ABSTRACT

General background of the problem

The Roaring Fork River, located in western Colorado and one of the major tributaries of the Colorado River, has a relatively large amount of surplus water available at present that could be used to expand the number of acres irrigated within its basin. The Bureau of Reclamation (8) in its 1946 report proposed four supplemental water irrigation projects within the Roaring Fork Basin. The report states that there is insufficient water available for all of the projects proposed within the Colorado River Basin and therefore suggests that economic analysis be made of each of the proposed projects.

The purpose of this report is (a) to provide a convenient description of the Roaring Fork River basin in general and of the four proposed projects within the basin, the Woody, Fourmile, Capitol and Cattle Creek projects in particular, and (b) to present pertinent economic and physical data and such problems as c
with the feasibility of the projects in question.

Physical description of the Roaring Fork River Basin

The Roaring Fork River, together with its tributaries, constitutes one of the most dependable, relatively

undeveloped sources of water for irrigation in Colorado. This river basin contains approximately 908,000 acres and, according to the land classification survey made by the Bureau of Reclamation in 1936, a total of 34,590 acres of irrigated land, and 7,450 acres of Class 1 and Class 2 arable land.

The basin is bounded to the east and south by comparatively high ranges of mountains, the Continental Divide and the Elk Mountains respectively, and on the west and north by relatively low ranges, the Huntman's Hills and Red Table Mountains.

The valley is approximately 45 miles long and varies in width from approximately one-fourth mile to approximately four miles. The floor of the valley's elevation varies from 5,823 feet to 7,913 feet.

Climate.--The climate within the basin may be broadly typified as "intermountain" with variations within the basin due to differences in elevation, exposure, and location. Precipitation is relatively uniform throughout the year, except for the month of June, which has a low average. The growing season varies from 71 to 171 days.

Types of farming.--The principal types of farming in the basin are livestock ranching and diversified livestock farming. The summer range for most livestock is on the Forest Service and Public Domain lands with spring and fall pasture on private land. The principal crops in the basin are alfalfa, grain and potatoes.

Problem

How feasible are the four irrigation projects in the Roaring Fork Valley of Colorado, as proposed in "A Comprehensive Report on the Development of the Water Resources of the Colorado River Basin for Irrigation, Power Production, and Other Beneficial Uses in Arizona, California, Colorado, Nevada, New Mexico, Utah and Wyoming"? (8)

Problem analysis.--As an aid to analysis of the problem, the following sub-questions are presented:

1. How much water has been diverted over a period of years for use in crop production in the areas concerned?
2. What is being done at present to increase the amount of water available for irrigation?
3. Is there sufficient surplus water available to adequately irrigate the acreage in the project proposed by the United States Bureau of Reclamation?
4. What are the present crop yields in the areas in question?
5. What will be the probable crop yields in the areas after the development?
6. What is the present acreage of each crop in the proposed project areas?

7. What will be the probable crop distribution after the development?

8. What effect will this increased production and change in crop distribution have on livestock production?

9. What prices are being paid in the areas concerned for the various crops produced?

10. What will be (a) the value per acre of the potential increased production, and (b) the construction costs per acre for new irrigation for these areas?

Methods and materials

The study followed the following procedure:

I. Examination was undertaken of the published and unpublished material that was available to the writer concerning the problem.

II. Pertinent physical data were gathered from the Bureau of Reclamation's (8) report published in 1946, the land classification map published by the same bureau, the topographical map printed by the U. S. Coast and Geodetic Survey in 1947, and interviews with farmers, Forest Service personnel, the Water Commissioner, and the Division Engineer.

III. Specific data on the individual project was

collected concerning water rights, water diversions, crop distribution, project costs, water needs, tax information, and agricultural prices.

IV. A project budget was set up in order to determine the ability of the water users to pay water costs.

V. A comparison was made between increased annual net income and annual repayment charges for the proposed project.

Capitol Creek project

There are approximately 3,200 acres of irrigated meadows and crop lands in this valley and approximately 200 acres of range lands which are irrigated annually. All operating units are livestock ranches. Timothy-clover hay is the principal crop, although there is a small acreage of alfalfa, native hay, and cereals. About one half of the area or 1,730 acres lacks a full water supply, but only 630 acres (19 per cent of the irrigated acreage) are seriously short of water. The average long-time cost of crop and meadow land in Capitol Valley was found to be about $45.00 per acre.

The project suggested by the Bureau of Reclamation (8) 1946 report was the construction of a 10-mile service canal to provide supplemental water to 2,000 acres of land in Capitol Creek Valley. The construction cost (1940

prices) is estimated at $130,000 or $38.19 per acre for the 2,000 acres or $75.14 per acre for the 1,730 acres that are in need of supplemental water.

Generalizations and suggestions for further study.--Since the construction cost per acre for those lands in need of supplemental water is $75.14 at 1940 prices, and since the long-time-average value of meadow and crop land with a full water supply is less than this figure, it was felt that the project was economically unfeasible.

The proposed Capitol Creek Project might be enlarged to include two additional areas, Sopris Valley and Elk Valley, at a slight increase in the project's cost. These two areas are chronically short of water and might assist materially in paying for the construction costs.

Woody Creek project

There are 2,470 acres of irrigated land and 190 acres of Class 2 arable land in the project area. The water supply for approximately 395 acres (16 per cent of the irrigated land) is deficient. Thus, most of the land in the area has an adequate water supply and certain acreages even have a surplus. The water supply for the area comes from Woody Creek and from the Roaring Fork River via the Salvation Ditch.

The project suggested for Woody Creek in the

Bureau of Reclamation's (8) 1946 report was the construction of a new 13-mile canal from the Roaring Fork River to supply supplemental water for 2,000 acres.

At present, the Salvation Ditch is being enlarged to increase its delivery rate by approximately 72 per cent, i.e., from 3,450 acre-feet to 5,950 acre-feet. Consequently in the near future the project area will have an adequate water supply for all irrigable acreage.

Generalization.--It was felt by the writer that there was no need for the proposed project since the potential water supply from the Salvation Ditch is more than sufficient to adequately supply all the lands deficient in water.

Fourmile Creek project

There are 1,435 acres of irrigated land and 140 acres of Class 2 arable land in this valley. Two types of farming are found in the area, livestock farming and cash-crop-livestock farming. Alfalfa and cereals are the principal crops raised. Approximately 845 acres (59 per cent of the irrigated acreage) lacks a full water supply.

The project as suggested by the U. S. Bureau of Reclamation's (8) comprehensive report published in 1946 was for the construction of a 2,000 acre-foot reservoir above the uppermost diversions. No new canals would be needed since the creek itself would be used as a

carrier for the reservoir water. The project would supply supplemental water for 1,400 acres and a full supply for 500 acres of new land. The construction costs (at 1940 prices) are estimated at $600,000 or $315 per acre for the 1,900 acres. This cost is approximately twice the average long-time value of land with a full water supply.

Generalization.--Since the cost of construction per acre for lands in the project area is $315, at 1940 prices, and since the long-time average value of crop land with a full water supply is approximately one half of $315, it was felt that the project was economically unfeasible.

Cattle Creek project

There are 4,040 acres of irrigated land and 532 acres of Class 1 and Class 2 arable land. The water supply for approximately 3,710 acres (92 per cent of the irrigated acreage) is deficient.

The principal type of farming on Missouri Heights is diversified crop-livestock farming, and the principal irrigated crops are alfalfa, cereal grains, potatoes, and pasture.

The project suggested for Cattle Creek, i.e., Missouri Heights, by the U. S. Bureau of Reclamation (8) in its 1946 comprehensive report called for the enlargement of the Missouri Heights reservoir from its present capacity of 2,800 acre-feet to 9,000 acre-feet and the

enlargement of the inlet canal from Cattle Creek. This project as proposed would provide a water supply for 900 acres of new land and furnish supplemental water for 5,500 acres.

Information from several sources indicates that there is enough water available in Cattle Creek to fill a 9,000 acre-foot reservoir at least eight out of 10 years. Enlargement of the Missouri Heights Reservoir to the proposed capacity would provide a full water supply for approximately 4,040 acres of irrigated land and 869 acres of non-irrigated irrigable land in the area.

Generalizations and suggestions.--The long-time economic value of supplemental water on Missouri Heights, as determined in this study, is $3.48 per acre-foot. This is a maximum estimate since this determination made no allowance for any increase in land valuations as a result of the reservoir-enlargement project. On the basis of this analysis, the opinions of farm operators, and correlation with Selby's (6) undated report it would seem that $2.80 to $3.00 per acre-foot would be the maximum average annual charge which landowners could afford to pay for supplemental water.

Undoubtedly before a Federal agency would construct this project, additional information as to the amount of water available for storage and the construction features of the project would have to be obtained.

Summary

The findings of this study led to the determination of the economic unfeasibility of the Capitol, Woody, and Fourmile Creek Projects and to the determination of the economic feasibility of the Cattle Creek Project. Therefore, of the $1,330,000 (based on 1940 costs) that the Bureau of Reclamation (8) in its 1946 report proposed to spend in the Roaring Fork River Basin, only $430,000 could be repaid by the water users under the terms of the Reclamation Laws repayment provisions.

Optimum size of the project based on the analysis of these additional data might be somewhat larger or smaller than the proposal considered in this report. However, the economics of the project would not be greatly different because a rough analysis of the probable costs of dams at the Missouri Heights site indicates relatively constant costs per acre-foot of capacity above 6,500 acre-feet.

T H E S I S

THE ECONOMIC FEASIBILITY OF INCREASING IRRIGATION IN THE ROARING FORK VALLEY

Submitted by

Elmer G. Hunter

In partial fulfillment of the requirements

for the Degree of Master of Science

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COLORADO AGRICULTURAL AND MECHANICAL COLLEGE

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I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY ELMER C. HUNTER

ENTITLED THE ECONOMIC FEASIBILITY OF INCREASING IRRIGATION IN THE ROARING FORK VALLEY

BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE

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CREDITS 7

R T Burdick
In Charge of Thesis

APPROVED R T Burdick
Head of Department

Examination Satisfactory

Committee on Final Examination

Robert L. Lewis — R T Burdick

James N. McClelland — Stanley W. Voelker

— D W Robertson

David H. Morgan
Dean of the Graduate School

Permission to publish this thesis or any part of it must be obtained from the Dean of the Graduate School.

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Chapter I
INTRODUCTION

The Roaring Fork River, located in western Colorado, is one of the major tributaries of the Colorado River. The Roaring Fork River at present has a relatively large amount of surplus water available that could be used to expand the number of acres irrigated within its Basin. Since most, if not all, the economically and structurally feasible irrigation projects in this basin have been previously developed, a careful economic analysis is needed before construction of additional projects is undertaken. The United States Bureau of Reclamation preliminary report (8) on The Colorado River Basin published in 1946 lists four potential supplemental irrigation projects in the Roaring Fork River Basin but does not present pertinent data concerning these projects.

The United States Bureau of Reclamation preliminary report listed most of the potential areas of water development in the several basin states----Arizona, California, Colorado, New Mexico, Nevada, Utah and Wyoming (8). While this report admittedly does not

cover all of the possible project developments, it does include 134 proposed irrigation, power, and storage projects, thus giving a general over-all picture of the basic problems that must be solved before the entire area is fully developed.

The chief problem brought out by the report is the insufficiency of water available for all of the proposed projects. Estimates presented in the United States Bureau of Reclamation report indicate that present depletions, together with the depletions required for potential projects within the basin and for proposed export diversions, plus possible increases in use on existing and authorized projects would total approximately 25 per cent more than the average annual amount of water available for use within the United States portion of the basin. "The Treaty with Mexico relating to the utilization of the waters of certain rivers" guaranteed to that country 1,500,000 acre feet of water annually, so that this amount is not available for use in the United States (11).

With this potential shortage of water it is obvious that some project selection process is necessary, preferably one based upon economic analysis. The United States Bureau of Reclamation report suggests that each state assume the primary responsibility for project selection.

Purpose of this report

Among the 134 projects listed in the comprehensive United States Bureau of Reclamation report are four supplemental-water projects in the Cattle, Capitol, Woody, and Fourmile Valleys located within the Roaring Fork Basin (8). The purpose of this report is: (a) to provide a convenient description of the Roaring Fork Basin in general and of the four project areas in particular; and (b) to present pertinent economic and physical data and problems that concern themselves with the feasibility of the four projects in question.

The problem

How feasible are the four irrigation projects in the Roaring Fork Valley of Colorado, as proposed in "A Comprehensive Report on the Development of the Water Resources of the Colorado River Basin for Irrigation, Power Production, and Other Beneficial Uses in Arizona, California, Colorado, Nevada, New Mexico, Utah and Wyoming" (8)?

Problem analysis.--As an aid to analysis of the problem, the following sub-questions are presented:

1. How much water has been diverted over a period of years for use in crop production in the areas concerned?
2. What is being done at present to increase

the amount of water available for irrigation?

3. Is there sufficient surplus water available to adequately irrigate the acreage in the project proposed by the United States Bureau of Reclamation?
4. What are the present crop yields in the areas in question?
5. What will be the probable crop yields in the areas after the development?
6. What is the present acreage of each crop in the proposed project areas?
7. What will be the probable crop distribution after the development?
8. What effect will this increased production and change in crop distribution have on livestock production?
9. What prices are being paid in the areas concerned for the various crops produced?
10. What will be (a) the value per acre of the potential increased production, and (b) the construction costs per acre for new irrigation for these areas?

Delimitations.--This study has been limited to the Capitol, Cattle, Woody and Fourmile Creek projects

in the Roaring Fork Basin as proposed in the preliminary United States Bureau of Reclamation report.

Definition of terms

Irrigable land.--Land suitable for irrigated farming within an existing project or within a potential development that could be reasonably furnished a water supply.

New lands.--Irrigable lands which could be irrigated after project development.

Stream flow.--The flow in a stream channel. The volume of flow is measured in acre-feet and the rate of flow in second-feet.

Acre-foot.--A unit of measure of volume equivalent to the quantity of water that will cover one acre (43,560 square feet) one foot deep.

Second-foot.--A unit of measure of the rate of stream flow or the flow of one cubic foot (7.48 gallons) of water passing a given point per second of time.

Run-off.--The precipitation that appears as stream flow, usually measured in volume per unit of time, such as acre-feet per day, month or year.

Return-flow.--That part of diverted stream flow returning to the stream.

Class 1 arable land.--That land, fit for cultivating, meeting the following conditions: a soil from

a sandy loam to a clay loam in texture, relatively deep and well drained, with no solid or loose rock that would interfere with ordinary cultivation, with slopes of not to exceed five per cent in general gradient and with a relatively even surface requiring only a minimum amount of leveling. 1/

Class 2 arable land.--That land, fit for cultivation, meeting the following conditions: loamy sand to friable clay in texture, moderately deep, drainage only fair, with only easily removable rock present, with slopes up to 10 per cent on an even gradient, and surface such that up to a considerable amount of leveling may be required. 1/

Discharge.--The rate of flow, commonly expressed in second-feet, gallons per minute, acre-feet per day, etc.

Stream depletion.--The reduction in stream flow due to man-made improvements affecting the virgin water supply of the stream flow.

"Soak up".--The irrigation practice of applying excessive amounts of water during periods of high stream flow in order to store up water in the ground to compensate for periods when water supplies are low.

"Flood" right.--A water right whose priority date is so recent that water deliveries based on this right are

1/ See Figure 1, Appendix B, for detail standards and requirements.

obtained only during that period of high stream flow occuring during the spring.

Physical description of the Roaring Fork Basin

The Roaring Fork River, together with its tributaries, constitutes one of the most dependable, relatively undeveloped sources of water for irrigation in Colorado. At present two transcontinental diversions export considerable quantities of water into the Arkansas Basin. Additional diversions to the Arkansas, Gunnison, and South Platte Basins are being considered at this time (8).

Geography.--The entire Basin contains approximately 908,800 acres. According to the land classification survey, made by the United States Bureau of Reclamation in 1936, there was a total of 34,590 acres of irrigated land, of which 5,290 acres (15 per cent) were classified as meadow land and 29,300 acres (85 per cent) as cultivated land. In addition there were 7,990 acres of non-irrigated arable land, of which 1,170 acres (15 per cent) were rated as Class 1 and 6,820 acres (85 per cent) as Class 2. It is estimated that one fourth of the irrigated and irrigable acreage is bottom and first bench land along the Roaring Fork, while three fourths lies in tributary valleys and on mesas which are 200 to 500 feet above the main valley floor. It is also estimated that

about 85 per cent of the entire basin is used for grazing or is suitable for grazing, while 10 per cent is unsuited for any agricultural enterprise.

The Basin is bounded on the east by the Continental Divide which has elevations in this area ranging from 12,000 to 14,000 feet above sea level. To the south lie the Elk Mountains, a relatively high range for the most part, with elevations varying on the divide from 9,500 to 14,259 feet above sea level. To the west lie the low range of mountains called the Huntsman's Hills, with elevations varying from 5,500 to 11,000 feet. To the north lie the Red Table Mountains, with elevations varying from 5,500 to 12,010 feet.

The Roaring Fork River rises on the western slope of the Continental Divide, about 15 miles southeast of Aspen, Colorado, and flows about 45 miles in a northwesterly direction to empty into the Colorado River at Glenwood Springs. The valley floor varies in width from approximately one fourth of a mile to approximately four miles.

The elevation of Glenwood Springs, which is situated at the mouth of the Basin, is 5,823 feet. The elevation at Aspen near the head of the valley's cultivated agriculture is 7,913 feet. Thus the average drop for the 37.5 miles of the valley floor is 10.3 feet per thousand. The upper

limit of hay meadows in the Basin is approximately 9,000 feet and the principal agricultural use above this elevation is grazing.

Soils and topography.--For the most part, the soils in the crop land areas of the main valley are inclined to be sandy or gravelly. Soil types in the tributary valleys generally are heavier than those in the main valley. Drainage in the Basin is generally very good, either because of gravelly sub-soils in the main valley or because of the steeper slopes along the side streams.

Most of the land has been farmed for over 50 years and some as long as 70. This continuous cropping, combined with frequent heavy applications of water, has leached much of the crop land, resulting in a gradual decline in crop yields per acre. This situation is especially true of the more gravelly bottom lands along the Roaring Fork River, but is not so characteristic of the side valleys where soils are heavier, sub-surface drainage is slower, and water supplies are less plentiful.

Types of farming.--Most of the farms in the Roaring Fork Basin fall into one of two classifications--livestock ranching and diversified livestock farming. There are a few "typical" crop farms concentrated around Carbondale, in the center of the valley, but these farms constitute a small percentage of the total number of the units. Even these are integrated into the livestock

operations of the areas because of their sales of surplus feed to livestock operators.

Livestock ranching will bear description in each of its two forms, cattle and sheep ranching. A typical cattle ranch runs from 100 to 150 head of beef-type cattle. The ranch itself usually has 80 or more acres of irrigated hay meadow land in addition to sufficient spring and fall pasture land for its herd. Most ranches in the area graze their cattle on the Forest Service or Public Domain during the summer months. There is little if any grazing during the winter months in this Basin because of the heavy snowfall and long winters.

The size and the scale of operation of the typical sheep ranch is normally much larger than that of the cattle ranch. The number of sheep usually exceeds 2,000 head divided into two or more bands. Spring and fall pasture is found on the ranch meadows, summer pasture on the high ranges in the Forest Reserve, and the winter range on the "desert" in western Colorado and eastern Utah.

The Forest Service has in the past 15 or so years been decreasing, wherever possible, the size of cattle and sheep permits. This policy has reduced the demand for hay grown on the diversified farms in the valleys and, if continued, as seems likely, will probably

cause many internal shifts within the valley.

Integrated to some extent with the livestock ranches are the diversified farms in the valleys. A typical diversified farm normally contains from 80 to 160 acres of irrigated crop land, a few milk cows (6 to 14), and either a few beef cows or a small farm flock of sheep.

Of the three principal crops (alfalfa, grain and potatoes), wheat and potatoes are of greatest cash value to most operators. Alfalfa hay, necessary in the farm rotation, has lost some of its importance as a cash crop and is being increasingly used now as a feed for farm flocks and herds. This change has come about because of the reduction in range permits as explained above, and the resultant decline in the local hay market.

Some operators, particularly those on the high lands north of Cattle Creek and east of the main valley, undertake dry farming operations in addition to their irrigated operations. In practically all cases the dry farming operations are carried on because of the lack of sufficient irrigation water and/or the inability to apply water to certain fields. In cases where the fields are located above the present ditch system, or where the ditch serving the field has a high evaporation or seepage loss, it is economically unfeasible to apply water.

About three fourths of the irrigated land is

used for hay and pasture and nearly one sixth for cereal grains (Table 1). For the Basin as a whole, alfalfa is the most important hay crop, but at higher elevations clover, timothy, and wild hay are more important. The principal grain crops, in order of importance, are spring wheat, oats, and barley.

Table 1.--ACREAGE OF CROPS IRRIGATED IN THE ROARING FORK BASIN, 1939-46.

[Compiled from annual reports of the Water Commissioner to State Engineer]

Year	Hay and pasture (acres)	Cereals (acres)	Potatoes (acres)	Other[1] (acres)	Total irrigated (acres)
1939	27,426	5,500	3,294	0	36,220
1940	27,950	6,045	3,180	0	37,175
1941	28,955	5,290	2,475	0	36,720
1942	26,275	5,430	2,970	0	34,675
1943	27,028	4,666	3,007	55	34,756
1944	28,241	6,165	3,365	20	37,791
1945	23,950	5,249	3,805	0	33,004
1946	23,985	5,650	3,164	30	32,829
Average	26,726	5,499	3,158	13	35,396
	Per cent	Per cent	Per cent	Per cent	Per cent
Average distribution	75.5	15.6	8.9	---	100.0

[1]Mostly truck crops.

Irrigation organization.--There are no large irrigation projects in the Roaring Fork Basin. The 1940

United States Census of Irrigation listed 244 enterprises in the Roaring Fork Basin. Therefore the average irrigated area per enterprise is only 145 acres, based on the average annual irrigated acreage given in table 1. Only the six largest of these 244 enterprises are under any formal type of organization. One of these is a commercial company, four are mutual ditch companies, and one is an unincorporated mutual association. The acreage irrigated by these six organized enterprises varies from 650 to 1,935 acres (Table 2). All other enterprises in the Basin are individually owned or are partnership ditches.

Table 2.--ORGANIZED IRRIGATION ENTERPRISES IN THE ROARING FORK BASIN.

Name of company	Type of organization	Source of water supply	Acreage usually irrigated
Carbondale Reservoir & Irrigation Co.	Commercial company	Cattle Creek	1,935
East Mesa Water Co.	Mutual company	Crystal River	1,170
Glenwood Irrigation Co.	Mutual company	Roaring Fork River	1,335
Park Ditch & Reservoir Co.	Mutual company	Cattle Creek	650
Salvation Ditch Co.	Unincorporated association	Roaring Fork River	1,220
Sweet-Jessup Canal Co.	Mutual company	Crystal River	1,315

Climate.--The climate of the Roaring Fork Basin may be broadly typified as "intermountain". Within the Basin, however, there is considerable variation in climate, due largely to the marked differences in elevation, exposure, and deflection of winds by mountain ranges and valleys. Unfortunately, the only two weather stations which have long-time records available in the area, Glenwood Springs and Aspen, are not located in the agricultural areas of the basin.

Differences in elevation are undoubtedly related to differences in precipitation, the general relationship being higher precipitation at higher elevations. While this relationship is a generality, it does not always hold true. Deflection of prevailing winds by mountain ranges and other local factors may have more effect on precipitation than differences in elevations. This may be illustrated by the records of two stations in the Basin. The 1935-47 average of precipitation at the two stations, Aspen and Glenwood Springs, are nearly identical, 19.64 and 19.94 inches, respectively. While Glenwood has the lower elevation by 2,090 feet, it is situated at the junction of the Roaring Fork Valley with the Colorado River Valley, where the two valley air currents coming together cause higher precipitation than the elevation factor alone would indicate. Aspen, on the other hand,

lies near the end of a relatively large valley where precipitation is not affected by local air currents.

Precipitation records at these two stations, however, do indicate in a general way the years of above and below normal precipitation for the Basin as a whole. In general, precipitation for 1946 and 1947, both on an annual basis and on a warm-season basis (i.e., May to September, inclusive) was just about average. Precipitation for 1943 and 1945 was above average, while that for 1942 and 1944 was considerably below average (Table 3).

Generally speaking, only about one third of the annual precipitation comes during the growing season. The average monthly distribution at both of the above stations is relatively uniform throughout the year, except for the month of June, which has a low average (Table 4). This low precipitation is due to the fact that in about two years out of three, there is a period of four to eight weeks of comparatively dry weather during May, June, and July. If this dry spell comes early in the season, when irrigation water is normally plentiful, it has little effect on irrigated crops. If it comes in late June or in July, when irrigation supplies are usually short, crops may suffer.

The length of growing season, i.e., the number of days between the last killing frost in the spring and

Table 3.--ANNUAL AND WARM-SEASON PRECIPITATION AT TWO STATIONS IN THE ROARING FORK BASIN.

[Compiled from "Climatological Data, Colorado Section", United States Weather Bureau, Denver, Colorado.]

Year	Annual precipitation		Warm-season precipitation[1]	
	Aspen (elev. 7,813)	Glenwood Spgs. (elev. 5,823)	Aspen (elev. 7,913)	Glenwood Spgs. (elev. 5,823)
	(inches)	(inches)	(inches)	(inches)
1933	--	18.26	--	10.35
1934	--	16.58	--	8.04
1935	24.24	18.44	11.87	8.27
1936	21.36	19.56	6.25	5.93
1937	22.37	24.12	8.78	9.85
1938	23.15	22.75	8.76	10.01
1939	12.83	18.12	4.05	7.35
1940	16.15	24.12	6.50	6.27
1941	21.68	23.19	7.99	8.02
1942	16.11	16.04	3.47	4.63
1943	26.37	24.83	12.98	14.07
1944	14.27	16.66	3.20	5.67
1945	19.33	18.55	7.82	8.05
1946	16.29	16.90	6.07	6.30
1947	21.23	15.93	7.57	6.13
Av.1935-47	19.64	19.94	7.33	7.73
Range: High	26.37	24.83	12.98	14.07
Low	12.83	15.93	3.20	5.87
Length of record	22 yrs.	48 yrs.	22 yrs.	48 yrs.

[1]Precipitation through months of May to September, inclusive.

Table 4.--AVERAGE SEASONAL DISTRIBUTION OF PRECIPITATION AT TWO STATIONS IN THE ROARING FORK BASIN.

[Compiled from "Climatological Data, Colorado Section", United States Weather Bureau, Denver, Colorado]

Month	Aspen (Elev. 7,913)		Glenwood Springs (Elev. 5,823)	
	Inches	Per cent	Inches	Per cent
January	1.76	9.2	1.48	9.0
February	1.99	10.4	1.45	8.8
March	1.80	9.4	1.55	9.4
April	1.77	9.2	1.54	9.3
May	1.73	9.0	1.34	8.1
June	0.93	4.8	0.93	5.6
July	1.52	7.9	1.43	8.7
August	1.59	8.3	1.71	10.3
September	1.52	7.9	1.43	8.7
October	1.57	8.2	1.29	7.8
November	1.47	7.6	1.09	6.6
December	1.56	8.1	1.27	7.7
Annual	19.21	100.0	16.51	100.0
Length of record	22 yrs.		48 yrs.	

the first killing frost in the fall, has varied from 71 to 117 days at Aspen, with an average of 95 days (Table 5). A short growing season such as this is to be expected at an altitude of nearly 8,000 feet and is the main reason why hay and pasture is the principal use for irrigated land. The growing season at Glenwood Springs has varied from 81 to 171 days, with an average of 132 days. Local

Table 5.--LENGTH OF GROWING SEASON AT TWO STATIONS IN ROARING FORK BASIN.

[Compiled from "Climatological Data, Colorado Section", United States Weather Bureau, Denver, Colorado]

	Aspen	Glenwood Springs
Elevation (feet)	7,913	5,823
Number of years of record	18	38
Date of last killing frost in spring:		
Earliest	May 14	April 11
Latest	July 1	June 23
Average	June 10	May 17
Date of first killing frost in fall:		
Earliest	Aug. 30	Sept. 7
Latest	Oct. 2	Oct. 18
Average	Sept. 15	Sept. 26
Length of growing season:		
Shortest (days)	71	81
Longest (days)	117	171
Average (days)	95	132

informants state that the growing season in the farming areas in the Basin a few miles above Glenwood Springs and on the heights north and east of Carbondale is somewhat longer than at Glenwood Springs, especially where there is a southern exposure and good air drainage. There are some indications that Glenwood Springs may be a localized "cold spot"; weather stations immediately above and below

Glenwood Springs along the Colorado River consistently report temperatures a few degrees warmer and a growing season of several days longer than does the Glenwood Springs station.

In any event, the diversified farming area has a growing season sufficiently long for cereals, potatoes, and most garden vegetables. In some years, of course, frosts may cause considerable damage. Although no sugar beets are grown in the area now, the growing season most years probably would be long enough. The area is not well adapted for corn, even for silage and forage, because of cool nights in the summertime. The average July temperature at Glenwood Springs is 67.3 degrees, which compares with 77.9 degrees at Grand Junction and 72.2 degrees at Greeley, both of which are in areas of successful corn production.

Water supply.--As was previously stated, the Basin's highest mountain ranges are to the east and south (the Continental Divide) and serve as the headwaters for the Roaring Fork River.

The Elk Mountains form the southern boundary of the Basin. This range is fairly high and receives normally a very heavy snowfall. Due to this range's favorable exposure, the flow of those streams having

headwaters located in this area holds up well throughout the year. Several important tributaries -- Crystal River and Maroon, Castle, and Snowmass Creeks, drain the northern slope of the Elk Mountains. The northern boundary of the Basin is formed by a comparatively low range known as Red Table Mountain whose snowfall is not as heavy as that of the Elk Mountains or the Continental Divide. Except for the Frying Pan River, the tributaries draining the northern part of the Basin are short lived and are characterized by very heavy stream flow during the early spring months of April and May. The western boundary of the Basin is formed by the Huntsman's Hills, a relatively low, flat range. Because of low snowfall, early run-off, and small drainage areas, no large tributary streams originate in these hills.

The major source of water for the Roaring Fork River is the melting snow from the high ranges on the southern and eastern boundaries of the Basin. The estimated annual run-off of the Basin is in excess of 1,100 acre-feet of water per square mile of drainage area. The Crystal River has an average yield of 2,360 acre-feet of water per square mile of drainage area, the highest unit run-off of any major watershed

in the Colorado River Basin (Table 6).

The total amount of water that the Roaring Fork Basin contributes to the Colorado River has varied from 499,100 acre-feet in 1934 to 1,194,000 acre-feet in 1938, with an eighteen year average of 883,620 acre-feet (Table 7). Nevertheless, it does not necessarily follow that all of the water flowing out of the Basin would be available for additional irrigation within the Basin or for export. A large part of the flow (and sometimes all) during the months of July, August, and September is needed to supply diversions from the Colorado River in the vicinity of Palisade and Grand Junction. There are times when the Roaring Fork River is larger than the Colorado at Glenwood Springs. If, later, the Green Mountain Dam effectively regulates the Colorado River stream flow, more water might possibly be available for the Roaring Fork Basin, but at this time this premise is not certain.

It is obvious, then, that any new projects within the area or any new projects exporting water from the area will necessitate a detailed analysis of stream-flow records and prior water rights and needs on the Colorado River below Glenwood Springs. It is also obvious after checking the stream-flow records

Table 6.--ESTIMATED WATER YIELDS OF VARIOUS DRAINAGE AREAS OF HIGH ELEVATION WITHIN ROARING FORK BASIN.

[Adapted from Follansbee, Robert, "Upper Colorado River and its utilization", United States Geological Survey, Water Supply Paper No. 617, 1929, pp. 27 and 48]

Stream and station	Drainage area	Portion of drainage area at various elevations			Estimated annual average precipitation for drainage area	Depth of average annual run-off	Average annual run-off per square mile of area
		Below 10,000 feet	10,000 to 12,000 feet	Above 12,000 feet			
	sq. miles	per cent	per cent	per cent	inches	inches	acre-feet
Roaring Fork at Aspen-----	109	20	62	18	39	24	1,260
Maroon Cr. near Aspen-----	42	21	58	21	44	29	1,560
Castle Cr. near Aspen-----	62	18	64	18	38	23	1,230
Snowmass Cr. at Snowmass--	95	55	34	11	33	18	[1]-----
Frying Pan Cr. at Thomasville---	175	30	59	11	36	21	1,110
North Fork at Frying Pan Cr. near Norrie--------	92	29	65	6	35	20	1,160
Crystal River at Marble---	77	22	52	26	59	44	2,360

[1]Not computed, because of numerous diversions for irrigation within the drainage area above station. On the basis of estimated annual precipitation for the drainage area and the depth of annual run-off, the annual run-off per square mile of drainage area would be about 1,000 acre-feet.

Table 7.--ANNUAL AND MAY-JUNE RUN-OFF OF ROARING FORK RIVER AT GLENWOOD SPRINGS, 1930 TO 1947.

[Not adjusted for transmountain and irrigation diversions. Compiled from data on file in office of Colorado State Engineer. Some of these data are also published in biennial reports of the State Engineer and in various United States Geological Survey water supply papers on the Colorado River.]

Water year, ending Sept. 30	Annual run-off (acre-feet)	Run-off during May and June	
		Acre-feet	Per cent of annual
1930	944,100	400,400	42.4
1931	547,900	253,340	46.2
1932	1,141,000	596,700	52.3
1933	948,600	539,900	56.9
1934	499,100	241,610	48.4
1935	899,200	484,400	53.9
1936	1,048,000	605,200	57.7
1937	789,100	433,700	55.0
1938	1,194,000	665,800	55.8
1939	767,100	409,700	53.4
1940	589,900	307,800	52.2
1941	861,600	477,200	55.4
1942	1,008,000	536,500	53.2
1943	933,500	465,100	49.8
1944	884,200	473,700	53.6
1945	895,700	414,000	46.2
1946	798,220	399,000	50.0
1947	1,156,000	565,600	48.9
Av. 1930-47	883,620	459,430	52.0
Range: High	1,194,000	665,800	57.7
Low	499,100	241,610	42.4

within the Basin that certain areas, such as the Crystal River, have ample surpluses, but other areas, such as Sopris and Landis Creeks, do not have surpluses large enough to feasibly permit increased irrigation development.

Certain areas such as Fourmile Creek have a surplus during the early spring months but are short during July and August. The valleys of Cattle, Fourmile, Capitol, and Woody Creeks, have been suggested as sites for supplemental water projects. The agricultural conditions and water-supply situations in each of these areas are analyzed in subsequent sections of this thesis.

Water-supply classification of ditches.--Within each of the four areas for which supplemental-water projects have been proposed, there is a wide variation in water supply for lands under the several ditches. The senior priorities on each creek are generally available, at least partially, throughout the season, while the availability of water for later priorities depends upon a number of factors, chief of which are the characteristic seasonal curve of stream flow, order of priority on the stream, and location of headgates with respect to return flow.

In order to express the net effect of these various factors affecting the water supply for each ditch, the following system of water-supply classification of ditches was devised, which expresses both the approximate amounts of water available in relation to acreage irrigated and the portion of the season these amounts are available:

A-1 One second-foot per 60 acres until July 15, plus at least 1 second-foot per 100 acres after July 15 for potatoes, pasture, and meadow aftermath.

A-2 One second-foot per 100 acres until July 15, plus at least 1 second-foot per 200 acres after July 15. (This classification is applicable only to areas of clay soils, highly retentive of moisture.)

B-1 One second-foot per 60 acres until July 15, but insufficient water thereafter.

B-2 One second-foot per 100 acres until July 15, but insufficient water thereafter. (This classification is applicable only to areas of clay soils, highly retentive of moisture.)

C One second-foot per 60 acres until July 1, but insufficient water thereafter.

D One second-foot per 60 acres until June 15, but insufficient water thereafter.

E Diversions possible only when the stream is in flood.

These classifications are based on the following general situations in both the diversified farming areas and the hay-ranching areas of the Basin:

(1) May 1 to about June 15 is the period of

heaviest draft on the streams. As previously indicated, there is very little precipitation during this period. All crops and pasture require irrigation; heavy applications of water are given alfalfa and other hay crops at least twice during this period. Grain, at least at lower elevations, may get one application of water. The streams are normally in flood from snow-melt during most of this period, however, and there is no general water shortage.

(2) From June 15 to July 1, stream-flow declines rapidly, while water needs for both hay and grain crops continues to be high. Moreover, precipitation is generally very low at this time of the season. At lower elevations, the availability of water during this period has a pronounced effect on grain yields and determines whether one or two cuttings of alfalfa will be possible. The amounts of water needed for a given acreage depend largely on type of soil - a diversion rate of one second-foot per 80 to 100 acres may be ample on soils that are clayey and highly retentive of moisture, while a diversion rate of one second-foot per 60 acres or less would be required for lighter soils from which drainage is rapid.

(3) The period from July 1 to July 15 is also a critical one in all parts of the Basin. At lower elevations, water is needed during this period for the second cutting of alfalfa. At higher elevations, where

haying begins about the middle of July, a water shortage the first part of July adversely affects the yield of wild hay and clover-timothy hay. As during the period June 15 to July 1, the amount of water required for a given acreage depends largely upon type of soil.

(4) After July 15, water is not needed in as large amounts as earlier in the season. Grain and hay crops are "made" by this time of the year and precipitation is much heavier on the average than during the May 1 to July 15 periods. Nevertheless, a certain amount of water is important from July 15 to well into September for potatoes, pasture, and meadow aftermath.

Admittedly, the above water-supply classifications are not highly accurate. There is a wide variation among ditches in climatic factors, soils, irrigation dates, and the proportions of various crops in a mountain-valley area such as the Roaring Fork Basin. Precise data, capable of being analyzed by statistical methods, are not available. The classification of each ditch was arrived at after careful study of daily stream-flow records, the closing dates of headgates reported by the Water Commissioner over a period of several years, and the general situation surrounding each ditch as brought out in conversations with the Water Commissioner, local farm and ranch operators, and irrigations engineers familiar with

this area.

Then, too, the fact that these classifications are by ditches rather than by individual priorities in each ditch may introduce an element of error into the classification system in some instances. For most of the ditches in this Basin, however, this seems to be of minor importance, because the ditches are small, individually owned or partnership affairs, in which all priorities are shared by all water users under the ditch, either because of joint ownership of priorities, or because of the custom of "exchanging" water among users on the same ditch. In a few cases where there appeared to be significant differences in the quality of water supply among different groups of water users as a result of differences in priorities and reservoir shares owned, separate classifications were established for each group.

All in all, it is believed that the water-supply classifications provide a convenient measure of the relative availability of water to the various ditches, from which a reasonable approximation can be made of the amount of storage and foreign water that would be required by each ditch to give it a full supply. It is quite possible that this classification system would not be applicable to other areas, unless the availability dates and amounts of water for each classification were revised considerably.

Chapter II

REVIEW OF LITERATURE

The review of literature will be presented under the following headings:

1. Need for irrigation development in the arid regions.
2. The proposed irrigation projects in the Roaring Fork Valley.
3. Need for economic analysis of feasibility of irrigation projects.
4. Method and limitations of the standard economic analysis procedure.
5. Summary.

Need for irrigation development in the arid regions

In his history of the arid Great Plains, published in 1931, Webb (12) interpreted the need for irrigation when he wrote:

> When rainfall is less than twenty inches, on an average, agriculture cannot be carried on by ordinary means. In a strictly arid climate rainfall may be considered as a negligible factor, and sole dependence is placed on irrigation. Hence.....provision must be made for at least supplemental irrigation, and the necessity for resort to such artificial aid will be imperative most of the time and advantageous always. (12:324-325)

The Bureau of Reclamation (8:11-18) in a report dated March, 1946, applied the need for irrigation development specifically to the Colorado River Basin and pointed out that optimum use of the land resources in this arid basin is dependent on water being made available for irrigation. Although the basin, without further irrigation development, makes a substantial contribution to our national economy, it could offer much more if its inherent problems were eliminated and its potentialities developed. The report specifies the need for expanded detailed investigations of individual potential projects as a means of formulating a comprehensive irrigation development plan for the entire basin.

Proposed irrigation projects in the Roaring Fork Valley

In the early 1940's, the Bureau of Reclamation did an important piece of work in attempting to catalogue all of the potential irrigation projects in the Colorado River Basin. Listed among the many proposed projects, and published in the comprehensive report in 1946, were four located in the Roaring Fork Valley of the Colorado River Basin. They have been described in the report (8) as follows:

> Capitol Creek project.--A new service canal 10 miles long would be required to bring water from Snowmass Creek to 2,000 acres of grass lands now insufficiently irrigated from Capitol Creek.

Both Snowmass and Capitol Creeks flow northeast and converge before joining Roaring Fork at Snowmass, 12 miles downstream from Aspen.

Woody Creek project.--Two thousand acres of irrigated land located near the junction of Woody Creek with Roaring Fork, six miles south of Aspen, could be furnished ample supplemental water by a new canal 13 miles long diverting from Roaring Fork at Aspen. Native grass is the principal crop on these lands.

Cattle Creek project.--Only storage would need to be provided to irrigate 900 acres of new land and to furnish 5,500 acres with supplemental water. The lands are located along Cattle Creek, which flows westward to join Roaring Fork, nine miles above Glenwood Springs. The off-stream Missouri Heights Reservoir of 2,800 acre-feet capacity could be enlarged to a capacity of 9,000 acre-feet and filled by an enlargement of its two-mile feeder canal from Cattle Creek.

Fourmile project.--Located eight miles southwest of Glenwood Springs, this project would irrigate 500 acres of new land and 1,400 acres in need of supplemental water. Existing ditches along Fourmile Creek, a tributary of Roaring Fork, could distribute the water, but a dam to store 2,000 acre-feet of water at Fourmile No. 4 reservoir site on Fourmile Creek would be required. (8:130-131)

Merrill (4), in a report published in 1940, has given some basic data on the Fourmile Creek project, the only one of the four proposed projects on which, to the writer's knowledge, any data have been gathered. His conclusions are paraphrased as follows:

(a) By strict economy in the use of water 800 acre-feet will sufficiently supplement present late summer water supply on Fourmile Creek to permit successful farming of the 1,400 acres now settled. No additional

area could be developed from this supply.

(b) The saving of money now spent in buying hay for winter feeding, with the possibility of growing more and better cash crops, should increase farm income by three times the annual cost of the supplemental water supply.

(c) The pasture irrigation project proposed, if at all successful, will so benefit the forage on range and pastures, and so increase ground water supplies, that the storage proposed will be quite adequate for the present cultivated area, and range improvement will result in increase of farm incomes.

The cost of the project as proposed by Merrill was $75,000. Using the terms of the Reclamation law, the repayment of cost in 40 years without interest, together with payment of operating and maintenance expenses, would amount to $2,675 annually. If paid equally by all farmers on the basis of 1,400 acres, the cost per acre would be $1.90. Sales of water on an acre-foot basis would require the payment of $3.30 per acre-foot.

Need for economic analysis of feasibility of irrigation projects

Widtsoe (14), in his book published in 1928, made the following statement which clearly indicates past

and present need for economic analysis of feasibility of irrigation projects:

> The history of the irrigation movement in the United States shows that many of the failures in the development of the irrigated area were due to wrong beginnings. Full and intelligent consideration was not given to the many factors involved in the selecting and building of irrigation projects. The history of private irrigation in the United States illustrates this fact; and a preponderance of the difficulties of the Federal projects has been due to inherent project conditions which might have been foreseen at the time the projects were launched. (14:16)

William Melcher (3:9), 1931, studied the economics of crop production on the Uncompahgre Reclamation Project in Colorado and in so doing uncovered many reasons for economic problems that arose as a result of inadequate planning and analysis. The principal problems were as follows: construction costs were estimated too low, the costs of leveling and developing the land were not taken into consideration, the amount of land that developed into seepland and the necessity for a drainage system was not considered, the difficulties of marketing crops were not foreseen, the operation and maintenance costs were estimated too low, the cost of production exceeded expectations, and anticipated crop production and prices were too high.

Method and limitations of the standard economic analysis procedure

According to an article by Selby (6:643),

published in 1942, the basic method used in determining the economic feasibility of irrigation projects is the budget method. A budget was defined by the Bureau of Agricultural Economics (7:45-47) in an unpublished manuscript dated 1943 as a "systematical recorded schedule for the organization and operation of a farm together with a detailed statement of the anticipated income and expenditure for a period of time." (7:45-46) It normally shows the acreage of each crop, expected normal yields, total production of the crop, the amount of this crop which will be sold, the price normally obtained, amount of feed fed, source of the feed, numbers and kinds of livestock, their production and sale, outlay of funds for various items of expense, amount of receipts and their source, and the resultant--the difference of expenses and income or the net income.

The Bureau of Agricultural Economics (7:45-47) in the same manuscript stated, "The significant consideration for monetary value for irrigation water is the future net increment of income arising from use of irrigation water." (7:45) Determining future net increment is the goal of analysis of economic feasibility and can best be accomplished through use of the budget approach.

The U. S. Repayment Commission (10) in its report published in 1938, set forth the following factors which affect the repayment of construction costs on

irrigation projects and which, therefore, must be included in the budgetary approach:

(a) the project construction costs

(b) the size of the farm units

(c) the tenancy rate

(d) the amount of taxes paid after development

(e) the mortgage debt

(f) interest rates

(g) the general economic situation and its effect principally on farm prices and prices paid by farmers

(h) the marketing scene

(i) the amount of water made available due to the construction of the project

(j) the type of crops grown

(k) the irrigation methods used

Mr. H. E. Selby (5:637-646) in his article published in 1942, stated:

> One of the most common fallacies in planning irrigation, is the assumption that the entire increment in net income over and above other direct cash costs, that results from an input of irrigation water, necessarily will be available to pay for the irrigation water. (5:637)

This author further elaborated this statement by saying that some of this increased net income results in increases in land values, level of living, taxes and other items.

Mr. Selby in this article stated that the determination of feasibility of most irrigation projects is by the "budget" method. This method estimates the probable increased returns to farmers due to the use of water that would be made available. Then the increased expenditures, except cost of water, are deducted from increased returns and this sum remaining is what is considered as available for meeting water charges. If the project can supply the water at a cost equal to or less than this figure, the project is considered feasible.

The author of the article does not feel, however, that this approach is infallible so he suggests that additional analysis should be made, comparing the proposed project's repayment ability with that of "similar type" projects that are already completed and are meeting successfully their repayment contracts. The author in his article draws some conclusions, illustrated in graphic form, as to the ability of various types of agriculture to pay water charges.

Mr. Selby in an undated unpublished report (5) stated:

> The amount that farmers can afford to pay for irrigation water depends very largely on the value of crops they can raise. The relationship between value of crops per acre and payment for water in the sixty-six counties included in this analysis is shown in figure 2. In this chart each dot represents the annual crop value per

acre and annual irrigation cost per acre of one of the counties. The diagonal line is an approximation of the average relationship between crop value and irrigation cost. On the average, the irrigation cost was equivalent to slightly more than 6 per cent of the crop value. In very few cases did it exceed 10 per cent. (5:1-2) 1/

Summary

The Colorado River Basin occupies a substantial portion of the arid area of the United States of America. Because the need for irrigation in this area is so vital to its development and because its development has import to the national economy, every effort must be made to insure the most efficient use of its water resources.

The Bureau of Reclamation (9) in its Colorado River Report contributed greatly to planning for maximum use of the water resources in this area by proposing a tentative overall basin program. The report recommended as the next logical step the selection of a group of sound projects, and this thesis, analyzing the four projects proposed in the Roaring Fork Valley, is intended as a very small beginning in that direction.

In the analysis of the four Roaring Fork Valley projects and undoubtedly in the future economic determination of the other 130 proposed projects, the standard

1/For Figure 2, referred to by this author, see Figure 3, Appendix B.

budgetary approach will be used. However, this approach has its limitations, the primary one being that all of the increased net increment from the application of additional water is not available for the payment of water charges, i.e., some of the net increment translates itself into increased land values, higher levels of living, etc. Because of these limitations, other criteria can and should be used before final project selection.

Chapter III

METHODS AND MATERIALS

The problem of this thesis is to describe and analyze as far as possible the four proposed irrigation projects, Fourmile, Woody, Capitol, and Cattle Creeks, in the Roaring Fork Valley. This chapter is concerned with the technique used in analyzing those projects, and with some of the problems encountered in the gathering of data.

Techniques used in analyzing the projects

This study followed the following procedure wherever practicable:

I. Examination and consideration was undertaken of the published and unpublished material available to the writer concerning the entire Colorado River Basin, the specific projects and project areas, and the methods and techniques of determining economic feasibility of irrigation projects.

II. Pertinent physical data available on the Roaring Fork River Basin were gathered from the Bureau of Reclamation's (8) Colorado River Report, published in 1946. These data were supplemented by data from the follow-

ing sources:

A. the land classification map published by the Bureau of Reclamation in 1936, 1/

B. the sectional aeronautical chart (Denver) as revised August 1947, compiled and printed by the U. S. Coast and Geodetic Survey, 2/

C. the writer's knowledge of the areas' soils and topography supplemented by interviews with the Water Commissioner and the Division Engineer, 3/

D. the writer's knowledge of the types of farming in the area supplemented by interviews with people in the area, including farmers, ranchers, the Water Commissioner, the Division Engineer, Forest Service personnel, and irrigation lawyers,

E. the climatological data, for the Roaring Fork and adjacent areas, from the U. S. Weather Bureau, Denver, Colorado,

F. data concerning the water supply found on file in the office of the Colorado State Engineer and in Robert Follansbee's (2) "Upper Colorado River and Its Utilization", published in 1929.

III. In order to set up a project budget, specific

1/ Figure 6, Appendix B.

2/ Figure 5, Appendix B.

3/ The writer lived on and assisted in the management of a cattle ranch in the Roaring Fork Basin from 1935 through 1941.

information on the individual projects was gathered from the following sources:

A. the U. S. Bureau of Reclamation report (8), published in 1946, concerning the proposed features of the projects and their costs,

B. published information concerning the projects in question,

C. data tabulated from the Water Commissioner's reports, the Division Engineer's files, and the Colorado River Report (8) concerning the amounts of water diverted, water rights, and crop distribution,

D. discussion with farmers, ranchers, irrigation lawyers, the Division Engineer, and the Water Commissioner as to what additional water was needed in each area, what is being done at present to increase the supply and what could be done to increase the supply, sources of additional water supply, crop production at present, and possible future crop production with increased amounts of irrigation water,

E. a farm schedule taken from a representative sample in each project area, 4/

F. price information for the area concerned obtained

4/ Figure 4, Appendix B.

from a Colorado Experiment Station bulletin, "Prices Received by Farmers in Each County of of Colorado for Principal Crops," dated 1948, 5/

G. tax information from the County Assessor's office in question concerning the assessed valuation of each farm and the mill levy of each school district in the project area,

H. analysis of the data gathered.

IV. A project budget was set up by the following procedure:

A. the number of acres in the proposed project area without an adequate water supply was determined by,

1. investigation of the water needs per acre, based upon types and distribution of crops,

2. investigation of water rights and water deliveries under each ditch within the project area,

3. comparison of sub-heading 1 with 2.

B. The amount of water, in acre-feet, needed by the inadequately irrigated areas was calculated by sub-headings 1 and 2 in sub-heading A above.

C. Present and future crop distribution was determined by use of information on the farm schedule and primarily by answers to the question, "If

5/ Table 36, Appendix B.

you had a full water supply, what changes would you make in cropping programs?" 6/

D. Present and future crop production was ascertained also by answers to the questions on the farm schedule, (a) "Yields per acre" by individual crops, (b) "What year of the past 10 did you receive the lowest crop yields? --- Why?", (c) "What year in the past 10 did you receive the best crop yields? --- Why?" 6/

E. The total net increment was calculated by subtracting present income to the land in question, based upon present average crop production, and average distribution multiplied by the average 1939-44 price, from the future income to land, based upon potential future crop production and the future distribution multiplied by the average 1939-44 price.

F. The additional costs to the project areas were estimated. These additional costs included probable increased taxes, probable increased land development costs, and increased costs of crop production.

G. The net increment that could be used for project repayment was determined by deducting additional

6/ Figure 4, Appendix B.

costs (sub-heading F) from the total net increment (sub-heading E).

V. A comparison was made between annual net increment and annual repayment charges for the proposed project.

Some problems encountered in gathering of data

In the process of gathering data, there were some deviations from the proposed procedure as outlined in the above paragraphs.

In only one of the four projects, the Cattle Creek project, did the writer complete all the steps in the individual project analysis. The analysis of the other three projects was carried only partially through the third phase. At this point it was felt by the writer, for reasons peculiar to each project, that no further data gathering was necessary on the Woody, Capitol, and Fourmile Creek projects. On Woody Creek the farmers had already initiated steps that would eliminate the need for the proposed Reclamation project; on Capitol Creek the water users felt there was no real need for additional water in the valley, and this feeling was substantiated by data obtained from the Water Commissioner's reports; on Fourmile Creek the cost per acre-foot of reservoir capacity was so high that the writer deemed it inadvisable to gather additional data.

The only difficulty encountered in the procedure was the inadequacy of the descriptions and of the details of construction costs as presented in the U. S. Bureau of Reclamation report. Had there been more description of the engineering features, more delimitation of the area concerned, and a breakdown of the construction costs, the writer might have had a better understanding of the projects, might have been saved much valuable time in determination of acreage concerned, and might have been able to suggest some practical changes in the proposed project.

Chapter IV

FOURMILE CREEK PROJECT

The project proposed for the Fourmile Creek Valley by the United States Bureau of Reclamation (8) is described in its comprehensive report on the Colorado River, 1946, as follows:

> Located 8 miles southwest of Glenwood Springs, this project would irrigate 500 acres of new land and 1,400 acres in need of supplemental water. Existing ditches along Fourmile Creek, a tributary of Roaring Fork, could distribute the water, but a dam to store 2,000 acre-feet of water at Fourmile No. 4 reservoir site on Fourmile Creek would be required. (8:130)

The estimated cost of the project was given as $600,000 at January 1, 1940, prices, or as $960,000 at January 1, 1946, prices. (8:4,16)

Description of the area

The project area lies from three to ten miles south of Glenwood Springs, Colorado. Most of the irrigated land in this basin does not lie along the main valley floor but rather in valleys parallel to Fourmile Creek. The area irrigated, either partially or entirely, by water from Fourmile Creek is 1,435 acres. About 60 acres in

addition are irrigated by water from Sunshine Creek, an upstream tributary. F. C. Merrill (4) in his report published in 1940, estimated, after conversations with farmers, that there were 500 acres of non-irrigated irrigable land in the Fourmile watershed. The land classification survey, made by the United States Bureau of Reclamation in 1936, showed only 140 acres of Class 2 irrigable land and no Class 1 land. This difference of 360 acres in estimates on irrigable land was probably due to a discrepancy in classification. Most of the 360 acres were probably on slopes too steep to be classified by the United States Bureau of Reclamation as Class 2 land, but were considered as irrigable by the farmers, because they could be used for hay and pasture.

The elevation of the project area ranges from 5,800 to 7,500 feet. The growing season averages from about 135 days in the lower end of the valley to less than 100 days at the upper end of the valley. Likewise the precipitation at the lower end of the valley is probably less than that at the upper end, due primarily to differences in elevation. The precipitation at the lower end of the valley probably is about the same as at Glenwood Springs, or about 20 inches long-time average, with 7 to 8 inches occurring during the warm-season months of May through September.

The soils, ranging from adobe clays to clay loams, are rather heavy and deep and very retentive of moisture. In spite of these facts, no drainage problems have been encountered in the area because of the steep slopes and well-defined surface drainage. (See Table 8 for a more detailed description of lands and soils under each ditch.)

Type of farming.--Two types of farming predominate--livestock ranching and cash-crop-livestock farming. Available adjoining the project area is considerable range land, both privately and publicly owned. Most operators carry all the livestock that their hay production can support. Alfalfa hay is the most important crop in the area. In 1946 there were about 50 acres of potatoes (3.5 per cent of the irrigated area) and 180 acres of cereal grains (12.5 per cent). The balance (85 per cent) was devoted to hay and pasture, of which alfalfa constituted the major portion. 1/

Water supply.--Fourmile Creek rises in the Huntsman's Hills, about 20 miles southwest of Glenwood Springs at an elevation of approximately 9,000 feet. The headwaters of this stream rise at a lower elevation than those of any other stream in the Roaring Fork Basin; consequently, its unit run-off is also lower. The annual

1/ Crop distribution for the Fourmile Creek Valley is given in Table 34, Appendix A.

Table 8.--FACTORS INFLUENCING CROP PRODUCTION ON LANDS IRRIGATED FROM DITCHES DIVERTING FROM FOURMILE CREEK AND TRIBUTARIES.

Name of ditch	Acres irrigated[1]	Water supply classification[2]	Crop production and yields[3]	Description of land and soils			
				Average elevation (feet)[3]	Topography[3]	Predominant type of soil[3]	Natural drainage[3]
Fourmile	160	A-2	Good	5,900	Gentle to medium slopes	Reddish brown sandy clay loam of good depth	Adequate
Atkinson	325	A-2	Fair to good	6,100	"	"	Good
Buck Farm	100	A-1	"	6,700	Bench and bottom lands	Dark brown loam, rich in humus	Adequate
Lignite	150	C	Fairly good	6,500	Sloping bench lands	Dark brown loam at good depth	Adequate
McKown	400	D	Fair[4]	6,400	Gentle to medium	Brown sandy loam	Good
Lynch	70	D	Fair	6,700	Sloping hillsides	Dark brown sandy loam	Good
Dearing	35	D	Fair	6,000	Gently rolling bench lands	Dark brown sandy clay loam at good depth	Adequate
Gristy	5	[5]A-1	---	5,800	Fairly level bench lands	----	Good
Lignite No. 2	40	D	Fair	6,600	Medium slope bench lands	Dark brown loam of good depth	Good
Smart & Green	[6]55	[5]A-1	Fair	5,800	"	Sandy clay loam to gravelly loam at fair depth	Good
Hamerick	25	D	Fair	6,100	Sloping bench lands	Dark brown sandy clay loam	Good
Perko	35	D	---	7,500	Mountain valley land	---	Adequate

Table 8.--FACTORS INFLUENCING CROP PRODUCTION ON LANDS IRRIGATED FROM DITCHES DIVERTING FROM FOURMILE CREEK AND TRIBUTARIES.--Continued

Name of ditch	Acres irrigated[1]--con.	Water supply classification[2]--con.	Crop production and yields[3]--con.	Description of land and soils--con.			
				Average elevation (feet)[3]--con.	Topography[3]--con.	Predominant type of soil[3]--con.	Natural drainage[3]--con.
Hardwick	90	C	Fairly good	6,300	Sloping hillsides	Dark brown sandy loam of good depth	Good
Waddell	60	C	Fair[7]	7,500	Mountain valley land	Dark brown sandy loam of fair depth	Adequate

[1]Compiled from annual reports of Water Commissioner (Water District No. 35) and the 1936 Land Classification survey of the U. S. Bureau of Reclamation.

[2]See text.

[3]From data supplied by Engineer-Appraiser, Federal Land Bank of Wichita.

[4]Normally, one fair cutting of alfalfa is obtained, but yield of other crops is not very good.

[5]Water supply is much better than would be indicated by ditch priorities due to the facts that there are no senior rights below this ditch and return flow from higher ditches is ample to fully supply this small acreage.

[6]There is only a small part of this acreage that cannot be reached from the Robertson Ditch which diverts from the Roaring Fork.

[7]Only one fair cutting of hay possible.

run-off at the gaging station established in 1942, in the upper part of the Fourmile Creek Basin above all irrigation diversions, has varied from 2,800 to 4,700 acre-feet, with a six-year average of 3,950 acre-feet. Better than one half of the run-off occurred during the month of May and 94 per cent during the three-months' period of April through June (Table 9).

This six-year average may not be representative of a long-time average, since it is known that the particular six-year period was above average for the Basin as a whole.

The years 1934 and 1936 were considered to be the driest of the last 25 or 30 in the Roaring Fork Basin, and known to be much drier than the year 1943. Spring run-off from the Basin, measured at Glenwood Springs, was far below normal during those two years, 61 per cent and 64 per cent of normal respectively. It would be reasonable to assume that the run-off in the Fourmile Valley in those years was correspondingly low. It is estimated that the run-offs on Fourmile would have been as follows:

Year	Estimated run-off
1934	2,410 acre-feet
1936	2,530 acre-feet

Since the run-off for 1943 was 2,808 acre-feet, it is probable the 1943 run-off was similar to those of 1934

Table 9.--RUN-OFF OF FOURMILE CREEK AT DAMSITE NO. 4 IN S E ¼ SECTION 36-T7S-R90W, BY MONTHS AND WATER YEARS, FROM APRIL 1942 TO SEPTEMBER 1947.

[Compiled from records in office of Colorado State Engineer]

Month	1941-42	1942-43	1943-44	1944-45	1945-46	1946-47	6-year average 1942-47	
							Amount	Distribution
	Acre-feet	Acre-feet	Acre-feet	Acre-feet	Acre-feet	Acre-feet	Acre-feet	Per Cent
Oct.	--	17	29	13	13	26	20	0.5
Nov.	--	23	29	23	24	14	23	0.6
Dec.	--	--	--	--	18	12	15	0.4
Jan.	--	--	--	--	12	6	9	0.2
Feb.	--	--	--	--	11	17	14	0.4
Mar.	--	--	--	--	25	31	28	0.7
Apr.	[1]846	[2]1,021	56	476	1,153	646	700	17.7
May	2,783	1,044	3,126	2,378	1,454	2,380	2,194	55.5
June	951	575	1,261	854	505	759	822	20.8
July	62	49	101	165	36	128	90	2.3
Aug.	18	53	4	55	8	15	25	0.6
Sept.	14	26	0	2	3	13	10	0.3
Water year	4,704	2,808	4,606	3,966	3,262	4,047	3,950	100.0

[1]Measured amount from April 14 to 30 was 616 acre-feet. Amount from April 1 to 13 was estimated at 230 acre-feet, based on correlation between daily stream-flow at this station and the one on West Divide Creek near Raven.

[2]Measured amount from April 24 to 30 was 442 acre-feet and amount from April 1 to 23 was estimated at 579 acre-feet by same method indicated in footnote 1.

and 1936. However, there is the possibility that there will be lower run-offs than that of the year 1943.

Direct-flow rights.--The initial water decrees on Fourmile were made at the rate of one second-foot per 50 acres of irrigated land. If this amount were available throughout the season, there would be no need for additional water. There is even the possibility that this amount would be excessive, but because of the highly seasonal character of the flow in Fourmile Creek, even some of the earliest rights seldom enjoy the full amount of their rights. Since water is not available throughout the season, most operators apply excessive amounts early in the season, when ample water is available, in an attempt to "soak up" the ground. In order to legalize this practice, most ditches have obtained additional late priorities in the 1936 general adjudication to bring their total diversion rates up to one second-foot per 25 acres.

The adjudicated direct-flow rights, in order of priority, are shown in Table 10. The appropriations for tributaries generally are not a charge on Fourmile Creek because, when there is any water in the tributaries, there is also ample water in the main channel for senior appropriators.

Water-supply classification of ditches.--The water-supply classification of the various ditches is

Table 10.--ADJUDICATED WATER RIGHTS ON FOURMILE CREEK AND TRIBUTARIES IN ORDER OF PRIORITY.

[Compiled from copies of decrees and other records in office of Divisional Engineer, Division No. 5, Glenwood Springs, Colorado]

Priority order on stream	Name of stream and ditch	Water district priority number	Date of decree	Amount of appropriation (second-feet)
	Fourmile Creek:			
1	Fourmile (orig.)	19	5-11-89	1.60
2	Atkinson (orig.)	33	5-11-89	4.00
3	Buck Farm (orig.)	104B	4-18-90	2.40
4	Atkinson (1st enl.)	109	5-11-89	3.00
5	Gristy	137B	4-28-03	0.30
6	Atkinson	147	5-11-89	0.70
7	Lignite	149A	4-18-90	2.40
8	Lignite	179A	4-18-90	0.60
9	McKown	181A	4-18-90	1.50
10	Lynch	182A	4-18-90	2.00
11	Dearing	185	5-11-89	0.90
12	Lignite (orig.)	219BB	11- 9-08	0.50
12	Lignite (add'l)	219BB	7-21-09	0.30
13	Fourmile (Rohwer-Isola ext.)	221AA	11-19-13	1.60
14	McKown	223	6-15-08	5.00
15	Smart & Green (orig.)[1]	228A	7-21-11	0.90
16	Hammerich	232A	9- 7-18	0.50
--	Hughes-Fourmile Cr.[2]	236	9-27-23	2.00
17	Perko	391	8-25-36	0.90
18	McKown (flood right)	406A	8-25-36	4.50
19	Buck Farm	406B	8-25-36	1.60
20	Lignite No. 2	406C	8-25-36	0.80
21	Lignite	406D	8-25-36	5.20
22	Atkinson	406F	8-25-36	5.50
23	Hammerich	406G	8-25-36	0.50
24	Fourmile	406H	8-25-36	4.00
25	Doose[3]	424	8-25-36	2.00
26	Doose[3]	426	8-25-36	2.00
	Dry Gulch:			
1	Dry Gulch[4,5]	226A	12- 4-11	1.50

Table 10.--ADJUDICATED WATER RIGHTS ON FOURMILE CREEK AND TRIBUTARIES IN ORDER OF PRIORITY.--Continued

[Compiled from copies of decrees and other records in office of Divisional Engineer, Division No. 5, Glenwood Springs, Colorado]

Priority order on stream-con.	Name of stream and ditch-con.	Water district priority number-con.	Date of decree-con.	Amount of appropriation (second-feet)-con.
	Hardwick (Overland) Gulch:			
1	Hardwick[5]	21A	5- 3-90	1.30
2	Hardwick[5]	406E	8-25-36	2.70
	Sunshine & Freman Creeks:			
1	Waddell[5]	133A	4-18-90	0.60
2	Waddell[5]	366	8-25-36	1.39
3	Fremont[5]	406AA	8-25-36	6.00
	Woodtick Creek:			
--	W. G. Smith[2]	226AA	11-23-12	1.50
	Midland Mines Gulch:			
--	Mines[2]	229A	8-25-36	4.00
--	Pipeline[2]	229B	8-25-36	3.20

[1]Most of the land under this dtich is also irrigated from the Robertson Ditch which diverts out of the Roaring Fork.

[2]This ditch has not been used for many years and apparently the right has been abandoned.

[3]This ditch is used mainly to carry flood water to lands under the Lignite and Hardwick Ditches.

[4]This is merely a feeder ditch which carries a small amount of waste water and seepage from the Rohwer Ditch (which diverts out of Threemile Creek) to the Fourmile Ditch. Apparently, not very important.

[5]Generally, this right is not a charge on Fourmile Creek, because usually when there is water in this tributary there is also ample water in Fourmile Creek to satisfy senior priorities.

given in Table 8. It will be noted that of the 1,435 acres dependent upon Fourmile Creek for basic supply, 590 acres (41 per cent) have an A-1 or A-2 water supply, 240 acres (17 per cent) have a Class C water supply, and 605 acres (42 per cent) have a Class D water supply.

Data obtained from the Water Commissioner's reports indicate in a general way the amount of water diverted over a given period of time. These records indicate the average diversion of water on an acre-foot per acre basis during the period 1940 to 1946 for the entire valley to be 3.15 acre-feet, with a range of 1.78 to 7.31. 2/

From the various data given above it may readily be seen that the area as a whole is short of water and that 59 per cent of the irrigated acreage does not have an adequate water supply. This shortage may be partially accounted for by the geology of the area which allows very little return flow to Fourmile Creek.

Need for supplemental water.--The amount of supplemental water needed by each ditch depends primarily upon the direct-flow priorities of the ditch and the types of crops which are, or could be, raised on the lands served by the ditch.

In 1940, Merrill (4), with the assistance of water users under each ditch, worked out a hypothetical

2/ Table 35, Appendix A.

schedule of reservoir releases from which he estimated that a total of 800 acre-feet was the least amount of storage water that would be practical in the valley. This estimate did not include any water for new lands nor did it include enough water to provide a full supply for presently irrigated lands. The table below, based on a general knowledge of the area, on a detailed study of water deliveries and water rights, and on conversations with several farm operators in the valley, gives an estimate of the amount of storage water which would be required for a full supply.

Table 11.--AMOUNT OF STORAGE WATER REQUIRED IN THE FOUR-MILE CREEK VALLEY FOR A FULL SUPPLY.

[The assumptions on which these estimates are based will be found in the appendix. 3/]

	Acres irrigated	Acre-feet per acre	Total acre-feet
Atkinson Ditch A-2	325	0.15	50
Other Class A-2 and A-1 ditches	265	0.00	0
Two Class C ditches	240	0.75	180
Six Class D ditches	605	1.00	600
New land (USBR Class 2)	140	2.50	350
	1,575		1,180
New land (additional acres based upon farmers' estimates)	360	2.50	900
	1,935		2,080

3/ Figure 2, Appendix B.

If only the 140 acres of new land shown by the U. S. Bureau of Reclamation land classification survey are brought into the project, the total storage water requirement estimated for the project will be 1,180 acre-feet delivered to the individual ditch headgates. If the full 500 acres of new land, which farmers considered irrigable in 1940 and which the Bureau of Reclamation included in its report, are brought into the project, the total water requirement estimated for the project will be increased to 2,080 acre-feet.

Amount of storage water available.--After determining the need for water on the proposed project, it is necessary to arrive at the amount of water available for storage. Many factors must be considered, such as the start and extent of the spring run-off, the amount of water diverted under direct-flow priorities during the run-off period, and the effect of the availability of storage water on the amount diverted. Most ditches in the project area start diverting water during the month of May, but a few located at the higher elevations do not start until early June. Thus most, if not all, of the run-off during the month of April would be available for storage as would that amount not being diverted under direct-flow priorities during the month of May.

Table 12, showing the amount of water that could

have been stored each year from 1942 to 1946, is based on daily stream-flow data and the following three assumptions: (a) that only the original decrees of one second-foot per 50 acres would be demanded by water users; (b) that all direct-flow priorities would receive their full right; and (c) that there would be no fall or winter storage. Using these assumptions, the table shows that a 2,000 acre-foot reservoir could have been filled every year with the exeption of one. It should be noted that no allowance was made for any return flow, and no consideration was given to fall

Table 12.--STORABLE WATER IN FOURMILE CREEK DURING APRIL AND MAY, 1942 TO 1946.

[Computed from daily stream-flow records of Colorado State Engineer and the date on which each headgate was opened, or given in the annual reports of the Water Commissioner of Water District No. 38 to the State Engineer]

Year	Assuming no use of flood rights[1]	Assuming full use of flood rights[2]
	Acre-feet	Acre-feet
1942.	2,600	1,920
1943.	1,600	1,590
1944.	2,300	1,540
1945.	2,100	1,850
1946.	2,120	2,040

[1] One second-foot per 50 acres irrigated.
[2] One second-foot per 25 acres irrigated.

and/or winter storage. The table also shows that if some or all of the "flood" rights, i.e., those rights based on one second-foot per 25 acres irrigated, were demanded, a 2,000 acre-foot reservoir would seldom be filled.

If enough storage water were available later in the season, the demand for water to satisfy the direct-flow "flood" right would be decreased and would, in fact, be unnecessary and undesirable in practically all cases because of the decreased need of "soaking up" the ground in the spring. However, since a 2,000 acre-foot reservoir would probably not provide a full supply for the project area, a few of the "flood" rights would probably still be demanded. Still other "flood" rights might be demanded by those users who have an adequate water supply under the present water-right system. Therefore, it is important to remember that "flood" rights are legal rights of the water users and could be demanded in spite of decreased need.

Reservoir costs.--The Bureau of Reclamation's report (8) published in 1946, stated that the construction cost of the project would be $600,000 at 1940 prices and $960,000 at 1946 prices. This is an average construction cost of $300 per acre-foot of reservoir capacity based upon 1940 costs and $480 based upon 1946 costs. If the construction costs (1940 costs) were paid without interest over a 40-year period on a contract similar to those used on

United States Reclamation Projects, the annual costs to the water users would be $7.50 per acre-foot of storage capacity. If all of the land shared the construction costs proportionately, on an irrigated-acreage basis, the cost would be $7.89 per acre.

The report did not include any information on the operation costs, but there is no reason to believe that operation costs for this project would be any less than those estimated by Merrill (4) in a report published in 1940, for a proposed project in the same area. The cost of operation for an 800 acre-foot reservoir was estimated by him to be $750.00 annually. This annual cost to the water users would be $0.38 per acre-foot of storage capacity, or, if all of the land shared the operation costs proportionately, on an irrigated-acreage basis, the cost would be $0.39 per acre.

The total annual costs, on both the acre-foot basis and the irrigated-acreage basis, are given in the table below: (see following page)

Table 13.--TOTAL ANNUAL COSTS FOR SUPPLEMENTAL WATER IN THE FOURMILE CREEK PROJECT.

	Total amount	Per acre-foot	Proportionate cost per acre of irrigated land
Construction cost	$15,000	$7.50	$7.89
Operation	750	.38	.39
TOTAL	$15,750	$7.88	$8.28

Chapter V

DISCUSSION OF THE ECONOMIC FEASIBILITY OF THE FOURMILE CREEK PROJECT

After analysis of the construction and operation costs of the Fourmile Creek project as proposed by the Bureau of Reclamation report (8), 1946, the writer deemed the project economically unfeasible.

Merrill's study (4), 1940, of a smaller proposed project in the area concluded that if costs were shared on a proportionate basis, the cost per acre of irrigated land would be $1.90. Although this charge would seem a reasonable one, the water users of the area voted down the proposal as being too costly. We can hardly assume, then, that they would consider as economically sound any proposal for a project that would cost on the same basis, $8.29 per acre of irrigated land.

Even if the majority of water users in the valley were to favor the proposed project, it can be assumed from the data presented in table 8, on water-supply classification of ditches, that landowners under three of the ditches, Fourmile, Buck Farm and Atkinson, would not be willing to pay on an acreage basis because they already have an

adequate supply of water for their present cropping systems. Therefore, the net increment to these particular lands due to the increased supply of water, would be practically nil. Following this reasoning still further, if the landowners under these three ditches withdrew from the project, the proportionate cost per irrigated acre to the remaining water users would increase to approximately $11.71 per acre, and thus would seem even more unfeasible.

The conclusion of unfeasibility is again supported by analysis of costs if these costs are estimated on an acre-foot basis rather than on a proportionate cost basis. The new land, i.e., the 500 acres of non-irrigated, arable land in the project area would require 2½ acre-feet of water per acre at a cost of $7.88 per acre-foot or a total of $19.70 per acre. If we add to this cost the cost of production on an acre of new land, the total costs will be greater than the value of the productivity of the new land. If cost is greater than productivity, then new land will not come into the project. If new land does not come in, less than half the water stored will be needed, and the water users on the remaining irrigated land would be unable to pay the estimated costs.

The costs per acre and per acre-foot of storage are so high for this project as to make it of doubtful economic feasibility, even under the most favorable

assumptions. Other conclusions to be drawn from the analysis are listed below.

1. There apparently would be sufficient water available in most years to fill a 2,000 acre-foot reservoir.

2. The annual cost per acre, $8.29 for 1,935 acres or $11.71 for 1,345 acres, is too high. The cost, computed on an acre-foot of water basis, would be $7.88, also a very high charge in an agricultural area devoted principally to hay and grain.

3. Inasmuch as the $1.90 per acre charge was not acceptable to the farmers in 1940, there is no reason to believe they would be willing to pay the above costs.

4. Since the farmers in the area have done practically nothing in the past to increase their water supply, there is no reason to believe a "home" constructed project would be feasible from their viewpoint.

Chapter VI

WOODY CREEK PROJECT

The project proposed for the Woody Creek Valley, by the Bureau of Reclamation (8) is described in its comprehensive report on the Colorado River, dated 1946, as follows:

> Two thousand acres of irrigated land located near the junction of Woody Creek with Roaring Fork, 6 miles south of Aspen, could be furnished ample supplemental water by a new canal 13 miles long diverting from Roaring Fork at Aspen. Native grass is also the principal crop on these lands. (8:131)

The estimated cost of the project was given as $170,000 at January 1, 1940, prices or as $272,000 at January 1, 1946, prices. (8:4,16)

Description of the area

Woody Creek rises on the western slope of the Williams Mountains at an elevation of approximately 11,000 feet and flows in a westerly and northwesterly direction for about 14 miles to join the Roaring Fork River nine miles below Aspen. Two small tributaries which drain low-lying watersheds enter Woody Creek from the northeast: Collins Creek, which is about four miles long, joins Woody

Creek about three miles above its mouth; and Little Woody Creek, which is about six miles long, joins Woody Creek about one mile above its mouth.

There is another stream, Dry Woody, on the northwest edge of the project area. This stream is approximately two miles long and joins the Roaring Fork River about one mile below the confluence of the latter stream with Woody Creek.

According to the land-classification survey, made by the Bureau of Reclamation in 1936, there were 2,470 irrigated acres in the Woody Creek Valley and adjacent bench lands, and 190 acres of Class 2 arable land. 1/

The elevation of the project area ranges from 7,200 feet to 7,800 feet. The growing season averages about 110 days for the valley as a whole, but slightly less than this for the upper end of the valley. The growing season is long enough in the area to successfully raise potatoes and two cuttings of alfalfa, and is occasionally long enough for a third cutting.

The principal soil types are a reddish brown silt loam, a reddish brown loam, and a dark brown sandy clay loam. All of these soils are productive, rather deep, and fairly retentive of moisture. Because of well-defined surface drainage and excellent subsurface drainage, no

1/ Figure 6, Appendix B.

drainage problems have been encountered.

Type of farming.--Most of the farms in the project area are diversified crop and livestock farms. All units either own a few range cattle, or winter cattle for others. Summer range is on the National Forest, while spring and fall grazing is on privately owned range land and irrigated hay meadows.

In recent years approximately two thirds of the irrigated acreage has been devoted to hay, principally alfalfa, and approximately one fifth to cereal grains (Table 14). From 12 to 19 per cent of the irrigated

Table 14.--ACREAGE OF VARIOUS CROPS IRRIGATED FROM SALVATION DITCH OUT OF ROARING FORK AND THE DITCHES OUT OF WOODY CREEK AND TRIBUTARIES.

[Compiled from annual reports of the Water Commissioner to Colorado State Engineer.
These estimates are no doubt larger than actual because of duplicating acreage, particularly between Salvation Ditch and the Woody Creek ditches. The Salvation Ditch is a source of supplemental water supply for the area and the irrigated acreage records of this ditch are not separate from those of Woody Creek.]

Year	Hay	Cereals	Potatoes	Total
	Acres	Acres	Acres	Acres
1940	1,800	585	355	2,740
1941	1,895	500	345	2,740
1942	1,865	495	390	2,750
1943	1,757	478	515	2,750
1944	1,735	635	370	2,740
1945	1,635	565	540	2,740
1946	1,555	635	490	2,680
Average	1,749	556	429	2,734

acreage normally is planted in potatoes, the most important cash crop. Barley, wheat, and alfalfa are also cash crops on many farms.

Water supply.--There are no gaging stations on Woody Creek. The area of the Woody Creek watershed above the principal diversions is 30 square miles, while the area of the Collins Creek and Little Woody Creek watersheds together total about 15½ square miles. The percentages of watershed areas at various elevations are as follows:

Range in elevation (Feet)	Woody Creek (Per cent)	Little Woody and Collins Creek (Per cent)
11,000 to 12,000	17.7	0
10,000 to 11,000	32.6	35.6
9,000 to 10,000	28.4	23.7
Below 9,000	21.3	40.7
	100.0	100.0

Applying the methodology and factors developed by Follansbee's report (2), 1929, to the above data, the average unit run-off for the entire Woody Creek watershed would be 570 acre-feet per square mile of area. Applying the estimated unit run-off to the area of the watershed gives a total average run-off for the entire Woody Creek Basin of 33,100 acre-feet.

Annual diversions reported by the water commis-

sioner, of all ditches from Woody Creek and its tributaries, have varied from 6,900 acre-feet in 1946 to 13,350 acre-feet in 1944, with an average of 9,870 acre-feet for the seven-year period, 1940 to 1946 (Table 15).

Table 15.--ANNUAL DIVERSIONS BY DITCHES IN THE WOODY CREEK PROJECT AREA, 1940 TO 1946.

Compiled from annual reports of Water Commissioner to Colorado State Engineer.

Year	From Woody Creek and tributaries	From Roaring Fork, via Salvation Ditch
	Acre-feet	Acre-feet
1940	7,791	5,500
1941	9.348	7,200
1942	10,488	7,200
1943	12,378	8,400
1944	13,350	9,450
1945	8,838	8,400
1946	6,906	7,200
Average 1940-46	9,870	7,610

Water rights.--The various priorities granted on the basis of one second-foot per 50 acres of irrigated land in ditches diverting out of Woody Creek and tributaries are shown in table 16. A summary of these priorities totals 26.93 second-feet on Woody Creek, 10.163 second-feet on Little Woody Creek, and 7.7764 second-feet

Table 16.--ADJUDICATED WATER RIGHTS ON WOODY CREEK AND TRIBUTARIES, IN ORDER OF PRIORITY.

[Compiled from copies of decrees and other records in office of Divisional Engineer, Glenwood Springs, Colorado.]

Priority order on stream	Name of stream and ditch	Water district priority number	Date of decree	Amount of appropriation (second-feet)
	Woody Creek:			
1	Waco (orig.)	1	5-11-89	4.00
2	Walthen (orig.)	65	5-11-89	3.00
3	Walthen (1st enl.)	88	5-11-89	3.20
4	Miller (orig.)	104	5-11-89	0.40
5	Waco (1st enl.)	105	5-11-89	5.75
--	Waco (2nd enl.)[1]	145	5-11-89	0.00
6	Collins Creek (ext. & 3rd enl.)[2]	161A	4-14-90	3.30
7	Paradice (orig.)	192	5-11-89	3.00
8	Paradice (1st enl.)	254	2-24-30	3.50
9	Paradice (2nd enl.)	255	2-24-30	0.50
10	Natal (orig.)[3]	398	8-25-36	0.28
11	Collins Creek (flood right)	403H	8-25-36	13.34
12	Natal (flood right)[3]	403I	8-25-36	0.63
13	Waco (flood right)	403J	8-25-36	13.19
14	Walthen (flood right)	403K	8-25-36	10.80
15	Paradice (flood right)	428	8-25-36	18.00
	Little Woody Creek:			
1	Little Woody (orig.)	11	5-11-89	1.00
2	Williams (orig.)	119	5-11-89	0.10
3	Tierney (orig.)	120	5-11-89	0.20
4	Clavel (orig.)[4]	159	5-11-89	1.80
5	D'Avignon (orig.)	203	5-11-89	2.80
6	D'Avignon (2nd enl.)	213C	4-22-22	0.659
7	Martin Scott (orig.)	213D	4-22-22	0.224
8	D'Avignon (1st ext. & Scott)[5]	221B	4-22-22	1.50
9	Harmon (orig.)	320	8-25-36	0.79
10	Martin Scott (flood right)	403A	8-25-36	3.65
11	Clavel (flood right)[4]	403B	8-25-36	1.70
12	Williams (flood right)	403C	8-25-36	0.40
13	Harmon (flood right)	403D	8-25-36	1.18
14	Little Woody (flood right)	403E	8-25-36	1.50

Table 16.--ADJUDICATED WATER RIGHTS ON WOODY CREEK AND TRIBUTARIES, IN ORDER OF PRIORITY--Continued.

[Compiled from copies of decrees and other records in office of Divisional Engineer, Glenwood Springs, Colorado.]

Priority order on stream-con.	Name of stream and ditch-con.	Water district priority number-con.	Date of decree-con.	Amount of appropriation (second-feet)-con.
	Springs trib. Little Woody Creek:			
	Clavel Pipeline[6]	392	8-25-36	0.30
	Harmon Feeder[7]	430	8-25-36	0.79
	Collins Creek:			
1	Collins Creek (orig.)[2]	25	5-11-89	1.70
2	Collins Creek (1st enl.)[2]	97A	4-14-90	1.30
3	Collins Creek (2nd enl.)[2]	148A	4-14-90	0.30
--	Collins Creek (1st enl.)[2]	182	4-14-90	0.00
4	Cerise (orig.)	241		1.1364
5	Bionaz (orig.)	242		1.45
6	Cerise (Ions enl.)	243	11-20-26	1.84
7	Bionaz (flood right)	403F	8-25-36	2.75
8	Cerise (flood right)	403G	8-25-36	2.98
	Seepage:			
--	Twining No. 1[8]	232AA	10-20-19	5.0
--	Twining No. 2[8]	234	10-20-19	2.0

[1]Canceled.

[2]The Collins Creek Ditch originally diverted only from Collins Creek. The supplementary decree of April 14, 1890, canceled Priority No. 182 on Collins Creek and granted an optional diversion out of Woody Creek. The maximum amount that may be diverted by both headgates is 3.3 second-feet, i.e., whatever amount is being diverted out of Woody Creek by virtue of Priority No. 161A.

[3]The Water Commissioner has not reported any diversions by this ditch for several years. It is not known definitely whether it is being used.

[4]Some of the lands with Clavel water rights are under the D'Avignon Ditch. Water for these lands is diverted by the Clavel Ditch and turned back into Woody Creek opposite the D'Avignon headgate.

Table 16.--ADJUDICATED WATER RIGHTS ON WOODY CREEK AND TRIBUTARIES, IN ORDER OF PRIORITY--Continued.

[Compiled from copies of decrees and other records in office of Divisional Engineer, Glenwood Springs, Colorado]

[5]The Scott Ditch is an enlargement and extension of the D'Avignon Ditch.
[6]Used for domestic purposes; no irrigation.
[7]Supplementary supply for Harmon Ditch.
[8]Has not been used for many years; apparently abandoned.

on Collins Creek. This is a net total of 41.5694 second-feet for the entire Woody Creek Basin, if allowance is made for the duplication of 3.3 second-feet by virtue of the optional diversion of the Collins Creek Extension Ditch. Flood rights, granted by the 1936 decree, total 55.96 second-feet on Woody Creek, 8.43 second-feet on Little Woody Creek, and 5.73 second-feet on Collins Creek, or a total of 70.12 second-feet.

The Walthen Ditch is the only ditch which heads on Woody Creek below the mouth of Little Woody Creek. This means that all priorities on Little Woody Creek, except No. 11 in the Little Woody Ditch, are subject to the senior priorities in the Walthen Ditch, No. 65 and No. 88.

The Waco, Walthen, and Miller Ditches head on Woody Creek below the mouth of Collins Creek, while the Natal, Collins Creek Extension, and Paradice Ditches head

on Woody Creek above the mouth of Collins Creek. This means that ditches diverting out of Collins Creek are directly subject to senior rights in the Waco, Walthen, and Miller Ditches, but have no direct relationship to rights in the Natal, Collins Creek Extension, or Paradice Ditches, except for the determination of which junior priorities will be shut off first to supply senior rights in the Waco, Miller, and Walthen Ditches whenever stream flow is insufficient to supply all rights.

There are two priorities in the Salvation Ditch out of the Roaring Fork River: No. 218A for 58.0 second-feet, granted by a decree of January 21, 1905; and No. 429 for 38.5 second-feet, granted by the decree of August 25, 1936. Although these priorities are used partially on lands in Woody Valley, they have no relationship to the priority system on Woody Creek and its tributaries, since they are diverting water from the Roaring Fork River.

Water-supply classification of ditches.--Water-supply classification presents a special problem in the case of Woody Valley because of the lack of data pretaining to the use of water from Salvation Ditch. No attempt was made in the field to locate the lands to which Salvation Ditch water is applied, either as a basic supply or as a aupplemental supply. Moreover, the amount of water actually delivered by the Salvation Ditch to the Woody area

is unknown because the seepage and evaporation losses of this 10-mile ditch are unknown. On the basis of priority and amounts of water diverted, the Salvation Ditch would have an A-1 classification. Because of the present condition of the ditch and its structures, however, it is doubtful whether the amount of water delivered is great enough to qualify for anything higher than a B-2 or, at the most, an A-2 rating.

There is a heavier concentration of potatoes in Woody Valley than in many other localities in the Roaring Fork Basin. Moreover, if water is available, a third cutting of alfalfa is usually possible. Both of these situations mean that more water is required per acre during July and August than in some of the other areas covered in this report. Consequently, for this study, the time requirements for the various water-supply classifications were extended 15 days to accommodate this greater need for late-season water, as follows:

A-1 1 second-foot per 60 acres until August 1, with 1 second-foot per 120 acres thereafter.

B-1 1 second-foot per 60 acres until August 1, but inadequate supply thereafter.

C 1 second-foot per 60 acres until July 15, but inadequate supply thereafter.

D 1 second-foot per 60 acres until July 1, but inadequate supply thereafter.

E 1 second-foot per 60 acres until June 15, but inadequate supply thereafter.

On the basis of water supplies out of Woody Creek and tributaries alone (i.e., ignoring the effect of the Salvation Ditch), four ditches serving 920 acres would have an A-1 rating and one ditch serving 150 acres would have a B-1 rating (Table 17). All other ditches would be seriously short of late-season water, with ratings ranging from Class C to Class E.

Supplemental water required for a full supply.--The amount of water that would be required in addition to amounts now received from Woody Creek and tributaries to give all lands under the various classes of ditches a full supply is estimated as follows:

	Acres	Acre-feet per acre	Total acre-feet
Four ditches with Class A-1 supply	920	0	0
One ditch with Class B-1 supply	150	0.5	75
Three ditches with Class C supply	90	1.0	90
Four ditches with Class D supply	285	1.5	425
Two ditches with Class E supply	60	2.5	150
Lands under Salvation Ditch which do not receive water from other ditches	965	3.5	3,375
New lands (USBR Class 2)	190	3.5	665
TOTAL	2,660		4,780

These estimates, of course, assume full use of water from Woody Creek and tributaries whenever and wherever possible and use of no water from Salvation Ditch.

Table 17.--FACTORS INFLUENCING CROP PRODUCTION ON LANDS UNDER VARIOUS DITCHES IN WOODY CREEK PROJECT AREA.

Name of ditch	Acres irrigated[1]	Water supply classification[2]	Crop production and yields[3]	Description of land and soils: Average elevation (feet)[3]	Topography[3]	Predominant type of soil[3]	Natural drainage[3]
Waco	450	A-1	Very good	7,400	Medium slopes	Reddish brown silt loam to sandy clay loam, good depth.	Good
Walthen & Miller[4]	260	A-1	Fair to good	7,300	Gentle to medium slopes	Reddish brown loam, of fair depth	Fair to good
Paradice	150	B-1	Fairly good	7,500	Gentle to medium slopes	Dark brown to reddish brown silt loam to sandy clay loam, good depth	Good
Natal[5]	15	D	----	----	----	----	----
Little Woody	50	A-1	Very good	7,200	Gentle to medium slopes	Reddish brown loam, deep and productive	Good
Williams	5	C	Good	7,200	Gentle slopes	"	Adequate
Tierney	10	C	Good	7,200	Gentle slopes	"	Adequate
Clavel	75	C	Fair to good	7,400	High, sloping land in scattered tracts	"	Good

Table 17.--FACTORS INFLUENCING CROP PRODUCTION ON LANDS UNDER VARIOUS DITCHES IN WOODY CREEK PROJECT AREA.--Continued.

Name of ditch	Acres irrigated[1]-con.	Water supply classification[2]-con.	Crop production and yields[3]-con.	Description of land and soils: Average elevation (feet)[3]-con.	Topography[3]-con.	Predominant type of soil[3]-con.	Natural drainage[3]-con.
D'Avignon and Scott	150	D	Good	7,500	Slopes are quite steep	Reddish brown loam, deep and productive	Good
Martin Scott	20	E	Fair to good	7,500	Slopes are quite steep	"	Good
Harmon	40	E	Fair	7,400	Medium slopes	"	Good
Collins Creek	160	A-1	Good	7,400	Gentle to medium slopes	Dark brown clay loam, of good depth	Adequate
Cerise	80	D	Fair	7,700	Steeply sloping hillsides	Reddish brown sandy loam, of fair depth	Good
Bionaz	40	D	Fair	7,700	"	"	Good
Salvation	[6]1,200	[7]A-1	Variable	7,500 to 7,800	Most of land has medium slopes	Highly variable but predominant types are brown to reddish brown sandy loam to silt loam, 1½ to 5 feet deep. Considerable portion is underlain with cobbles.	Good

Table 17.--FACTORS INFLUENCING CROP PRODUCTION ON LANDS UNDER VARIOUS DITCHES IN WOODY CREEK PROJECT AREA.--Continued.

[1]Compiled from annual reports of Water Commissioner and 1936 land-classification survey of U. S. Bureau of Reclamation.

[2]See text.

[3]From data supplied by Engineer-Appraiser, Federal Land Bank of Wichita.

[4]Includes 10 acres under Miller Ditch, which may also be irrigated from Walthen Ditch.

[5]This ditch was not viewed in the field. The Water Commissioner has not listed this ditch in his annual report for several years and it is not definitely known whether this ditch is still in operation. It is thought, however, that this ditch serves several small patches of hay meadow at the upper end of Woody Valley.

[6]Partial duplication between this figure and those given for several ditches diverting from Woody Creek and tributaries. See text.

[7]On the basis of priority and amount of water diverted annually, the Salvation Ditch would rate an A-1 classification. Because of the present condition of the ditch, however, it is doubtful whether the amount actually delivered would justify more than about a B-2 or possibly an A-2 rating.

Even at that, these estimates may seem very conservative, especially when compared with amounts actually diverted by Woody Valley ditches in recent years. The annual diversions for the 920 acres under the four Class A-1 ditches out of Woody Creek and tributaries, for example, have averaged 7.8 acre-feet per acre irrigated during the past seven years which is considered to be more than adequate. The 4,780 acre feet of water required annually for the project area, in addition to that supplied from Woody Creek and tributaries, is considerably less than the amounts diverted annually by Salvation Ditch (Table 15). Apparently this area needs a better distribution of water rather than more water. The estimated requirements however, are in terms of water delivered to farm headgate and make no allowance for delivery losses.

A substantial portion of the irrigation water used in the area comes from the Roaring Fork River, through the Salvation Ditch, to Woody Creek Valley to be applied as supplemental water for certain tracts and as original supply for others. The Salvation Ditch Company was organized in 1902 by a group of landowners who realized that Woody Creek was over-appropriated. The diversion point of the ditch constructed is at Aspen, Colorado. The course of the ditch follows the north side of the Roaring Fork Valley, turns east into Woody Valley, crosses Woody Creek

above most of the principal diversions, and ends approximately one-fourth mile beyond the crossing. The end of the Salvation Ditch and the head of the Salvation Extension Ditch, owned by a few stockholders of the Salvation Ditch Company, are the same. The initial capacity of the Salvation Ditch was about 60 second-feet, declining progressively to about 15 second-feet at the head of the Extension Ditch. The main ditch is now being enlarged so that the intake capacity will be 100 second-feet.

Annual diversions from the Roaring Fork River by the Salvation Ditch, as estimated by the Water Commissioner, have varied from 5,500 acre-feet in 1940 to 9,450 in 1944 with an average of 7,610 acre-feet during the seven-year period, 1940-46 (Table 15).

The distribution of the acreage, according to the source of water supply for the Woody Creek Valley and adjacent benchlands is as follows: (see following page)

Table 18.--ACREAGE SERVED BY DITCHES OUT OF WOODY CREEK AND TRIBUTARIES.

Entire supply from Woody Creek and tributaries	1,270
Supplemental supply from Salvation Ditch	235
Total acreage irrigated from Woody Creek and tributaries	1,505
Entire water supply from Salvation Ditch:	
Acreage in Woody Valley	450
Acreage of scattered tracts in Roaring Fork Valley	515
Total irrigated only from Salvation Ditch	965
Total irrigated acreage in the project area	2,470

Only 157 acres of the 2,470 in the project area and only 19 acres of the 190 of non-irrigated, arable land in the area lie above the Salvation Ditch.

Chapter VII

DISCUSSION OF WOODY CREEK PROJECT

It is fairly evident that most of the Woody Creek Valley at present receives an adequate water supply. The 4,780 additional acre-feet estimated to be needed for a full supply in the area, did not include the water brought into the proposed project area by the Salvation Ditch, and did not make allowance for the excessive amounts used under the A-1 rights.

Figuring the minimum annual diversion and the highest probable evaporation and seepage loss, the Salvation Ditch is probably delivering to the irrigation laterals in the Woody Creek Valley at least 3,450 acre-feet, even in the poorest years.

The enlarging of the Salvation Ditch from its present capacity of 60 second-feet to a capacity of 100 second-feet will increase the amount of water delivered to the project area by an estimated 2,500 acre-feet. This estimate is a very conservative one since it was based on a 50 per cent seepage and evaporation loss. While losses by the ditch previously ran somewhere between 40

and 50 per cent, expected losses in the future should be considerably less as a result of the improvements being made in the process of the ditch enlargement.

With a minimum of 3,450 acre-feet being delivered by the Salvation Ditch at present and with an additional delivery rate of 2,500 acre-feet contemplated, this ditch in the future will deliver to the Woody Creek area 5,950 acre-feet of water annually, which is considerably in excess of the 4,780 acre-feet needed to provide a full water supply for the lands in this area.

Having reached this conclusion, the writer felt that no further analysis was necessary. The spending of $170,000 to supply water that is not needed is, to say the least, unfeasible.

Chapter VIII

CAPITOL CREEK PROJECT

The project proposed for the Capitol Creek Valley by the United States Bureau of Reclamation (8) is described in its comprehensive report on the Colorado River, 1946, as follows:

> A new canal 10 miles long would be required to bring water from Snowmass Creek to 2,000 acres of grass lands now insufficiently irrigated from Capitol Creek. Both Snowmass and Capitol Creeks flow northeast and converge before joining Roaring Fork at Snowmass, 12 miles downstream from Aspen. (8:131)

The estimated cost of the project is $130,000 at January 1, 1940, prices and $208,000 at 1946 prices. (8:4,6)

Description of the area

Capitol Creek rises in Capitol Lake (elevation about 11,000 feet) which is situated on the north slope of the Elk Mountains approximately 30 miles southeast of Glenwood Springs. Capitol Creek flows in a northeasterly direction for 13 miles, joining Snowmass Creek 1½ miles above its confluence with the Roaring Fork River.

According to the Bureau of Reclamation Land Classification Survey made in 1936, 3,118 acres of crop

and meadow land were irrigated from Capitol Creek and tributaries. 1/ Undoubtedly more land is irrigated now, because (a) a number of small irrigated tracts of mesaland were not included in the survey, and (b) the 82 acres shown by the survey to be Class 2 arable land have been brought "under the ditch" since that time. The total number of acres of crop and meadow land now irrigated by Capitol Creek would probably be in excess of 3,200 acres. In addition at least 200 acres of private range and public land are estimated to be irrigated infrequently from the creek.

The elevation of the project area varies from 7,200 feet at the mouth of the creek to approximately 8,200 feet at the highest irrigated meadow.

The soils, ranging from clays to sandy clay loams, are vary heavy and very retentive of moisture. Nevertheless, very few drainage problems have been encountered because of the steep slopes and well-defined surface drainage. (See table 19 for a more detailed description of lands and soils under each ditch.)

Type of farming.--The principal type of farming is hay-livestock ranching. Nine of the 17 ranches in Capitol Valley run both cattle and sheep, three run only

1/ Figure 6, Appendix B.

Table 19.--FACTORS INFLUENCING CROP PRODUCTION ON LAND IRRIGATED FROM DITCHES DIVERTING FROM CAPITOL CREEK.

Name of ditch	Acres irrigated[1]	Water supply classification[2]	Crop production and yields[3]	Description of land and soils			
				Average elevation (feet)[3]	Topography[3]	Predominant type of soil[3]	Natural drainage[3]
Williams No.2	150	A-1	Fair yields of hay	7,200	Gently sloping meadow land	Brown clay loam, very shallow, underlain with gravel	Poor to fair[4]
Boran & White	275	A-1	Fairly good	7,300	Fairly level mountain meadow land	Brown clay loam, very shallow, underlain with gravel. Gravel wash containing large boulders is strewn over much of the area	Fair to good
Williams No.1	350	A-1	Fair	7,200	Medium to gently sloping	Sandy clay loam, shallow, underlain with gravel	Poor to good[5]
Green Meadow[6]	750	A-1	Fair	7,400	Sloping hillsides to gently sloping meadowlands	Highly variable, from medium light loams to rather shallow, heavy gray clay	Poor to good[7]
Capitol Park	125	A-1	Fair	7,500	Medium to gently sloping mountain parks	Reddish brown sandy clay loam, of shallow depth	Adequate

Table 19.--FACTORS INFLUENCING CROP PRODUCTION ON LAND IRRIGATED FROM DITCHES DIVERTING FROM CAPITOL CREEK.--Continued.

Name of ditch	Acres irrigated[1]--con.	Water supply classification[2]--con.	Crop production and yields[3]--con.	Description of land and soils: Average elevation (feet)[3]--con.	Topography[3]--con.	Predominant type of soil[3]--con.	Natural drainage[3]--con.
Horgan	120	B-1	Fair	7,400	Medium slopes	Soil is shallow with large boulders scattered over the area	Adequate
Williams No.3	50	[8]A-1	Fair	7,100	Sloping valley land	Soil is shallow and somewhat rocky	Adequate
McPherson No.1	200	B-1	Fair	7,400	Gently to medium sloping valley lands	"	Good, for most of area
Hughes	180	B-1	Poor	7,500	Medium to steeply sloping	Dark gray, disintegrated shale, which is unproductive	Adequate
Maurin	250	B-2	Fair	7,400	Gently to medium sloping valley lands	Soil is shallow and rocky; surface is strewn with large boulders	Adequate

Table 19.--FACTORS INFLUENCING CROP PRODUCTION ON LAND IRRIGATED FROM DITCHES DIVERTING FROM CAPITOL CREEK--Continued.

Name of ditch	Acres irrigated[1]-con.	Water supply classification[2]-con.	Crop production and yields[3]-con.	Description of land and soils			
				Average elevation (feet)[3]-con.	Topography[3]-con.	Predominant type of soil[3]-con.	Natural drainage[3]-con.
Capitol Falls	150	B-1	----	7,800	Medium to steeply sloping	----	Adequate
Staats-Harmon	60	C	Fair	7,500	Sloping hillsides	Dark brown clay loam of fair depth	Adequate
McCabe	100	B-2	----	7,800	Medium to steeply sloping	----	Adequate
Rowan & Jacobson	100	C	Fair	7,700	"	----	Adequate
Sandy	70	C	----	7,900	"	----	Adequate
Jacobson & Solberg	140	C	Fair	7,400	Gentle to medium slopes	Meadow and pasture land	----
Desert and Lime Creek	225	C	Poor to fair	7,500	Sloping hillsides to gently sloping	Dark gray clay to clay loam of fair depth	Adequate for meadow hay

Table 19.--FACTORS INFLUENCING CROP PRODUCTION ON LAND IRRIGATED FROM DITCHES DIVERTING FROM CAPITOL CREEK--Contined.

Name of ditch	Acres irrigated[1]-con.	Water supply classification[2]-con.	Crop production and yields[3]-con.	Description of land and soils			
				Average elevation (feet)[3]-con.	Topography[3]-con.	Predominant type of soil[3]-con.	Natural drainage[3]-con.
Watson	35	D	Fairly good	7,400	Gently sloping meadow land	-----	Adequate for meadow hay

[1]Compiled from annual reports of Water Commissioner and the 1936 land-classification survey of the U. S. Bureau of Reclamation.

[2]See text.

[3]From data supplied by Engineer-Appraiser, Federal Land Bank of Wichita.

[4]Because of soil and drainage conditions, much of the land is suited only to production of grass hay. Artificial drainage recently was installed by the landowner on the wettest part of this meadow.

[5]Drainage is good in the upper part of the area, but in the lower part, the water table is so high that the land is used only for hay.

[6]Includes data for lands under Little Elk and Light Seepage Ditches.

[7]Drainage is good on sloping lands. Water table is so high on the bottom lands that only hay is raised.

[8]Water supply of this ditch is much better than its priorities would indicate because it is the lowest ditch on the creek and gets full benefit of return flow.

sheep and one runs only cattle. The sheep bands of these ranches are run together in a "summer pool" for grazing on the National Forest. For both cattle and sheep most of the summer range is on the National Forest, and winter pasture is on deeded range land and meadow aftermath. For a number of years, the Forest Service has followed a consistent policy of reducing the size of the permits. Because of this, many ranchers have become interested in the possibilities of irrigated range, both Federal and private, as an alternative to reducing herds in accordance with reduced permits.

The most important irrigated crop is hay. All available data indicate that about 85 or 90 per cent of the irrigated acreage in Capitol Valley is in hay and pasture. There is a small acreage of wild hay and alfalfa, but about two-thirds of the hay acreage is composed of timothy and clover, which are preferred to alfalfa because of the tendency of the latter to winter-kill at this elevation. Only one cutting of alfalfa, timothy or clover is possible, even in the lower, more favorable exposed sections of Capitol Valley. About 10 to 12 per cent of the irrigated acreage is in cereal grains, principally oats, with only a few acres in spring wheat and barley. A large part of the oats is cut for hay. Only an insignificant acreage of potatoes is raised most years because of the high risks from hail and frost. Table 20 gives the distribution of

crops for the years 1940 through 1946.

Table 20.--CROP DISTRIBUTION AND AREA IRRIGATED OUT OF CAPITOL CREEK, 1940 TO 1946.[1]

Year	Hay and pasture	Cereals	Potatoes	Total irrigated
	Acres	Acres	Acres	Acres
1940	3,740	575	5	4,320
1941	3,925	495	0	4,420
1942	3,585	540	60	4,185
1943	3,395	360	30	3,785
1944	4,250	385	40	4,675
1945	4,100	655	20	4,775
1946	4,320	470	0	4,790
Average	3,902	497	22	4,421

[1]Compiled from field books of the Water Commissioner, which are filed with Divisional Engineer, Glenwood Springs, Colorado. These figures are undoubtedly excessive because of the manner in which they are compiled.

Water supply of Capitol Creek.--Because of the high average elevation of the watershed, the water yield per square mile of drainage area is very high, possibly as much as 1,500 acre-feet or more on the average. Moreover, because of the northerly exposure and high elevation, the spring flood-flow extends over a longer period than do those of the other important creeks in the Roaring Fork Basin.

There are no gaging stations on Capitol Creek,

and consequently no specific data available on stream flow. Some idea of the general quantity of the water supply may be gained from the amounts diverted, as estimated by the Water Commissioner in his reports to the Division Engineer. According to these data, the average amount of water diverted by all ditches has varied from 4.1 acre-feet per acre in 1940 to 5.7 acre-feet per acre in 1942, with an average of 5.0 acre-feet per acre for the seven-year period, 1940-1946 (Table 21).

The accuracy of the Water Commissioner's estimates is questionable. His estimates are based upon infrequent visits to the area, incomplete diversion records, and inadequate measuring devices on some of the ditches.

In spite of inaccuracies, there is a reasonably close correlation between the amounts of water diverted annually and the relative amount available in the creek, as indicated by the winter and spring precipitation at Aspen, Colorado, the nearest weather station (Table 21). Thus, for the area as a whole, it would seem that the Water Commissioner's estimates are at least fairly consistent from year to year.

Direct-flow rights.-- The various priorities of the 22 ditches diverting out of Capitol Creek and its tributaries are shown in table 22. The initial water

Table 21.--DIVERSIONS FROM CAPITOL CREEK AND OCTOBER-JUNE PRECIPITATION AT ASPEN, 1940 TO 1946.

Year	Total amount of water diverted[1]	Average amount per acre irrigated[2]	Precipitation, October through June, at Aspen[3]
	Acre-feet	Acre-feet	Inches
1940	14,050	4.1	9.17
1941	16,690	4.9	14.66
1942	19,815	5.8	15.33
1943	19,505	5.7	19.87
1944	17,455	5.1	12.31
1945	17,160	5.1	12.25
1946	15,030	4.4	11.77
1947			19.04
Average	17,100	5.0	13.62

[1] Compiled from field books of Water Commissioner which are filed with Divisional Engineer, Glenwood Springs, Colo.
[2] Assuming 3,400 acres irrigated each year; i.e., 3,200 acres of crop and meadow lands and 200 acres of range land.
[3] Compiled from "Climatological Data, Colorado Section", U. S. Weather Bureau, Denver, Colorado.

decrees on Capitol Creek were made at the rate of one second-foot per 50 acres of irrigated land. The first 25 priorities were granted on this basis and total 102.41 second-feet. The next six priorities were flood-rights (totaling 26.71 second-feet) granted by the 1936 general adjudication in order to bring diversion rates up to 25 acres per second-foot.

The three priorities on Lime Creek, which enters Capitol Creek about half-way up the valley, are subject

Table 22.--ADJUDICATED WATER RIGHTS ON CAPITOL CREEK, IN ORDER OF PRIORITY.

[Compiled from records in the office of Divisional Engineer, Glenwood Springs, Colorado.]

Priority order on stream	Name of stream and ditch	Water district priority number	Date of decree	Amount of appropriation (second-feet)
	Capitol Creek:			
1	Williams No.2 (orig.)	01	6-21-02	6.00
2	Boram & White (orig.)	9	5-11-89	2.50
3	Williams No.1 (orig.)	14A	6-21-02	15.00
4	Green Meadow (orig.)	33A	6- 2-02	17.44
5	Capitol Park (orig.)	41	5-11-89	2.50
6	Boram & White (1st enl.)	57	5-11-89	2.60
7	Capitol Park (1st enl.)	62	5-11-89	2.50
8	Horgan (orig.)	85A	4-28-03	3.00
9	Williams No.3 (orig.)	107A	6-21-02	1.00
10	McPherson No.1 (orig.)	160A	11-10-02	7.60
11	Boram & White (2nd enl.)	174A	3-18-04	1.00
12	Hughes (orig.)	203A	4-30-03	4.00
13	Maurin (orig.)	204A	11-10-02	3.00
14	Hughes (transfer)	210AAAA	11-15-15	7.20
15	Staats-Harmon (orig.)	210AAAB	5-29-17	2.33
16	Capitol Falls (transfer)	212A	11-17-02	4.00
17	McCabe (orig.)[1]	212A	11-17-02	0.80
18	Rownan & Jacobson (orig.)	213BBB	4-11-04[2]	0.80
19	Capitol Falls (orig.)	214AA	5-31-05	2.00
19	Capitol Falls (additional)	214AA	3-19-17	4.18
20	Rownan & Jacobson (1st enl.)	217A	4-11-04[3]	0.10
21	Desert (orig.)	219D	3-21-17	3.96
22	Sandy (orig.)	--	4- 2-18	3.40
23	Jacobson & Solbert (orig.)	266	10-10-31	2.80
24	Maurin (1st enl.)	270	10-30-33	2.70
25	Capitol Falls (flood right)	412A	8-25-36	6.00
26	Maurin (flood right)	412B	8-25-36	5.10
27	Desert (flood right)	412D	8-25-36	1.71
28	Horgan (flood right)	412E	8-25-36	3.00
29	Boram & White (flood right)	412F	8-25-36	10.00
30	Williams No.3 (flood right)	412G	8-25-36	0.90

Table 22.--ADJUDICATED WATER RIGHTS ON CAPITOL CREEK, IN ORDER OF PRIORITY.--Continued.

[Compiled from records in the office of Divisional Engineer, Glenwood Springs, Colorado.]

Priority order on stream-con.	Name of stream and ditch-con.	Water district priority number-con.	Date of decree-con.	Amount of appropriation (second-feet)-con.
	Lime Creek:[4]			
1	Lime Creek (orig.)	40	5-11-89	1.00
2	Watson (orig.)	265	10-10-31	1.50
3	Lime Creek (flood right)	412C	8-25-36	2.56
	Little Elk Creek:[5]			
1	Light Seepage (orig.)	72A	3-18-04	1.40
2	Little Elk (orig.)	143	3-18-04	0.80
3	Little Elk (1st enl.)	207A	3-18-04	2.44
4	Little Elk (2nd enl.)	310	8-25-36	0.26

[1]Headgate is on Falls Creek, an upper tributary of Capitol Creek. Inasmuch as there are no headgates on Capitol Creek above the confluence with Falls Creek, this priority is subject to all senior priorities on Capitol Cr.

[2]There is also a conditional decree for 1.2 second-feet with this priority which has never been made final.

[3]There is also a conditional decree for 0.9 second-feet with this priority which has never been made final.

[4]These priorities are subject to senior priorities of Boram & White and the Williams No.1, No.2, and No.3 Ditches, the only ditches which divert from Capitol Creek below the confluence with Lime Creek.

[5]These priorities are not a charge on Capitol Creek, because the confluence is below all headgates on Capitol Creek except that of the Williams No.3 headgate to supply its senior priority of 1 second-foot. The Light Seepage and Little Elk Ditches supply water to a meadow, the main supply of which is from a lateral off of the Green Meadow Ditch.

to the senior rights of the Boram & White and the Williams No. 1, No. 2, and No. 3 Ditches. The four priorities on Little Elk are not a charge on Capitol Creek because the confluence of the two creeks is below all of the headgates on Capitol Creek except that of the Williams No. 3 Ditch which is one of the smallest ditches in the valley.

The total of all water rights in Capitol Creek Valley is 129 second-feet. There are only a few weeks during the irrigation season when there is this amount of water in the stream, but because of the return flow, most of the ditches can and do divert water at their maximum rates for a considerable period after the stream flow drops below 129 second-feet. The return flow, which is quite large due to the steep slopes, well-defined drainage channels, and close proximity of the irrigated tracts to the main stream, can be utilized to the maximum by the ditches in the valley because of their scattered position along the streambed. Consequently the evaluation of individual water rights is based not only on the relative priority of rights but also on the location of the diversion points of the ditches.

Any water draining into Little Elk and East Sopris Creeks is lost to the valley. One of these streams has a confluence with Capitol Creek below all ditch diversions, and the other stream drains into another valley.

Unfortunately, some of the senior rights on the Creek with diversion points in the upper part of the Capitol Valley irrigate lands that drain into either Little Elk and/or East Sopris Creek. For example, the Green Mountain Ditch, the largest ditch in the valley, with a diversion point that is one of the highest in the valley, has an early priority and irrigates lands that drain into both of these streams. A large part of the return flow from the Rowan and Jacobsen, Sandy Ford, McPherson No. 1, and Maurin Ditches drains into Little Elk.

Another effect upon water supply by location of diversion points is illustrated by the Desert, Hughes, Staat-Harmon, and Capitol Park Ditches. These ditches divert water fairly high in the valley, but irrigate lands which drain into Lime Creek, whose confluence with Capitol Creek is about three-fourths of the way down the valley. As a result, all medium, early, and late priorities in other ditches taking out of Capitol Creek above the confluence with Lime Creek are deprived of return flow from those ditches first named. These priorities, then, are somewhat poorer rights than their priority numbers would indicate.

Irrigation practices in Capitol Creek Valley.--The irrigation season normally begins about May 15 to June 1 for most ditches. The opening date varies

from ditch to ditch, depending primarily upon the elevation of the lands served by the ditch. Water is first applied to the hay meadows and is available in large quantities because the creeks are in flood at this time of the year. Depending upon the opening date of the ditches, water is next applied about the middle of June either to the hay meadows again, or to the irrigation of cereals. If the ditches are late in opening, the second irrigation of hay meadows follows that of cereals. Except in very dry years, only one irrigation of cereals is necessary. Since stream flow has been dropping throughout June, the third irrigation of hay requires more time than the first two. The haying season starts sometime between the middle and end of July. As soon as the hay is off, whatever water is still available is turned back on the meadows to produce fall grazing.

Water-supply classification of ditches.--The water-supply classification of the various ditches is given in table 19. It should be noted that of the 3,400 acres irrigated, 1,700 acres (49.6 per cent) was given an A-1 classification and 650 acres (20 per cent) was given a B-1 classification.

From these data it may readily be seen that only 1,080 acres (30 per cent) are in need of much supplemental water for irrigation. Because of the irrigation

practices followed in the valley even this acreage has enough water for hay and cereals, although frequently it does not have enough water for meadow aftermath and pasture after haying season.

Two ditches, serving 350 acres (11 per cent of the irrigated acreage), were classified as B-2 because they lack sufficient water for the acreage they serve, although they receive sufficient amounts of water through most of the irrigating season.

Five ditches, serving 595 acres (18 per cent of this irrigated acreage) were given a water supply classification of C. These ditches normally have ample water until the last of June or the first week in July, but are short of water thereafter. Operators under these ditches stated that although they could use some additional water in most years, they have experienced serious water shortages, on an average, in only one or two years out of ten.

The only ditch given a water classification of D was the Watson, which diverts out of the lower section of Lime Creek to serve 35 acres. There is usually more than enough return flow in Lime Creek at the ditch's diversion point to satisfy this priority. Although this water could be demanded by senior appropriators diverting in the Lower Capitol Valley, it seldom, if ever, is

demanded because of the small amount of water involved and because of the insignificant consumptive use. As a result the Watson Ditch actually receives more water than the D classification would indicate.

Need for supplemental water.--It will be seen from the above discussion that most of the ditches diverting from Capitol Creek can divert some water, at least, throughout the season, even in years of low stream-flow. During the 1946 season, for example, both water diversions and water supply, as indicated by the October-June precicitation at Aspen, were way below average (Table 21), yet all ditches operated well into the fall season. Moreover, there were no notations in the Water Commissioner's field book which indicated that any of the headgates had to be closed during the critical part of the season, namely, the few weeks just prior to haying.

In fact, from data in the annual field books, the Water Commissioner has had to close down headgates only twice during the past 8 years. Both of these occurred during July of 1943, which will be noted was a year of very heavy diversion (Table 21). Apparently, the spring run-off came earlier than usual that year as a result of heavy rains during May. From June 3 to July 30, 1943, was a prolonged drought period, during which time all water users attempted to divert as much water as possible, with little or no thought to priorities and rights of others.

The Commissioner closed down the Morgan headgate completely on July 24 and reduced the discharge of the Capitol Falls headgate from 8.0 second-feet to 3.0 second-feet. The situation was relieved by heavy rains during August, 1943, and all ditches resumed diversion freely.

The principal supplemental-water needs of Capitol Valley, then, are for relatively small amounts per acre during July and August to supplement stream flow and precipitation for pastures and meadow aftermath. Large amounts of supplemental water for hay and grain are not needed, except for a very limited area.

The estimated amounts of additional water needed for the various groups of ditches to bring them up to a full supply is as follows:

	Acreage irrigated	Acre-feet per acre	Total acre-feet
Capitol Valley:			
Six ditches with Class A-1 supply	1,700	0	0
Four ditches with Class B-1 supply	1,650	0.25	165
Two ditches with Class B-2 supply	350	0.50	175
Five ditches with Class C supply	595	0.60	360
One ditch with Class D supply	35	1.00	35
Total, Capitol Valley			735

Construction costs.--The Bureau of Reclamation's report (8:4,16) published in 1946, stated that the con-

struction costs of the project would be $130,000 at 1940 prices and $208,000 at 1946 prices. This is an average construction cost of $190.49 per acre-foot needed for a full water supply for the area based upon 1940 costs and $282.99 based upon 1946 costs. If the construction costs (1940 costs) were paid without interest over a 40-year period on a contract similar to those used on United States Reclamation projects, the annual costs to the water users would be $4.42 per acre-foot of water delivered and needed, or, if all of the land shared all of the construction costs proportionately, the annual cost per acre of irrigated land would be $0.95.

This report did not include any information on maintenance and operation costs, but since a canal 10 miles long in the high mountains would be subject to many slides, washouts, etc., it seems logical to assume that these costs would be high. Because of lack of specific data, the writer did not attempt to make estimates on these costs.

Chapter IX

DISCUSSION OF THE CAPITOL CREEK PROJECT

Economic feasibility of the project

The need for additional water for supplemental irrigation in the Capitol Creek Valley is minor. With only 1,730 acres out of the 3,430 acres of crop land requiring any additional water, it is fairly evident that those ranchers who already have an adequate supply of water are not going to be interested in the proposed irrigation project. If these ranchers refused to "come into the project", the annual proportional repayment cost per acre of irrigated land would increase from $0.95 per acre to $1.88 per acre for construction costs alone.

The total construction costs (1940 costs) per acre within the project would be $65.00. If only the 1,730 acres under the Class B, C, and D ditches were included, the construction cost per acre would increase to $75.14. This cost, compared with the value of land in the area, indicates that the economic feasibility of the project is questionable. Good hay-meadow lands with A-1 water rights have been selling for $90 to $95 per acre in

recent years and these prices are considered, locally, to be highly inflated. The long-time average value per acre is in the neighborhood of $45. Obviously to be feasible the project cost per acre must be less than the long-time cost per acre of land with a full water supply.

If the operation and maintenance costs were estimated at $1,000 annually, which seems ridiculously low for a 10-mile ditch in a high mountain region, the annual costs on an acre-foot basis and on a proportionate value basis per irrigated acre for 1,730 acres, would be those given below.

Table 23.--ESTIMATED ANNUAL WATER COSTS ON THE CAPITOL CREEK PROJECT.

	Total annual cost	Acre-foot	Proportionate cost per acre irrigated
Construction	$3,250	$4.42	$1.88
Operation and maintenance	1,000	1.36	.58
Total	$4,250	$5.78	$2.46

In an area where hay production averages approximately 1.3 tons to the acre, the water users under the Class B ditches could not expect any increase in their hay production and the water users under the Class C rights

could reasonably expect only 0.2 to 0.3 tons increase to the acre. In an area where the average county price for hay is $8.75 per ton, during the six year period, 1939-45, the small increase in hay production would not pay for the cost of the water. 1/

There would be no appreciable increase in grain yields in the valley because there is adequate water available during the period that the grain is irrigated. Consequently the grain acreage would have little or no ability to pay additional irrigation costs.

In every case the 1940 costs of the proposed project were used in the analysis. If the costs were increased to the estimated 1946 figure, the benefit-cost ratio would be even more unfavorable.

Suggestions for further study

The writer feels that the proposed Capitol Creek Project might be made economically feasible by extending it to include two additional areas, Sopris Valley and the Elk Creek Basin.

Sopris Valley, which lies northwest of Capitol Valley, is chronically short of water. A number of years ago, a group of water users in Sopris Valley started con-

1/ "Prices Received by Farmers in Each County of Colorado for Principal Crops", Colo. Agr. Expt. Stat. mimeo. bull., May 1949, Table 36, Appendix A.

struction on a ditch that would permit the diversion of water from Capitol Creek into the Sopris watershed. The project was subsequently abandoned because of the lack of available water in Capitol Creek. Probably it would not be a difficult matter to extend the Capitol Creek Project to serve Sopris Valley. An additional ditch about three miles long from Capitol Creek to Sopris Valley required for this new diversion could be easily constructed and at a much lower cost per mile than the proposed 10-mile service canal, making the cost per unit for the entire new 13 miles less than for the proposed 10 miles.

Undoubtedly, the proposed service canal would be able to provide irrigation water for two ditches diverting water out of Elk Creek, a tributary of Snowmass Creek. No data are presently available as to the acreage which might be newly irrigated in Sopris Valley. It should be over 2,000 acres.

The writer suggests that, since the addition of these two units might place the entire project in the "economically feasible" classification, further study might be made along these lines.

Chapter X

CATTLE CREEK PROJECT

The project proposed for the Cattle Creek Valley by the Bureau of Reclamation (8) is described in its comprehensive report on the Colorado River, published in 1946, as follows:

> Only storage would need to be provided to irrigate 900 acres of new land and to furnish 5,500 acres with supplemental water. The lands are located along Cattle Creek, which flows westward to join Roaring Fork, 9 miles above Glenwood Springs. The off-stream Missouri Heights Reservoir of 2,800 acre-feet capacity could be enlarged to a capacity of 9,000 acre-feet and filled by an enlargement of its 2-mile feeder canal from Cattle Creek. (8:131)

The estimated cost of the project was $430,000 at January 1, 1940 prices, and $688,000 at January 1, 1946 prices. (8:4,16)

Description of the area

The project area lies 14 miles south and east of Glenwood Springs, Colorado. Most of the irrigated land in this proposed project area does not lie along the main valley but rather on a mesa, Missouri Heights, to the south of Cattle Creek Valley.

The headwaters of Cattle Creek rise on the western slope of Red Table Mountain at an elevation of approximately 11,000 feet and the stream flows for 23 miles in a westerly direction to join the Roaring Fork River 6½ miles above Glenwood Springs. Five small tributaries enter Cattle Creek from the north. These tributaries rise on the southern slopes of a relatively low range known locally as Cottonwood Divide. Fisher's Branch, the lowest of these tributaries, is about five miles long and joins Cattle Creek five miles from its mouth. Mesa Creek, also five miles long, joins Cattle Creek six miles from its mouth. West Coulter, four miles long, and East Coulter, seven miles long, join to form Coulter Creek, which in turn flows slightly over a mile south to join Cattle Creek approximately seven miles above its mouth. Shippee Run, the smallest of the five tributaries, is three and one-half miles long and flows in a southwesterly direction to a confluence with Cattle Creek less than a mile above the mouth of Coulter Creek.

According to the 1936 land-classification survey of the Bureau of Reclamation, the irrigated and non-irrigated irrigable acreages in the entire area are as follows: 1/

1/ Figure 6, Appendix B.

	Irrigated acreage	Irrigable acreage
Under ditches out of Cattle Creek in Cattle Creek Valley	286	226
Under ditches out of northern tributaries	1,466	809
Missouri Heights	4,040	532
Total under ditches out of Cattle Creek and tributaries	5,792	1,301

Twenty-eight acres of the non-irrigated irrigable acreage in Cattle Creek Valley were rated as Class 1. All other irrigable lands were rated as Class 2.

To facilitate further analysis, the term Missouri Heights as used in the above will not only include the Missouri Heights proper but also certain lands under the Park, Eureka No. 1, Sweede, Sommers and the C. & L. High-line Ditches that lie to the north and west of the Heights area itself.

Missouri Heights.--Missouri Heights has an elevation ranging from 7,000 to 8,200 feet and has a growing season of approximately 135 days. The principal soils of the area are a reddish brown clay loam and a reddish brown silty clay loam of good depth and productivity.

History of Spring Park Reservoir Project.--The Mountain Meadow Ditch was constructed in 1905 as a partner-

ship ditch by a small group of landowners on Missouri Heights. The original capacity of the ditch was about 36 second-feet. In 1911, the Carbondale Reservoir and Irrigation Company was organized to construct the Spring Park Reservoir, which is also known as the Missouri Heights Reservoir. The company enlarged the Mountain Meadow Ditch to a capacity reported to be about 90 second-feet as a feeder ditch for the reservoir. In return for the ditch right-of-way, the company guaranteed perpetual delivery of direct-flow water due the Mountain Meadow right holders free of charge. Apparently, the original plans for the Spring Park Reservoir called for an eventual capacity of 25,000 acre-feet. The dam, however, was constructed to a maximum height of only 27 feet. On the basis of the blue prints of the survey, filed with the State Engineer in 1911, a 27-foot dam would result in a reservoir capacity of 2,823 acre-feet, if allowance is made for the necessary freeboard. This is also the adjudicated capacity of the reservoir, granted by the 1918 decree. This decree also granted a direct-flow priority of 40 second-feet out of Cattle Creek for lands under the reservoir project. Both appropriations relate back to December 28, 1911.

At the time the Spring Park Reservoir was constructed, a large portion of the land to be served by the

project was government owned. The Carbondale Reservoir and Irrigation Company sold "water rights" to entrymen for this land; each "right" being the amount of water deemed necessary for 40 acres, namely, 40 acre-feet of reservoir water delivered to laterals from the reservoir outlet canal and four-sevenths of a second-foot of the 1911 direct-flow priority. Some water rights also were sold for lands which already had direct-flow rights in the Monarch, Mountain Meadow, and Needham Ditches.

The water-right contracts and water-right deeds provided that the reservoir company would operate the project, maintaining all facilities in good working order, until 75 per cent or more of the reservoir capacity has been sold. The actual operation and maintenance cost for this service was to be assessed annually against the purchasers of the reservoir rights, with the limitation that these assessments were not to exceed $40 per right, i.e., $1 per acre, annually. Whenever 75 per cent or more of the reservoir capacity was sold, the reservoir company agreed to deed over to the right holders--or to a mutual company organized by the right holders--the reservoir, canals, water rights, and accompanying assets.

One of the basic weaknesses of the Spring Park Reservoir Project is the fact that not enough water was allowed per acre in the original planning. The 1911

direct-flow priority is little more than a flood right, which is available only during the period when the reservoir is being filled. The inlet ditch, as will be shown later, lacks sufficient capacity to fill the reservoir and at the same time to deliver the original direct-flow Mountain Meadow rights and the 1911 enlargement direct-flow rights. It now appears that the project should have been set up for at least twice as much reservoir water per acre as was originally planned.

The project has been operated in an informal, haphazard sort of fashion in recent years, with the result that the facilities are in rather poor repair at the present time. Water users continually complain that they do not receive the full amount to which they are entitled. They feel that the careless way in which the project is operated, particularly with respect to storing whatever water is available, is one of the reasons for the chronic water shortage.

On September 25, 1946, a group of landowners representing the Missouri Heights Reservoir Association (an unincorporated association of water users under the project) filed suit against the Carbondale Reservoir and Irrigation Company, alleging that more water rights had been sold in the reservoir than its capacity. They requested that the Court direct the company to convey

the water system to the water users. As a second cause of action, they alleged that the company had collected operation and maintenance assessments at the rate of $40 per right annually, but had failed to keep the reservoir and canal system in good condition and had appropriated a large part of the maintenance funds to its own use, contrary to the terms of the water-right contracts. The plaintiffs requested that the company be forced to give an accounting of the maintenance and operation funds for the previous six years and any unexpended balance be returned to the water users or applied against delinquent assessments.

In its answer and counter-claim, the reservoir company alleged that it had sold only 49¼ rights (1,970 acre-feet), that the actual capacity of the reservoir was as great as its adjudicated capacity (2,823 acre-feet) and, therefore, that it could sell 3.6 additional rights in the reservoir (i.e., rights for 108 acres) before it could be forced to turn the project over to the water users.

Evidence brought out at the trial, although conflicting in minor details, indicates that the actual capacity of the reservoir may be somewhat less than the adjudicated capacity. The number of rights in the reservoir actually outstanding was also a matter of considerable dispute, because of the possible legal effects of delinquent operation and maintenance assessments. The plaintiffs contended that

there are 56.3 rights outstanding, of which 54 rights are definitely attached to specific tracts, 2 rights have never been used, and 0.3 was never located on any particular tract of land although it has been rented out annually to various water users.

When the case is settled it is hoped that the Court will rule on three questions of fact: (a) What is the actual capacity of the reservoir, i.e., what is the actual number of rights outstanding, and, therefore, who holds legal title to the reservoir project? (b) Was there an overcharge on operation and maintenance assessments during the past six years? (c) What disposal should be made of the delinquent assessments?

Types of farming.--The predominant type of farming on Missouri Heights is diversified crop and livestock farming. Twenty-one of the 23 farms contacted in this area were of this type. The chief crops on the diversified farms are alfalfa hay, barley, wheat, potatoes and irrigated pasture. Potatoes, one of the most important cash crops in terms of value, probably account for less than five per cent of the total irrigated acreage. Table 24 gives the acreages of the various crops on 23 farms on Missouri Heights for the year 1947.

The 1947 survey of 23 operating units on Missouri Heights gives a good picture of the type of farming there.

Table 24.--CROP DISTRIBUTION AND LAND USE, 23 FARM UNITS ON MISSOURI HEIGHTS, 1947.

Land use and crops	Acres	In per cent of total irrigated acreage	In per cent of total farm land
Irrigated land:			
Alfalfa hay	1,501	62.3	--
Oat hay	5	0.2	--
Wheat	213	8.8	--
Barley	133	5.5	--
Oats	154	6.4	--
Potatoes	57	2.4	--
Pasture	346	14.4	--
Total irrigated	2,409	100.0	40.8
Non-irrigated crop land:			
Wheat	31	--	--
Alfalfa	51	--	--
Idle and fallow	76	--	--
Total dry cropland	158	--	2.7
Other land[1]	3,337	--	56.5
Total farm land	5,904	--	100.0

[1]Includes farmsteads, waste, and dry pasture.

Two of these units were part-time farms, containing 26 and 30 acres of irrigated land respectively. While all of the other units were full-time farms, most of them were rather small. The size of these units, as measured in acreage irrigated in 1947, ranged from 46 acres to 208 acres, with an average of 105 acres. Only four units irrigated more

than 150 acres.

Less than 41 per cent of the land in these units was irrigated in 1947. Almost three per cent was dry farmed or idle crop land to which no water was applied. All other land in these units, principally grazing land, amounted to 56 per cent (Table 24). Potatoes accounted for only 2.4 per cent of the irrigated acreage, while alfalfa accounted for 62 per cent, cereals for 22 per cent, and irrigated pasture for something over 14 per cent.

Interviews with 14 operators who had been farming the same farms for two or more years showed a distinct shift in crop distribution on these farms between 1946 and 1947. Alfalfa acreage increased 3.8 per cent and irrigated pasture 12.7 per cent while grain acreage decreased 18.5 per cent and potato acreage decreased 46.5 per cent (Table 25).

Livestock enterprises account for a substantial part of the farmers' income in this area. Out of the 23 farms contacted, 11 had beef cattle, eight had sheep, 12 raised hogs, and all but one had some dairy cattle. While the numbers of livestock in each category were small there was evidence that the entire livestock program was well integrated, both within itself and with the cropping program.

The importance of the livestock enterprises will

Table 25.--CROP DISTRIBUTION, 14 FARM UNITS ON MISSOURI HEIGHTS, 1946 AND 1947.

Land use and crops	1946		1947		Per cent change 1946 to 1947
	Acres	Per cent	Acres	Per cent	
Irrigated land:					
Alfalfa hay	947	59.6	983	62.8	+3.8
Oat hay	---	--	---	--	
Wheat	145	9.1	118	7.5	-18.6
Barley	122	7.7	68	4.4	-44.3
Oats	84	5.3	100	6.4	+19.0
Potatoes	56	3.5	30	1.9	-46.4
Pasture	236	14.8	266	17.0	+12.7
Total irrigated	1,590	100.00	1,565	100.00	-1.6
Non-irrigated cropland					
Wheat	6		6		
Alfalfa	--				
Idle and fallow	--				
Total dry cropland	6				
Other land[1]	2,138		2,127		
Total farmland	3,734		3,734		

[1]Includes farmsteads, waste, and dry pasture.

probably increase in the future, judging from the intentions of the operators. Seventeen of the 23 operators plan to increase the size of their livestock operations in the next few years and none of the remainder plan to decrease

their livestock numbers. Eight of the operators plan to increase their number of dairy cows, five plan to increase their number of beef cattle, and seven plan either to add a farm flock of sheep or to expand their sheep flock enterprise. Only one operator plans to expand hog production.

One reason for the increased interest in livestock is the fact that Missouri Heights normally has a considerable surplus of alfalfa. Alfalfa was a leading cash crop in the past but has been declining in importance. Several of the farmers complained of the decreased demand in recent years for hay and gave this as one of the reasons why they were planning an increased livestock program.

The most serious problem encountered by the farmers in increasing the size of their livestock is the lack of available summer pasture. Only two of the operators contacted had Forest Service permits, one for 90 head of cattle and the other for 19 head. The grazing period for these permits is June 10 to October 10. The unit with the larger permit also has a Public Domain permit for 165 animal-unit months. Five operators obtained summer grazing from private landowners during 1947 for small numbers of livestock. The complaints of a considerable number of operators concerning the lack of available range helps to explain the considerable increase in irri-

gated pasture between 1946 and 1947 and the accompanying decrease in potatoes and grain acreage.

Water supply.--The drainage basin area above the uppermost diversion on Cattle Creek is approximately 31 square miles and ranges in elevation from 8,000 to 9,000 feet. Follansbee's(2) report published in 1929 estimated the unit run-off of an acre at this elevation to be 700 acre-feet per square mile of drainage area and the total average annual run-off therefore to be 21,700 acre-feet. The basin elevations of the northern tributaries range from 7,500 to 8,500 feet, which with the prevailing topography and rainfall is too low for the factors developed by Follansbee to be applied. The average unit run-off in these basins is comparatively low, probably not over 400 acre-feet per square mile or approximately 10,000 acre-feet for the basins' combined drainage areas of 25 square miles.

As may be seen from the above estimates the water supply on Cattle Creek and its tributaries is not particularly good. The low elevations and southern exposure of the drainage area means that the run-off is low and of a highly seasonal nature.

Water rights.--The direct-flow rights in the various ditches out of the main stem of Cattle Creek total 152.58 second-feet, of which 149.6 second-feet are original

and enlargement appropriations and 2.98 second-feet are flood rights granted by the 1936 decree (Table 26). In recent years, water-administration officials have recognized only 136.58 second-feet of these appropriations. About 1927 or 1928, the Divisional Engineer ordered the Water Commissioner to reduce Priority No. 217BB of the Mountain Meadow Ditch from 25.6 second-feet to 13.6 second-feet and Priority No. 218B in the C. & M. Ditch from 8 second-feet to 4 second-feet. The Divisional Engineer contended that these adjudicated priorities were excessive and had been obtained by fraud and falsified evidence. Under Colorado law, however, neither the Divisional Engineer nor the Water Commissioner has any authority to reduce the amount of an appropriation. This may be done only by the District Court upon petition presented by other priority holders who feel their rights have been infringed upon by a fraudulent or erroneous appropriation. Moreover, even these protestants may not reopen an adjudication for fraud or error except within four years after the date of the decree. The two disputed priorities were granted by decrees of August 1, 1905, and May 31, 1905, respectively. Consequently, the time for reopening the adjudication expired in 1909. The conclusion, therefore, is that these are now valid appropriations. Although 12 second-feet of Priority No. 217BB and four second-feet of Priority No. 218B

Table 26.--ADJUDICATED DIRECT-FLOW RIGHTS ON CATTLE CREEK AND TRIBUTARIES, IN ORDER OF PRIORITY.

[Compiled from copies of decrees and other records in the office of Divisional Engineer, Glenwood Springs, Colo.]

Priority order on stream	Name of stream and ditch	Water district priority number	Date of decree	Amount of appropriation (second-feet)
	Cattle Creek:			
1	Barger (orig.)[1]	37A	5-11-89	0.50
2	Lewis (orig.)	39	5-11-89	0.60
3	Staton (orig.)	53	5-11-89	1.00
4	Staton (1st enl.)	79	5-11-89	1.00
5	H. C. & L. (orig.)	85	5-11-89	1.40
6	Hueschkel & Chapman (orig.)	97	5-11-89	0.60
7	Needham (orig.)	100	5-11-89	3.00
8	Mason (orig.)	110	5-11-89	1.00
9	Barger (1st enl.)[1]	113	5-11-89	1.00
10	Sommers (orig.)	126	5-11-89	0.20
11	C. & M. (orig.)	128	5-11-89	6.00
12	H. C. & L. (1st enl.)	131	5-11-89	0.10
13	Monarch (orig.)	133	5-11-89	5.00
14	Monarch (1st enl.)	134	5-11-89	5.00
15	Fonder (orig.)	139	5-11-89	0.195
15	Fonder (transfer)	139	5-11-89	0.805
16	Sweedes (orig.)	152	5-11-89	0.50
17	Needham (1st enl.)	163	5-11-89	11.00
18	Mason (1st enl.)	171	5-11-89	1.50
19	Sommers (1st enl.)	175	5-11-89	0.50
20	Hueschkel & Chapman (1st enl.)	193	5-11-89	0.50
--	Dutchman (orig.)[2]	196	5-11-89	[3]6.80
21	C. & L. Highline (orig.)	199	5-11-89	[3]1.40
--	Gregory (orig.)[2]	201	5-11-89	[3]0.90
22	Staton (2nd enl.)	206A	3-18-15	0.20
23	Needham (2nd enl.)	210	3-15-94	2.90
24	Sheaffer (orig.)[4]	113C	12-16-01	1.30
--	R. J. Roberts (orig.)[5]	209AA1	3- 5-10	0.50
25	Mountain Meadow (orig.)	217BB	8- 1-05	[6]25.60
26	C. & M. (C.&F. or 1st enl.)	218B	5-31-05	[7]8.00

Table 26.--ADJUDICATED DIRECT-FLOW RIGHTS ON CATTLE CREEK AND TRIBUTARIES, IN ORDER OF PRIORITY.--Continued

[Compiled from copies of decreds and other records in the office of Divisional Engineer, Glenwood Springs, Colo.]

Priority order on stream-con.	Name of stream and ditch-con.	Water district priority number-con.	Date of decree-con.	Amount of appropriation (second-feet)-con.
27	Park (orig.)	221A	6-26-13	9.00
27	Park (additional)	221A	4-16-17	1.80
28	Stand Pat (orig.)	221AAA	11-13-16	2.40
29	Eureka No.1 (orig.)	227AA	3-15-16	9.50
30	Mountain Meadow (1st enl.)	231A	9-23-18	40.00
31	Park (Hueschkel enl.)	232	6- 9-16	4.10
31	Park (Long & Hueschkel enl.)	232	9- 5-18	2.00
32	Staton (flood right)	299	8-25-36	2.98
	Waste and seepage, tributary to Cattle Creek:			
1	Foster-Walthen Waste Water	213BB	3-24-04	2.40
	Fisher's Branch:			
1	Lafayette Co. (orig.)	75A	4- 3-93	1.00
2	Sheaffer (orig.)[4]	113C	12-16-01	1.30
	Mesa Creek:			
1	Strang No.1 (orig.)	71	5-11-89	1.20
2	Strang No.1 (1st enl.)	86	5-11-89	1.00
3	Keeton & Emisoh (orig.)	124A	4-18-90	1.20
4	Van Cleve-Fisher[8] Res.	10	11-10-08	25.40
5	Fisher & Haaf (orig.)	216AAA	9- 2-09	3.80
	Springs tributary to Mesa Creek:			
1	Strang No.2 (orig.)	56	5-11-89	0.30
	West Coulter Creek:			
1	Coulter Westside (orig.)	35	5-11-89	1.00
2	Coulter Westside (1st enl.)	76	5-11-89	1.00
3	Ralston No.1 (orig.)	104A	4-18-90	1.00
4	West Highline (orig.)	195	5-11-89	3.60

Table 26.--ADJUDICATED DIRECT-FLOW RIGHTS ON CATTLE CREEK AND TRIBUTARIES, IN ORDER OF PRIORITY--Continued.

[Compiled from copies of decrees and other records in the office of Divisional Engineer, Glenwood Springs, Colo.]

Priority order on stream-con.	Name of stream and ditch-con.	Water district priority number-con.	Date of decree-con.	Amount of appropriation (second-feet)-con.
	East Coulter Creek:			
1	Prior (orig.)	27	5-11-89	0.70
2	Prior (1st enl.)	67	5-11-89	0.70
3	Prior (2nd enl.)	103	5-11-89	0.40
4	Pat McNulty No.1 (orig.)	189A	3-15-94	0.80
4	Pat McNulty No.2 (orig.)	189A	3-15-94	0.50
5	East Highline (orig.)[10]	197	5-11-89	1.90
6	Ralston (orig.)	198	5-11-89	0.20
--	Lewis & Lavine (orig.)[5]	200	5-11-89	2.00
7	Waters-Coulter Creek (orig.)	209AA		1.70
8	Thomas McNulty (orig.)[11]	252		3.00
	Shippee Run:			
1	McNulty No.2 (orig.)	164	5-11-89	0.50
2	Waters (orig.)	167A	4-18-90	0.70
3	McNulty No.2 (1st enl.)	190	5-11-89	1.50
	Springs tributary to Shippee Run:			
1	McNulty No.1 (orig.)	135	5-11-89	0.40
	Cottonwood Creek (transbasin diversion from Water District No. 52):			
1	Hueschkel No.1 (orig.)	40		3.50
2	Hueschkel No.2 (orig.)[12]	41		1.50
3	Shadigee (orig.)	42		2.00
4	Hueschkel No. 1 & No.2 (J. Hueschkel enl.)	90		1.20
	Gulch, tributary to Roaring Fork:			
1	Needham Waste Water (orig.)[13]	208BB	5- 2-93	0.10
2	Pat Rodgers Feeder (orig.)[13]	210B	5- 2-93	0.60
3	Needham Waste Water (1st enl.)[13]	212B	5- 2-93	0.16

Table 26.--ADJUDICATED DIRECT-FLOW RIGHTS ON CATTLE CREEK AND TRIBUTARIES, IN ORDER OF PRIORITY--Continued.

[Compiled from copies of decrees and other records in the office of Divisional Engineer, Glenwood Springs, Colo.]

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[1]Frequently, water is actually diverted by Staton and Mason ditches because of poor condition of Barger Ditch. This transfer, however, has not been approved by the Court.

[2]It is not known whether this ditch was ever constructed. In any event, this right has not been used for many years and since the decree was conditional, this right is assumed to be abandoned.

[3]Conditional decree, which has not been made final.

[4]Sheaffer Ditch may divert this priority either from Cattle Creek or from Fisher's Branch.

[5]This right has not been used for many years and is assumed to be abaondoned.

[6]This is the amount originally decreed for this right. Water-administration officials, however, honor only 13.6 second-feet of this priority. See text for explanation.

[7]This is the amount originally decreed for this right. Water-administration officials, however, honor only 4.0 second-feet of this priority. See text for explanation.

[8]The appropriation for this project is called a "reservoir priority" in the decree of November 10, 1908. This decree contains the following unusual provision: "....and that there be allowed to flow from Mesa Creek through the feeder ditch to said reservoir (i.e., the Van Cleve-Fisher Reservoir) a sufficient quantity of water to keep said reservoir reasonably well filled, not exceeding at any one time 25.4 cubic feet of water per second of time." With no limitation on refilling the reservoir, this amounts to a combination storage and direct-flow appropriation. The date of appropriation is April 27, 1901, which is a few months senior to the Fisher-Haaf priority (October 29, 1901), but is junior to the three priorities in the Strang No. 1 and Keeton-Emison Ditches, which date from 1883, 1884, and 1885, respectively.

[9]Of this amount, 2.0 second-feet are conditional and 1.8 second-feet are final. The conditional decree has not been made final.

[10]The East Highline Ditch uses the Prior headgates. In effect, the West Highline Ditch is a lateral or extension ditch from the Prior Ditch.

[11]Used mainly to carry early-season supplemental water from East Coulter Creek to lands under McNulty No. 1 and No. 2 Ditches out of Shippee Run.

[12]The Hueschkel No. 2 Ditch is really an extension of

Table 26.--ADJUDICATED DIRECT-FLOW RIGHTS ON CATTLE CREEK AND TRIBUTARIES, IN ORDER OF PRIORITY--Continued.

[Compiled from copies of decrees and other records in the office of Divisional Engineer, Glenwood Springs, Colo.]

Hueschkel No. 1 Ditch. [13]	These ditches are used for supplemental supply for lands under the Needham Ditch and the Missouri Heights Reservoir Project. Water supply is limited and not very dependable.					

have not been used by anyone for many years, these amounts are not subject to abandonment, because they were not intentionally abandoned, but have been wrongfully withheld from the water users by water-administration officials. It is believed that the full amount of the original appropriations could be reinstated by the water users merely by requesting the Divisional Engineer to honor the original decrees. If he refuses to grant the request, he can be forced to do so by a court order. As a matter of fact, one of the newer land owners under the Mountain Meadow Ditch contemplates developing 140 acres of additional land during 1948 by reinstating 3 second-feet of the 12 second-feet of Priority No. 217BB withheld by water-administration officials. It may be assumed that other landowners under these two ditches will follow his example.

There are two appropriations in Fisher's Branch totaling 2.3 second-feet. On the basis of location and priority, these appropriations are junior only to the

original priorities in the Barger and Staton Ditches on the main stem of Cattle Creek.

The direct-flow priorities in ditches out of Mesa Creek total 7.2 second-feet. In addition, there is a reservoir appropriation which apparently is being used as a direct-flow priority because of a peculiar wording in the decree which contains the following unusual provision: ". . . . and that there be allowed to flow from Mesa Creek through the feeder ditch to said reservoir (i.e., the Van Cleve-Fisher Reservoir) a sufficient quantity of water to keep said reservoir reasonably well filled, not exceeding at any one time 25.4 cubic-feet of water per second of time". With no limitation on refilling the reservoir, this amounts to a combination storage and direct-flow appropriation. The priorities in the four ditches out of Mesa Creek are subject to the senior priorities in the Staton, Barger, Mason, Fonder, and Sheaffer Ditches.

The appropriations in the three ditches out of West Coulter Creek total 6.6 second-feet and those in the six ditches out of East Coulter Creek total 9.9 second-feet. The priorities on both East Coulter and West Coulter Creeks are subject to the senior priorities on Cattle Creek in the Staton, Barger, Mason, Fonder, Sheaffer, and Park Ditches. The priorities in the two ditches out of Shippee Run total 2.7 second-feet. These priorities are also

subject to the senior priorities in the above six ditches out of Cattle Creek, plus those in the Lewis and Sommers Ditches.

There are eight reservoirs with adjudicated storage priorities in the Cattle Creek area (Table 27). Only three are large enough to be of much importance. The largest is the Spring Park or Missouri Heights Reservoir, described in a previous section. The Van Cleve-Fisher Reservoir was not viewed in the field, but it is believed to be considerably smaller than its adjudicated capacity. Since it is operated on the basis of intermittent refilling during the irrigation season, this storage set-up partakes of the nature of a direct-flow appropriation, as mentioned above. The Consolidated Reservoir is owned jointly by several individuals and the Park Ditch and Reservoir Company. This company is a mutual which was organized in 1931 to take over and operate the Park Ditch on Missouri Heights. It also owns a part interest in the Consolidated Ditch which diverts water from Mesa Creek to Coulter Creek. The natural channels of Coulter and Cattle Creeks are used to carry water from both the Consolidated Ditch and the Consolidated Reservoir to the Park headgate on Cattle Creek. The Park Ditch and Reservoir Company obtains part of its operating revenue by renting out about 800 acre-feet of early-season water annually, mainly for lands in

Table 27.--ADJUDICATED STORAGE RIGHTS FROM CATTLE CREEK AND TRIBUTARIES.

[Compiled from copies of decrees and other records in the office of Divisional Engineer, Glenwood Springs, Colorado.]

Name of reservoir	Source of supply	Water district priority number	Date of decree	Amount of appropriation (acre-feet)
Monarch (offstream)	Cattle, Lost, and Blue Creeks	6	3-18-95	115
McNulty (channel)	Shippee Run	8	6- 3-05	32
Consolidated (channel)	West Coulter Creek	8B	2-15-21	[1]595
Van Cleve-Fisher (offstream)	Mesa Creek	10	11-10-08	[2]553
Ralston No. 1 (offstream)	West Coulter Creek	10AAA	1-17-21	34
Ralston No. 2 (offstream)	West Coulter Creek	10AA	1-17-21	4
Waters (channel)	East Coulter Creek	11AA	3-16-17	17
Spring Park (offstream)	Cattle Creek	12A	9-23-18	2,823

[1]Annual storage use averages about 400 acre-feet; so apparently this reservoir gets at least the equivalent of a partial refill each year.

[2]This reservoir is believed to be smaller than this adjudicated appropriation. See text for description of operations.

Coulter Valley.

It will be seen from the above discussion that the priority system on Cattle Creek makes for rather complicated stream administration. There is a large number of small, individual priorities, instead of a few large ones. The transbasin diversions from Water District No. 52, the use of natural stream channels to convey reservoir water and water diverted from one watershed to another within Cattle Creek Basin, and relationships among priorities on tributary streams and to those on the main stem all present special problems for the Water Commissioner. Moreover, return flow is quite important, despite the fact that the drainage from 40 per cent or more of the land irrigated from Cattle Creek and tributaries drains to the Roaring Fork rather than into Cattle Creek.

Operation of the Missouri Heights Reservoir.--The Mountain Meadow original priority (No. 217BB) and the Mountain Meadow enlargement (No. 231A) are the two largest appropriations out of Cattle Creek. The headgate of the Mountain Meadow Ditch is just about the farthest upstream, being exceeded only by that of the Stand Pat Ditch. Although there are 47.2 second-feet of downstream priorities senior to the Mountain Meadow Ditch, in practice only about eight second-feet usually must pass the Mountain Meadow headgate to satisfy these senior rights, the great

difference between these two amounts being made up by return flow and by the discharge of the five tributary streams.

The Water Commissioner apparently does not pay much attention to how the water, diverted by the Mountain Meadow Ditch, is handled after it passes the measuring flume, his main interest being to see that enough water passes this headgate to supply senior downstream rights. Theoretically, the reservoir company must deliver the original Mountain Meadow direct-flow rights before any water diverted may be stored. As previously explained, the legal amount of these rights is 25.6 second-feet, although only 13.6 second-feet have been allowed since 1928. It is quite possible, however, that more than 13.6 second-feet will be demanded by water users in the future. Moreover, the holders of reservoir rights also have direct-flow rights by virtue of the enlargement priority (No. 231A) at the rate of 1 second-foot per 70 acres. Assuming that 2,252 acres have reservoir rights, the practical amount of the enlargement appropriation would be 32.2 second-feet instead of the 40.0 second-feet shown in table 26.

Thus, by a strict interpretation of the rule of priority, the reservoir company may store only whatever water it diverts in excess of 45.8 second-feet and even-

tually this amount may be increased up to 65.6 second-feet. The rated capacity of the Mountain Meadow Ditch is 90 second-feet, but according to men who have acted as ditch riders in recent years, it is not practical to carry more than 80 to 85 second-feet, except for brief periods. The maximum amount of water that the Mountain Meadow Ditch can carry legally for storage, therefore, is about 35 to 40 second-feet during the irrigation season. If the ditch is operated at capacity, it would take about 36 to 41 days to fill the reservoir. In order for the ditch to be operated at capacity, however, there must be a flow in Cattle Creek at the Mountain Meadow headgate of 114.1 second-feet for the following purposes:

	Second-feet
To satisfy downstream rights, senior to the original appropriations for the Mountain Meadow Ditch	8.0
For original Mountain Meadow direct-flow rights	13.6
For priorities in Park and Eureka Ditches which are junior to Mountain Meadow original rights, but senior to Mountain Meadow enlargement and Missouri Heights storage priorities	20.3
For Mountain Meadow enlargement direct-flow rights	32.2
For storage in Missouri Heights Reservoir	40.0
TOTAL	114.1

The 114.1 second-feet does not include the 12.0 and 4.0 second-feet illegally denied the Mountain

Meadow and C. & M. Ditches mentioned previously.

Although the flow of Cattle Creek at the Mountain Meadow headgates frequently exceeds 200 second-feet during the spring run-off, a flow of 114 second-feet or more does not last for very many days and probably a flow this great has never extended over a 40-day period in any one year. The conclusion is, therefore, that a large part of the water stored in Missouri Heights Reservoir is water that was diverted legally on the basis of the Mountain Meadow original and enlargement priorities. Water users under the reservoir project are well aware of this situation and at times complain a bit about it. They are faced with a dilemma, however; they may demand the full amount of their direct-flow priorities during May and June, but if they do so they jeopardize the amount of storage water which would be available for July and August.

The opening dates of the Mountain Meadow headgate in recent years, as reported by the Water Commissioner, were as follows:

Year	Date	Year	Date
1940	March 27	1944	May 5
1941	March 15	1945	May 1
1942	March 15	1946	March 21
1943	April 1	1947	April 15

Since the irrigation season usually starts sometime between May 1 and May 15, the ideal arrangement, in view of the limited capacity of the Mountain Meadow Ditch, is to have

as much water in the reservoir as possible prior to the start of the irrigation season. That is why the opening dates for most years have been in March or April. In order for the Mountain Meadow Ditch to divert in March, it is necessary for the snow to be cleaned out of the intake canal. This is usually done by shovelling out a small ditch through the snow in the center of the canal. If the amount of water in the canal is carefully controlled, the remaining snow and ice in the ditch can be washed out without endangering the canal embankments. In order to insure a full reservoir, the water users themselves have performed the snow shovelling job some years, the reservoir company allowing them a credit against their operation and maintenance assessments for this labor.

The closing dates of the Mountain Meadow Ditch during the last eight years were as follows:

Year	Date	Year	Date
1940	June 12	1944	July 8
1941	June 30	1945	June 30
1942	July 1	1946	June 16
1943	July 3	1947	July 12

Generally, the only water carried in the ditch during the week or ten days prior to closing date is water due the original Mountain Meadow rights, although as noted above, some of this water may be stored. Most operators attempt to get over their hay meadows at least once during May with direct-flow water, although in dry years some

reservoir water may have to be used for part of this first irrigation of hay. Reservoir runs normally start during the second or third week in June. The first runs are used for the one and only irrigation of cereals and the second irrigation of hay. Reservoir runs are scheduled for the several laterals and sections of the outlet canal according to the wishes of the majority of the water users. At best, distribution losses are relatively high because of the low capacity of the laterals, the flat grade of the outlet canal, and the general condition of the canal and structures. For this reason, an attempt is made in scheduling reservoir runs to avoid turning small heads down the canal and to keep the number of runs as few as possible. The determination of the schedule, therefore, is a source of considerable dispute among neighboring water users. Those raising potatoes want a large part of their water from late July to early September, while those raising only hay and grain want most of their water from late June through July. The resulting compromises seldom are satisfactory to all water users on a lateral or section of the main canal.

Water-supply classification of ditches.--If water is available, three cuttings of alfalfa usually are possible in most parts of the Cattle Creek area. This is especially so on Missouri Heights. Moreover, a consider-

able acreage is now devoted to potatoes and more potatoes would no doubt be raised if more late-season water were available. Both of these facts mean that more water would be required per acre during July and August to constitute a full supply than is the case in some of the other areas covered in this report. Consequently, the following time requirements for the various water-supply classifications were adopted to reflect this greater need for late-season water:

A-1 1 second-foot per 60 acres until August 1, and at least 1 second-foot per 120 acres thereafter.

A-2 1 second-foot per 60 to 100 acres until August 1, plus at least 1 second-foot per 200 acres thereafter.

B-1 1 second-foot per 60 acres until August 1, but inadequate supply thereafter.

B-2 1 second-foot per 60 to 100 acres until August 1, but insufficient supply thereafter.

C 1 second-foot per 60 acres until July 15, but inadequate supply thereafter.

D 1 second-foot per 60 acres until July 1, but inadequate supply thereafter.

E 1 second-foot per 60 acres until June 15, but inadequate supply thereafter.

The water-supply classifications of the various ditches, based on the above schedule, together with data obtained from annual field books of the Water Commissioner and conversations with water users, are given in the second column of table 28.

Table 28.--FACTORS INFLUENCING CROP PRODUCTION ON LANDS UNDER VARIOUS DITCHES OUT OF MISSOURI HEIGHTS.

Name of ditch	Acres irrigated[1]	Water supply classification[2]	Crop production and yields[3]	Description of land and soils			
				Average elevation (feet)[3]	Topography[3]	Predominant type of soil[3]	Natural drainage[3]
Needham (orig., no res. rights)	156	A-1	Fair	7,000	Gentle to medium slopes	Brown silt loam to silty clay loam, of good depth	Adequate
Needham (1st & 2nd enl. with res. rights)	544	B-1	Good	7,000	"	"	"
C. & M. (no res. rights)	380	B-2	Fairly good	7,000	Medium to gently rolling	Reddish brown clay loam, of good depth, occasional outcrops of lava	Good
Monarch (no res. rights)	23	C	Fair	7,500	Medium slopes	Brown silty clay loam, of good depth	Adequate
Monarch (with res. rights)	277	B-1	Good	7,500	"	"	"
Mountain Meadow (orig., no res. rights)	197	D	Fair	7,500	Medium to gently rolling	Brown to reddish brown silt loam and silty clay loam, of good depth	Adequate

Table 28.--FACTORS INFLUENCING CROP PRODUCTION ON LANDS UNDER VARIOUS DITCHES OUT OF MISSOURI HEIGHTS.--Continued.

Name of ditch	Acres irrigated[1]--con.	Water supply classification[2]--con.	Crop production and yields[3]--con.	Description of land and soils: Average elevation (feet)[3]--con.	Description of land and soils: Topography[3]--con.	Description of land and soils: Predominant type of soil[3]--con.	Description of land and soils: Natural drainage[3]--con.
Mountain Meadow (orig., with res. rights)	340	C	Good	7,200	Medium to gently rolling	Brown to reddish brown silt loam and silty clay loam, of good depth	Adequate
Mountain Meadow (1st enl., with res. rights)	997	D	Good	7,200	"	"	Adequate
Park (with Consolidated res. rights)	556	C	Fair to good	6,500	"	Reddish brown sandy clay loam of good depth	Adequate
C. & L. Highline	72	[4]D	Fair	7,100	Medium rolling	Reddish brown sandy clay loam, rather shallow	Good
Eureka No. 1	284	E	Fair	7,000	Medium rolling	Reddish brown loam, of fair depth	Good

Table 28.--FACTORS INFLUENCING CROP PRODUCTION ON LANDS UNDER VARIOUS DITCHES OUT OF MISSOURI HEIGHTS--Continued.

Name of ditch	Acres irrigated[1]--con.	Water supply classification[2]--con.	Crop production and yields[3]--con.	Description of land and soils			
				Average elevation (feet)[3]--con.	Topography[3]--con.	Predominant type of soil[3]--con.	Natural drainage[3]--con.
Sommers	13	C	Fair yields of hay	6,800	Gently sloping meadow land	Brown clay loam.	Fair
Sweedes	27	C	Fair yields of hay	6,900	"	"	Fair

[1]Compiled from annual reports of Water Commissioner, 1936 land-classification survey of U. S. Bureau of Reclamation, and farm schedules taken on Missouri Heights in 1947.

[2]See text.

[3]From data supplied by Engineer-Appraiser, Federal Land Bank at Wichita.

[4]Low rating due both to late priorities and high conveyance losses of the ditch.

Water supply classifications for three of the ditches on Missouri Heights were broken down according to direct-flow and reservoir rights under each ditch, instead of according to ditch averages, as was done for ditches in other parts of the Cattle Creek area and for other project areas. The acreages under all ditches on Missouri Heights with each water-supply classification are as follows:

Classification	Acreage	Per cent
A-1	156	4.0
B-1	821	21.3
B-2	380	9.8
C	959	24.8
D	1,266	32.8
E	284	7.4
Total	3,866	100.0

Thus, less than five per cent of the irrigated acreage on Missouri Heights has what might be called a full water supply and over half of the acreage is seriously deficient for a general-crop type of farming.

Supplemental water required for a full supply on Missouri Heights.--The amount of water that would be required on Missouri Heights in addition to amounts now received from the various ditches is estimated to be 9,515 acre-feet (Table 29). Consequently, this area alone could absorb all of the storage water in the 9,000 acre-foot reservoir proposed by the Bureau of Reclamation.

Amount of storable water in Cattle Creek.--Follansbee (2) wrote in 1929, concerning the storage water

Table 29.--ACREAGE IN NEED OF ADDITIONAL WATER IN THE MISSOURI HEIGHTS AREA AND AMOUNT OF RESERVOIR WATER NEEDED FOR FULL SUPPLY.

Name of ditches	Present water supply class-fication	Water-supply classi-fication without reservoir rights	Acres	Present reservoir rights (acre-feet)	Reservoir water needed for full supply	
					Acre-feet per acre	Total acre-feet
Needham (1st & 2nd enl., with reservoir rights)	B-1	C	544	520	0.9	490
Monarch (no reservoir rights)	C	C	23	0	0.9	20
Monarch (with reservoir rights)	B-1	C	277	185	0.9	250
Mountain Meadow (orig., no reservoir rights)	D	D	197	0	1.5	295
Mountain Meadow (orig., with reservoir rights)	C	D	340	291	1.5	510
Mountain Meadow (1st enl., with reservoir rights)	D	E	997	1,164	2.2	2,190
C. & M. (no reservoir rights)	B-2	B-2	380	0	0.9	340
New cropland[1]	--	--	1,028	0	3.0	3,085

Table 29.--ACREAGE IN NEED OF ADDITIONAL WATER IN THE MISSOURI HEIGHTS AREA AND AMOUNT OR RESERVOIR WATER NEEDED FOR FULL SUPPLY--Continued.

Name of ditches-con.	Present water supply classification-con.	Water-supply classification without reservoir rights-con.	Acres-con.	Present reservoir rights (acre-feet)-con.	Reservoir water needed for full supply	
					Acre-feet per acre-con.	Total acre-feet-con.
New pasture land[1]	--	--	347	0	2.5	870
Park	C	C	556	0	1.1	610
Eureka No. 1	E	E	284	0	2.2	625
Sweedes and Sommers	C	C	40	0	0.9	35
C. & L. Highline[2]	D	D	72	0	1.5	110
New cropland under Park Ditch	--	--	29	0	3.0	85
Total irrigated acreage			3,710			
Total new lands			1,404			
TOTAL			5,114			

[1]From farm schedules taken on Missouri Heights.
[2]Reservoir deliveries would have to be made by exchange with H. C. & L. and Hueschkel & Chapman Ditches.

available for the Spring Park Reservoir:

> The drainage area above the intake for the reservoir is 31 square miles, ranging in altitude chiefly from 8,000 to 9,000 feet and the unit run-off is estimated as 700 acre-feet per square mile. This gives a total run-off of 21,700 acre-feet. As 7,500 acres is under ditch from Cattle Creek, of which 5,800 acres is irrigated, the diversion requirement for this area will be about 12,000 acre-feet, leaving a surplus of 9,700 acre-feet for additional storage. (2:62)

This estimate seems to be fairly good for a long-time average. At least it checks quite closely with estimates made by local people on an entirely different basis.

The Divisional Engineer, from his personal knowledge of Cattle Creek, estimated that a 9,000 acre-foot reservoir could be filled six years out of 10 and that at least 6,000 acre-feet could be stored in years of extremely low run-off. A former ditch rider for the Carbondale Reservoir and Irrigation Company estimated that a 9,000 acre-foot reservoir could be filled "better than 60 per cent of the time if some water was stored in the fall." The ditch rider also said that in order to accomplish this the intake canal would have to be enlarged to a 150 second-foot capacity.

It therefore seems probable that a 9,000 acre-foot reservoir could be filled at least 60 per cent of the time if the storing of water was reasonably well managed.

Chapter XI

DISCUSSION OF THE ECONOMIC FEASIBILITY OF THE CATTLE CREEK PROJECT

There is more land in need of supplemental water on Missouri Heights than the reservoir could possibly supply. If any other areas, i.e., lands north of Cattle Creek are to be supplied water, either a fairly long outlet canal for the project or a siphon of approximately three miles must be constructed. For these reasons the study confined itself to that part of the project area that could reasonably be reached by the present distribution system of the Spring Park Reservoir or by minor changes thereof.

All lands that are potential users of reservoir water on Missouri Heights are listed in table 29. The lands under the Park, Eureka No. 1, Sweedes, Sommers and C. & L. Highline would have to extend the lateral system of the present reservoir distribution system. All other ditches would require only enlargement of the present distribution system.

Data analyzed in the following paragraphs were

secured mainly from interviews with 23 of the operators in the project area whose farm units contain 60 per cent of the currently irrigated land. Data from the interview schedules indicate conclusively that the reservoir-enlargement project would not be accompanied by any major change in type of farming or crops raised. Instead, there would be a continuation of the trend begun during the war years toward more reliance on livestock enterprises and less on cash crops.

As might be expected, some shifts in crop distribution would be made as a result of increased water supply. A smaller proportion of the acreage would be devoted to alfalfa and a larger proportion to cereals and irrigated pasture (Table 30). Oddly enough, the farm operators do not contemplate any great expansion of potato acreage as a result of greater availability of late-season water. In the past, resort to potato production was made by the typically small farms in the area to obtain fuller utilization of family labor and to increase the size of the farm business. In the future, with more water available, some operators would go out of potato production entirely and would expand their irrigated acreage, raising only hay and grain to support their expanded livestock production. Only a few operators, particularly those whose units do not contain very much irrigable land capable of being

Table 30.--ESTIMATED SHIFTS IN CROP ACREAGES TO ACCOMPANY ENLARGEMENT OF MISSOURI HEIGHTS RESERVOIR.

Crop	[1]Project area during 1947		Project area after suggested development	
	Acres	Per cent of irrigated	Acres	Per cent of irrigated
Alfalfa	2,517	62.3	2,508	51.1
Barley	222	5.5	511	10.4
Wheat	355	8.8	466	9.5
Oats	267	6.6	368	7.5
Potatoes	97	2.4	182	3.7
Irr. pasture	582	14.4	874	17.8
Total irr. land	4,040	100.0	4,909	100.0
[2]Dry cropland	210	--	0	--
[2]Dry pasture	659	--	0	--
TOTAL IRRIGABLE	4,909		4,909	

[1]Estimates based upon interview schedules from 23 of the operating units in the project area, which contain 57 per cent of Missouri Heights area. Two hundred and five acres of the 5,114 acres analyzed in table 29 were not included due to insufficient availability of water.

[2]This figure includes only dry land capable of being irrigated.

developed into good crop land, would expand potato production. The estimated increased average yields per acre as given in table 31, in the computations of increased annual income to land, are, if anything, conservative. Some operators during the last two years obtained alfalfa

Table 31.--INCREASE IN ANNUAL GROSS INCOME TO LAND TO RESULT FROM ENLARGEMENT OF MISSOURI HEIGHTS PROJECT.

Crop	Production units	Crop dist.[1]	Average yield per acre[2]	Total production for area	Average price per unit[3]	Total value of production for project area	Customary landlord's share	Gross income to land
Project as now constituted:								
Alfalfa	tons	2,517	1.2	3,020	$10.35	31,257	1/2	$15,628
Barley	bu.	222	32	7,104	.68	4,831	1/3	1,610
Wheat	"	355	28	9,940	.94	9,344	1/3	3,115
Oats	"	267	44	11,748	.50	5,874	1/3	1,958
Potatoes	cwt.	97	130	12,610	1.55	19,546	1/4	4,887
Irrigated pasture	acres	582	--		5.00	2,910	1/2	1,455
Dryland wheat	bu.	210	[4]7.5	1,575	.94	1,480	1/3	493
Dry pasture	acres	659	--		.25	164	1/2	82
TOTAL		4,909				75,406		29,228
Project after suggested development:								
Alfalfa	tons	2,508	2.0	5,016	10.35	51,916	1/2	25,958
Barley	bu.	511	42	21,462	.68	14,594	1/3	4,865
Wheat	"	466	35	16,310	.94	15,331	1/3	5,110
Oats	"	368	50	18,400	.50	9,200	1/3	3,067
Potatoes	cwt.	182	175	31,850	1.55	49,368	1/4	12,342
Irrigated pasture	acres	874	--	--	10.00	8,740	1/2	4,370
TOTAL		4,909				149,149		55,712
Increase average gross income to land						73,743		26,484

Table 31.--INCREASE IN ANNUAL GROSS INCOME TO LAND TO RESULT FROM ENLARGEMENT OF MISSOURI HEIGHTS PROJECT.

[1]From table 30.

[2]These estimates are based upon the interview schedule, Figure 4, Appendix B, and seem to be reasonable when compared with Widtsoe's (13:241-313) findings published in 1915. No direct comparison could be made as Widtsoe's findings were based upon the amount of water applied to the cropland and these estimates are based upon lateral headgate deliveries.

[3]Average prices in Garfield County, 1939-44, from "Prices Received by Farmers in Each County of Colorado for Principal Crops", Colo. Agr. Expt. Sta. Mimeo. release, 1948.

[4]Annual equivalent of a 15-bushel yield per harvested acre on an alternate crop and summer fallow basis. The long-time average yield of spring wheat on dryland is 13.1 bushels per harvested acre based upon tabulations from the State Statistician's Office.

yields ranging up to three tons per acre, barley yields up to 61 bushels per acre, wheat yields up to 60 bushels per acre, oat yields up to 90 bushels per acre and potato yields up to 200 sacks per acre.

The explanation of these high yields is due to several factors, including exceptional farming ability, concentration of reservoir water, better than average direct-flow rights, and favorable weather conditions such as better than normal precipitation, low hail damage and lack of killing frosts in late spring and early fall. In view of these potential weather hazards, the long-time average yields with a full water supply were set at a conservative level which should be attainable as an average.

On the basis of the average yields in the past and the 1939-44 average farm prices, the annual gross value of crop production from the project area at present is estimated at $75,406, of which the landlord's share would be $29,228. With full development of the project and the estimated probable average yields, the total value of crop production would be increased to $149,149, of which the landlord's share would be $55,712. The probable increase in average annual crop income to land as a result of the project, therefore, is $26,484 (Table 31).

The probable effect of the reservoir-enlargement

project on land costs is much more difficult to anticipate with any degree of accuracy. It is quite certain, however, that the project would be accompanied by significant changes in land costs.

There would be a considerable increase in general property taxes as a result of the project. The present average assessed valuations per acre for the various assessment grades for land within the project area are as follows:

Assessment grade	Eagle County	Garfield County
Irrigated cropland	$38.06	$35.43
Irrigated pasture	---	9.27
Non-irrigated cropland	12.50	---
Grazing land	3.06	2.05
Average irrigable tracts in project area	$29.46	$21.86

Some of the land now being irrigated is not assessed as irrigated cropland. Since water supply is one of the important factors in the determination of assessment grades and values, a general reassessment of land within the project area, which likely would accompany the project development, would result in most, if not all, of the project lands being assessed as irrigated cropland with assessed valuations per acre approximating the highest rates now being used in the area, namely, $43 per acre in Eagle County and $41 in Garfield County.

The trend in millage rates in both counties has been definitely upward since 1943. The present level is

much higher than pre-war and may go even higher before levelling off. The average total tax rate for all units of government in the Eagle County portion of the project for the tax years 1946 and 1947 was 38.4 mills and in the Garfield County portion, 35.4 mills. It is probable that tax rates for the next few years, at least, will be no lower. If the 1946-47 average tax rates are assumed to represent the future long-time average and are applied to the present assessed values and those probably to result from the reservoir enlargement project, the effect of the project will be to increase land taxes for the area as a whole by $2,893 (Table 32). It should be noted that this analysis does not take into consideration any increase in taxation of improvements. Present improvements, although modest for the most part, are generally adequate for the area. There will be little, if any, subdivision of operating units as a result of the project. Moreover, assessors of both counties apparently follow the practice of assessing improvements at a very low ratio to actual value.

Some new laterals and farm ditches would have to be constructed and most of the existing laterals from the main canal to the farms would have to be enlarged as a result of the project. Moreover, at least a minimum amount of levelling and land preparation would have to be done to bring new land into production. In the absence of

Table 32.--COMPUTATION OF AVERAGE ANNUAL VALUE OF SUPPLEMENTAL WATER FROM MISSOURI HEIGHTS RESERVOIR.

Item	Project as now constituted	Project when fully developed	Increase to accompany enlargement project
	Dollars	Dollars	Dollars
Gross value of crop production[1]	75,406	149,149	73,743
Gross income to land[1]	29,228	55,712	26,484
Annual land costs:			
Property taxes	[2]4,508	[3]7,401	2,893
Interest on additional investment in laterals, levelling, and farm ditches[4]		3,682	3,682
Increase in land costs by virtue of reservoir enlargement project			6,575
Increase in net income to land:			
Total amount			19,909
Average per acre (4,909 acres)			4.06
Average per acre-foot of additional res. water[5]			3.48

[1]From table 31.

[2]Annual average taxes levied against land within project area in recent years.

[3]See text for method of computation.

[4]Interest computed at five per cent on an additional capitalization of $15 per acre. See text for explanation.

[5]Present delivery of reservoir water is estimated at 1,680 acre-feet annually. The proposed delivery of 7,398 acre-feet, less 1,680 acre-feet, equals 5,718 acres on which this average was computed.

a complete farm conservation survey, the amount and cost of these items is anybody's guess. For purposes of this study these costs are estimated at an average of $15 per acre, which is low, if anything. Allowing five per cent interest on this additional investment in levelling land amounts to $3,682 for the area as a whole. Deducting this amount and the increase in general property taxes from the estimated average increased crop income to land attributable to the project gives a net increase of income to land of $19,909 annually (Table 32).

The present average annual delivery of reservoir water to laterals is estimated at 1,680 acre-feet. The delivery under the project, as proposed in this report, would be 7,398 acre-feet, an increase of 5,718 acre-feet. The increase in net income to land, therefore, is equivalent to $3.48 per acre-foot of water to be delivered by the proposed project over and above the amount now being delivered. This must be considered as the maximum estimated value of supplemental water. It will be noted that the above analysis does not take into consideration any increase in land prices, other than that necessary to cover development costs. In the past, land prices on Missouri Heights have been relatively low and increases in market prices during and since World War II have been comparatively modest because of the poor water supply.

The trend in land prices during the next few years will depend to a large extent on how much additional water is made available and how much land owners have to pay for it. In any event, the amount charged per acre-foot delivered would have to be something less than $3.48 to cover any increase in land valuation and provide an incentive for land owners to participate in the project.

What water users believe they can pay for water.--One of the questions asked the 23 operators on Missouri Heights who were interviewed: "What do you think the average landowner could pay annually for a full water supply over a long period of time?" Nine of the operators did not answer this question on the grounds that their farming experience in this area was too limited for them to have any ideas regarding the value of water. The answers of the other 14 operators ranged from $1 to $4 per acre-foot (Table 33). One possible reason for this wide variation in opinions expressed may be that some of the answers were conditioned by the amount and priorities of the direct-flow rights available to the operators, since all operators in this area tend to consider direct-flow water as being "free." Then, too, some of the operators have no concept of what an acre-foot of water means in terms of irrigation practice. In some cases, the question had to be rephrased in terms better understood by the

Table 33.--SUMMARY OF OPERATORS' OPINIONS AS TO AMOUNTS LANDOWNERS COULD AFFORD TO PAY FOR SUPPLEMENTAL WATER OVER A LONG-TIME PERIOD.

[Compiled from interview schedules from 23 operators on Missouri Heights, 1947.]

Annual charge per acre-foot	Operators with reservoir rights	Operators without reservoir rights	All operators interviewed
	Number	Number	Number
$1.00	1	0	1
1.50	2	0	2
2.00	1	0	1
2.50	1	2	3
3.00	3	3	6
3.50	0	0	0
4.00	1	0	1
Total number replying	9	5	14
Number, no reply	9	0	9
Total number of operators	18	5	23
Average charge suggested by those who replied	$2.39	$2.80	$2.54

operators, such as second-feet per day or for a certain number of days. There is also the possibility that operators with reservoir rights tend to think in terms of acre-feet contracted in the reservoir rather than in terms of acre-feet delivered to their laterals. Since water users have been getting less than 75 per cent of the amount contracted, their opinions as to the value of an acre-foot of water would tend to be low. That this may be the case

is indicated by the fact that the opinions of present project water users averaged considerably lower per acre-foot than those of non-project water users (Table 33). The three tenants who answered this question all gave answers as high or higher than the highest figure given by owner-operators, the averages for the two groups being $3.33 per acre-foot for tenants and only $2.32 per acre-foot for owner-operators. This may be the result of tenants being less conscious of possible increases in land costs to accompany enlargement of the project than are owner-operators.

Economic feasibility of Cattle Creek project.--On the basis of the above opinions and the estimated annual value of water discussed previously, it would seem that $2.80 to $3.00 per acre-foot would mark the extreme safe upper limit for average annual water charges if all known and unknown increases in land costs are to be covered and still provide a comfortable margin as an incentive to induce landowners to participate in the project.

On the basis of the lower of these two figures the project contemplated would have an average annual income of $18,262 broken down as follows:

(see following page)

Missouri Heights Project Reservoir Income
as Proposed

Present water rights, 2,252 acre-feet at $1.00 per acre-foot (1,680 acre-feet delivered)	$ 2,252
Potential water rights, 5,718 acre-feet delivered at $2.80 per acre-foot	16,010
Total income for the reservoir	$18,262

Operation and maintenance costs of the present project have been about $2,100 annually, although admittedly more should have been spent on maintenance. In place of the present part-time services of a ditch rider employed six or seven months, the enlarged project would require full-time services for 10 months at least. In view of these considerations the annual operation and maintenance costs of the proposed project would probably average approximately $4,500, leaving $13,762 available for debt service. This amount would repay the construction costs of $550,500 over a 40-year period with no interest under a repayment contract similar to that used by the U. S. Bureau of Reclamation.

On the basis of the higher of the two figures representing an annual average water charge ($3.00 per acre-foot) and using the same method as given above for computation, an amount of $14,706 would be available to repay construction costs of $596,200.

Therefore when the budgetary approach is used in determining the economic feasibility of the Cattle Creek Project, as proposed by the Bureau of Reclamation, the project would be considered feasible.

When the annual crop value, $30.39 per acre, is computed and plotted on Selby's (5) graph, results indicate that the proposed water charges ($2.80) are about 40 per cent above the recommended annual irrigation cost per acre. It should be noted, however, that Selby's (5) recommended cost of water is the cost for all water used in crop production rather than the cost of supplemental water alone. All farm operators in the Missouri Heights area at present receive water "free" under their direct-flow rights. Therefore their average annual water costs per acre-foot would be considerably less than $2.80 and probably would be within the range recommended by Selby.

Suggestions and recommendations

The writer feels that, before conclusive proof can be presented as to the economic feasibility of this project, more definite information must be gathered concerning the amount of water available for storage and the construction features of the proposed project. The first step in this direction would be the establishment of gaging stations above all diversions on Cattle Creek and its tributaries in order to obtain accurate stream-

flow data.

Chapter XII

SUMMARY

There is a considerable amount of surplus water available within the Roaring Fork Basin. Even though the basin as a whole has a surplus of water, certain areas are chronically short of water. The Bureau of Reclamation (8) in its report published in 1946 proposed four supplemental-supply projects on tributaries on the Roaring Fork River.

The purpose of this thesis is to describe and analyze as far as possible the four proposed irrigation projects, Fourmile, Woody, Capitol, and Cattle Creeks, in the Roaring Fork Valley.

Data collected for the study came from many and varied sources, the most important of which were (a) U. S. Bureau of Reclamation's (8) 1946 report, (b) interviews with and computations from the files of the Water Commissioner of district 38 and the Division Engineer concerning water needs and supplies in the areas concerned, (c) interviews with farmers in the project areas concerning crop yields and distribution, water supplies and needs, and

possible changes in crop distribution that would accompany increased water supplies, and (d) climatological data.

The methods used in analysis of the data were the examination and consideration of the available published and unpublished material related to the study, the consideration of physical data on the area in general and of specific information on the individual project, the setting up of a project budget, and the comparison of annual net increment with annual repayment charges for the proposed project.

Fourmile Creek Project

The cost of construction on this project per acre of irrigable land was greater than the long-time value of land with a full water supply; therefore, it was felt that the project was not economically feasible.

Woody Creek Project

The water supply in this area is being increased considerably by an enlargement to the Salvation Ditch, diverting water from the Roaring Fork River into the project area. This increased amount of water will provide a more than adequate supply for the area; therefore, the problem is being solved by the land owners themselves.

Capitol Creek Project

The construction costs per acre of irrigated

land are higher than the long-time average price of land in the area will a full water supply; consequently the project was considered to be economically unfeasible.

Cattle Creek Project

The analysis of data for the Cattle Creek Project indicates the probability that if the project is constructed the annual net increment would be $3.48 per acre-foot of water and the annual repayment charges plus operation and maintenance costs per acre-foot of water would be $2.67 (using 1940 costs). Since the net increment is $ .80 per acre-foot more than the repayment costs, and since this amount is more than enough to provide the water users an incentive for project development, it is felt that the project as analyzed is economically feasible.

APPENDIX A

Table 34.--CROP DISTRIBUTION ON FOURMILE CREEK

[Source: Annual report of the Water Commissioner of District No. 38 to the Divisional Engineer]

Crop	Acreage
Alfalfa	1,130
Natural grass	75
Cereals	180
Potatoes	50
Total irrigated acreage	1,435

Table 35.--WATER DIVERSIONS, FOURMILE CREEK, 1940 TO 1946.

[Compiled from field books of Water Commissioner which are filed with the Divisional Engineer, Glenwood Springs, Colorado]

Name of ditch	Acre-feet per acre average 1940-46	Range in acre-feet per acre 1940-46
Fourmile	4.3	2.9 to 8.3
Atkinson	4.5	3.0 to 10.8
Buck Farm	3.3	1.7 to 8.1
Gristy[1]		
Lignite[2]		
McKown	1.4	0.2 to 4.1
Lynch[2]		
Dearing	3.7	0.6 to 15.4
Lignite No. 2[2]		
Smart and Green[2]		
Hammerich[2]		
Hughes-Fourmile Cr[2]		
Perko[2]		
Doose[2]		
Name of Ditches on tributaries of Fourmile Creek		
Dry Gulch[2]		
Hardwick[2]		
Waddell[2]		
Fremont[2]		
W. A. Smith[2]		

Table 35.--WATER DIVERSIONS, FOURMILE CREEK, 1940 TO 1946-Continued.

[Compiled from field books of Water Commissioner which are filed with the Divisional Engineer, Glenwood Springs, Colorado]

Name of Ditches on tributaries of Fourmile Creek - continued.
Mines[2]
Pipeline[2]

[1]This ditch has not been used for a number of years.
[2]No data available.

Table 36.--PRICES RECEIVED BY FARMERS IN EACH COUNTY OF COLORADO FOR PRINCIPAL CROPS

Table 1.- County price relatives for important crops in Colorado
(Average county prices in percent of State average prices for years 1935-43)

County and district	Winter wheat	Spring wheat	Corn	Oats	Barley	Rye	Grain sorghums	Potatoes	Dry beans	Sugar beets	Broom-corn	Alfalfa hay	Other tame hay 1/	Wild hay	Forage Sorghums	Apples 2/	Peaches 2/	Pears 2/	Sour Cherries 3/	Sweet Cherries 3/
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
Chaffee	--	100.5	--	106.3	107.4	--	--	107.3	--	--	--	110.7	107.9	106.2	--	117.7	--	--	--	--
Clear Creek	--	--	--	--	--	--	--	--	--	--	--	--	109.3	107.7	--	--	--	--	--	--
Eagle	--	99.4	--	101.7	108.9	--	--	99.7	--	--	--	92.7	99.7	97.6	--	--	--	--	--	--
Gilpin	--	--	--	103.1	--	--	--	106.9	--	--	--	--	104.5	102.6	--	--	--	--	--	--
Grand	96.0	97.9	--	102.9	105.0	107.0	--	107.3	--	--	--	94.4	100.0	93.3	--	--	--	--	--	--
Gunnison	95.9	99.0	--	104.1	108.5	--	--	106.1	--	--	--	97.5	97.1	97.6	--	--	--	--	--	--
Jackson	--	--	--	--	--	--	--	--	--	--	--	--	--	93.7	--	--	--	--	--	--
Lake	--	--	--	--	--	--	--	--	--	--	--	--	--	100.0	--	--	--	--	--	--
Moffatt	93.7	95.0	106.0	99.0	107.4	104.8	--	103.6	--	--	--	93.5	97.4	91.5	--	--	--	--	--	--
Park	--	--	--	103.1	105.6	103.4	--	105.3	--	--	--	108.4	109.4	107.2	--	--	--	--	--	--
Pitkin	--	99.4	--	102.9	109.4	105.5	--	102.9	--	--	--	95.9	100.9	98.5	--	--	--	--	--	--
Rio Blanco	94.1	95.6	105.6	100.7	109.3	109.5	--	102.2	--	--	--	92.3	98.0	94.1	--	--	--	--	--	--
Routt	94.5	96.4	--	97.1	103.0	103.6	--	101.6	--	--	--	90.5	87.2	87.4	--	--	--	--	--	--
Summit	96.9	--	--	102.4	106.9	--	--	106.0	--	--	--	--	102.0	104.1	--	--	--	--	--	--
Teller	--	101.6	--	105.0	106.1	--	--	103.9	--	--	--	112.8	114.5	110.6	--	--	--	--	--	--
N. W. and Mountain District	94.4	97.0	106.0	101.7	108.9	105.7	--	102.2	--	--	--	93.8	96.7	96.3	--	117.7	--	--	--	--
Boulder	100.2	102.1	102.7	101.9	100.7	105.0	--	--	100.6	100.7	--	103.1	101.7	109.1	102.5	98.5	--	--	98.1	--
Jefferson	101.5	103.2	104.0	103.6	104.1	102.3	--	102.7	99.7	100.9	--	109.4	108.0	107.5	102.7	98.5	--	--	109.3	100.0
Larimer	100.0	102.1	103.2	100.2	100.2	103.8	104.2	99.1	97.8	100.5	--	99.7	98.8	108.4	103.4	100.6	--	--	101.9	100.0
Logan	101.0	102.9	97.3	94.0	97.4	100.2	104.2	99.6	99.2	99.8	97.6	96.2	92.7	98.5	100.2	--	--	--	98.1	100.0
Morgan	100.6	102.4	99.5	100.5	101.7	99.6	103.7	100.1	98.9	100.0	--	96.1	93.2	98.1	99.5	--	--	--	98.1	100.0
Sedgwick	100.2	103.0	97.2	96.2	96.3	99.5	103.3	101.8	99.4	100.2	--	93.8	93.8	95.0	98.5	--	--	--	--	--
Weld	100.1	102.4	101.2	100.0	100.2	96.6	103.0	95.2	99.4	100.7	--	98.5	95.4	106.6	101.2	99.6	--	--	98.1	100.0
N. Central & N. E. District	100.2	102.4	100.0	99.5	100.0	98.4	103.9	95.8	99.4	100.5	97.6	99.1	96.5	103.5	100.2	99.7	--	--	101.9	100.0
Adams	100.2	102.4	100.8	104.3	100.2	97.7	104.2	98.7	99.4	100.7	--	99.4	103.8	107.7	104.7	97.4	--	--	100.0	100.0
Arapahoe	100.1	102.0	100.0	103.6	100.7	98.4	102.5	--	99.7	100.5	--	112.8	109.1	109.4	105.9	97.4	--	--	92.6	--
Cheyenne	99.4	--	99.9	--	95.6	--	98.1	--	--	--	--	--	106.3	--	101.2	--	--	--	--	--
Denver	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Douglas	99.9	102.0	102.5	106.5	105.9	102.7	102.6	--	100.0	--	--	114.3	111.2	112.1	106.2	95.3	--	--	--	--
Elbert	100.0	101.6	100.9	103.1	104.4	101.4	103.0	--	99.7	--	--	111.7	107.5	108.8	101.3	--	--	--	96.3	--
El Paso	100.9	102.4	103.2	108.9	108.0	105.7	104.8	--	100.3	99.8	--	119.5	111.5	118.2	104.7	99.6	--	--	94.4	100.0
Kiowa	101.1	--	101.7	--	--	--	98.3	--	--	--	95.7	115.4	103.0	105.5	99.7	--	--	--	--	--
Kit Carson	100.7	102.5	96.9	100.7	93.9	108.1	99.7	--	100.0	--	--	--	101.8	102.7	100.0	--	--	--	98.1	100.0
Lincoln	99.1	101.3	97.3	99.0	96.9	102.7	102.3	--	97.7	--	--	--	98.3	104.0	101.7	--	--	--	--	--
Phillips	101.3	102.7	96.2	95.2	93.9	98.2	100.2	--	--	--	--	--	96.6	--	99.3	--	--	--	92.6	--
Washington	99.4	101.6	95.7	94.5	94.1	96.2	103.3	--	99.7	99.8	--	101.6	94.5	97.7	100.3	--	--	--	96.3	--
Yuma	100.1	101.4	96.7	99.0	92.2	99.8	102.6	--	97.2	--	--	96.0	95.1	99.5	101.8	--	--	--	96.3	100.0
E. Central District	100.5	101.8	98.1	101.7	96.3	100.4	101.2	98.7	100.0	100.4	95.7	111.9	101.0	106.4	101.2	97.2	--	--	98.1	100.0
Archuleta	94.6	96.3	103.1	107.0	103.5	--	--	103.9	101.9	--	--	98.9	95.9	100.8	--	103.9	--	--	--	--
Delta	95.9	98.2	101.8	98.1	105.6	--	--	96.5	100.0	98.2	--	97.1	94.4	94.8	94.3	101.3	96.6	97.5	96.3	100.0
Dolores	94.2	96.6	104.5	102.6	108.1	--	--	103.9	99.4	--	--	103.8	101.9	99.7	97.1	--	--	--	--	99.0
Garfield	93.8	97.3	105.2	100.7	106.7	--	--	98.2	100.8	97.9	--	96.0	97.2	97.7	95.3	103.9	95.8	99.2	96.3	103.9
Hinsdale	--	--	--	--	--	--	--	--	--	--	--	--	106.3	103.6	--	--	--	--	--	--
La Plata	94.5	97.2	103.9	101.4	108.9	--	--	105.6	102.2	--	--	97.8	99.1	102.8	96.0	107.0	--	100.7	109.3	104.9
Mesa	97.2	99.0	102.7	100.7	110.0	--	--	101.4	97.5	98.2	--	100.3	101.7	97.6	94.0	107.0	100.6	100.3	99.1	104.9
Montezuma	95.0	97.2	105.2	106.8	110.9	--	--	99.7	98.6	--	--	103.6	103.3	102.2	96.6	96.7	95.2	97.1	98.1	92.2
Montrose	95.3	95.8	103.4	98.3	104.4	--	--	95.3	98.1	98.2	--	94.8	97.5	95.7	94.5	100.6	99.5	95.6	101.9	94.2
Ouray	94.8	96.0	103.0	98.6	104.3	--	--	101.8	--	--	--	99.6	101.3	99.0	--	--	--	--	--	--
San Juan	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
San Miguel	94.2	96.0	104.0	100.0	106.7	--	--	105.3	100.8	--	--	101.1	103.1	100.0	--	--	--	--	--	--
W. Central and S. W. District	95.0	97.0	103.1	100.7	106.9	--	--	98.3	98.6	98.1	--	97.6	99.1	98.7	95.6	100.9	99.8	100.1	96.3	103.9
Alamosa	--	97.6	--	96.9	99.6	--	--	102.9	--	96.7	--	98.8	97.6	100.0	--	--	--	--	--	--
Conejos	--	97.6	106.2	96.4	98.5	--	--	102.9	99.4	96.5	--	98.2	94.5	97.2	--	--	--	--	--	--
Costilla	98.6	98.2	105.8	94.7	99.4	--	--	101.4	98.1	96.5	--	97.8	95.2	100.1	--	--	--	--	--	--
Mineral	--	--	--	--	--	--	--	--	--	--	--	104.3	102.3	106.6	--	--	--	--	--	--
Rio Grande	--	98.0	--	95.9	100.7	--	--	103.4	--	96.3	--	101.8	99.3	100.8	--	--	--	--	--	--
Saguache	--	97.6	--	96.6	100.2	--	--	103.0	--	96.3	--	103.3	102.6	102.1	--	--	--	--	--	--
South Central District	98.6	97.9	105.8	94.7	99.8	--	--	103.1	98.3	96.5	--	100.0	98.9	100.6	--	--	--	--	--	--
Baca	101.4	--	102.2	--	99.6	--	97.8	--	98.6	--	100.0	107.0	97.1	--	96.3	--	--	--	--	--
Bent	101.1	101.6	102.7	102.9	99.3	--	97.7	--	98.1	96.8	104.5	103.5	97.4	--	96.3	--	--	--	--	--
Crowley	101.4	--	103.0	103.6	100.2	--	100.8	--	99.7	98.2	--	105.7	104.5	--	98.7	97.4	--	--	98.1	--
Custer	99.0	101.4	105.6	101.7	107.0	--	--	107.4	102.2	--	--	111.8	108.4	112.6	--	--	--	--	--	--
Fremont	102.1	103.0	106.0	108.4	106.7	--	102.2	107.5	101.4	96.3	--	114.5	110.8	115.7	102.7	97.4	96.5	89.0	94.4	75.7
Huerfano	100.0	100.7	105.2	106.3	101.3	--	--	--	101.1	96.3	--	99.1	102.0	104.1	103.0	92.0	--	--	--	--
Las Animas	101.8	101.0	104.8	106.7	102.6	--	96.6	--	100.6	99.1	99.8	110.7	111.2	107.9	102.3	93.2	--	--	96.3	--
Otero	101.8	103.0	103.4	105.0	101.7	--	100.0	--	99.7	98.4	--	100.2	106.0	104.6	97.0	95.3	96.5	--	--	--
Prowers	101.1	102.1	101.8	101.0	99.6	--	98.1	--	98.1	98.8	102.6	102.6	100.3	101.8	97.1	--	--	--	100.0	--
Pueblo	102.5	103.2	106.1	108.0	105.7	--	104.4	--	101.1	98.2	--	112.3	111.1	115.9	103.9	96.3	--	--	101.9	--
Southeast District	101.6	102.1	103.9	105.0	101.5	--	98.1	107.5	100.3	98.2	101.6	104.1	106.3	111.3	97.8	97.4	96.5	89.0	94.4	75.7
State Average	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

1/ See text for method of computation.
2/ Four-year average, 1940-43, instead of 1935-43 average.
3/ Three-year average, 1941-43, instead of 1935-43 average.

Table 36.--PRICES RECEIVED BY FARMERS IN EACH COUNTY OF COLORADO FOR PRINCIPAL CROPS-Continued.

Table 2.- Average annual prices received by Colorado farmers, 1924 to 1947.
(Crops for which county price relatives are available.)

Year 1/	Winter wheat	Spring wheat	Corn	Oats	Barley	Rye	Grain sorghums	Potatoes	Dry beans 2/	Sugar beets 3/	Beet tops
	Per bu.	Per bu.	Per bu.	Per bu.	Per bu.	Per bu.	Per bu.	Per cwt.	Per cwt.	Per cwt.	Per ton of beets
1924	$1.18	$1.18	$ .88	$ .58	$ .72	$ .85	$ .90	$1.00	$ 4.60	$ 7.59	$ .42
1925	1.36	1.35	.70	.50	.58	.67	.71	2.58	3.85	5.98	.36
1926	1.08	1.04	.71	.44	.55	.71	.60	2.17	4.80	7.92	.50
1927	1.05	1.00	.68	.48	.56	.70	.65	.92	5.20	7.84	.49
1928	.86	.84	.68	.45	.54	.70	.60	.75	5.50	6.97	.37
1929	.93	.92	.71	.47	.55	.73	.58	1.90	4.90	6.93	.32
1930	.53	.54	.48	.35	.40	.40	.40	1.15	2.80	6.91	.26
1931	.33	.34	.36	.27	.27	.23	.20	.55	1.40	5.44	.27
1932	.36	.38	.28	.22	.20	.23	.16	.43	2.20	4.62	.22
1933	.66	.64	.40	.29	.31	.49	.34	1.02	2.90	4.62	.24
1934	.85	.83	.97	.52	.65	.71	1.04	.98	5.50	5.04	.64
1935	.92	.89	.66	.34	.44	.52	.66	1.00	2.75	5.81	.34
1936	1.01	.99	1.10	.49	.72	.77	.96	1.85	4.45	5.70	.40
1937	.92	.90	.63	.38	.51	.62	.47	.75	3.80	4.80	.50
1938	.49	.48	.45	.27	.30	.34	.34	.93	3.30	4.17	.30
1939	.64	.63	.62	.36	.46	.41	.56	1.00	3.40	4.64	.50
1940	.62	.63	.61	.34	.42	.40	.40	.70	2.45	4.99	.50
1941	.89	.86	.71	.37	.44	.47	.47	1.32	3.40	6.20	.50
1942	1.04	1.03	.89	.48	.63	.56	.77	1.92	4.65	6.46	.50
1943	1.29	1.29	1.14	.72	.94	.92	1.11	2.15	5.70	8.42	.80
1944	1.35	1.34	1.05	.68	.92	.92	.89	2.38	5.90	10.70	5/ .80
1945	1.41	1.41	1.19	.66	.93	1.19	1.15	2.02	5.50	10.20	5/ .80
1946	1.85	1.83	1.46	.83	1.23	1.74	1.26	1.83	11.90	10.20	5/ .90
1947 4/	2.25	2.25	2.30	1.00	1.45	2.30	1.79	2.58	11.80	---	---
Av. 1924-43	$ .651	$ .838	$ .683	$ .416	$ .510	$ .572	$ .596	$1.25	$ 3.88	$ 6.05	$ .422
Av. 1939-44	.972	.963	.837	.492	.635	.613	.700	1.58	4.25	6.90	.600

Year 1/	Broom-corn	Alfalfa hay	Other tame hay 6/	All tame hay	Wild hay	Forage sorghums	Apples	Peaches	Pears	Sour cherries 7/	Sweet cherries 7/
	Per ton	Per ton	Per ton	Per ton	Per ton	Per ton	Per bu.	Per bu.	Per bu.	Per ton	Per ton
1924	$ 60	$11.70	$ 8.60	$11.00	$ 9.70	8/ 7.40	$1.18	$1.45	$1.40	$---	$---
1925	140	12.50	10.50	12.00	10.80	8/ 8.80	1.30	2.15	1.15	---	---
1926	83	9.20	6.40	8.60	8.00	8/ 5.80	.78	1.10	.65	---	---
1927	120	9.70	7.70	9.20	8.40	8/ 8.80	1.21	1.40	1.40	---	---
1928	85	12.70	8.90	11.70	10.30	8.20	.89	1.20	1.05	---	---
1929	106	11.20	8.80	10.60	10.30	8.00	1.11	1.35	1.50	---	---
1930	50	9.50	7.85	9.10	8.80	6.30	.86	1.45	1.30	---	---
1931	36	8.40	6.45	7.85	7.50	4.80	.61	.50	.60	---	---
1932	33	7.00	5.45	6.50	5.40	4.75	.42	.55	.40	---	---
1933	93	6.00	3.60	5.30	5.20	4.10	.58	1.35	.65	---	---
1934	177	12.50	10.40	12.00	11.90	10.40	.84	1.00	.60	---	---
1935	47	7.20	4.70	6.50	6.00	5.40	.69	.80	.50	---	---
1936	88	8.80	6.50	8.20	8.00	7.50	.98	1.05	.85	---	---
1937	54	8.60	5.50	7.80	7.00	6.20	.73	.90	.85	---	---
1938	45	6.70	4.50	6.10	6.00	3.90	.70	.70	.50	45	60
1939	97	9.20	8.80	9.10	8.50	6.40	.66	.80	.75	50	85
1940	55	8.30	6.10	7.70	7.80	4.90	.72	.90	.75	50	100
1941	94	6.90	4.70	6.30	6.20	4.20	.74	1.10	1.00	66	120
1942	179	8.30	6.30	7.80	7.30	4.70	1.12	2.15	1.90	90	160
1943	250	16.80	13.90	16.10	14.10	10.60	2.10	3.80	3.20	164	316
1944	200	9/ 15.20	12.20	14.60	13.80	10.20	1.89	2.65	2.75	150	320
1945	249	9/ 15.70	13.20	15.10	12.20	9.80	2.99	2.15	2.00	194	340
1946	270	9/ 20.70	18.00	20.00	16.50	13.00	2.30	2.20	2.45	260	370
1947 4/	280	---	---	---	---	14.00	2.05	2.60	2.40	190	400
Av. 1924-43	$ 95	$ 9.56	$ 7.23	$ 8.97	$ 8.36	$ 6.46	$ .911	$1.285	$1.050	$---	$---
Av. 1939-44	$146	10.78	8.67	10.27	9.62	6.83	1.205	1.900	1.725	95	187

Source: Compiled from price estimates, as revised prior to April 1, 1948, by Colorado State Statistician, U. S. Bureau of Agricultural Economics, Denver, Colorado.

1/ For years 1924 to 1928, inclusive, figures given are December 1 prices. For 1929 and later years, figures given are marketing season average prices, i.e., average of the 15th of the month prices, weighted according to estimated monthly marketings.

2/ Cleaned beans.

3/ Includes support prices per ton, made under War Food Administration program, as follows:

1943	1944	1945	1946
$1.28	$2.82	$2.05	0

These prices do not include, however, program payments made under the Jones-Costigan Act and the Sugar Act of 1937. The average amounts of these payments per ton of beets were as follows:

1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946
$0.25	$1.75	$1.13	$ 0	$1.78	$1.75	$1.93	$1.77	$1.79	$2.28	$2.49	$2.69	$2.53	$2.25

4/ Preliminary

5/ Estimates supplied by officials of Great Western Sugar Company.

6/ Prices for other tame hay are not reported, as such, by BAE. Prices given here are computed by subtracting the tonnage and value of alfalfa hay produced each year from the tonnage and value, respectively, of all tame hay.

7/ Prices for sweet cherries and sour cherries were not reported separately prior to 1938.

8/ Prices of forage sorghums were not reported prior to 1928. Prices given here are estimates based on the line of regression between the other tame hay series and sweet sorghum series for the years 1928 to 1943, inclusive. The coefficient of correlation (r) is $+.899 \pm .032$.

9/ Prices of alfalfa hay have not been reported separately from all tame hay since 1943. Prices given here are based on the line of regression between the alfalfa price series and the all tame hay price series for the years 1924 to 1943. Since alfalfa comprises about 75 percent of all tame hay, it is to be expected that the relationship between these two series would be very close. The coefficient of correlation (r) is $+.997 \pm .001$.

Table 36.--PRICES RECEIVED BY FARMERS IN EACH COUNTY OF COLORADO FOR PRINCIPAL CROPS-Continued.

Table 3.- Average annual prices received by Colorado farmers, 1924 to 1946
(Crops for which county price relatives are not available.)

Year 1/	Field peas	Alfalfa seed	Sweet clover seed	Grapes	Snap beans For mkt.	Snap beans For mfg.	Early Cabbage For mkt.	Late Cabbage For kraut	Late cabbage	Cantaloupes for mkt.	Honeydews for mkt.
	Per cwt.	Per bu.	Per bu.	Per ton	Per bu.	Per ton	Per ton	Per ton	Per ton	Per crate	Per crate
1924	$2.60	$10.90	$7.50	$---	$---	$60.00	$---	$8.00	$11.98	$---	$---
1925	2.15	10.90	5.70	---	---	56.67	---	8.00	14.99	---	---
1926	2.50	9.50	7.30	---	---	53.33	---	6.38	8.20	---	---
1927	2.50	10.60	4.50	---	---	60.00	---	7.00	14.30	---	---
1928	2.40	12.00	3.70	---	.95	60.00	11.10	7.00	14.40	.94	.65
1929	2.40	9.80	3.90	70	.85	58.00	26.90	15.20	19.50	.83	.40
1930	2.35	9.80	3.70	65	.90	60.00	10.50	7.00	8.10	.80	.40
1931	1.50	6.30	3.10	50	.85	44.00	18.00	6.40	13.00	.85	.40
1932	1.45	5.50	2.35	45	.50	38.00	8.20	3.70	4.00	.70	.30
1933	1.30	5.90	2.55	55	.60	39.50	20.00	12.00	15.00	.55	.40
1934	1.75	5.80	3.95	44	1.05	40.00	22.00	15.80	17.50	.90	.50
1935	1.50	8.30	3.00	43	.80	41.60	7.20	5.40	7.50	.75	.45
1936	1.65	10.60	4.90	52	1.05	45.30	43.50	14.50	30.00	.65	.55
1937	2.00	14.50	4.60	55	.90	43.30	10.70	6.30	11.00	1.25	.55
1938	1.90	10.60	2.55	57	.75	42.70	5.70	4.70	5.00	.60	.50
1939	2.10	11.40	3.00	49	.70	39.40	14.80	9.70	13.00	.75	.50
1940	2.25	9.20	2.85	40	.70	38.10	7.60	4.40	7.50	.63	.56
1941	3.00	11.90	4.15	45	1.00	40.50	25.30	14.30	17.40	.77	.71
1942	3.25	16.60	4.35	65	1.35	56.70	19.40	9.90	16.00	1.25	1.20
1943	4.15	19.90	5.90	120	1.90	79.30	26.00	22.00	27.50	2.50	2.00
1944	4.40	20.20	6.20	110	1.70	80.40	29.00	15.80	23.50	1.70	1.35
1945	3.55	20.20	6.00	100	2.60	79.50	15.50	13.20	16.10	2.20	1.55
1946	5.20	21.40	6.10	120	2.05	80.60	22.40	13.00	20.00	1.65	1.35
1947	2/ 4.60	2/ 16.00	2/ 6.50	2/ 94	2.40	97.50	40.80	17.90	30.00	1.95	1.75
Av. 1924-43	$2.23	$10.70	$4.18	$ ---	$ ---	$49.82	$ ---	$ 9.38	$13.79	$ ---	$ ---
Av. 1939-44	3.19	14.87	4.41	71.50	1.225	55.73	20.35	12.68	17.48	1.27	1.05

Year 1/	Carrots for market	Cauliflower for mkt.	Celery for market	Cucumbers for pickles	Lettuce for market	Dry onions for mkt.	Green peas For mkt.	Green peas For mfg.	Spinach for market	Tomatoes For mkt.	Tomatoes For mfg.	Watermelons for mkt.
	Per bu.	Per crate	Per crate	Per bu.	Per crate	Per 50# sack	Per bu.	Per ton	Per bu.	Per bu.	Per ton	Per 1000 melons
1924	$---	$1.80	$ ---	$1.00	$2.16	$1.02	$1.85	$52.54	$ ---	$1.13	$10.25	$128
1925	---	.71	---	1.00	1.58	1.37	3.07	60.00	---	1.20	11.50	168
1926	---	1.15	---	.87	1.43	.88	1.94	60.00	---	.76	12.00	95
1927	---	1.78	---	.75	1.63	.80	2.84	60.00	---	.85	12.00	242
1928	.90	1.20	1.24	.60	1.07	2.62	1.60	50.00	.80	.90	11.00	150
1929	.45	.70	.82	.60	1.25	1.09	1.30	44.00	.70	.95	11.00	165
1930	.40	.80	.68	.53	.85	.75	1.65	46.00	.40	.80	10.90	170
1931	.60	.70	.90	.48	1.30	2.27	1.45	45.80	.25	.60	10.50	150
1932	.35	.40	.68	.36	.50	.43	.50	34.80	.25	.35	8.10	90
1933	.50	.40	1.05	.38	1.00	1.09	.65	33.30	.40	.45	8.70	100
1934	.65	.45	1.05	.48	.80	1.22	1.10	37.40	.50	.85	9.20	120
1935	.50	.55	.76	.40	.70	1.17	.70	39.10	.35	.60	10.20	100
1936	.80	.45	1.28	.47	1.30	.88	.85	38.80	.45	.70	9.20	150
1937	.65	.60	1.42	.48	1.00	1.30	.70	46.60	.40	.60	10.60	150
1938	.50	.40	.98	.52	.90	1.00	.75	42.40	.45	.50	10.40	100
1939	.47	.30	2.32	.45	1.00	.50	.75	37.00	.45	.53	9.60	130
1940	.50	.35	1.99	.40	1.05	.95	.80	39.90	.45	.55	10.80	100
1941	.63	.40	1.76	.51	1.20	1.20	.70	40.60	.58	.70	11.60	140
1942	.95	.65	2.75	.65	2.10	1.55	1.15	54.00	.65	.95	16.80	180
1943	1.10	1.00	3.50	.78	2.15	2.60	1.55	71.10	.90	1.25	22.10	300
1944	1.30	.75	3.70	.92	2.00	.80	1.30	72.50	.75	1.75	24.20	260
1945	1.30	.90	3.70	.94	2.20	1.40	2.00	72.40	.85	1.95	24.10	350
1946	1.00	.95	2.20	1.55	1.80	.60	1.55	73.10	.75	2.00	25.00	380
1947	1.40	1.05	3.30	1.20	2.75	1.50	1.50	77.80	.85	1.80	24.00	390
Av. 1924-43	$---	$ .740	$ ---	$ .586	$1.25	$ 1.24	$1.30	$46.67	$---	$ .761	$11.35	$146
Av. 1939-44	.825	.585	2.67	.618	1.58	1.28	1.04	52.52	.630	.955	15.85	185

Source: Compiled from price estimates, as revised prior to April 1, 1948, by Colorado State Statistician, U. S. Bureau of Agricultural Economics, Denver, Colorado.

1/ Marketing seasons for each crop.

2/ Preliminary.

Table 36.--PRICES RECEIVED BY FARMERS IN EACH COUNTY OF COLORADO FOR PRINCIPAL CROPS-Continued.

Table 4.- Estimated average prices received by farmers in each county of Colorado during the 6-year period, 1939-44.

County and District	Winter wheat	Spring wheat	Corn	Oats	Barley	Rye	Grain sorghums	Potatoes	Dry beans	Sugar beets	Broom Corn	Alfalfa hay	Other tame hay	Wild hay	Forage sorghums	Apples	Peaches	Pears	Sour Cherries	Sweet Cherries
	Per bu.	Per bu.	Per bu.	Per bu.	Per bu.	Per bu.	Per bu.	Per cwt.	Per cwt.	Per cwt.	Per ton	Per ton	Per ton	Per ton	Per ton	Per bu.	Per bu.	Per bu.	Per ton	Per ton
Chaffee	$ --	$ .97	$ --	$ .52	$ .68	$ --	$ --	$1.70	$ --	$ --	$ --	$11.93	$9.35	$10.22	$ --	$1.42	$ --	$ --	$ --	$ --
Clear Creek	--	--	--	--	--	--	--	--	--	--	--	--	9.48	10.36	--	--	--	--	--	--
Eagle	--	.96	--	.50	.69	--	--	1.58	--	--	--	9.99	8.64	9.39	--	--	--	--	--	--
Gilpin	--	--	--	.51	--	--	--	1.69	--	--	--	--	9.06	9.87	--	--	--	--	--	--
Grand	.93	.94	--	.51	.67	.66	--	1.70	--	--	--	10.18	8.67	8.98	--	--	--	--	--	--
Gunnison	.93	.95	--	.51	.69	--	--	1.68	--	--	--	10.51	8.42	9.39	--	--	--	--	--	--
Jackson	--	--	--	--	--	--	--	--	--	--	--	--	--	9.01	--	--	--	--	--	--
Lake	--	--	--	--	--	--	--	--	--	--	--	--	--	9.62	--	--	--	--	--	--
Moffatt	.91	.91	.89	.49	.68	.64	--	1.64	--	--	--	10.08	8.44	8.80	--	--	--	--	--	--
Park	--	--	--	.51	.67	.63	--	1.66	--	--	--	11.69	9.48	10.31	--	--	--	--	--	--
Pitkin	--	.96	--	.51	.69	.65	--	1.63	--	--	--	10.34	8.75	9.48	--	--	--	--	--	--
Rio Blanco	.91	.92	.88	.50	.69	.67	--	1.61	--	--	--	9.95	8.50	9.05	--	--	--	--	--	--
Routt	.92	.93	--	.48	.66	.64	--	1.61	--	--	--	9.76	7.56	8.41	--	--	--	--	--	--
Summit	.94	--	--	.50	.68	--	--	1.67	--	--	--	--	8.84	10.01	--	--	--	--	--	--
Teller	--	.98	--	.52	.67	--	--	1.64	--	--	--	12.16	9.93	10.64	--	--	--	--	--	--
N. W. and Mountain District	$ .92	$ .93	$ .89	$ .50	$ .67	$ .65	$ --	$1.61		$ --	$ --	$10.11	$8.38	$ 9.26	$ --	$1.42	$ --	$ --	$--	$ --
Boulder	$ .97	$ .98	$ .86	$ .50	$ .64	$ .64	$ --	$ --	$4.28	$6.95	$ --	$11.11	$8.82	$10.50	$7.00	$1.19	$ --	$ --	$ 93	$ --
Jefferson	.99	.99	.87	.51	.66	.63	--	1.62	4.24	6.96	--	11.79	9.36	10.34	7.01	1.19	--	--	104	187
Larimer	.97	.98	.86	.49	.64	.64	--	1.57	4.16	6.93	--	10.75	8.57	10.43	7.06	1.21	--	--	97	187
Logan	.98	.99	.81	.46	.62	.61	.73	1.57	4.22	6.89	142	10.37	8.04	9.48	6.84	--	--	--	93	187
Morgan	.98	.99	.83	.49	.65	.61	.73	1.58	4.20	6.90	--	10.36	8.08	9.44	6.80	--	--	--	93	187
Sedgwick	.97	.99	.81	.47	.61	.61	.72	1.61	4.22	6.91	--	10.11	8.13	9.14	6.73	--	--	--	--	--
Weld	.97	.99	.85	.49	.64	.59	.72	1.50	4.22	6.95	--	10.62	8.27	10.25	6.91	1.20	--	--	93	187
N. Central & N. E. District	$ .97	$ .99	$ .84	$ .49	$ .64	$ .60	$ .73	$1.51	$4.22	$6.93	$142	$10.68	$8.37	$ 9.96	$6.84	$1.20	$ --	$ --	$ 97	$187
Adams	$ .97	$ .99	$ .84	$ .51	$ .64	$ .60	$ .73	$1.56	$4.22	$6.95	$ --	$10.72	$9.00	$10.36	$7.15	$1.17	$ --	$ --	$ 95	$187
Arapahoe	.97	.98	.84	.51	.64	.60	.72	--	4.24	6.93	--	12.16	9.46	10.52	7.23	1.17	--	--	88	--
Cheyenne	.97	--	.84	--	.61	--	.69	--	--	--	--	--	9.22	--	6.91	--	--	--	--	--
Denver	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Douglas	.97	.98	.86	.52	.67	.63	.72	--	4.25	--	--	12.32	9.64	10.78	7.25	1.15	--	--	--	--
Elbert	.97	.98	.84	.51	.66	.62	.72	--	4.24	--	--	12.04	9.32	10.47	6.92	--	--	--	91	--
El Paso	.98	.99	.86	.54	.69	.65	.73	--	4.26	6.89	--	12.88	9.67	11.37	7.15	1.20	--	--	90	187
Kiowa	.98	--	.85	--	--	--	.69	--	--	--	140	12.44	8.93	10.15	6.81	--	--	--	--	--
Kit Carson	.98	.99	.81	.50	.60	.68	.70	--	4.25	--	--	--	8.83	9.88	6.83	--	--	--	93	187
Lincoln	.96	.98	.81	.49	.62	.63	.72	--	4.24	--	--	--	8.52	10.00	6.95	--	--	--	--	--
Phillips	.98	.99	.81	.47	.60	.60	.70	--	--	--	--	--	8.38	--	6.78	--	--	--	88	--
Washington	.97	.98	.80	.46	.60	.59	.72	--	4.24	6.89	--	10.95	8.19	9.40	6.85	--	--	--	91	--
Yuma	.97	.98	.80	.49	.59	.61	.72	--	4.13	--	--	10.35	8.25	9.57	6.95	--	--	--	91	187
E. Central District	$ .98	$ .98	$ .82	$ .50	$ .61	$ .62	$ .71	$1.56	$4.25	$6.93	$140	12.06	$8.76	$10.24	$6.91	$1.17	$ --	$ --	$ 93	$187
Archuleta	$ .92	$ .93	$ .86	$ .53	$ .66	$ --	$ --	$1.64	$4.33	$ --	$ --	$10.66	$8.31	$ 9.70	$ --	$1.25	$ --	$ --	$ --	$ --
Delta	.93	.95	.85	.48	.67	--	--	1.52	4.25	6.78	--	10.47	8.18	9.12	6.44	1.22	1.84	1.68	91	187
Dolores	.92	.93	.87	.50	.69	--	--	1.64	4.22	--	--	11.19	8.83	9.59	6.63	--	--	--	--	185
Garfield	.91	.94	.88	.50	.68	--	--	1.55	4.28	6.76	--	10.35	8.43	9.40	6.51	1.25	1.82	1.71	91	194
Pinadale	--	--	--	--	--	--	--	--	--	--	--	--	9.22	9.97	--	--	--	--	--	--
La Plata	.92	.94	.87	.50	.69	--	--	1.67	4.34	--	--	10.54	8.59	9.39	--	1.29	--	1.74	104	194
Mesa	.94	.95	.86	.50	.70	--	--	1.60	4.14	6.78	--	10.81	8.82	9.39	6.42	1.29	1.91	1.73	93	194
Montezuma	.92	.94	.88	.52	.70	--	--	1.58	4.19	--	--	11.17	8.96	9.83	--	1.17	1.81	1.67	93	172
Montrose	.93	.92	.87	.48	.66	--	--	1.51	4.17	6.78	--	10.22	8.45	9.21	6.45	1.21	1.89	1.65	97	176
Ouray	.92	.92	.86	.49	.66	--	--	1.61	--	--	--	10.74	8.78	9.52	--	--	--	--	--	--
San Juan	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
San Miguel	.92	.92	.87	.49	.68	--	--	1.66	4.28	--	--	10.90	8.94	9.62	--	--	--	--	--	--
W. Central and S. W. District	$ .92	$ .93	$ .86	$ .50	$ .68	$ --	$ --	$1.55	$4.19	$6.77	$ --	$10.52	$8.59	$ 9.49	$6.53	$1.22	$1.90	$1.73	$ 91	$194
Alamosa	$ --	$ .94	$ --	$ .48	$ .63	$ --	$ --	$1.63	$ --	$6.67	$ --	$10.66	$8.45	$ 9.62	$ --	$ --	$ --	$ --	$ --	$ --
Conejos	--	.94	.89	.47	.63	--	--	1.63	4.22	6.66	--	10.59	8.19	9.35	--	--	--	--	--	--
Costilla	.96	.95	.89	.47	.63	--	--	1.60	4.17	6.66	--	10.54	8.25	9.63	--	--	--	--	--	--
Mineral	--	--	--	--	--	--	--	--	--	--	--	11.24	8.87	10.25	--	--	--	--	--	--
Rio Grande	--	.94	--	.47	.64	--	--	1.63	--	6.64	--	10.97	8.61	9.70	--	--	--	--	--	--
Saguache	--	.94	--	.48	.64	--	--	1.63	--	6.64	--	11.14	8.90	9.82	--	--	--	--	--	--
South Central District	$ .96	$ .94	$ .89	$ .47	$ .63	$ --	$ --	$1.63	$4.18	$6.66	$ --	$10.78	$8.57	$ 9.67	$ --	$ --	$ --	$ --	$ --	$ --
Baca	$ .99	$ --	$ .86	$ --	$ .63	$ --	$ .68	$ --	$4.19	$ --	$146	$11.53	$8.42	$ --	$6.58	$ --	$ --	$ --	$ --	$ --
Bent	.98	.98	.86	.51	.63	--	.68	--	4.17	6.68	153	11.16	9.44	--	6.58	--	--	--	--	--
Crowley	.99	--	.86	.51	.64	--	.71	--	4.24	6.78	--	11.39	9.06	--	6.74	1.17	--	--	93	--
Custer	.96	.98	.88	.50	.68	--	--	1.70	4.34	--	--	12.05	9.40	10.83	--	--	--	--	--	--
Fremont	.99	.99	.89	.53	.68	--	.72	1.70	4.21	6.64	--	12.34	9.61	11.13	7.01	1.17	1.83	1.54	90	142
Huerfano	.97	.97	.88	.52	.64	--	--	--	4.30	6.64	--	10.68	8.84	10.01	7.03	1.11	--	--	--	--
Las Animas	.99	.97	.88	.52	.65	--	.68	--	4.28	6.84	146	11.93	9.64	10.38	6.99	1.12	--	--	91	--
Otero	.99	.99	.87	.52	.65	--	.70	--	4.24	6.79	--	10.80	9.19	10.06	6.63	1.16	1.83	--	--	--
Prowers	.98	.98	.85	.50	.63	--	.69	--	4.17	6.82	150	11.05	8.90	9.76	6.63	--	--	--	95	--
Pueblo	.99	.99	.89	.53	.67	--	.73	--	4.30	6.78	--	12.10	9.63	11.15	7.10	1.16	--	--	97	--
Southeast District	$ .99	$ .98	$ .87	$ .52	$ .64	$ --	$ .69	$1.70	$4.26	$6.78	$148	$11.22	$9.22	$10.71	$6.68	$1.17	$1.83	$1.54	$ 90	$142
State Average	$ .972	$ .963	$ .837	$ .492	$ .635	$ .613	$ .70	$1.58	$4.25	$6.90	$146	$10.78	$8.67	$ 9.62	$6.83	$1.205	$1.90	$1.725	$ 95	$187

APPENDIX B

SEMIDETAILED LAND CLASSIFICATION STANDARDS

Land Characteristics	Class 1 - Arable	Class 2 - Arable
Soils		
Texture	Sandy loam to friable clay loam.	Loamy sand to friable clay.
Depth*		
To sand, gravel or cobble	18-24 inches plus- good free working soil.	12-18 inches plus- good free working soil.
To relatively impervious subsoil material	48 inches plus.	36 inches plus.
To penetrable lime zone	18 inches with 48 inches penetrable.	14 inches with 36 inches penetrable.
Alkalinity	pH less than 8.8 unless soil is calcareous, total salts are low, and evidence of black alkali is absent.	pH 9.0 or less, unless soil is calcareous, total salts are low, and evidence of black alkali is absent.
Salinity	Total salts not to exceed 0.2 per cent. May be slightly higher in open premeable soils exhibiting good drainage qualities.	Total salts not to exceed 0.5 per cent. May be slightly higher in open permeable soils exhibiting good drainage qualities.
Rock and Rocky Soil	No solid or loose rock that will interfere with ordinary cultivation.	No rock in place, easily removable loose rock limited to that generally cleared in similar communities where irrigation is practiced.

*At the minimum depths the texture must be fine sandy loam or heavier with some soil mixed with the gravel or cobble, and at the greater depths it must be as heavy as sandy loam. Loamy sands underlain by coarse sand or gravel should be 24-30 inches deep (depending on the per cent of silt and clay) to qualify for class 2.

Figure 1.--Semidetailed land classification standards.

Land Characteristics	Class 1 - Arable	Class 2 - Arable
Topography		
Slopes	Smooth slopes up to 5% in general gradient; reasonably large-sized bodies sloping in the same plane.	Smooth general slopes of 5 to 10% or rougher slopes less than 5% in general gradient.
Surface	Even enough to require only small amount of levelling and no heavy grading.	May require considerable levelling and moderate grading but in amounts generally found feasible in similar areas where irrigation is practiced.
Drainage	Soil and topographic conditions such that no specific drainage requirements are anticipated.	Soil and topographic conditions such that some drainage will probably be required, but artificial drainage practicable at reasonable cost.

Source: U. S. Bureau of Reclamation, looseleaf manual (9).

Figure 1.--Semidetailed land classification standards--con.

(1) The Fourmile and Gristy Ditches most likely would not use any storage water directly. They already have good direct-flow rights and are in the best strategic position to pick up any return-flow water in the creek. A conservative estimate of the return flow to Fourmile Creek from the application of 830 acre-feet of reservoir water above the headgates of these ditches is about 130 acre-feet, which is undoubtedly more water than they could use in addition to what they normally divert on their direct-flow rights.

(2) The small amount of reservoir water estimated for the Atkinson Ditch is the amount needed for a small expansion of potato acreage. The direct-flow rights of this ditch would be enhanced somewhat by return flow from application of reservoir water from ditches above the Atkinson headgate and in excess of the 1.6 second-foot priority of the Fourmile Ditch.

(3) No additional water would be used by the Buck Farm Ditch because hay will continue to be the principal crop on account of elevation. A small acreage of cereals will continue to be raised, primarily as nurse crops for reseedings of alfalfa and other hay crops, but there is ample June water for grain.

(4) The amounts estimated for the Class C and Class D ditches are believed adequate to permit two full cuttings of alfalfa, a moderate acreage of cereal grains, a small acreage of potatoes (where the elevation is not too high), and a small amount of late water for meadow aftermath, pasturage and fall plowing.

(5) New land probably would require an average of about 2½ acre-feet of storage water per acre. This is a liberal estimate due to the fact that all new land would be under the Fourmile and McKown Ditches, both of which have fairly large flood rights for early-season irrigation, part of which could be applied to the new acreage.

Figure 2.--Assumptions upon which estimates of water needs on Fourmile Creek were based.

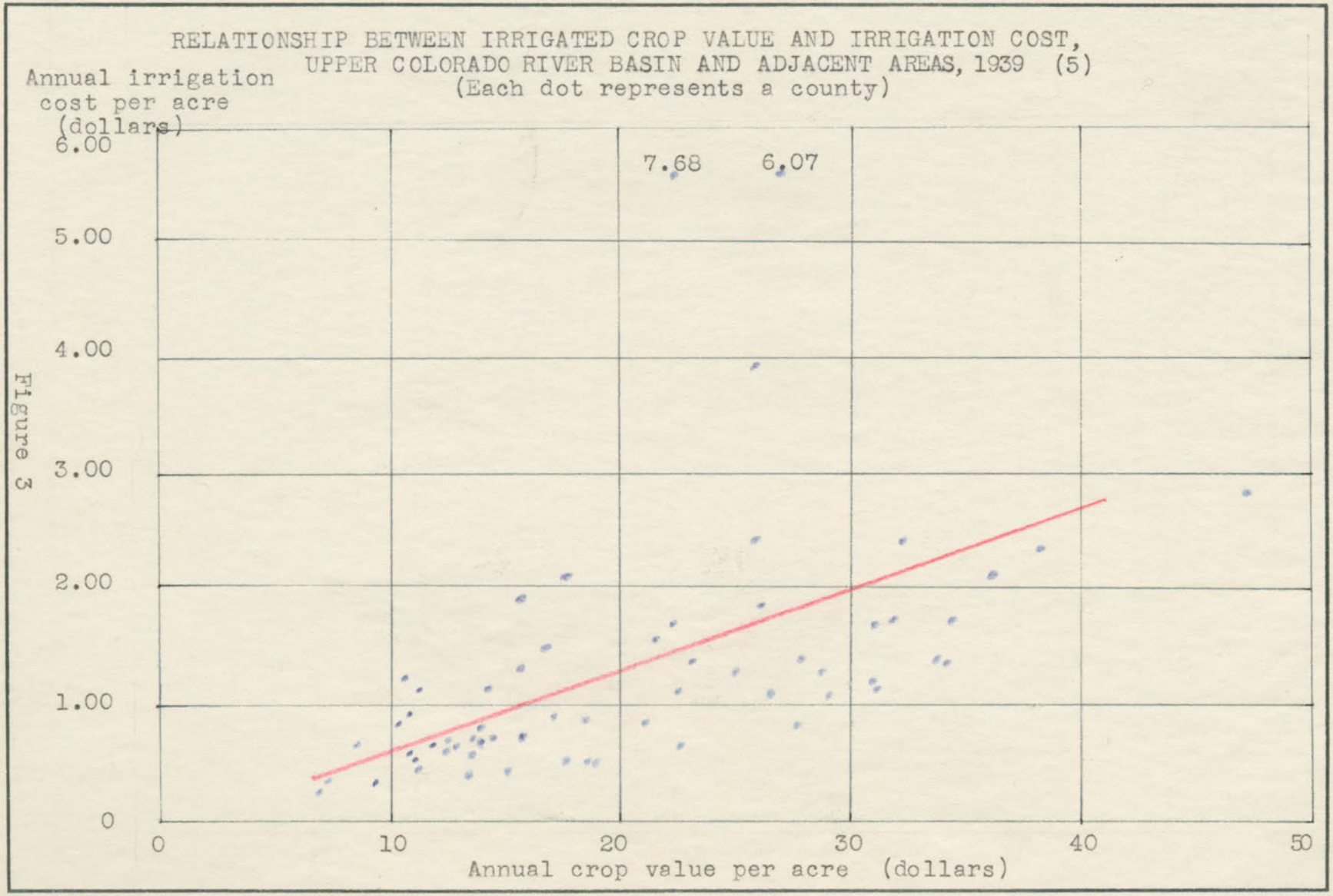
RELATIONSHIP BETWEEN IRRIGATED CROP VALUE AND IRRIGATION COST,
UPPER COLORADO RIVER BASIN AND ADJACENT AREAS, 1939 (5)
(Each dot represents a county)
Annual irrigation cost per acre (dollars)
6.00
5.00
4.00
3.00
2.00
1.00
0
7.68
6.07
0
10
20
30
40
50
Annual crop value per acre (dollars)

Figure 3

Confidential

Project_____

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UPPER COLORADO RIVER BASIN SURVEY
Colorado Agricultural Experiment Station

Name of operator_____ Type of Farm_____

Address_____

Land description	Sec.	Twp.	Rge.	Acres	Name of owner

Description of ditch and reservoir rights_____

Grazing, 1947 season

Type of stock	Forest Service permits			Grazing Service permits			Private permits			Owned and leased land		
	No. of head	Date on	Date off	No. of head	Date on	Date off	No. of head	Date on	Date off	No. of head	Date on	Date off

Livestock wintered and pastured for other operators, 1947-48 season

Type of stock	Winter feeding		Pasture		
	No. of head	Tons of hay fed	No. of head	Date on	Date off

Inventory, Jan. 1, 1947

Dairy cattle_____

Beef cattle_____

Sheep_____

Sow & gilts_____

What changes do you plan to make in livestock operations in the near future?_____

What year of the past 10 did you receive the lowest crop yields?_____ Why?_____

What year of the past 10 did you receive the best crop yields?_____ Why?_____

(6644-47)

Figure 4

Crop Record

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Crop and Land Use	Acreage		Yields per acre			
	1947	1946	1947	1946	Best Yr.	Worst Yr.
Irrigated land:						
Alfalfa hay						
Other tame hay						
Wild hay						
Barley						
Potatoes						
Pasture			xxx	xxx	xxx	xxx
Sub-total			xxx	xxx	xxx	xxx
Under ditch, but not irrigated:						
Alfalfa						
Other tame hay						
Wild hay						
Barley						
Pasture			xxx	xxx	xxx	xxx
Sub-total			xxx	xxx	xxx	xxx
Dryland, not under ditch:						
Wheat						
Barley						
Pasture			xxx	xxx	xxx	xxx
Sub-total			xxx	xxx	xxx	xxx

Number of irrigations, by months, 1947 and 1946

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Crop	1947							1946						
	Apr.	May	June	July	Aug.	Sept.	Oct.	Apr.	May	June	July	Aug.	Sept.	Oct.
Alfalfa														
Other tame hay														
Wild hay														
Barley														
Potatoes														
Pasture														

If you had all the water you needed for all land under ditch, anytime you wanted it, how much more land would you irrigate than you did in 1947?_____

If sufficient water were available, how much dry land would you develop for irrigation?_____

If you had a full water supply, what changes would you make in cropping programs?

_____

_____

If you had a full water supply, what changes would you make in livestock operations

_____

_____

Cost of water in 1947, by ditch and reservoir

Name of ditch or reservoir	Total cost	Cost per acre

What do you think the average land owner could pay annually for a full water supply over a long-time period? Per acre_____ Per acre-foot_____

Remarks:_____

B I B L I O G R A P H Y

BIBLIOGRAPHY

1. Colorado. Agricultural Experiment Station. Economics and Sociology Section. Prices received by farmers in each county of Colorado for principal crops. Fort Collins, Colo., Colorado A & M College, 1948. (Misc. series no. 419.)
A mimeographed issue of about 9 pages in process of being published.

2. Follansbee, Robert. Upper Colorado River and its utilization. Washington, U.S. Govt. Print. Off., 1929. 387 p. (U.S. Geological Survey, Water supply paper, no. 617.)

3. Melcher, William. The economics of crop production on the Uncompahgre Valley Reclamation Project, Madison, Wisconsin, 1931. 132 p. mimeographed.
Thesis (Ph.D.) University of Wisconsin, 1931.

4. Merrill, F. C. Preliminary Report, Fourmile Project, Garfield County, Colorado, 1940. Grand Junction, Colorado, Colorado Conservation District, 1940. 52 p. mimeographed.

5. Selby, H. E. Data on value of irrigated crops and cost of irrigation water, upper Colorado River Basin and potential water export areas, 1939. Washington, U.S. Bureau of Agricultural Economics, n.d. 8 0. mimeographed.
Preliminary draft for review.

6. Selby, H. E. A method of determining feasible irrigation payments. Journal of Farm Economics, 24:637-643, August 1942.

7. U. S. Bureau of Agricultural Economics. Value and price of irrigation water; a preliminary statement prepared in the regional office of the Bureau of Agricultural Economics, Berkeley, California, for the benefit of CVPS committees concerned with various aspects of this problem, October 1943. Washington, 1944. 87 p. mimeographed
Preliminary statement, for administrative use only.

8. U. S. Bureau of Reclamation. The Colorado River; A comprehensive report on the development of the water resources of the Colorado River Basin for irrigation, power production, and other beneficial uses in Arizona, California, Colorado, Nevada, New Mexico, Utah and Wyoming. Washington, U. S. Govt. Print. Off., 1946. 295 p.

9. U. S. Bureau of Reclamation. Manual. Washington, U. S. Govt. Print. Off., 1927. Looseleaf.

10. U. S. Repayment Commission. Repayment of the costs of Federal and Indian Reclamation Projects, 1938. Washington, U. S. Govt. Print. Off., 1938. 38 p. (U. S. 75th Congress, 30 Session, House Document no. 673.)

11. U. S. Treaties, etc. 1945. Utilization of waters of the Colorado and Tijuana rivers and of the Rio Grande. Treaty between the United States of America and Mexico. Washington, U. S. Govt. Print. Off., 1946. 57 p. (U. S. Department of State. Treaty series 994.)

12. Webb, Walter Prescott. The Great Plains. Boston, Mass., Ginn and Company, 1931. 525 p.

13. Widtsoe, John A. The principles of irrigation practices. New York, The Macmillan Company, 1915. 496 p.

14. Widtsoe, John A. Success on irrigation projects. New York, John Wiley & Sons, 1928. 153 p.