowledge and understanding of the facts and the possibilities.

Many plans will develop and require careful study and analysis.

There will be many difficult angles to the problem of finding an
Phone call to Mr. J. R. Halsey, Feb 3 1966.

He says that the Dille study was never published. Mr. Halsey has, however, incorporated this and other material in some studies of his own. Mr. Dille's study was made after he retired. R.G. 2-3-66.

J.M. Dille: Superintendent of the Riverside and Bijou Irrigation Systems, Secretary-Manager of the Northern Colorado Water Conservancy District.

(By phone from Mr. Erker at Colburn's office.)

I.R. Halsey (at Loveland, 667-0393 worked with him.)
economically feasible plan with an acceptable cost-benefit ratio.

Basically, it seems that the problem is to find a site or sites where enough unappropriated water is normally or periodically available and where the benefits of any construction would exceed the cost.

More water does not always mean better crops. Some of the most productive years in the valley have been those when supplies were somewhat limited and had to be economically used.

As far as present acreage is concerned, the benefits would be to help equalize the annual basic supplies and seasonally to replace to the river the losses from the pumping drafts.

Very large amounts of long-time storage will be needed to even approach equalization of the annual basic flows.

The organization of a contracting agency with an acceptable repayment program will be required.

There should be some write-offs for such non-reimbursable items as flood control and recreation but the major part of the cost may have to be underwritten by the prospective beneficiaries.

Who and where they are and how far they will go in assuming the burden will depend on the results of a thorough analysis of all the facts and possibilities throughout the entire water shed and of the economic feasibility of any proposed construction program.

However, the problem of what to do about the unequal supplies will continue until a feasible place to solve it is found.

The "market price" of water in the South Platte Valley is low compared to many other western areas but as the country grows and the need for more crop production develops, proposals that may seem questionable now will become economically feasible.

With Federal and State agencies cooperating with local interests from all parts of the valley, some justifiable program should eventually develop that will help equalize supplies for the present irrigated acreages and perhaps find ways to serve additional areas.

(Dated)

J.M. Dille.

Fort Morgan, Colorado.

May 1961.


(By phone from R. Madsen, Nov 19, 1965)
SOUTH PLATTE RIVER BASIN WATER SUPPLY

by

R.M. Gildersleeve, Chief Engineer
Ivan C. Crawford, Director
Colorado Water Conservation Board

This basin, by far the most populous in the State of Colorado, is composed of 19,022 square miles of land area of which twenty-three percent is above 8,700 feet in elevation according to U.S. Engineers Report on Flood Control, South Platte River and Tributaries, 1954. The rim of the basin goes up to 14,000 feet above sea level. Fifty-four percent of the total area is above the 6,000 foot contour. It contains 18.4 percent of the total land area of the State of Colorado.

The 1950 census says that there are 300,000 people, or sixty percent of the population of the State, in this basin. Since that date the area has experienced a greater growth in population than any other basin in the State.

From studies made in the office of the Colorado Water Conservation Board, the irrigated area in this water shed may be divided into the following sub-groups which contain a total of 1,220,000 acres of irrigated land:

Table I

<table>
<thead>
<tr>
<th>Irrigated area</th>
<th>Acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. South Park</td>
<td>45,000</td>
</tr>
<tr>
<td>b. Main stem above Denver (WD8)</td>
<td>22,000</td>
</tr>
<tr>
<td>c. Main stem Denver-Kersey (WD2)</td>
<td>210,000</td>
</tr>
<tr>
<td>d. Main stem Kersey-Balzac (WD1)</td>
<td>177,000</td>
</tr>
<tr>
<td>e. Main stem Balzac-Julesburg (WD64)</td>
<td>155,000</td>
</tr>
<tr>
<td>f. Bear, Clear, St. Vrain, Boulder, Big Thompson &amp; Cache La Poudre</td>
<td>611,000</td>
</tr>
<tr>
<td>Total for basin</td>
<td>1,220,000</td>
</tr>
</tbody>
</table>

This vast area secures its water supply largely from the melted snows of the Front Range mountains and of the Park Range which is the westernmost boundary.

Table IIIa which follows gives the sources of the total water supply as these sources debouch onto the plains. The period 1930-1955 is used because of availability of records, and also because it represents the recent 26 years of record, including two rather extended dry periods.

Table IIIa

<table>
<thead>
<tr>
<th>Mountain Inflow – 1930-1955</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>a. South Platte at So. Platte</td>
<td>247,400</td>
</tr>
<tr>
<td>b. Bear Cr. at Morrison</td>
<td>35,800</td>
</tr>
<tr>
<td>c. Clear Cr. at Golden</td>
<td>157,100</td>
</tr>
<tr>
<td>d. St. Vrain Cr. at Lyons</td>
<td>84,400</td>
</tr>
<tr>
<td>e. Boulder Cr. nr. Orodeell</td>
<td>60,600</td>
</tr>
<tr>
<td>f. So. Boulder Cr. at Eldorado Spgs.</td>
<td>50,200</td>
</tr>
<tr>
<td>g. Big Thompson nr. Drake</td>
<td>110,500</td>
</tr>
<tr>
<td>h. Cache La Poudre nr. Ft. Collins</td>
<td>240,800</td>
</tr>
</tbody>
</table>
|                            | 986,900     | acre feet
Table IIb shows the water brought into the South-Platte Water Shed from across the front range by transmountain diversions. The left-hand column gives the average for 1930 to 1955 or for the period of actual operation through the year 1955, while the right-hand column gives the estimated potential future, average diversions during a period of water supply such as 1930 to 1955.

Table IIb

<table>
<thead>
<tr>
<th>Transmountain Diversion</th>
<th>Avg. for 1930-1955</th>
<th>Potential thru 1955</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Denver System (Fraser and Williams)</td>
<td>35,700</td>
<td>106,000</td>
</tr>
<tr>
<td>b. Colorado-Big Thompson</td>
<td>101,000</td>
<td>260,000</td>
</tr>
<tr>
<td>c. North Platte</td>
<td>2,300</td>
<td>2,800</td>
</tr>
<tr>
<td>d. Laramie</td>
<td>25,100</td>
<td>21,000</td>
</tr>
<tr>
<td>e. Grand River Ditch</td>
<td>17,300</td>
<td>19,000</td>
</tr>
<tr>
<td>f. Englewood</td>
<td></td>
<td>13,600</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>181,900 ac. ft.</strong></td>
<td><strong>422,400 ac. ft.</strong></td>
</tr>
<tr>
<td><strong>Denver-Blue</strong></td>
<td></td>
<td>175,000</td>
</tr>
</tbody>
</table>

It is seen that for the period 1930 to 1955 a total of Tables IIa and IIb is 1,168,800 acre feet and that the potential for the future, taking the 1930-1955 period as a base, may amount to 1,409,300 acre feet and to this latter figure may be added a portion of the Denver-Blue transmountain diversion, the amount being uncertain at this time, because of restrictions on its use.

Outflows

Measured outflows from the several tributaries of the South Platte River and outflows at Denver, Kersey, Balzac, and Julesburg are given in Table III. For the tributaries these outflows are the water delivered at the mouth of the tributary to the South Platte River.

Table III

<table>
<thead>
<tr>
<th>Outflows: 1930-1955</th>
<th>Avge. Acre Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bear Cr. at Mouth</td>
<td>24,900</td>
</tr>
<tr>
<td>Clear Cr. at Mouth</td>
<td>59,500</td>
</tr>
<tr>
<td>St. Vrain at Mouth</td>
<td>123,400</td>
</tr>
<tr>
<td>Big Thompson at Mouth</td>
<td>30,200</td>
</tr>
<tr>
<td>Cache La Poudre at Mouth</td>
<td>46,300</td>
</tr>
<tr>
<td>South Platte at Denver</td>
<td>226,500</td>
</tr>
<tr>
<td>Sewer Return-Denver</td>
<td>57,500</td>
</tr>
<tr>
<td>South Platte at Kersey</td>
<td>424,170</td>
</tr>
<tr>
<td>South Platte at Balzac</td>
<td>207,600</td>
</tr>
<tr>
<td>South Platte at Julesburg</td>
<td>269,300</td>
</tr>
</tbody>
</table>

By adding the outflows from the several tributaries below Denver to that of the South Platte at Denver, plus the sewer return, the total measured flow entering the river and available for diversion below Denver is found to be 551,900 acre feet.
Diversions

The diversions for the four stretches of the river and for the tributaries are given in Table IV.

a. Diversions Main Stem: 1930-1955

South Platte to Denver (WD8) 116,400
Denver to Kersey (WD2) 350,700
Kersey to Balzac (WD1) 535,300
Balzac to Julesburg (WD64) 211,000
Subtotal (1,213,400) ac. ft.

b. Diversions Tributaries: 1930-1955

Bear Creek (WD9) 26,200
Clear Creek (WD7) 125,400
Boulder Creek (WD6) 94,600
St. Vrain (WD5) 75,800
Big Thompson (WD4) 136,900
Poudre (WD3) 267,800
Subtotal (726,700) ac. ft.

Diversions totals 1,940,100 ac. ft.

For the main stem, the diversions shown are those made from river water by canals and reservoirs. The diversions on tributaries are those reported by the water commissioners as being made from river water, and do not include canal diversions made from reservoir water.

Accretions - Return Flows

An indication of the amount of return flow to a river section may be obtained by subtracting the measured surface inflow to the section from the sum of the diversions and the river outflow from the section. The "accretion" thus calculated includes, in addition to seepage and surface return from irrigation diversions, an unknown amount of unmeasured surface runoff from precipitation, and also the effect of channel losses in the river section.

Since it is not practicable to accurately separate these factors in the calculation, over an extended period of time the average accretions have generally been designated return flows.

Taking the mountain inflow to the basin from Tables IIIa and IIIb for the period 1930-1955, the total is found to be 1,168,300 acre feet. Diversions plus the outflow at Julesburg add up to 2,209,400 acre feet. The aggregate diversions for the entire length of the river are about 1.66 times the inflow as shown. Excluding undivertable mountain inflow in years of exceptionally high runoff and considering the period averages of transmountain diversions, the ratio of total diversion to dependable mountain inflow would be closer to 2 to 1.

Starting at the uppermost section of the main river and continuing, section by section, to Julesburg, the return flows or accretions in each water district are as follows:
TABLE V

1. From South Platte, Colorado to Denver, Colorado
   (Water District 8)

   River Inflow - So. Platte at So. Platte
   Bear Creek at Mouth
   \[ \frac{247,400}{24,900} \]
   \[ \frac{272,300}{116,400} \text{ a.f.} \]

   Diversions

   River Outflow - So. Platte at Denver
   Accretions = 70,600 a.f. or about 60% of diversions.
   \[ 226,500 \text{ a.f.} \]

TABLE VI

2. From Denver, Colorado to Kersey, Colorado
   (Water District 2)

   River Inflow - So. Platte at Denver
   Clear Creek at Mouth
   St. Vrain at Mouth
   Big Thompson at Mouth
   \[ \frac{226,500}{59,500} \]
   \[ \frac{125,400}{36,200} \text{ a.f.} \]

   Diversions

   River Outflow - So. Platte at Kersey minus
   Poudre at Mouth
   Accretions = 280,500 a.f.
   Minus 57,500 Sewer return at Denver
   223,000 a.f. or 63% of diversions.
   350,700 a.f.
   377,400 a.f.

TABLE VII

3. From Kersey, Colorado to Balzac, Colo
   (Water District 1)

   River Inflow - So. Platte at Kersey
   Diversions
   River Outflow - So. Platte at Balzac
   Accretions = 318,700 a.f. = 59% of diversions
   (includes unmeasured flow of Bijou Creek,
   and other tributaries which at times con-
   tribute substantial amounts from rain
   floods)
   \[ 424,200 \text{ a.f.} \]
   \[ 535,300 \text{ a.f.} \]
   \[ 207,600 \text{ a.f.} \]

TABLE VIII

4. From Balzac, Colorado to Julesburg, Colorado
   (Water District 64)

   River Inflow - So. Platte at Balzac
   Diversions
   River Outflow - So. Platte at Julesburg
   Accretions = 272,700 a.f. or 130% of diversions of river water
   (includes unmeasured flow of Lodgepole Creek, etc.
   and also return flow from releases of reservoir
   water diverted above Balzac)
   \[ 207,600 \text{ a.f.} \]
   \[ 211,000 \text{ a.f.} \]
   \[ 269,300 \text{ a.f.} \]
Another view of the magnitude of the accretion in percentage of diversions is presented if we consider the river from Kersey to Julesburg as one section. The inflow at Kersey is 424,200 acre feet. The diversions between Kersey and Julesburg amount to 748,300 acre feet. Flow passing Julesburg as shown above is 269,300 acre feet so that the inflow at Kersey is only 41.5% of diversions between Kersey and Julesburg, plus outflow at the latter point.

A Bureau of Reclamation study in 1950 showed that the total return flow in this stretch averaged 552,000 acre feet during the period 1925-1948. For the period 1930-1955, the accretion averaged 591,000 acre feet according to this study.

THE NARROWS DAM

This structure, when, and if, constructed, would play an important role in the water supply as well as flood control of the lower river basin. With irrigation capacity of 323,000 acre feet as now designed, it "would provide supplemental water for about 230,000 acres of presently irrigated land through regulation of flood and surplus South Platte River flows and return flows from the Colorado-Big Thompson Project."

SURPLUS FLOWS

About 25 years ago some studies were made relative to surplus flows, which might be considered as storable, in the South Platte River and tributaries, provided that reservoir capacity should be constructed. These studies were based on streamflows occurring during the 1918-1928 period.

For example, it was estimated at that time that there was a storable surplus of about 27,000 acre feet on Clear Creek above Golden. For the 15 year period between 1941 and 1955, the runoff at Golden has been about 85 percent of that of the 1918-1928 period. A rough study was made by the Water Conservation Board to determine what the storable surplus might be for the 1941-1955 period with storage in a potential reservoir at the forks of Clear Creek below Empire. Based on streamflows at the reservoir site, the river orders issued by the State Engineer's office and demands on the South Platte itself, it was found that water could have been stored during summer months in only 5 years of the 15 year period. The average amount storable would be less than 10,000 acre feet during such a period.

It was also estimated at that time that some 46,000 acre feet of surplus water could be stored from the Cache La Poudre River at the HANEX canyon mouth. A similar check was made of the storage possibility for the 1930-1955 period at a potential reservoir at the Elkhorn site. It was found that when downstream calls for water were analysed in connection with runoff at the mouth of the canyon and at the mouth of the river near Greeley, there were only 6 years in that 26 year period when storage at the Elkhorn site would have been definitely possible.

Studies have not been made with respect to other tributaries. It is apparent, however, that the lower runoffs of the past 25 years would provide considerably less storable surplus than was indicated by estimates based on earlier runoff periods.
Probable error of flow measurement
(U.S.G.S. Ratings)

\[
\frac{2}{\sqrt{n}} \int_0^x e^{-u^2} du
\]

95% of daily discharges are within:

- **Excellent**: 5%
- **Good**: 10%
- **Fair**: 15%
- **Poor**: 15%

1975 Station Records
- good: Kersey, good: Baca
- good: Weldona, good: fair: Julesburg
- fair: Balzac, fair: poor: good: fair


Factor 0.344 = 0.477

1.386

0.477 (checked 6/15/78) 3.44%.

1.72% probable error: "excellent"
if "good"
if "fair"
if "poor"

More than 5.16%
Northern Colorado Water Conservancy District  
U.S. Highway 34 - West of Loveland  
P.O. Box 679 Loveland Colorado - 80537  
Phone 667-2437 - R.J. Barkley, Secretary-Manager

Lower South Platte Water Conservancy District  
205½ Main Street  
P.O. Box 1725 Sterling, Colorado - 80751  
Phone 522-1378.

Colorado Water Congress  
Livestock Exchange Building - Room 328  
East 47th Avenue and Lafayette - 80216  
Val Killan, Director C.N. Feast, Newsletter Editor

**NOTICE!!! CHANGE OF ADDRESS!!!!! 4/1/76**

The COLORADO WATER CONGRESS has moved from its offices at 328 Livestock Exchange Building, Denver, CO 80216, to the Greenwood Plaza Office Campus in Southeast metro Denver on I-25 near the Bellevue interchange. The new address is:

COLORADO WATER CONGRESS  
5600 South Syracuse Circle #311  
Englewood, Colorado 80110

Frederick C. Caruso, Exec. Dir. / Ph. (303) 779-0693
Dr. A.H. Barnes - Department of Civil Engineering - CSU -
Fort Collins, Colo. - 80521

Dr. A.R. Chamberlain - 102 Administration Bldg. - CSU -
Fort Collins, Colo. = 80521.

Dr. J.W.N. Fead - Head, Department of Civil Engineering - CSU. -
Fort Collins, - Colorado - 80251

Mr. Clifford Jenkins - 2425 N. Kline - Lakewood, Colo. - 80215 .


Jack Oder, Manager - Ground Water appropriators of the South Platte
P.O. Box 974, Fort Morgan , Colo. - 80701.

W.G. Wilkinson, P.E. -Irrigation Division Engineer - Division of
Water Resources, - Room 208, 8th & 8th Office Bldg.-
Greeley, Colo - 80631.

Dr. Ray J. Winger, 4050 Ammons - Wheatridge, Colo - 80033.
Factors for estimating return flows or pump depletions based upon

\[ \alpha = 1.50 \text{ ft}^2/\text{sec} \quad L = 21120 \text{ ft(4 miles)} \]

Months of 2628000 seconds

These are appropriate for South Platte Valley conditions.

Factors obtained by use of the part remaining table.

One half of the monthly quota is applied at the end of the first week and the other half at the end of the third week (Weeks of 657 000 seconds). Factor applied to the monthly quota, applied in month 1, gives the effect on the stream for a specified succeeding month. Factors for the fifth year are adjusted so that the total of the factors is 1.00000.

Factors obtained by use of the Maasland-DelManzo procedure.

The monthly quota is applied by a steady infiltration \( i \) (if return flow is being computed). The infiltration is maintained for the first month and then ceases. Factors give the return flow to the river during a specified succeeding month. (Pump depletion can be treated as a negative infiltration). The water applied during the first month is \( iLt \) where \( t \) represents the time equivalent to the first month. After the fifth year there still remains a residue of \( 1.00000 - 0.99548 = 0.00452 \). To account, approximately, for the contributions of years prior to the fifth add the product of this factor and the average monthly quota for the prior years.

The factors are arranged with the factor for the month of application (Month 1) at the bottom so that they can be applied to quantities listed to run forward in time. The total return flow during the specified month is the sum of the products of these factors and the monthly quotas.
Factors obtained by use of the part-remaining table.

Factors obtained by the Maasland-Delmanzo procedure.

1,000,000
995,487
4,52T
Conclusions from the South Platte Studies.

(1) Technically sound formulas for ground water flow have been developed and tested against the historic performance of the river. Successful correlations of this type have been produced for the South Platte by R. Glover and by D.D. DelManzo Jr., for the Arkansas by R. Glover and J.W. Patterson (unpublished) and for the Rio Grande by Patrick Hurley.

(2) Using these formulas, the depletion of the South Platte by pumps is estimated to be 266.100 acre feet per year. This estimate is based upon records of power used for pumping collected by CSU (The period covered is 1961-1965) (R. Theodore Hurry of the USGS states: "Withdrawal by wells during 1947-70 reduced ground water discharge to the river by about 250,000 acre feet annually" from "Effects of Water Management Practices on the Flow of the South Platte, Colorado" 1975).

(3) The average flow of the South Platte is about 1600 ft³/sec or 1,200,000 acre feet per year. Then the pump depletion is about 1/5 of the yield of the watershed.

(4) In the ten year period 1961-1970 power for pumping totaled about 94,500,000 kilowatt hours per year. Of this about 56,700,000 KWH/yr was used in the main valley of the South Platte. It requires about 100 KWH of power to lift an acre foot of water. About 71 percent of the pumps are electrically driven.

(5) Surface diversions from the South Platte in the Denver-Julesburg reach during the period 1961 - 1965 inclusive totaled about 1,000,000 acre feet per year. These include diversions to irrigation and diversions to storage.

(6) The water lifted by pumps in the main valley of the South Platte is about 800,000 acre feet per year. This is about 2/3 of the yield of the watershed.

(7) Under furrow irrigation methods the consumptive use is about 1/3 of the water diverted and for pumped water the consumptive use is about 1/3 of the water lifted.

(8) The consumptive use of the water in the South Platte area is 2.1 feet per year, of which 1.1 ft/yr is supplied by precipitation.

(9) Crawford and Gildersleeve have estimated (1958) that the irrigated area of the South Platte Valley is 1,220,000 acres.

(10) It is estimated, (Glover 1975) that about 28,300 acre feet of replacement water would be needed during the irrigation season each year, to restore the river, to what it would have been had no pumping ever been done. This is valid providing the return flow gradient is everywhere predominant. In 1976 the replacement water totaled 2,109,454 acre feet.

(11) The ground water reservoir contains, normally, about 8,000,000 acre feet of water. This is about six times the annual yield of the watershed. It is enough, if properly used, to carry a full agriculture through a drought period, such as that of the 1950's.
(12) If pumpers with potable pipe sufficient to reach adjacent canals would be alerted to pump into canals in time of need, it is estimated that capability of 100 ft³/sec should enable them to meet the 5% requirement when storage is unavailable and a 1000 ft³/sec capability should enable them to supplement river flows sufficiently to carry a full agriculture through drought periods.

(13) At present, about 3/4 of the yield of the watershed is consumed in production of crops in the South Platte Valley.

(14) In the period 1916 - 1930 the return flows to the South Platte reached about 1400 ft³/sec. Since that time they have decreased due to the development of pumping.

(15) It will never be wise to allow pumping to develop anywhere to the point where pumping consumes all of the return flow since all salinity brought in by the irrigation water will then accumulate in the pumpers lands to eventually salt him out.

(16) If furrow irrigation were practiced the water lifted by pumps could probably be allowed to approach the surface diversions before intolerable salinities would be encountered.

(17) It would never be feasible to abandon surface diversions entirely and to supply all irrigation waters by pumping. To do so would ultimately cause salt to accumulate in the irrigated areas in sufficient amounts to make farming so unproductive that the costs of farming could not be met.

(18) Salinity levels at the State line now run around 1400 parts per million.

(19) So long as pumping is held to such levels that return flows predominate, the interstices of the river bed are plugged by waters flowing upward through them to the river. Under these conditions a release can be propagated down the river to a senior appropriator without loss due to leakage from the river bed.

(20) If the pumpers operations reverse the return flow gradient at the river he then begins to take toll of the river and a release can not be propagated by him, without loss, unless enough additional water is released to pay his toll.

(21) It is difficult to understand how any effective permanent stream management can be realized if pumpers are permitted to reverse the return flow gradients either locally or generally.

(22) If the total utilization of water by surface diveters and pumpers is permitted to exceed the yield of the watershed then disaster will be brought to all.

(23) The provision of paragraph 148-21-17-3 of the law granting a right to use of a well as an alternate point of diversion is technically unsound in that it permits, under certain conditions, the taking of water, by a junior well owner, which belongs to a Senior under the Constitution. This difficulty is overcome if the pumper supplies replacement water.
(24) An effective administration of the waters of the South Platte Valley can not be realized until every pumper provides his share of replacement water.

(25) An increase of utilization of water causes an increase of the salinity of the river at Julesburg.

(26) Flood waters are, salinity-wise, the best waters we have. Their capture and utilization would tend to reduce the salinity at Julesburg.

(27) Paragraph 148-21-17-3 provides that the division engineer in each division and the State Engineer shall be governed by water right priorities. New priority lists have been assembled which include well priorities along with ditch priorities and the decision of 15 March 1974 of the District Court for Water Division No 1 resulted in Amended Rules and Regulations of the State Engineer dated 16 March 1974 which requires replacement water in an amount equal to 5 per cent of the projected annual volume of a ground water diversion. This is to be used by the Division Engineer to compensate for any adverse effect of such ground water diversion on a lawful Senior requirement. It is understood that this 5 per cent is construed as being sufficient to meet the provisions of Paragraph 148-21-34-1 so that the pumper can not be shut down so long as the required replacement water has been supplied.

It is considered possible, however, that, during a period of drought, sufficient replacement water may not, at some time, be obtainable and that a call would put into operation the provisions of Paragraph 148-21-17-3. Such a case would then precipitate a crisis. This provision seems to have been enacted under the presumption that if any well in the valley is shut down the flow the well was delivering will immediately appear back in the river. But Natural law will decide the restoration rate and computations indicate that the above presumption will not be honored. Such computations indicate that the restoration will, in fact, be so meager that all the wells in the valley might need to be shut down to bring relief to a Senior and this only after a considerable delay.

Such a drastic curtailment at a crucial time in the growing season might destroy more than 40 per cent of the agriculture in the valley.

Robert E. Glover 5/18/77
Irregular documents not scanned

See originals in folder

Water Resources Archive
Colorado State University Libraries
Computations

Check of estimate of stream depletion - South Platte

Depletions based upon 1966-1970 power records.
Irregular documents not scanned

See originals in folder

Water Resources Archive
Colorado State University Libraries
Restoration flow computations.
Diversions to irrigation basis.
Consumptive use basis, and
Priorities for Restoration Flows.