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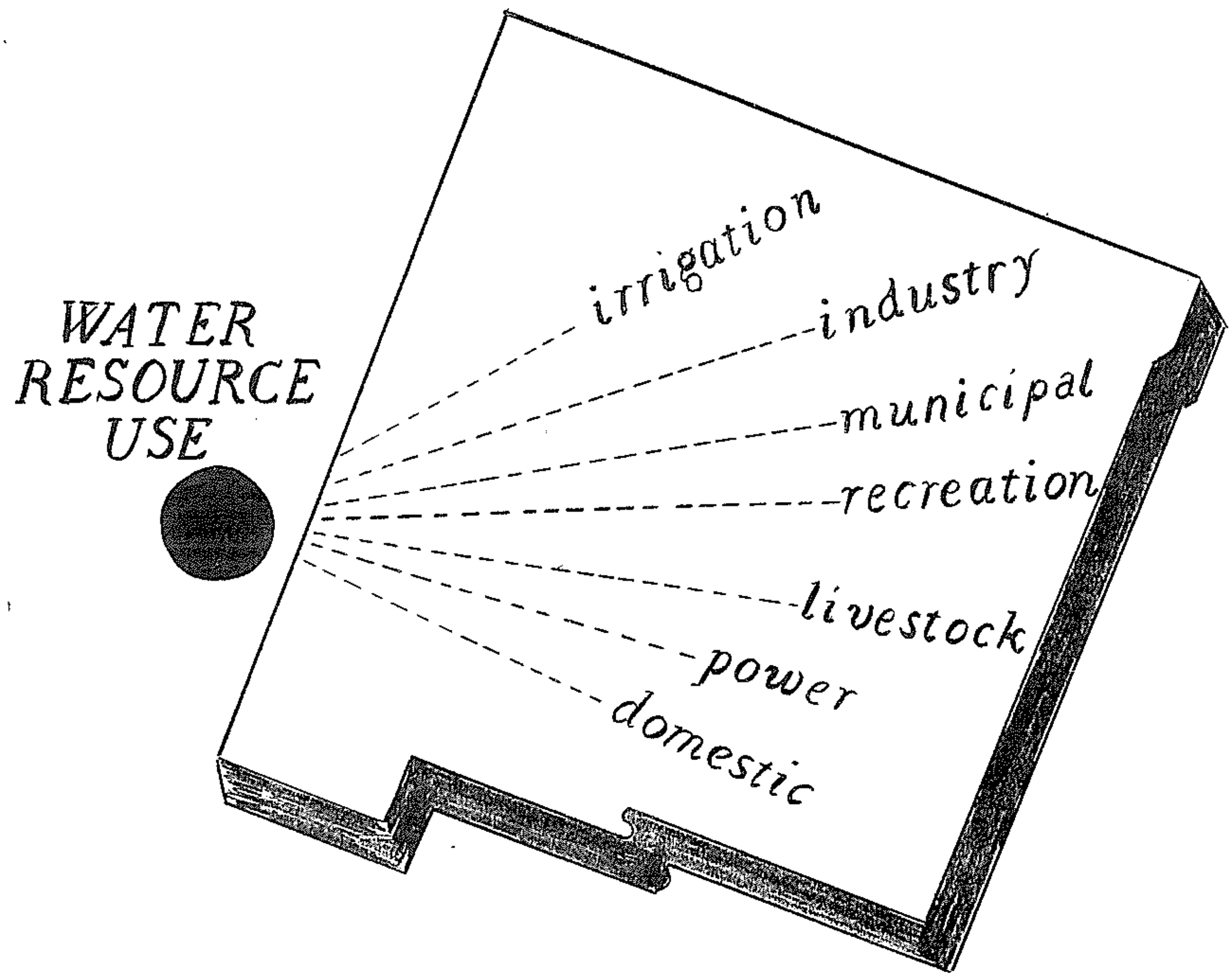
WATER RESOURCES

And

THEIR ECONOMIC IMPORTANCE IN NEW MEXICO



A Set of Papers Presented at a Staff and Graduate Seminar

Conducted by the

Agricultural Economics Department

NEW MEXICO COLLEGE OF AGRICULTURE AND MECHANIC ARTS

State College, New Mexico

Harold B. Elmendorf.

FOREWORD

The papers included in this publication were presented in a staff and graduate seminar conducted by the Agricultural Economics Department of New Mexico College of Agriculture and Mechanic Arts during the period January 26 to May 24, 1956.

The purpose of the seminar was to bring in well qualified men who would present various phases of the New Mexico water problem and assist in the discussions. The hope was that these seminar discussions would inform the A & M staff members and graduate students of the various phases of New Mexico's water problems so they may be in a better position to assist in the solution of these problems.

Speakers came from the following: Elephant Butte Irrigation District; State Engineer's Office; Soil Conservation Service; Forest Service; Agricultural Research Service; U. S. Geological Survey; Army Engineers; Burea of Reclamation; Civil Engineering and Agricultural Economics Department of New Mexico A & M A.

Among the general topics discussed were: 1. Supply of water, 2. review of water studies conducted in New Mexico, 3. underground water, 4. watershed control, 5. water yield from forest and rangelands, 6. interstate compacts, 7. new irrigation proposals, 8. water supply and cost of water for irrigation, 9.Costs of operating a project, 10. uses of water for other than irrigation, 11. flood control.

The discussions of the above problems brought out the complexity of the entire water situation. It pointed out how all interested, including agriculture, industry, recreation, armed services and all others, are vitally concerned with working out the best possible use of our limited water supply. With the assistance of the river compacts, New Mexico and the states of Texas, Colorado, Utah, Wyoming, Arizona and California are working toward proper allocation of stream flows.

The water seminar attracted considerable state wide attention. Many people indicated an interest in attending the seminars. Others asked for any reports which might be available from the meetings. As a result, New Mexico College of Agriculture and Mechanic Arts is sponsoring a state-wide water conference. The dates for the Conference are October 31, November 1 and 2, 1956.

This publication is being mimeographed for limited distribution for reference purposes.

H. R. Stucky, Head
Department of Agricultural Economics
New Mexico College of A & M A

September 17, 1956

Water Resources and Their Economic Importance in New Mexico

A set of papers presented at a
Staff and Graduate Seminar

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New Mexico College of Agricultural and Mechanic Arts

January 26 through May 24, 1956

The water resources of New Mexico are of great economic importance to the state. For this reason a staff and graduate seminar was held for the purpose of bringing together information about the water resources, review the past, present and proposed future uses of water and to analyze the water resource problems which have a bearing on the economic welfare of the State of New Mexico.

This seminar was organized and conducted by the Agricultural Economics Department. It met once every 2 weeks for a 2 hour period on New Mexico A & M Campus. This was primarily a staff and graduate student seminar.

The papers presented were of sufficient public interest that those in attendance and others requested they be made available for reference purposes.

No attempt has been made to edit any of the papers. They are presented here in the form they were received from the author. Some are in more of an outline form than others but these give considerable information in a limited space. Others are more or less the complete presentation.

The following is the order in which the papers were given in the seminar and is the order in which they are presented in this publication.

Source and Disappearance of the Total Water Supply

in

New Mexico

by

H. R. Stucky*

This paper is presented to give a broad picture of the total amount of water received in New Mexico and in a broad way to account for its disappearance.

Water is received by (1) precipitation falling on the state and (2) the flow of streams into the state,

Water disappears or is used as follows: (1) domestic and stock water, (2) municipal and industrial uses, (3) irrigation, (4) native and cultivated plants on non-irrigated lands, (5) evaporation, (6) percolation and (7) run off through streams leaving New Mexico.

A broad accounting is all that is attempted here. This is necessary because the precipitation varies widely from year to year. There is only limited information on plant use and on evaporation. Stream flows fluctuate widely from year to year and the minimums and maximums do not come in the same years, see tables 1 and 2.

WATER RECEIVED IN NEW MEXICO

Surface Area in New Mexico - Acres	77,866,240
13.88" or equivalent in acre feet Average Annual Precipitation 13.88 inches (1892-1954 U.S. Weather Bureau)	1.156
Average acre feet of precipitation for state	90,013,373
Mean in-flow of major streams	1,901,050
Total acre feet received	91,914,423

Tables 1 and 2 give the inflow and outflow of waters through the major streams. There was an average of about 300,000 acre feet more per year flowing out of the state during the period 1945-54 than flowed into New Mexico.

*Head of Department of Agricultural Economics, New Mexico College of Agriculture and Mechanic Arts.

TABLE 1

In-Flow of Major Streams in New Mexico

Minimum, Maximum, and average for

10 year period 1945-54

	Minimum		Maximum		Average
	acre feet	year	acre feet	year	acre feet
San Juan River at Rosa, N.M.	327,900	1951	1,235,000	1952	656,900
Los Pinos River at Ignacio, Colo.	26,670	1951	297,700	1948	123,700
Animas River near Cedar Hill, N.M.	372,900	1951	985,400	1952	620,000
La Plata River at Colo. N.M. state line	3,400	1934	39,430	1937	14,330*
Rio Grande River near Lobastos, Colorado	71,570	1954	678,000	1948	274,500
Vermejo River near Dawson, New Mexico	1,480	1951	20,180	1948	8,520
Rio Chama at Park View, New Mexico	92,900	1946	384,200	1952	203,100
Total	—		—		1,901,050

* 7 year average

Source: From work sheets in U.S., Geological Survey, Surface Water Branch Office, Santa Fe, New Mexico

TABLE 2

Out-flow of Major Streams in New Mexico

Minimum, Maximum and Average for

10 year Period 1945-54

	Minimum		Maximum		Average
	acre feet	year	acre feet	year	acre feet
Rio Grande at El Paso	273,000	1951	631,800	1943	471,800
Pecos River At Red Bluff, N.M., plus flow of Delaware River near Red Bluff, New Mexico	32,590	1953	165,890	1950	94,360*
Canadian River at Logan, N.M.	21,310	1954	123,600	1947	76,200
Cimarron River near Guy, N.M.	4,340	1947	16,590	1948	7,450
Gila River below Blue Creek near Virden, N.M.	31,880	1951	318,000	1949	96,180
San Francisco River near Glenwood, N.M.	15,660	1953	107,800	1949	37,280
San Juan River at Shiprock, New Mexico	668,300	1951	2,482,000	1952	1,411,000
Puerco River at Gallup, New Mexico	1,470	1944	14,450	1941	6,200**
Total (acre feet)	___		----		2,200,470

* 9 year average
** 5 year average
Source: From work sheets in U.S., Geological Survey, Surface Water Branch Office, Santa Fe, New Mexico

WATER DISAPPEARANCE - NEW MEXICO

Domestic, Municipal and Industrial Use

The 1950 use of water in certain communities in the Rio Grande Valley, based on estimates from several sources,* vary from 25 to 175 gallons per capita. Estimates of future use indicates a need of from 130 to 240 gallons per person in the year 2000.

Using a figure of 100 gallons per person for the entire state of New Mexico, we would have the following domestic and urban requirements.

Estimated population of New Mexico Jan. 1, 1956	806,000
100 gallons x 365 = use per person per year	36,500 gal.
806,000 x 36,500= 29.4 billion gallons or	91,500 (acre feet)

Note: Albuquerque's reported use in 1954 was 159 gallons per person. Albuquerque's present total use is about 26,300 acre feet.
(150,000 people @159 gallons per day= 8.6 billion gallons or 26,350 acre feet).

Estimates Future Domestic and Industrial Uses

1. It is estimated that the population of Albuquerque may exceed 375,000 by the year 2000.

2. New Mexico may have a population of 1,250,000 to 1,500,000 by the year 2000.*
   The population of New Mexico was 531,818 in 1940. It is estimated to be 806,000 in 1956 or an increase of 274,000 or 51.6 percent. At the 1940-56 rate the above estimate seems quite conservative.

3. With modern homes and industrialization, the water use is likely to increase from the above estimate of 100 gallons, to 150 to 175 gallons per person per day.
   By the year 2000 cities, domestic and industrial uses might require about 300,000 acre feet.
   (1,500,000 people at 175 gallons per day = 297,000 acre feet).

*Bureau of Reclamation, City of Albuquerque and other sources.

Note: Some of this water may be available for other uses. This will depend on whether the water returns to the stream channels and whether adequate sewage reclamation is practiced.

Irrigation Requirements

Acres irrigated in New Mexico (from 1950 census of irrigation)	776,000

Water requirements per acre (Mesilla Valley)

Alfalfa and similar crops	4.52	acre feet
Cotton and similar crops	2.57	acre feet
Average all crops	3.63	acre feet

Acres irrigated in New Mexico	776,000
Estimated requirements per acre (acre feet)	3
Estimated irrigation requirements (acre feet)	2,328,000

Water Use and Outflow of Streams

Present, domestic and industrial use	91,500
Present irrigation requirements	2,328,000
Out-flow major streams (average)	2,200,470
Total acre feet	4,619,970

Some of the water flowing out of the state has been allocated to New Mexico through inter-state compacts as follows:

Canadian River	200,000 acre feet
San Juan River	800,000 acre feet

Some of the 800,000 acre feet in the San Juan may be lost to New Mexico unless it is allocated to beneficial use in the state in the near future. This could come about by a revision of the total supply available to all states from the Colorado river.

Notes on Water Use

I. Plant use per acre of Alfalfa

Needed for irrigated alfalfa in Mesilla Valley	4.52 acre feet
Normal consumptive use by alfalfa plants	2.49 acre feet
Water loss in irrigation (seepage,etc.)	2.03 acre feet

II. Evaporation from water surface

a. Tests in pans

Las Cruces	- 80"	Santa Fe	- 51"
Deming	- 67"	Farmington	- 52"

b. Elephant Butte Reservoir

Average content	800,000 acre feet
Average loss	151,600 acre feet
Percent loss	18.95

Conclusion

New Mexico receives, on an average, about 92 million acre feet of water per year. About 90 million of this comes from precipitation and about 2 million from streams flowing into the state. This water supply varies from possibly 60 million acre feet in drought years to above 150 million in the high rainfall years. Some additional water is secured by pumping from underground water which has been, like oil and coal, stored for ages.

The following shows the total amount of water received, amount of water used and outflow, and the amount 87,294,453 or almost 95% of our total supply, where the use might be improved or losees reduced.

Average total acre feet received New Mexico	91,914,423
Average total use and outflow New Mexico	4,619,970
Average use or loss through: (1) grass, forest and brush) (2) percolation) (3) transportation) (4) evaporation)	87,294,453

The above 87 million acre feet, (available on the average) is used or disappears in the following ways:

1. Some is used by forests.

2. Some is used on range land to produce grass for sheep and cattle.

3. A little falls on parks and recreational areas.

4. A considerable amount comes in small showers and evaporates from the hot ground without serving any economic purpose.

5. A large amount of the total is used by non-economic plants, such as pinon, juniper, salt cedar and mesquite.

   Note: Plants and trees breath off or transpire from 60 to 300 gallons of water for every 1 pound of dry matter produced.

6. Reservoirs lose about 6 feet of water from every surface acre during a year from evaporation.

<u>Small Percentage Reduction in Loss Would Add a High Percentage to Water Available for Use</u>

If we could save only 3% of this 87,294,000 acre feet of water we would more than double our estimated present requirements for irrigation 2,328,000 acre feet and for domestic and industrial uses 91,500 acre feet.

There appears to be many opportunities to make small reductions in water losses, such as losses through evaporation and through use by non-economic plants. The total of these savings of water could contribute heavily to the economic development of New Mexico.

We have some real opportunities to make economic use of the waters of the approximately 800,000 acres of San Juan water and the 200,000 acres of Canadian River which is allocated to New Mexico but is only partially used at present.

A Brief Review of Surface Water Studies in New Mexico

by

Morris Evans*

Purposes

Studies of surface waters in New Mexico have been made-and are still being made - for many purposes. The more important purposes include:

Stream flow measurements and discharges for (a) flood flows; (b) direct diversion for irrigation; and (c) reservoir storage for irrigation and flood storage, power, and fish and wildlife.

Domestic and Industrial Use
Power Development Possibilities
Inter-state Stream Compacts
Flood Control Investigations to determine feasibility of construction programs
Joint Investigations - Rio Grande and Pecos Rivers, Arkansas, White, Red Rivers Basin studies
Fish and Wild Life on live streams
Rehabilitation of small irrigation systems
Federal Water Program. (President Truman's Committee)

Agencies

Most of the studies have been made by agencies of the Federal Government acting alone or in cooperation. State Agencies also act alone or in cooperation with other state and with Federal Agencies. At times public utilities and private corporations have been cooperators or have made their own studies.

New Mexico State Agencies include the Agricultural Experiment Station, Extension Service, and the Department of Civil Engineering of New Mexico College of A & M A. The State University, the New Mexico Institute of Mining Technology, the State Engineer, Fish and Game Department, Public Health Service and State Highway Department are other New Mexico institutions or agencies active in surface water studies.

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The following is a partial list of Federal Agencies that have been or are concerned with surface water studies.

Department of Agriculture; Bureau of Agricultural Economics, Farmer's Home Administration. (Formerly Farm Security Adm.), Production and Marketing Administration, Forest Service, Soil Conservation Service, Rural Electrification Administration and Bureau of Public Roads
Department of Army; Corps of Engineers
Department of Interior; Bureau of Reclamation, United States Geological Survey, Fish and Wildlife, Bureau of Indian Affairs
Department of Commerce; Weather Bureau
Department of Health and Public Welfare
Federal Power Commission
National Resources Committee
Public Utilities cooperated in the study of the 1941 Rio Grande Flood.

Studies made

The United States Geological Survey began stream flow measurements in 1889, at San Marcial on the Rio Grande. Between that date and the present, gaging station records have been taken on almost all streams in the state. These records cover long periods at specific locations or shorter periods at other places. From 1889 to 1925 gaging stations were in operation for varying periods at 160 different places on 72 streams including streams flowing into closed basins.

The United States Geological Survey records are the basis for stream flow studies made by other agencies for a great variety of purposes. Forecasted possible flood flows are based on stream flow and storm pattern records. Possible supplies for direct or reservoir diversion for irrigation, and possibility of power development are based on United States Geological Survey data.

Flood control investigations are relatively new in the southwest. The first one authorized by Congress was made by the Corps of Engineers on the Dry-Cimarron prior to 1938. The engineers also made surveys on the Pecos and the South Canadian drainage. Their studies are limited primarily to the streams and the flood plains. The U.S.D.A. was directed by Congress to make watershed surveys for erosion prevention and flood control. The U.S.D.A. has made the following surveys: preliminary - Major Long's Creek, Dry Cimarron, Pecos, Rio Puerco, and Rio Grande. A full survey also was made on the Rio Puerco and the Pecos. The survey of the Dry Cimarron by both agencies resulted in negative reports, as did the Major Long's Creek survey. Definite programs for flood control were made for the Rio Puerco and Pecos. No action has been taken by Congress on these programs. A survey of the Rio Grande has resulted in a flood and sediment control dam on the Jemez River and channel rectification work on the Rio Grande above Elephant Butte reservoir.

The U.S.D.A. was assigned the task of determining damages from and the cost of fighting the Rio Grande flood of 1941 while the flood was in progress. Cooperating agencies included State Engineer and State Highway Departments, Bureau of Reclamation, Bureau of Indian Affairs, Fish and Wildlife Service, Civilian Conservation Corps, Middle Rio Grande Conservancy District, the Santa Fe Railroad, Mountain States Telephone Company, and the three U.S.D.A. Agencies Bureau of Agricultural Economics, Soil Conservation Service and Forest Service.

Public flood control hearings were held in all watersheds prior to the start of preliminary surveys. The announced purpose of the hearings was to find out the wishes, desires and attitudes of the people in local areas who would be affected by measures to control floods.

<u>The Bureau of Reclamation</u> made feasibility and engineering studies of proposed irrigation projects involving federal funds. Irrigation projects that were initialed by the Bureau or with which the Bureau later became connected include: Elephant Butte, Carlsbad, Ft. Sumner, Tucumcari, and Vermejo. Recently the Bureau has taken over the Middle Rio Grande Conservancy District. Recent engineering and economic feasibility studies of the Bureau have covered the tributaries of the south Canadian above Conchas reservoir, Ute Creek, the tributaries of the Rio Grande above the Chama River, proposed projects in the San Juan area, and the proposed San Juan trans-mountain diversion.

Water Facilities studies were conducted by the U.S.D.A. in the late 1930's and early 1940's. The S.C.S. made the physical survey, the B.A.E. determined the economic feasibility and the F.S.A. was the financing agency. The program covered only small areas, or small groups of water users whose water supply was frequently interrupted by flash floods or arroyo flows. The users were not able to finance rehabilitation except through a long time payment plan which became available through this program. The projects were cooperative. Most projects were in the North Central part of the state. Projects larger than $50,000 could not be approved. The Farmer's Home Administration now handles the program.

Joint Investigations were made in 1936-37 on the Rio Grande, in 1938-41 on the Pecos, and the Canadian and Dry-Cimarron were covered in the Arkansas, White, and Red River Basins study 1951-55. The Rio Grande and Pecos investigations were under the direction of the National Resources Committee. In all three investigations both State and Federal Agencies were included. Principal items in all three investigations relating to surface water were: normal, minimum, maximum and flood flows, reservoir storage, stream and reservoir sedimentation, beneficial and non-beneficial use of water, water loss through pondage, seepage, evaporation and stream bank overflow, and quality of stream flow and reservoir storage. The reports of the investigations included recommended programs for better methods of water use and control.

Interstate Stream Compacts based on extensive studies of water supply and disappearance cover three major streams and one tributary. They are: the Rio Grande Compact covering the drainage above Ft. Quitman Texas; the Pecos River Compact covering the entire drainage; Costilla Creek, tributary to the Rio Grande, in Colorado and New Mexico; and the South Canadian River from Conchas Reservoir to Oklahoma. The Compacts were worked out by commissions, approved by the legislatures of all states affected, and finally approved by Congress.

The Arkansas, White, Red River Basins investigation is more than a study of water as it was set up to develop plans for the best use of all natural and man made resources of the entire basins. The surface water studies included direct and storage irrigation, flood control, power development, stream pollution, recreation, fish and wildlife, and control of surface runoff.

Storage Reservoirs. There is a large number of reservoirs in New Mexico but only a few are important other than locally. The more important reservoirs include:

El Vado, on the Chama; Storage for Middle Rio Grande project. 200,000 A.ft.
Jemez, on Jemez River; flood and silt control. 120,000 A.ft.
Costilla, on Costilla Creek. Irrigation and power. 14,500 A.ft. Max. for 60 days.
Elephant Butte, on Rio Grande. Irrigation and supplemental power. The latest estimate of capacity is 2,273,000 A.ft.
Caballo, on Rio Grande. Holding reservoir for water released for power at Elephant Butte; 246,000 A.ft. for irrigation, 100,000 A.ft. for flood control.
Bluewater, on Bluewater Creek. Irrigation. 46,000 A.ft.
Storrio, off channel from Gallinas River originally for irrigation, and original capacity 21,700 A.ft. Now operated by New Mexico Fish and Game Dept.
Alamogordo, on Pecos. Storage for Carlsbad project, 148,000 A.ft. plus flood control.
McMillan, on Pecos. Transient storage for Carlsbad project. Estimated present capacity about 28,000 A.ft.
Avalon, on Pecos. Transient storage for Carlsbad project, present capacity about 6,200 A.ft.
Eagle Nest Lake, on Cimarron Creek. Irrigation and recreation, 78,000 A.ft.
Conchas, on South Canadian. Irrigation for Tucumcari project 287,000 A.ft. 202,000 A.ft. flood control and 110,000 dead storage.
Vermejo, off channel from Vermejo River. Irrigation for Vermejo project. 26,500 A.ft. in 4 reservoirs.

GENERAL OBSERVATIONS ON UNDERGROUND WATER
IN NEW MEXICO

By

W. P. Stephens*

I. Water Laws:

State Constitution

1. Confirmed existing right
2. Declared unappropriated water of natural streams to be public. Priority of appropriation shall give the better right.
3. Beneficial use shall be the basis, the measure and the limit of the right to the use of water. This is different to eastern states where riparian rights is the basic guide for use of water.

Ground Water Law

Legislative act of 1931 declares: The water of underground streams, channels, artesian basins, reservoirs, or lakes, having reasonable ascertainable boundaries, are hereby declared to be public waters and to belong to the public and to be subject to appropriation for beneficial use.

1949 law required drillers to be licensed.
1. Bond required
2. Licensed drillers in declared basins
3. Must have State Engineer's permit to drill.

1955 law
Cannot drill wells in New Mexico and take water across state line.
Office of State Engineer created in 1907.
Some conflict between surface and ground water laws.
The administrative, judicial and legislative decisions as regards water can materially effect the economy of an area.
Declared basins- State Engineer has authority to declare basins, once declared he has control over drilling.

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II. Increase Use of Ground Water

1. For Irrigation - - Table 1 shows that the acreage irrigated from wells increased about 200,000 acres from 1940 to 1950. By 1955 the irrigated land receiving water from wells had increased to about 66 percent of the total.

TABLE I

Acreage Irrigated by Source of Water for Various Years in New Mexico

	1955a acres	1950 acres	1940 acres	1930 acres	1920 acres
Flowing Wells	2,000[b]	19,120	23,262	27,693	36,586
Pumped Wells	574,000[c]	297,880[e]	97,304	37,295	24,291
Total Wells	576,000[c]	317,000[e]	120,566	64,988	60,877
% of Total Irrigated Land	66%	45%	21%	12%	11%
Streams and Other Sources	297,000[d]	383,000[e]	459,286	468,935	486,082
Total	873,000	700,000	579,852	533,923	546,959

Source: 1950 U. S. Census of Agriculture Irrigation of Agriculture Lands. Volume III - pt. 12.

a. Estimates by U.S. Geological Survey, Ground water Branch.

b. Estimated, primarily Roswell Basin, does not include wells which flow in the winter but are pumped in the summer.

c. Includes about 131,000 acres also furnished surface water.

d. Does not include about 131,000 acres also furnished ground water. Includes about 4,000 acres furnished sewage.

e. Includes approximately 34,000 acres also receiving surface water.

Increased number of pumps -- as indicated in Table 2, the number of irrigation pumps more than doubled from 1940 to 1950. For the five year period 1950 to 1955 the number of wells again almost doubled. There has also been substantial increases in the number of irrigation wells in specific oounties from 1950 to 1955. For example Dona Ana County reported only 46 pumps in 1950, compared with about 1200 in 1955. Curry County reported about 16 pumps in 1950 and by 1956 there is more than 400 in this county.

TABLE 2

A Comparison of Number of Pumps, Average Lift, and Additional Cost of Water for 1940 and 1950 and number of pumps 1955, by Counties in New Mexico

Area	Irrigation Pumps No.			Average Pumping Lift		Decrease	Additional** cost per acre-foot
	1940	1950	1955[a]	1940	1950	1940 to 1950	
State	1558	3942	7500b	46	70	-24	1.56
Bernalillo	3	32	*	*	43	--	
Catron	16	1	*	-42	--	--	
Chaves	597	943	1000	38	61	-23	1.50
Colfax	1	2	*	--	20	--	
Curry	*	16	400/	*	162	--	
DeBaca	*	4	*	*	47	--	
Dona Ana	7	46	1200	--	65	--	
Eddy	206	491	750	46	64	-18	1.17
Grant	29	51	70	35	73	-38	2.47
Guadalupe	--	--	9	--	--	--	
Hidalgo	17	74	160	38	82	-44	2.86
Lea	47	692	1000	55	70	-15	.98
Lincoln	3	52	*	63	60	/3	
Luna	204	413	570	68	93	-25	1.63
McKinley	--	1	*	--	85	--	
Mora	--	2	*	--	--	--	
Otero	4	38	100	112	108	/4	
Quay	12	55	65	74	66	/8	
Rio Arriba	1	6	*	--	15	--	
Roosevelt	330	772	1100	46	68	-22	1.43
Sandoval	1	2	*	--	40	--	
San Juan	1	20	*	*	50	--	
San Miguel	1	8	*	*	79	--	
Santa Fe	4	23	43	26	129	-103	6.70
Sierra	59	60	*	18	42	-24	1.56
Socorro	2	--	*	*	--	--	
Taos	2	3	17	*	225	--	
Torrance	5	104	200	68	85	-17	1.10
Union	3	9	40	*	80	--	
Valencia	--	22	35	--	127	--	

* Not Available

** Based on a cost of 6.5¢ per acre foot, per foot of lift.
Source: 1950 U. S. Census of Agriculture, Irrigation of Agri. Lands, V. III - Pt. 12 / U.S.G.S.

a. Estimates by U.S.G.S. Ground Water Branch and Stephens.

b. County figures do not add up to the 7,500 state total. The additional pumps are in counties where estimates were not made.

2. Domestic use - The increased domestic use of ground water in Albuquerque is a good example of the general trend in the state. Table 3 shows that in 1947 the City of Albuquerque used about 9,000 acre-feet, by 1954 this had increased to about 27,000 acre-feet. The principal source of this water is deep wells. In 1954 the average daily use of water per person averaged 159 gallons in Albuquerque.

TABLE 3

Use of water by the City of Albuquerque 1947 and 1954

Year	No. Wells	Bil. of gal. used	Ac/ft
1947	17	2.9	8,891
1954	54	8.7	26,761

Source: Albuquerque Progress, Vol. XXII, No. 6, Albuquerque National Bank, June 1955, p-1

3. Industrial use - as industry in our state increases it demands and gets additional water. Ground water is the principal source of this water.

III. Location of Irrigated land in New Mexico

Table 4 shows the location of irrigated land in the state by counties and by source of water. It is indicated that for the entire state about 70 percent of the irrigated land receives part of all of the water from wells.

TABLE 4

Irrigated Acreage in State by Source of Water and by Counties, 1955

County	Irrigated Acreage: Wells	Surface stream	Combination surface & well	Total
Bernalillo	---	1,700	24,000	25,700
Catron	---	2,200	---	2,200
Chaves	90,100	4,000	---	94,100
Colfax	---	23,000	---	23,000
Curry	63,000	---	---	63,000
DeBaca	---	4,300	---	4,300
Dona Ana	4,900	5,500	80,000	90,400
Eddy	43,000	6,500	20,000	69,500
Grant	---	7,500	1,900	9,400
Guadalupe	250	3,100	---	3,350
Harding	---	100	---	100
Hidalgo	12,600	---	5,000	17,600
Lea	85,000	---	---	85,000
Lincoln	350	1,200	4,700	6,250
Luna	30,000	---	1,000	31,000
McKinley	---	3,500	---	3,500
Mora	---	15,000	---	15,000
Otero	5,500	2,500	1,000	9,000
Quay	3,500	36,520	---	40,020
Rio Arriba	---	34,000	---	34,000
Roosevelt	50,000	---	---	50,000
Sandoval	---	10,000	5,000	15,000
San Juan	---	42,900	---	42,900
San Miguel	---	15,000	---	15,000
Santa Fe	3,000	8,000	---	11,000
Sierra	1,000	4,200	---	5,200
Socorro	---	2,200	13,000	15,200
Taos	2,100	33,000	---	35,100
Torrance	20,000	100	---	20,100
Union	4,370	1,000	---	5,370
Valencia	4,500	5,500	22,000	32,000
State	423,170	272,520	177,600	873,290

Source: Estimated by Stephens based on report by C. B. Thompson, State Waters, New Mexico Interstate Stream Commission, Santa Fe, New Mexico, June 1953 and estimates by U.S.G.S. Ground Water Branch.

IV. Declared Basins

1. Roswell Artesian Basin
   a. Declared August 12, 1931
   b. Artesian basin closed at this time. (1931)
   c. Shallow water basin closed 1937
   d. Water table dropped from 38 feet in 1940 to 61 feet 1950 or 23 feet.
   e. This would be an additional cost of 23 x 6.5¢= $1.50 per acre foot.
   f. Dropped 10 feet around Hagerman from 1953 to 1954

2. Carlsbad Basin
   a. Declared basin October 16, 1947
   b. Open to filing of application for ground water for supplemental use of lands with existing surface water rights.
   c. Water table dropped from 46 feet in 1940 to 64 feet in 1950 or 18 feet.
   d. An increased cost of $1.17 per acre-foot.
   e. South of Loving dropped 6 feet from 1953 to 1954 Just south of Carlsbad dropped 6 feet for this same period.

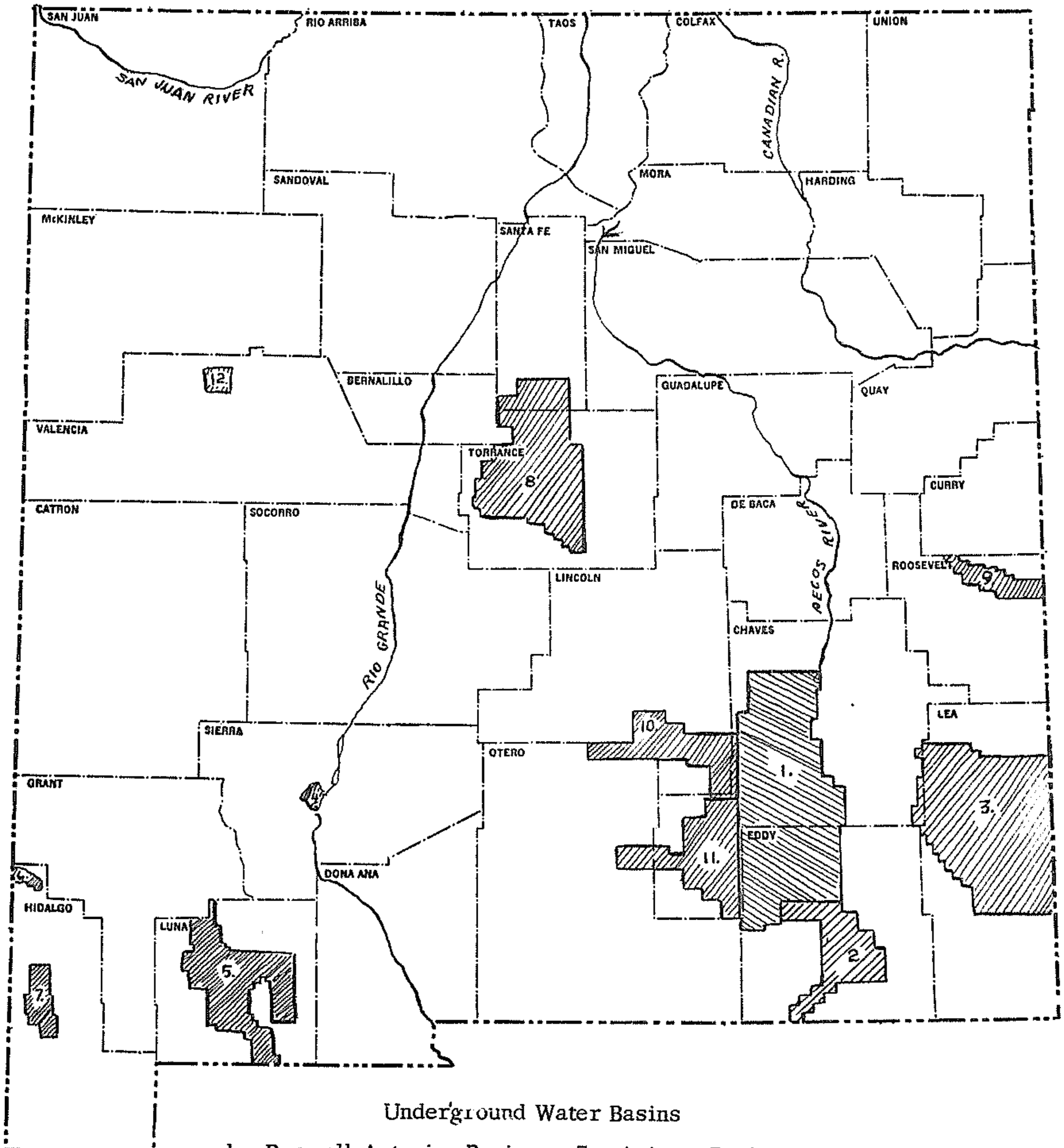
3. Lea County Basin

   a. Declared August 21, 1931
   b. Closed December 29, 1948
   c. Reopened on a township basis 1953
   d. Water table dropped from 55 feet in 1940 to 70 feet in 1950 or 15 feet
   e. An increased cost of about $1.00 per acre-foot
   f. Dropped as much as 8 feet in some areas from 1953 to 1954

4. Hot Springs Artesian Basin
   a. Declared April 15, 1935
   b. Closed to mineral (hot) water July 1, 1937 Various portions reopened in 1947 and 1950
   c. Closed to fresh (cold) water August 26, 1947

5. Mimbres Basin
   a. Declared July 29, 1931, extended in 1942
   b. Closed April 20, 1945
   c. Reopened part of it April 26, 1950
   d. Water table lowered from 68' in 1940 to 93' in 1950 or 25'
   e. An increased cost of about $1.62 per acre-foot
   f. Lowered 4' to 5' in some areas from 1953 to 1954

DECLARED UNDERGROUND WATER BASINS *



Underground Water Basins

1.	Roswell Artesian Basin	7.	Animas Basin
2.	Carlsbad Basin	8.	Estancia Basin
3.	Lea County Basin	9.	Portales Basin
4.	Hot Springs Basin	10.	Hondo Basin
5.	Mimbres Basin	11.	Penasco Basin
6.	Virden Valley Basin	12.	Bluewater Basin

*Source: office of State Engineer

6. Virden Valley Basin
   a. Declared December 5, 1938
   b. Still open to filing

7. Animas Basin
   a. Declared May 5, 1948
   b. Closed June 14, 1948
   c. Dropped from 38' in 1940 to 82' in 1950 or 44'
   d. A cost increase of about $2.86 per acre-foot
   e. In concentrated pumping area dropped 7' from 1953 to 1954

8. Estancia Basin
   a. Declared January 31, 1950
   b. Still open to filing
   c. Water table dropped from 68' in 1940 to 85' in 1950 or 17'
   d. A cost increase of about $1.10 per acre-foot

9. Portales Basin
   a. Declared May 1, 1950
   b. Open to filing
   c. Water table dropped from 46' in 1940 to 68' in 1950 or 22'
   d. A cost increase of about $1.43 per acre-foot
   e. Dropped 6' - 8' from 1953 to 1954

10. Hondo Basin

11. Penasco Basin

12. Grants-Bluewater Basin

V. Other Ground Water Areas

1. Quay County - House Area
2. Curry County - Clovis Area
3. Hidalgo County - East of Animas - Playas
4. Taos County - Sunshine Valley
5. Sierra and Dona Ana Counties - Rincon and Mesilla Valleys
6. Sandoval, Bernalillo, Valencia, and Socorro Counties - Middle Rio Grande Valley
7. Grant County - Upper Gila River Valley
8. Grant and Luna Counties - Upper Mimbres Valley
9. Otero County - Tularosa Valley

VI. Summary

New Mexico with the possible exception of the Middle Rio Grande Valley has no known extensive ground water areas in which the available supply is sufficient to meet ultimate demand.

At present in the major pump areas the draft exceeds the recharge.

What are the economic limits on depth of pumping?

Relationship of costs and returns:

1. Cost

   a. Technology of pump, motor and fuel
   b. Prices paid

2. Returns

   a. Crops that can be grown, yields, etc.
   b. Prices received.

LEGAL STATUS OF WATER IN NEW MEXICO

By

Charles D. Harris,
Special Assistant Attorney General

THE APPROPRIATION DOCTRINE

In 1846, four years before New Mexico was established as a territory, Brig. Gen. S. W. Kearny promulgated the Kearny Code[1] which provided that the laws theretofore enforced concerning water courses would continue in force except that such regulation as was required was transferred from the governing officials of the villages to those of the counties.

In 1851, the first session of the territorial legislature declared that the courses of ditches or acequias already established should not be disturbed and that all rivers and streams theretofore known as public ditches or acequias were thereby established and declared to be public.

In 1891, the legislature provided that a sworn statement describing any water control works thereafter constructed must be filed within ninety days after the commencement of the work. The penalty for failure to file said statement was a loss of priority. The 1891 law was superceded by two statutes in 1901 and these were in turn replaced by the comprehensive legislation of 1907 which is the basic law in force in New Mexico today.[2]

The 1907 statute showed the clear legislative intent that the surface waters of New Mexico were public waters and New Mexico would follow the doctrine of prior appropriation. This water appropriation statute[3], is still in effect and provides that:

> "All natural waters flowing in streams and water courses, whether such be perennial or torrential, within the limits of the state of New Mexico, belong to the public and are subject to appropriation for beneficial use. A water course is hereby defined to be any river, creek, arroyo, canyon, draw or wash, or any other channel having definite banks and bed with visible evidence of the occasional flow of water."

The 1907 water code set out the method of appropriating water and provided that it could be done only by application to and permit from the state engineer. The New Mexico courts have held that the statutory method of appropriating water is exclusive.[4]

If there were any doubt about the status of surface water in New Mexico, it was removed by provisions of the constitution adopted January 21, 1911 before New Mexico became a state. The constitution provides in Article XVI: (1) All existing rights to the use of any water in this state for any useful or beneficial purpose are hereby recognized and confirmed. (2) The unappropriated water of every natural stream, perennial or torrential, within the state of New Mexico, is hereby declared to belong to the public and to be subject to appropriation for beneficial use in accordance with the laws of the state. Priority of appropriation shall give the better right. (3) Beneficial use shall be the basis, the measure and the limit of the right to the use of water.

As has been pointed out above, the legislature and the constitutional convention have always upheld the doctrine of prior appropriation; however, the courts have consistently held that the legislation implementing the appropriation doctrine has been merely declaratory of the law in New Mexico as it has always been and the legislation has been merely procedural, setting up fair rules and procedures for acquiring water rights. The territorial, state and federal courts have consistently held that the doctrine of appropriation is the law governing water rights in New Mexico and that this doctrine grew out of the conditions of the country and the necessities of its inhabitants.[5]

GROUND WATER

As was pointed out in the report of the President's Water Resources Policy Commission:[6]

> "New Mexico, while not the first state to enact ground water legislation, has pioneered in this field, in that its ground water administrative statute, after having been declared unconstitutional and subsequently re-enacted in correct form, was the first of the western state ground water statutes to be put into active operation and has set the pattern for much of the subsequent legislation in that field in the West."

An example of the effect that New Mexico legislation has had on the ground water law of the West is the "Uniform Underground Water Law for Western States" promulgated by the Assn. of Western State Engineers in 1934. The similarity to the New Mexico code is striking.

The first New Mexico statute, enacted in 1927, was overthrown by the New Mexico Supreme Court in the celebrated case of Yeo vs. Tweedy[7]. Although the court held the statute invalid because it violated a constitutional prohibition against legislation by mere reference to pre-existing legislation, the court went on to state that the statute was declaratory of existing law, was not subversive of vested rights of owners of lands overlying the waters of an artesian basin the boundaries of which had been ascertained, and was fundamentally sound.

At the 1931 session, the present law was enacted. The pertinent statutes are short and to the point and are contained in three pages of the Annotated Statutes. Section 75-11-1 provides that bodies of ground water with reasonably ascertainable boundaries belong to the public and are subject to appropriation. The statute further provides: "Existing water rights based upon application to beneficial use are hereby recognized." There is also a provision for forfeiture of rights after four years' nonuse. According to the administrative provisions of the act, an applicant for a permit to appropriate must apply to the state engineer, who must cause a notice of such application to be published in order that the public and prior appropriators will be advised. If objections are filed, the state engineer conducts a hearing. Whether any protests have been filed or not, the state engineer must grant the application unless he finds that there is no unappropriated water or that the appropriation will impair existing rights. Under the law as it has been administered, all appropriations, changes of water rights, changes of method of use and changes in well location or construction require a permit form the state engineer. By this procedure, all records involving the use of underground waters are maintained in one state office.

Until 1949, the state was hampered in its administration of ground water law by the absence of legislation dealing specifically with well drillers. To remedy this deficiency, the 1949 session of the legislature passed a law which provided that well drillers operating in basins designated by the state engineer must obtain a license from that official and post a $5,000 bond with him. It was made unlawful for an owner to permit drilling except by a licensed driller. Furthermore, the regulations of the state engineer prohibit the driller from sinking a well unless the landowner has a permit issued by the state engineer.

For almost 20 years after the passage of the ground water law of New Mexico, there was no serious court challenge to its constitutionality. In 1949, however, the validity of the entire act was questioned in the case of State vs. Dority.[8] The defendants claimed that, as they had acquired title to their land through United States government patents which did not reserve the water, the defendants were the owners of the land and the water underlying it. The court held that, since the passage of the Desert Land Act of 1877, federal patents of land did not carry with them any title to the water.

The court stated:

> "The Desert Land Act provided that all waters upon the public lands except navigable waters were to remain free for the appropriation and use of the public. It was not intended to be taken literally that such water must be upon the surface of the earth to be of such use. The waters of underground rivers with defined banks have always been subject to appropriation. We conclude that all water that may be used for irrigation was reserved by the Desert Land Act to be used beneficially by the public as provided by the laws of the arid states. No interest in such waters was conveyed by the United States patent. The United States Supreme Court has always looked to the laws and decisions of the state courts to determine the extent to which the authority of the state over such water has been exercised.
>
> "No right to the use of water from such sources was obtained by its use by defendants in violation of law nor can it be. The statutory method of securing such rights is exclusive."

The court went on to say:

> "There is another consideration which requires the affirmance of the trial court's decree. The decision of Yeo v. Tweedy, supra, has become a rule of property. In the nineteen years since that decision it may be assumed that many thousands of acres of the one hundred thousand irrigated with water from the Roswell Artesian basin and the valley fill have been sold to purchasers who relied on that decision as determining title to the right to use the water here involved, and the water rights to which would be injured or destroyed if Yeo v. Tweedy is overruled. Whether it stated the correct rule of law (and we are of the opinion that it did), it is now a rule of property that we will not disturb."

In a case involving artesian water,[9] the defendant's well was drilled outside the defined boundaries of an artesian basin and without a permit. The Conservancy District brought an action to enjoin the use of the well and on appeal the supreme court concluded that the Conservancy District had a right to maintain the suit to enjoin the use of water from the defendant's artesian well even though the well was drilled on land outside the territory defined as within the boundaries of the basin as well as the boundaries of the district. On the second appeal in the same case discussed above[10], the supreme court followed the rule that in a contest over water rights, prior appropriators who complain of injury must prove that their use of water is reasonable and beneficial and that the new appropriators must show that there is a surplus which he may take without injuring prior rights.

The 1953 Legislature set up three types of preferential use of water. The applicable provisions of the act[11] are as follows:

> "Any person, firm or corporation desiring to use any of the waters described in this act for watering livestock, for irrigation of not to exceed one acre of non-commercial trees, lawn, or garden; or for household or other domestic use shall make application or applications from time to time to the state engineer on a form to be prescribed by him. Upon the filing of each such application, describing the use applied for, the state engineer shall issue a permit to the applicant to so use the waters applied for.
>
> "From time to time whenever any person, firm or corporation desired to use not to exceed 3 acre feet of the water described in this act for a definite period of not to exceed one year in prospecting, mining or drilling operations designed to discover or develop the natural mineral resources of the state of New Mexico, only the application or applications referred to in section 3, chapter 131, Laws of 1931 (section 77-1103, New Mexico Statutes Annotated, 1941 Compilation), shall be required. Separate application must be made for each proposed use, whether in the same or in different basins. Upon the filing of such application, the state engineer shall make an examination of the facts, and, if he finds that the proposed use will not permanently impair any existing rights of others, he shall grant the application. If he shall find that the proposed use sought will permanently impair such rights, then there shall be advertisement and hearing as provided in the case of applications made under section 3, chapter 131, Laws of 1931 (now being section 77-1103, New Mexico Statutes Annotated, 1941 Compilation)."

There is some question as to whether or not preferential use of water may be obtained under the New Mexico theory of appropriation. The question arises as to whether later domestic users may take water without any regard to the impairment of prior rights.

The writer has no opinion as to whether this act would be considered to deprive prior appropriators of water without due process of law. There also may be a question as to whether this act violates the federal constitutional provisions as to equal protection of law.

In 1953, the legislature also established the public policy of New Mexico as regards underground water. Under the 1931 act, underground streams, channels, artesian basins, reservoirs or lakes having reasonably ascertainable boundaries were declared to be public waters and to belong to the public and to be subject to appropriation for beneficial use. The 1953 act provides:[12]

> "For the purposes of this act * * *all underground waters of the state of New Mexico are hereby declared to be public waters and to belong to the public of the state of New Mexico and to be subject to appropriation for beneficial use within the state of New Mexico. All existing rights to the beneficial use of such waters are hereby recognized.
>
> "No person shall withdraw water from any underground source in the state of New Mexico for use in any other state by drilling a well in New Mexico and transporting the water outside the state or by drilling a well outside the boundaries of the state and pumping water from under lands lying within the territorial boundaries of the state of New Mexico.
>
> "No permit and license to appropriate underground waters shall be required except in basins declared by the state engineer to have reasonably ascertainable boundaries."

By the passage of this act and the acts of 1907 and 1931, all water in the State of New Mexico for all practical purposes was declared to be public. In addition, the 1953 act prohibited using ground water outside the territorial boundaries of the state.

ADMINISTRATION OF WATER RIGHTS

The 1907 Code provides that one intending to acquire the right to the beneficial use of water, before commencing any construction for such purpose, shall make application to the state engineer for a permit to appropriate the water.[13] If the state engineer approves the application, he endorses his approval thereon which thereupon becomes a permit to appropriate the water. A certificate of construction is issued upon the conclusion of the works and upon the final inspection of the project, a license to appropriate water is issued to the extent and under the condition of the actual application thereof to beneficial use but in no manner extending the rights described in the permit.

The 1907 Code requires the state engineer to reject an application to appropriate water if there is no unappropriated water available for the benefit of the applicant and provides that he may refuse to consider or approve an application if in his opinion the approval thereof would be contrary to the public interest. The statute also provides that the state engineer at his discretion may approve an application for a lesser amount of water than applied for or may vary the periods of annual use of the water and that the approved permit shall be regarded as so limited.[14]

Any discussion of the administration of water rights requires mention of the requirements of appropriation. A valid appropriation of water requires a legal diversion and application of water to beneficial use. To constitute a rightful diversion under the New Mexico statutes there must be an application to appropriate filed with the state engineer[15] plus actual diversion of water. Apart from statute, under the arid region doctrine of appropriation, there must be an intention to appropriate together with the diversion and use of water. The intention alone is not sufficient to initiate a right. There must be some substantial act giving notice of the proposed appropriation and the appropriator must diligently proceed to complete his appropriation by construction of works and by application of water to beneficial use.[16]

Although intention to appropriate plus diversion of water are necessary elements of appropriation, nevertheless, application of the water to beneficial use is necessary to complete the appropriation. The supreme court has stated:[17]

> "Diversion is one of several elements necessary to a legal appropriation of water, and while a valid appropriation may follow immediately upon the diversion of water from a stream by reason of a concurrence of the other necessary elements, it is still but an element of that appropriation, and is not equivalent to it. Water may be diverted from a stream, and still not be appropriated, and it is only when diversion is accompanied or followed by application to some beneficial purpose, that the water is appropriated so as to prevent a subsequent appropriator from acquiring a right to its use."

It is fundamental with the doctrine of appropriation that priority as to time gives the superior right as has been pointed out above. The appropriation is not completed until there has been an application of water to beneficial use but, if the priority attached at the time of completion of the application to beneficial use, there would be resulting hardship. This has given rise to the doctrine of relation.

The doctrine of relation was formally incorporated into the 1907 water code as follows:[18]

> "* * *Priority in time shall give the better right. In all cases of claims to the use of water initiated prior to March 9, 1907, the right shall relate back to the initiation of the claim upon the diligent prosecution to completion of the necessary surveys and construction for the application of the water to beneficial use. All claims to the use of water initiated thereafter shall relate back to the date of the receipt of an application therefor in the office of the territorial or state engineer subject to the compliance with the provisions of this article and the rules and regulations established thereunder."

As has been pointed out, this particular provision of the 1907 law was a mere codification of the law as it already existed in New Mexico. The courts have taken the position that the New Mexico water law has been based in part on custom and usage apart from the statutes and yet, New Mexico does not recognize any common law other than codivied law and the English common law.

The appropriator is in danger of losing his priority unless he is diligent in completing his works and applying the water to beneficial use. Financial inability to complete the project has been held to be no excuse for delay in completion of works. The statute, as amended in 1941,[19] provides:

> "* * *that the state engineer may upon the request of the applicant allow additional time for the completion of works equal to the time during which work was prevented by acts of God, operation of law, or other causes beyond the control of the applicant."

LOSS OF WATER RIGHTS

In addition to the method of losing water rights whereby an intending appropriator fails to diligently complete his work and thereby loses his priority, the 1907 code provides:[20]

"When the party entitled to the use of water fails to beneficially use all or any part of the water claimed by him, for which a right of use has vested, for the purpose for which it was appropriated or adjudicated, except the waters for storage reservoirs, for a period of four (4) years, such unused water shall revert to the public and shall be regarded as unappropriated public water; Provided, however, that forfeiture shall not necessarily occur if circumstances beyond the control of the owner have caused nonuse, such that the water could not be placed to beneficial use by diligent efforts of the owner."

In a case decided in 1950 on the question of forfeiture, the court stated:[21]

"It is true there were long intervals between 1913 and 1932, the period in which nonuse sifficient to constitute abandonment is claimed to have occurred, when no irrigation of the lands in tract No. 8 actually took place. Nevertheless, the evidence is abundant that throughout such periods of nonuse, droughts producing a shortage of water, the progressively increasing depth and width of Chavez Cnayon, which had its course across a portion of tract No. 8, all combined to render irrigation impractical or impossible.

"* * *Under the conditions shown to exist, a forfeiture through abandonment will not take place. * * *Our statutes recognize the unfairness in loss of a water right through nonuse where conditions beyond the control of the owner of such right prevent use."

Note that Webster defines abandonment as the act of giving up with the intent of never again claiming one's rights of interest in; giving over or surrendering completely; deserting. In the field of water rights there must be an intentional relinquishment of claim in order to constitute abandonment. Forfeiture, on the other hand, is by operation of law and is accomplished in New Mexico by a four years' period of nonuse. It would appear from a reading of Section 75-5-26[22] that the only way that a water right could be lost in New Mexico would be by forfeiture. The writer submits that a forfeiture takes place only through nonuse and that the intent of the appropriator will not control except in the event he is unable to divert water.

The New Mexico law has not been settled on the question of prescriptive rights, limitations and adverse possession. This writer knows of no case in which the supreme court has held that water rights can be obtained by adverse use or by prescription. The writer would submit that if such rights can be lost or gained by adverse users or by prescription, it will necessitate resolving what interest the public has in such water.

ADJUDICATION OF WATER RIGHTS

The statute governing the appropriation of water contains procedure for the adjudication of water rights.[23] Such adjudications are made exclusively in the courts. Upon completion of the hydrographic survey of any stream system by the state engineer, the attorney general is authorized to initiate a suit on behalf of the State to determine all water rights concerned, unless such suit has been brought by private parties. Also, the attorney general is directed to intervene on behalf of the State in a suit begun by private parties, if notified by the state engineer that in his opinion the public interest requires it. In any suit to determine water rights, all claimants are to be made parties, and the court is required by statute to direct the state engineer to furnish a complete hydrographic survey. Upon the adjudication of rights to the use of waters of a stream system, a decree is issued adjudging the several water rights to the parties involved, containing all conditions necessary to define the right and its priority.

A suit decided in 1931 involved questions relating to both ground waters and stream waters.[24] Jurisdictional principles so decided are stated in the syllabus prepared by the court as follows:

> 1. A statutory suit to adjudicate water rights of stream systems is all-embracing, and includes claim to rights of appropriators from artesian basin within such system.
>
> 2. The jurisdiction of the district court in which is pending a suit to adjudicate water rights of stream system is exclusive of jurisdiction of another district court to entertain suit of artesian basin appropriators attacking right of stream appropriator asserted in adjudication suit or claiming a priority over it.

A suit to adjudicate water rights is of the nature of a suit to quiet title to realty.[25]

INDEX OF REFERENCES

1. Kearny Code, Sec. 1

2. N.M. Laws, 1907, Chap. 49; N.M.S.A. 1953, 75-et seq.

3. N.M.S.A., 1953, 75-1-1

4. Harkey v. Smith, 31 NM 521; 247 P. 550 (1926)

5. Snow v. Abalos, 18 NM 681; 140 P 1044 (1914)
   Albuquerque Land & Irr. Co. v. Gutierrez, 10 NM 177; 61 P. 357 (1900); Affirmed, Gutierrez v. Albuquerque Land & Irr. Co., 188 US 545 (1900)
   Hagerman Irr. Co. v. McMurray, 16NM 172; 113 P. 823 (1911)
   Murphy v. Kerr, 296 Fed. 536 (1923)
   Yeo v. Tweedy, 34 NM 611; 286 P. 970 (1929, 1930)
   Hinderlider v. La Plata River & Cherry Creek Ditch Co., 304 US 92 (1938)
   Lindsay v. McClure, 136 Fed. 2d. 65 (1943)
   St. ex rel. Game Com. v. Red River Valley Co., 51 NM 207; 182 P. 2d 421 (1945)

6. Water Resources Law, US Gov. Print. Office, Vol. 3, p. 746

7. Yeo v. Tweedy, 34 NM 611; 286 P. 970 (1929, 1930)

8. State v. Dority, 55 NM 12; 225 P. 2d. 1007 (1950)

9. P.V.A.C.D. v. Peters, 50 NM 165; 173 P. 2d 490 (1945, 1946)

10. P.V.A.C.D. v. Peters, 52 NM 148; 154; 193 P. 2d 418 (1948)

11. N.M.S.A., 1953, 75-11-1

12. N.M.S.A., 1953, 75-11-22

13. N.M.S.A., 1953, 75-5-1 to 75-5-13

14. N.M.S.A., 1953, 75-5-5 & 75-5-6

15. N.M.S.A., 1953, 75-5-1

16. Harkey v. Smith, 31 NM 521; 247 P. 550 (1926)
    Snow v. Abalos, 18 NM 681; 140 P. 1044 (1914)
    Albuquerque Land & Irr. Co. v. Gutierrez, 10 NM 177; 61 P. 357 (1900). Affirmed, Gutierrez v. Albuquerque Land & Irr. Co., 188 US 545 (1900)
    Murphy v. Kerr, 296 Fed. 536 (1923)
    Hinderlider v. La Plata River & Cherry Creek Ditch Co., 30 US 92 (1938)

17. Milheiser v. Long, 10 NM 99; 61 P. 111 (1900)

18. N.M.S.A. 1953, 75-1-2; N.M. Laws, 1907, Chap. 49

19. N.M.S.A. 1953, 75-5-7

20. N.M.S.A. 1953, 75-5-26

21. Chavez v. Gutierrez, 54 NM 76; 213 P. 2d 597 (1950)

22. N.M.S.A. 1953, 75-5-26

23. N.M.S.A. 1953, 75-4-2- to -75-4-10

24. El Paso & R.I. Ry. v. Dist. Court, 36 NM 94, 95; 8P. 2d 1064 (1931)

25. P.V.A.C.D. v. Peters, 52 NM 148; 154; 193 P. 2d 418 (1948)

THE WATERSHED PROTECTION PROGRAM - PUBLIC LAW 566

By

Harold B. Elmendorf*

A. Legislative history
   1. First Congressional attempt to deal with flood damages at their source was in Flood Control Act of 1936, Public Law 738.
      a. Assigned responsibility to U. S. Department of Agriculture for surveys and treatment of upper watersheds to reduce flood-water and sediment damages.
      b. Procedure was cumbersome; program aroused little public interest; only 11 watersheds were authorized by the Congress for operations.
      c. Authority was repealed in 1954 when Public Law 566 was enacted.
   2. Poage Bill, introduced by Congressman Poage several years ago.
      a. Was designed to bring treatment of watersheds down to local level, where people can understand and participate in it.
      b. Was generally supported by the public and by both political parties, but failed of passage because of more pressing business.
   3. "Pilot Watersheds" in 1953, inspired chiefly by Congressman Hope.
      a. Initial appropriation of $5,000,000 under authority of Public Law 46.
      b. About 60 projects selected throughout the country, as demonstrations.
      c. Will continue only until these selected projects are completed.
   4. Watershed Protection and Flood Prevention Act, Public Law 566, was enacted on August 4, 1954.
      a. Also known as Hope-Aiken Act, for its principal sponsors.
      b. Original bill was virtually same as Poage Bill.

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c. Bill was sponsored by both political parties. General purpose had no opposition but some details were debated in Senate committee.

B. General provisions of the Act

1. Public Law 566 re-states the national interest in upstream flood prevention and in improving watershed conditions. Assistance by the Federal government to communities is justified in obtaining these results.
2. It is aimed primarily at alleviating local flood-water and sediment problems which originate on small watersheds.
3. Program is based on a complete watershed program consisting of sound land use, improvement of soil and plant cover to provide best practical watershed conditions, small and medium-sized water-retarding and sediment control structures to deal with surplus storm runoff and sediment.
4. The Act also provides for agricultural phases of water development and use, with improvement of watershed conditions above project works.
5. Program is to be carried on by a partnership of local communities and the Federal and state governments.
6. It provides for a continuing program, under responsibility of the Secretary of Agriculture.

C. Program requirements

1. Limitations on use of funds
   a. The Act restricts this program to small watersheds, of 250,000 acres (about 391 square miles) or less.
   b. The Act also prohibits using watershed protection funds for any single structure exceeding 5,000 acre-feet of total capacity.
   c. Watershed protection funds cannot be used to pay any cost for providing storage capacity for irrigation and other beneficial use of water. A flood-retarding reservoir can be enlarged to provide such storage, if sponsors have required water rights and state permits, but additional cost must come from other sources.

2. Economic justification

In every project, anticipated benefits must exceed the estimated costs, on an average annual basis. Project as a whole, and each major structure and separable part of the project plan, must be economically justified in accordance with Circular A-47, issued by Bureau of the Budget.

3. Cost Sharing
    a. Local interests must provide rights-of-way, assume responsibility for future maintenance of project, acquire any water rights needed, insure that state water laws are respected, and pay an equitable share of project costs.
    b. In general, Departmental policy requires that non-Federal interests contribute:
        (1) about one-half of total project cost, including essential land treatment measures on the watershed, value of rights-of-way, capitalized value of O & M costs for 50 years, and some incidental project expense;
        (2) a substantial cash contribution to the contract cost of sturctures such as detention dams and channel improvements.

4. Other items of local cooperation
    a. In general, local people must recognize their problem and be anxious to solve it. They must furnish local initiative and leadership in developing the project. Federal government will assist by furnishing technical services and some financial help.
    b. To insure well-rounded watershed plan, local sponsors must obtain agreements to carry out proper farm plans and conservation measures essential to successful operation of the project, from owners of at least 50 percent of land which drains into each reservoir built with Federal assistance. This is to reduce storage capacity needed for storm runoff and sediment over the 50 years used for amortizing investment, thereby minimizing construction and maintenance costs.

5. Duration of project

   Departmental policy aims at projects which can be completed in five years or less, although up to ten years may be acceptable in some circumstances.

D. Applicatinns for watershed protection projects
   1. The Congress intends that this program shall be controlled by people living in and directly affected by these small watersheds.
   2. A project can be initiated only by application from a legally organized local group.
   3. Applications must be approved by the governor or his designated state agency before Secretary of Agriculture can assist the applicants.

E. Project work plans
   1. Responsibilities in planning
      a. Work plan must be acceptable to local sponsors, Soil Conservation Service, and to government agencies for lands under their jurisdiction.
      b. Work plan that is presented to the Congress covers all lands, private, state, and Federal, in the watershed project.
      c. Major responsibilities in project planning
         (1) local sponsors are primarily responsible for project plan.
         (2) By delegation from Secretary of Agriculture Soil Conservation Service has major responsibility for assisting local sponsors to plan and develop watershed project, and for presenting a coordinated, technically sound and economically justified work plan to the Congress.
         (3) Forest Service is responsible for program on forested lands.
         (4) Other Federal land-management agencies, such as Bureau of Land Management, plan improvements on their lands.
   2. Relations with other programs
      a. A project work plan must be compatible with full development of major river basin.

b. State and other Federal agencies with water programs in major river basin, such as Bureau of Reclamation and Corps of Engineers, are consulted while project is being planned.

c. Local sponsors must insure that all local water programs are considered adequately in planning the project.

3. Review by other interested agencies

   a. Draft of work plan is informally reviewed by all interested local, state, and field offices of Federal agencies, including all technical branches of Soil Conservation Service.

   b. When satisfactory work plan is completed by state conservationist, it is sent by the Administrator (SCS) to all interested Federal departments at Washington level and to the governor. They are allowed 60 days for comments, which accompany work plan when it goes to the Congress.

4. Submission to the Congress

   a. Work plan is then submitted by Secretary of Agriculture through the President and Bureau of the Budget to the Congress.

   b. Agricultural committees in both houses have 45 session days to act on work plan. It is not acted on by the entire Congress.

   c. Approval by both Congressional committees is authority for construction.

F. Project installation

1. Allotment of funds

   Secretary of Agriculture allots watershed protection funds, from lump sum appropriation for this program, to specific approved projects, dependent on progress of land treatment by land owners, readiness of local sponsors to contribute their share of cash cost, proper distribution of projects throughout the country, and other criteria.

2. Responsibilities in installation

   a. Soil Conservation Service will place Federal funds in trust fund with that of local sponsors before each contract is awarded.

b. After June 30, 1956, calling for bids, awarding of contracts, and actual conduct of project construction must be done by local sponsors.

c. Soil Conservation Service will continue to furnish technical assistance in connection with designing stuctures and preparing plans and specifications for bidders, and will furnish day-by-day inspection during construction to insure that Federal funds are spent properly.

d. Land owners install essential land treatment on private and states lands at their own expense with whatever help is available through going programs.

e. Essential land treatment on Federal land in watershed project is installed by land management agencies, with normal appropriations as far as possible, supplemented by watershed protection funds when necessary.

3. Responsibilities in operation and maintenance

   a. After project construction is completed, local sponsors assume responsibility for operation and maintenance of all works installed primarily to benefit private lands.

   b. Maintenance of land treatment installed to protect and improve Federal lands is done by land-management agencies at Federal expense.

G. Principal problems

1. Many low-income communities need and apply for a local watershed protection project but find that they are unable to finance the non-Federal share of the cost.

2. Most states are not prepared to accept financial responsibility under the concept of a three-way partnership of the Federal government, state, and local community. It seems that protection of its tax base, by preventing lowering of property values caused by flood damages, would justify the state providing a part of the local or non-Federal share of project cost.

3. In New Mexico and other western states, large ownership of Federal land complicates development of watershed projects. It is accepted policy that

the Federal government should improve and maintain its property in as good condition as is expected of private land owners. Unfortunately, few Federal land-management agencies receive appropriations adequate to restore badly deteriorated watershed lands. Such lands become the source of flood-water and sediment damages to private irrigated farms and small communities.

4. Many local sponsoring organizations have no experience in construction and are not equipped to handle contracts and construction.

H. How the Watershed Protection Program operates in New Mexico

1. Organization
   a. State conservationist, R. A. Young, responsible for carrying out the program.
   b. Applications studied and approved for the state by State Engineer.
   c. Authority to plan specific projects issued by Administrator, SCS, who also approves project work plans before being sent to the Congress.
   d. Technical assistance to local sponsors in planning a project given principally by work plan party, consisting of geologist, hydrologist, hydraulic engineer, economist, survey engineer, and rodmen.
   e. Assistance in soils, range and other technical fields furnished as needed by other technicians in the state.
   f. Technical training and supervision in planning given by Engineering and Watershed Planning Unit at Albuquerque. This unit also helps in Arizona, Colorado, and Utah.
2. Nineteen applications have been accepted by State Engineer.
3. Washington has authorized planning for the Hatch Valley Arroyos, Dona Ana Arroyo, Upper Rio Penasco, and Tramperos Creek.
4. Work plan party has initiated project planning on first three listed.
5. Project work plan for Hatch Valley Arroyos is being reviewed by all Federal agencies at Washington level; will soon be submitted to the Congress. Dona Ana Arroyo work plan almost completed.

I. Inter-agency cooperation in water resource programs

1. Federal departments are directed to establish committees to facilitate coordination of Federal activities in water and related land resources.
2. Committees usually consist of Federal Departments of Agriculture; Army; Commerce; Health; Education and Welfare; Interior; and Federal Power Commission. Field committees also include representatives of the states.
3. Existing committees
    a. Washington - Inter-Agency Committee on Water Resources.
    b. Field - Missouri Basin Inter-Agency Committee, Columbia Basin IAC, Pacific Southwest IAC, Arkansas-White-Red Basins IAC, New York-New England IAC.
    c. PSIAC includes New Mexico west of Continental Divide. AWRBIAC includes Canadian and Dry Cimarron Basins in northeastern New Mexico.
4. Section 6 of Public Law 566 specifically authorizes Secretary of Agriculture to engage in cooperative surveys and water developments with other agencies and the states.

THE SOIL AND WATER CONSERVATION PROGRAM IN NEW MEXICO

By

Robert C. Young*

I. Brief chronological history of the soil conservation movement in the U.S.A.

1930 - Congress recognized the erosion problem and appropriated money for soil erosion investigations. Soil Erosion Experiment Stations were set up under the direction of the Bureau of Chemistry and Soils and the Bureau of Agricultural Engineering.

August 25, 1933 - The Soil Erosion Service was established as a temporary organization in the Department of the Interior. Dr. H. H. Bennett was the first Chief. The first soil erosion project was established in Wisconsin.

March 25, 1935 - Soil Erosion Service was transferred to the U. S. Department of Agriculture.

April 27, 1935 - Congress passed enabling legislation (Public 46 - 74th Congress) establishing the Soil Conservation Service in the Department of Agriculture.

August 4, 1937 - The first soil conservation district in the United States was organized under State enabling laws - in North Carolina. Today there are over 2,700 soil conservation districts in the 48 states and three Territories, covering about 90 percent of the agricultural land.

There are 61 soil conservation districts in New Mexico, covering 85 percent of the farm and ranching units.

Practically all of the Soil Conservation Service resources are now earmarked for technical assistance to soil conservation districts, to flood control on eleven approved projects, and for assistance under Public Law 566, the Small Watershed Protection and Flood Prevention Act, which will be discussed later in this Seminar.

*State Director, Soil Conservation Service

II. In retrospect now after 20 years, it seems strange indeed that the conservation of water is not mentioned specifically in the original enabling legislature, setting up the Soil Conservation Service. For it did not take us long to discover that the conservation of soil and water are inseparable. If I may be permitted to paraphrase in somewhat "corny" fashion, a popular song, it would go something like this: "Soil and Water go together", like the song, "Love and Marriage". This fact you can't disparage, whether it be at a seminar or with the local gentry - it still is elementary. Regardless of how you look at the matter - you can't separate soil and water -- you can't have one without the other!

So for the past 17 or 18 years, we have always spoken of our program as one of conserving <u>soil</u> and <u>water</u>. However, for a number of practical reasons, we do think of the water part of our program under two broad phases:

A. The conservation of water <u>per se</u> for its best use, but in New Mexico and the other Western States, primarily for its direct application on the land, under irrigation. (Also including drainage or other necessary water disposal.) This program includes practices which will improve the conservation of water at:

1. Source or supply - direct diversion - wells and springs.
2. Transmission to the land.
3. Land preparation for irrigation - land leveling - ditches and structures.
4. Proper application of water.
5. Drainage or other water disposal problems.

The principal water conservation practices used in New Mexico under this category are:

1. <u>CONSERVATION OF WATER</u>

(a) <u>Canal construction or ditch construction</u> Constructing, cleaning or reshaping an open channel by removing earth or rock below the normal ground line.

(b) Canal lining or ditch lining (includes pipe lines) - Installing an impervious lining in a canal to prevent seepage.

(c) Closed drains -- Conduits laid to grade beneath the surface to remove excessive water from wet land. Includes tile, metal, stone, woodbox and other covered drains.

(d) Drainage -- Collecting and removing excessive surface or ground-water from land to improve growing conditions, to permit tillage or harvest, or to prevent crop damage. It includes installation of open ditches, tile, pumps and levees, floodgates, and other methods for removal or control of excess water.

(e) Improved water application -- The best practical use and control of available irrigation water under existing physical conditions, as an interim means of improving irrigation efficiency until more complete water management can be installed.

(f) Irrigation water management - The use and management of irrigation water according to a planned farm-irrigation system where all necessary control structures have been installed, where the quantity of water used for each irrigation is determined by the need of the crop and the water-holding capacity of the soil, and where the water is applied at a rate and in such a manner that the crops are able to use it efficiently and significant erosion does not occur.

(g) Land leveling -- The reshaping of the land surface to a planned grade to permit uniform distribution of irrigation water without erosion or to provide necessary surface drainage.

(h) Open drains -- Ditches constructed for the purpose of removing surplus water from wetland; may also include cross-slope ditches on sloping land.

(i) Pond and Irrigation dam construction Impounding water by constructing a fill across a stream or watercourse or by excavating a basin in the ground.

(j) Spring development -- Improving springs by excavating, cleaning, capping, providing storage facilities or necessary fencing.

(k) Waterway development -- Constructing or shaping a waterway and protecting it by establishing suitable vegetation with or without grade-control structures.

(l) Well location and development -- Construction or improvement of wells, (including casing, installation of pumping equipment, and provision for storage facilities) for livestock or irrigation water.

B. The conservation of water in connection with practices primarily designed to control or minimize erosion or flood damage. Among these practices are:

(a) Contour farming -- Farming in such a way that field operations, such as plowing, pitting, planting, or cultivating are done by following the contours of the land or by following terrace grades.

(b) Terracing -- Constructing an embankment of earth or a combination of embankment and channel across a slope to control or retain runoff and check erosion.

(c) Contour furrowing, chiseling or pitting (will be reported as one practice) -- Plowing furrows on the contour or pasture on land to reduce runoff and thereby provide added moisture to increase the forage.

(d) Cross-slope farming -- Farming in such a way that plowing, planting, tillage, and other field operations are done across the general slope of the land, but not on the contour as in contour farming.

(e) Check Dams -- A small, low dam constructed in a gully or other watercourse to decrease the velocity of stream flow. The purpose is to minimize channel scour or promote the deposition of eroded material.

(f) Diversion dam -- A barrier built to divert part or all of the water from a waterway or stream into a different watercourse, an irrigation canal, or a water spreading system.

(g) Debris basins -- The construction of a basin, usually at or near the point where a high velocity stream emerges onto an area of lesser gradient, to trap course sediment and debris which is removed periodically.

(h) Diversion dikes and ditches -- Construction of ditches or dikes to divert the flow of water for the purpose of reducing erosion and flooding. Includes such items as seeding and sodding in the immediate waterflow area.

(i) Floodwater retarding structures -- A dam with a fixed drawdown tube of concrete, corrugated metal, or tile and having an emergency spillway of concrete or grass. In some cases it may be installed primarily for the purpose of protecting land from inundation while in other cases may be used principally to reduce the flow and permit use of a more economical system of stabilizing structures. Sometimes called detention dam or reservoir.

(j) Water spreading -- Diverting floodwater from a watercourse or gully and spreading it over a relatively flat area for erosion control, to increase the forage by flood irrigation, or to replenish groundwater supplies. Usually done by constructing diversions, dikes, or other structures that will divert and distribute runoff.

(k) Roadside erosion control -- Controlling erosion along roads and highways through the use of vegetation, structures, or grading.

(l) Streambank stabilization -- Protecting streambanks from erosion by the use of vegetation and structures.

WATER PRODUCTION FROM FOREST LANDS OF NEW MEXICO

By

George D. Hardaway*

There seems to be a great deal of misunderstanding regarding water production in the Southwest. We appreciate this opportunity to discuss the situation before your seminar and only hope that we can contribute something in a small way.

The discussion will be directed along three main lines:

1. The situation of forested areas--particularly national forests.
2. The water supply reaching the national forests--precipitation.
3. Water production and its relation to influencing factors.

Multiple use of National Forests is a guiding principle in managing these federally-owned lands. Although the production of usable water is by far the highest service of these watershed lands in the State, there are other resources such as timber, grazing, wildlife and recreation which, if properly managed, can be concurrently maintained without material loss of water or long-term values.

The six National Forests which are wholly or partially within New Mexico are the Carson, Santa Fe, Cibola, Lincoln, Gila and Apache. Parts of the latter two are in Arizona. Within the exterior boundaries of these units in New Mexico are about 9,800,000 acres of land. Approximately 8,600,000 acres of this total are federally owned and this constitutes 11% of the State's area. Additionally there are 740,900 acres of federal land in the so-called L. U. units and other categories recently transferred to the administration of the U. S. Forest Service. Prior to transfer, most of these lands were managed by the Soil Conservation Service. Purchased during the dust bowl days of the thirties for purposes of protection and rehabilitation, these lands contain very small areas of true forest type, and probably will not be added to the National Forests. They are of only moderate importance from the standpoint of water yield and will be given little attention in this discussion.

The high mountains and foothill areas of New Mexico are generally

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occupied by National Forests. The fact that precipitation increases with elevation explains this location. Forests occur only on the mountain ranges because precipitation is sufficient there to support them; on the remainder of the State's area, precipitation is not ample. It therefore follows, logically, that these same National Forests are the highest water yielding parts of the State. The terrain is rugged and these lands are primarily noteworthy as watersheds.

It is difficult to estimate the value or even the quantity of the water which comes from National Forest watersheds. For instance--what is the value of water for irrigation? For municipal use? Economists will disagree and even the answers of the experts have holes in them. Certainly the value is considerably above the price paid by the farmer which is the cost of distribution only. A look around the State shows us quickly that every important agricultural area is tied in economically with one or more mountain watersheds which is the source of its water supply. Most of these source areas are on National Forests.

Irrigation in the Rio Grande Valley derives most of its water from the Rio Grande National Forest in Colorado and the Carson, Santa Fe, Cibola and Gila National Forests in New Mexico. In the Pecos Valley, an important headwater supply originates on the Santa Fe National Forest, and is the mainstay of Pecos River flow. Along the western divide of this watershed the Lincoln National Forest contributes supplies from above Roswell to below Carlsbad. The main recharge areas for pump irrigation (formerly partially artesian) in this part of the valley receive water from the Lincoln National Forest. Gila Valley irrigation water has its source on the Gila National Forest and much of the surface flow of the Gila River passes across the State line into Arizona, augmented by flows from the Apache National Forest. San Juan Valley irrigation water comes from national forests in Colorado and to a minor extent from the Carson National Forest in New Mexico. Eagle Nest Reservoir in the north on the Cimarron and the Bluewater Reservoir in the western part of the State are dependent partially on national forest watersheds. Water for pumping in the Mimbres Valley originates on the Gila National Forest.

Explanation of the foregoing relationships lies simply in the fact that the mountain ranges of the State are the areas where higher amounts of precipitation fall. Here also, temperatures are lower with consequently less evaporation, and the growing season is short, thus limiting transpiration.

Cognizant of the need to stay clear of the subjects to be handled by other speakers, some discussion of precipitation is necessary here. Elementary as it may appear, it must be borne in mind that the State's water resources and to a large extent their economic importance are entirely dependent, at the present time at least, on the natural precipitation which occurs.

Watersheds may be rated in importance approximately in accordance with the amount of precipitation which they receive. Generally, but not always, those which receive the most water from the skies produce the most yield. Water which leaves an area in surface or underground channels and which is later available for use may be considered as the yield. The water production from a watershed may be likened to a farm crop. It is an annual "crop", much large some years than others. Its value is somewhat dependent on the use to which it is put, on its quality and on the season and nature of its flow from the watershed.

Records of precipitation and stream gaging have been wholly inadequate to provide much basis for establishing the relationship between water received and water produced by our mountain watersheds. Even less do they provide data for establishing trends in this relationship as over the years man's use of the watersheds causes changes in the vegetative cover. Research is providing some information which is very helpful in understanding the principles involved, but it is meager and usually applies to small areas and findings require many years of time.

The Branch of Administration of the Forest Service has attempted to extract some facts regarding water yield, using available records, which would contribute to our knowledge of the performance of the watersheds being administered. As a result of these studies, a typical average curve was obtained which applies roughly to many mountain watersheds of northern New Mexico. Like most averages, however, it probably does not apply without adjustment to any particular watershed or year.

The curve shows relationship between annual precipitation and local water production from areas of moderate size seldom in excess of 300 square miles. This is not the same as water productinn reaching Elephant Butte Reservoir or other downstream points, from a small upstream area. Points on the curve are tabulated as follows:

Tabulation Illustrating Precipitation--Water Production Relationship
On Basis of Annual Averages

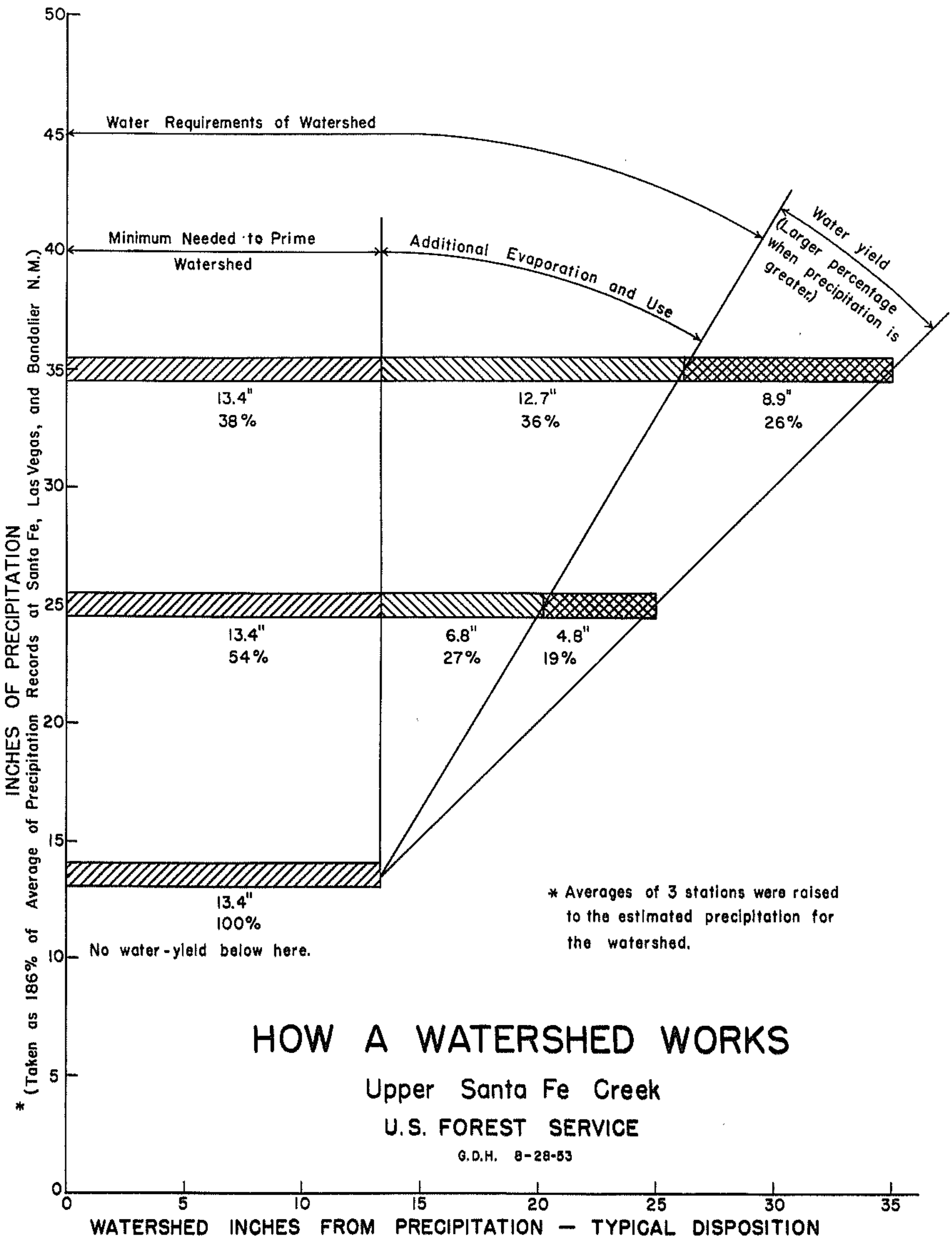
Precipitation In Inches	Water Production		
	In Inches	In Ac. Ft. per Sq.Mi.	In % of Precipitation
10	0.1	5	1
15	0.5	25	3
20	1.6	83	8
25	3.7	195	15
30	6.3	335	21
35	9.3	500	27
40	12.8	685	32

It is not difficult to understand, with this relationship existing, the much greater importance of watersheds receiving higher precipitation than the average. The Weather Bureau gives, with qualifications, the average for New Mexico as slightly less than 14 inches per year. At the lower elevations on National Forests precipitation may be as low as 11 or 12 inches. It ranges from that amount up to about 18 inches throughout the grassland-wooded belt. Above this is usually a belt of ponderosa pine receiving from 18 or 19 up to about 28 inches; then a spruce-fir belt extends from there to the top rate which may be 40 to 50 inches, the latter occurring only on a very small part of the Sangre de Cristo Mountains on the Carson National Forest.

The tabulation also illustrates what happens to one particular watershed as precipitation varies from year to year. For example, where 25 inches of water is normal, a drop to 20 inches during a few years of drought may cut the water production in half; twenty per cent decline in rainfall producing fifty per cent decline in water production.

From the study which was made of the relationships prevalent in Santa Fe Canyon, the chart titled "How A Watershed Works" was prepared. Its main use has been in getting the idea over to our own Forest Service personnel. It is attached here.

The chart was based on precipitation data at three stations surrounding Santa Fe Canyon as there were no records on the immediate area (see chart). These average data were uniformly adjusted upward to the approximate actual amounts falling on the area. The adjustment makes it more realistic and has no effect on the correlation between precipitatinn and streamflow. Actual streamflow records were used. The data extended over a period of 27 years.



Water Requirements of Watershed
Minimum Needed to Prime Watershed
Additional Evaporation and Use
Water yield (Larger percentage when precipitation is greater)
13.4"
38%
12.7"
36%
8.9"
26%
13.4"
54%
6.8"
27%
4.8"
19%
13.4"
100%
No water-yield below here.
* Averages of 3 stations were raised to the estimated precipitation for the watershed.
INCHES OF PRECIPITATION
* (Taken as 186% of Average of Precipitation Records at Santa Fe, Las Vegas, and Bandalier N.M.)
WATERSHED INCHES FROM PRECIPITATION — TYPICAL DISPOSITION
HOW A WATERSHED WORKS
Upper Santa Fe Creek
U.S. FOREST SERVICE
G.D.H. 8-28-53

Note that the first block of precipitation--13.4 inches--is required to wet or "prime" the watershed before water production starts to be of importance. Precipitation in excess of this amount makes more water available for evaporation, plant use, and for water yield.

As precipitation (and number of storms) increases, the opportunity for evaporation from vegetation, litter, and soil surface also increases, and transpiration occurs in larger amounts. However, water production occurs and continues to build up with added precipitation.

The amount required for "priming" the watershed will vary by watersheds; soil types; vegetative cover; amount, pattern and nature of precipitation; and other factors. It will also vary from year to year because of varying residual soil moisture.

The chart is intended to illustrate general principles of watershed performance. Important points are that water yield for a period of drought cannot be compared directly with that for a period of ample precipitation; neither can water yield be expected to be a constant percentage of precipitation year by year.

Southwest Watershed Studies of Agricultural Research Service

By

Joel E. Fletcher and J. L. Gardner*

Water.

Land has no value, agriculturally speaking, without water. It is not the water that falls as rain that gives the value but only that portion which can be used to give plant growth or quality.

In excess of 90% of all the water we use in New Mexico and Arizona for irrigation falls on areas above 8000 feet in elevation and this is only about 12% of the area of the respective states.

Approximately 6% of the water comes from the grassland areas.

High water producing areas mentioned above yield between 15 and 80 percent of their rainfall as streamflow. In the grassland areas this decreases until the yield is only 1 to 3 percent of the rainfall, or in other words, we lose 97 to 99 percent of the rainfall as far as streamflow is concerned. The actual loss to beneficial use is not nearly so high, however, since grasslands of this type generally allow about 50% of the rainfall to infiltrate to the end that it is used to produce forage and other growth which may serve to support animals and hold sediment. Thus the water that enters stream channels may be made more usable also.

Sediment.

Sediment is important because it's movement generally does damage. This damage is centered in three locales. First, the soil from which it originates is left depleted. Second, the paths or channels through which it passes are abraded by it's action. Third, the area in which it is deposited ie. reservoirs, canals, etc. are damaged by losing capacity, burial, etc.

The main sediment producing areas of Arizona and New Mexico are in the grasslands and from stream channels. Approximately 90% of all the sediment originates in these grassland areas while only about 1 percent comes from the high water yielding areas.

Conservation Measures.

The exact effects of conservation measures on water yield and

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sediment production is unknown. Studies on the high water yielding areas by the U. S. Forest Service are beginning to give us some quantitative data for these areas. The low water yielding areas produce such widely spaced flows that any studies here are extra expensive per unit of data obtained. For these reasons, the Soil Conservation Service Research group (now ARS Watershed Hydrology Division) began work on the two great grassland areas of Arizona and New Mexico (blue and black grama grassland). These are the areas where the information is most needed since they are the main grazing areas and they are the areas where present information is most meager.

Some of the questions that need to be answered by this study are as follows:

1. What happens to water yield and sediment production as rangeland improves?

2. What happens to the rain that falls?

3. What is the effect of a conservation program on economic returns to the rancher? What effect does it have on the plant cover and time of water yield?

4. What happens to the water and sediment after they reach established flow channels?

In order to establish a sound program for obtaining these answers a set of criteria which must be met by any watershed selected for study were set up. These were as follows:

1. The area must be between 25 and 75 square miles.

2. There must be adequate control sites.

3. The channel must be of such a nature that channel losses could be measured.

4. The watershed must be tributary to a large watershed used for irrigation and which is gaged.

5. The land owner must be willing to cooperate.

6. The vegetation and soils must be typical of the blue and black grama grasslands respectively.

7. The areas should not be so deteriorated that there is no hope of recovery in a reasonable time.

8. The rainfall must be typical of the blue grama grassland (15-17 inches) and the black grama grassland (10-15-inches) respectively.

9. The areas should be accessable. Roads, trails, etc.

Measurements to be taken are as follows:

1. Soil and vegetation surveys. These include a detailed classification of the density and species of the plants on the watershed and a range-site and condition survey and a detailed reconnaissance soil survey.

2. Sediment source and deposition survey.

3. Rainfall intensity, distribution and amounts.

4. Stream gaging.

5. General cost of livestock operation.

6. Joint planning of conservation practices with the ranchers.

The watershed chosen to represent the blue grama grassland of New Mexico is the upper Alamogordo Creek watershed above the reservoir. Work has begun here and the main control structure is in operation.

The watershed chosen to represent the black grama grassland of Arizona is the Walnut Gulch watershed at Tombstone, Arizona. On this area five flumes were installed and some measurements of stream flow have been made. Both areas have been gaged for rainfall and Soil and range-site surveys completed. The detailed vegetation-soil studies of Walnut Gulch watershed are nearly completed and those for Alamogordo Creek are well under way.

By way of results to date, it can be concluded that rainfall in both areas is extremely variable. For any one season, it is not uncommon to get differences of 300 percent per mile in the total rainfall. While these differences get smaller on an annual basis, they are still very pronounced.

"Unusual" storms have occurred on both watersheds as far as intensity and frequency are concerned. It is our opinion that at least to a considerable degree this phenomenon is due to such poor coverage by gages in the past.

Because of the big demand for data of this kind in construction of roads, flood control structures, etc. the study has been very productive to date even though neither watershed is in full operation.

OUTLINE

I. Introduction

- A. Procedures for resolving interstate water controversies
- B Legal basis of interstate compacts
- C Compact mechanisms for establishing equities

II. Reviews of New Mexico's interstate stream compacts

- A. Colorado River Compact of 1922
- B. Upper Colorado River Compact
- C. LaPlata River Compact
- D. Costilla Creek Compact
- E. Canadian River Compact
- F. Pecos River Compact
- G. Rio Grande Compact

III. Conclusion

- A. Effects of Compacts
  1. Delay due competition
  2. Delay due litigation

The Effects of Interstate Compacts On

New Mexico Water Supply

By

S. E. Reynolds, State Engineer

Outline

Introduction

Controversies involving interstate streams may be resolved by any one of several procedures. When the controversy involved private persons who are citizens of different states, the matter may be adjudicated by a Federal District Court. An example of this type action is the decree on the Gila River in southwestern New Mexico. Such action is not generally satisfactory since the decision of the court may be altered or negated by subsequent Supreme Court decisions of interstate compacts. The settlement of controversies over interstate waters in suits in which the states concerned are not before the courts is a troubled subject where, according to James Rogers* much easy deciding may have to be unsaid and undone in the years to come.

When the controversy is between states, or between a state and citizens of another state, the Supreme Court of the United States has original jurisdiction. The finality of the decrees of this court overcomes the objections to Federal Court decisions. The Supreme Court has been extremely wary of establishing a set of principles as guides to later decisions and has served more as an arbiter. The first purpose of ordinary law is the promulgation of a code of conduct which shall be certain even before being just, but the Supreme Court has found it unwise to adhere to this principle in considering the broader issues of interstate comity.

War is of course a common method of resolving controversies between sovereignties and, in his darker moments, the State Engineer has often felt that war is the only practical answer to many of our interstate problems. This forthright solution is, however, forbidden by the Constitution.

*Interstate Compacts, Colorado Water Conservation Board, 1946

The legal basis of all interstate stream compacts is the Constitution of the United States which forbids alliances and treaties between states, but permits agreements or compacts to be consummated with the consent of Congress. Compacts are generally preferable to judicial procedures for the resolution of controversies over interstate waters, because of the inflexibility of court decrees. Compacts usually provide the flexibility necessary to meet changing physical and economic conditions in the areas involved.

The negotiation of compacts is at best a difficult procedure requiring a blending of engineering and legal talent. It is essential that the lawyers involved in the negotiations fully comprehend the engineering aspects of the negotiations, and that the engineers have a clear conception of the legal considerations. Unless this is so, inequities and ambiguities which will be the subject of future controversies will inevitably find their way into the compact.

Compacting has as a procedure for the resolution of interstate controversies, beeen criticized because the states cannot maintain the trained diplomatic corps required for negotiations and because of the fact that a relatively small number of persons negotiate and resolve issues of tremendous importance to diverse local interests not adequately represented in the negotiations. I feel that the provision requiring any compact to be ratified by the legislature of each State and approved by the Congress largely overcomes this latter objection.

New Mexico is a party to seven interstate stream compacts. All of our major interstate streams are covered by such compacts. The mechanisms used in these compacts to establish the equities of the states were varied to meet the conditions encountered in each basin. These mechanisms are divided into four general classifications and one or more of these mechanisms can be detected in any one compact:

1-Priority

By this mechanism the decreed rights in both states are supplied in strict accordance with the priority of the use, and the state boundary is largely ignored.

2-Lump Sum

By this mechanism a fixed amount of water is allocated to one or more of the parties to the compact for its consumption annually.

3-Limitation of Storage

In its strictest form this mechanism provides for water use limited only by the amount of conservation storage which the state is permitted to construct and utilize.

4-Inflow-Outflow Schedules

By this mechanism the upstream states' obligation to deliver water is determined by the relationship of the inflow above major areas of use to the outflow therefrom. This mechanism has the virtue of accommodating, at least in a measure, the vagaries of climatology.

I will attempt a brief review of each of our water compacts.

Colorado River Compact of 1922

The Colorado River Compact was signed in the Ben Hur Room at the old Governor's Palace in Santa Fe, New Mexico, on November 24, 1922. It was the first interstate water compact to be negotiated in the United States. Stephen B. Davis, Jr., signed as Commissioner for the State of New M xico. It is of interest that former President Herbert Hoover served as Chairman of the compacting commission having been appointed by the President as the representative of the United States. Signatory states were Arizona, California, Colorado, New Mexico, Nevada, Utah and Wyoming. New Mexico's share of the waters of the San Juan, Little Colorado, and Gila River Basins is involved in this agreement.

The major purposes of the compact are to provide for the equitable division and apportionment of the use of the waters of the Colorado River system; to establish the relative importance of different beneficial uses of water, and to secure the expeditious agricultural and industrial development of the Colorado River Basin, the storage of its waters, and the protection of life and property from floods. To these ends the Colorado River Basin is divided into two basins and the use of part of the water of the Colorado River system is apportioned between the two with the provision that further equitable apportionments may be made. The Upper Basin states are Arizona, Colorado, New Mexico, Utah and Wyoming. These are the states from which waters naturally drain into the Colorado River system above Lee Ferry, a point on the main stream of the Colorado River about one mile below the mouth of the Paria River. The Lower Basin states are Arizona, California, Nevada, New Mexico and Utah. Tributaries of the Colorado River drain from these states into the main stream of the Colorado below Lee Ferry.

The compact apportions in perpetuity to the Upper Basin states and the Lower Basin states respectively, the exclusive beneficial consumptive use of 7,500,000 acre-feet of water per annum. The compact also gives the Lower Basin the right to increase its beneficial consumptive use of waters by 1,000,000 acre-feet per annum over and above 7,500,000 acre-feet per annum. This additional allotment, I presume, was to permit the lower basin the unrestricted use of the waters of the Gila River, which is tributary to the Colorado at Yuma, Arizona.

The Upper Division states are restricted from causing the flow at Lee Ferry to be depleted below an aggregate of 75,000,000 acre-feet in any period of ten consecutive years.

It was recognized that because of the construction of Laguna dam above Yuma the Colorado River had ceased to be navigable and the use of its waters for this purpose was declared subservient to domestic, agricultural and power uses.

The compact provided for the impoundment of water for generation of power but declared this use subservient to agricultural and domestic uses. It provides that the States of the Upper Division shall not withhold water and the States of the Lower Division shall not require the delivery of water which cannot reasonably be applied to domestic and agricultural uses.

At the time the Colorado River Compact was negotiated it was thought that the average annual water supply at Lee Ferry exceeded by about 4,000,000 acre-feet the 16,000,000 acre-feet per annum allocated; accordingly, provision was made for further apportionment after October 1, 1963, if and when either basin had reached its total beneficial consumptive use of water allocated. This delayed apportionment, I presume, was intended to provide for the apportionment of water in a manner to fit best whatever pattern the development of the Upper and Lower Basin states might follow. Probably it was also intended to afford a margin of safety in the allocation of water.

In a report dated October 1953, Raymond A. Hill states his belief that the average annual water supply at Lee Ferry may be less than 14,000,000 acre-feet - - inadequate for the 7,500,000 acre-feet per annum allocated respectively to the Upper and Lower Basins. If this is true, it may become necessary at some future date to resolve the question of whether the Upper and Lower Basins share such shortages equally, or whether the Upper Basin is bound unconditionally to the section providing that it shall not deplete the flow of the stream below 75,000,000 acre-feet per annum in any ten year period. Most Upper Basin interests contend that the intent of this section was to provide for over and under deliveries at Lee Ferry and not to establish the priority of the Lower Basin allocation.

Arizona and California are at this time involved in litigation in the Supreme Court seeking an equitable apportionment of the waters allocated to Lower Basin states. New Mexico in her role as a Lower Basin state, is a party to this litigation. The Gila and Little Colorado Rivers, which are tributary to the Colorado below Lee Ferry, carry about 275,000 acre-feet per annum from New Mexico into Arizona. Presumably New Mexico's share in these waters will be adjudicated in the suit. As a part of her strategy to delay or defeat the Upper Colorado River Storage Project, California tried urgently to involve the Upper Basin States as necessary parties in this litigation. This effort was rejected by the Supreme Court which held that only New Mexico and Utah, which are also Lower Basin states, are necessary parties and necessary only in their roles as Lower Basin States.

Upper Colorado River Compact

The Upper Colorado River Compact was signed in Santa Fe in October 1948. Colorado, New Mexico, Utah, Wyoming and Arizona are the signatory states. Mr. Tom McClure, then State Engineer, was appointed by the New Mexico Interstate Stream Commission to negotiate for New Mexico. However, Mr. McClure died soon after his appointment and was replaced by Fred E. Wilson, who signed for the State of New Mexico.

The primary objective of the Upper Colorado River Compact was to equitably apportion among the Upper Basin states the water allocated to the Upper Basin by the Colorado River Compact. The water was divided in the following manner: Arizona was allocated the consumptive use of 50,000 acre-feet per annum, and the remaining consumptive use was allocated 51.75% to

Colorado, 14% to Wyoming, 23% to Utah and 11.25% to New Mexico. New Mexico's 11 1/4% of the 7,500,000 acre-feet allocated the Upper Basin amounts to 843,000 acre-feet. New Mexico's allotment is available from the waters of the San Juan River and its tributaries which discharge an average of 2,200,000 acre-feet per annum of water past the Shiprock gage.

Colorado assented to the diversions and storage of water in Colorado for use in New Mexico. The construction, maintenance and operation of any facilities by New Mexico in Colorado, however, are subject to Colorado law including the payment of property taxes. This provision foresaw and enabled the San Juan-Chama transmountain diversion, which contemplates three storage reservoirs, and other diversion works in the State of Colorado, to bring water from the San Juan Basin into the Rio Grande Basin in New Mexico.

The compact also apportions reservoir losses. The importance of a provision of this sort is emphasized by the fact that the total evaporation loss from the four storage reservoirs recently approved by the Congress in authorizing the Upper Colorado River Storage Project is 630,000 acre-feet per annum. Losses from reservoirs existing at the time of the signing of the compact are charged to the state in which the reservoir is located. Losses from reservoir capacity constructed in the future to supply water for use in a particular state is charged against the allocation of that state. Loss resulting from reservoir capacity constructed to meet the obligations to deliver at Lee Ferry, imposed by Article III of the Colorado River Compact, are charged against the states in proportion to the water allocated them under the Upper Colorado River Compact. Such reservoir capacity is deemed to be for the common benefit of all the states of the Upper Division. The reservoirs in the Upper Colorado River Storage Project are in this category.

The compact sets forth that the water apportionment made in the compact shall not be taken as any basis for the allocation among the signatory states of any benefits resulting from the generation of power. This provision makes it evident that the States foresaw that power revenues in excess of repayment costs of the structures would be forthcoming from contemplated storage reservoirs. This provision figured in the negotiations leading up to the authorization of the Upper Colorado River Storage Project, when Colorado argued that excess power revenue credits should be allocated among the states, for use in financing participating irrigation projects in the same proportion that the Upper Colorado river waters were allocated. The authorizing legislation finally allocated these power revenues in accordance with a formula based on each state's proportion of undeveloped water and need for power revenues to finance participating irrigation projects. Although New Mexico's proportion of undeveloped water is less than 16% the State was allocated 17% of the power revenue credits.

The compact provides for an administrative commission to insure the equitable operation of the compact, and John Bliss, who has recently retired as State Engineer after many years in that office, is at this time Commissioner for New Mexico. He has played an important and effective role in the negotiations leading up to the authorization of the Colorado River Storage Project and Participating Projects.

LaPlata River Compact

The LaPlata River Compact between the states of Colorado and New Mexico was signed in 1922 in Santa Fe just three days after agreement was reached on the Colorado River. Stephen B. Davis, Jr., signed for the state of New Mexico and Delph E. Carpenter, who has been called the "father of the compact method" signed for Colorado.

The compact provides for the equitable distribution of the waters of the LaPlata River by a few simple provisions. Operation is based upon the stream flows at two gaging stations, the Hesperus station near the head of irrigation in Colorado and the State Line station.

Each year from the 1st of December to the 15th of February, each state is given the unrestricted right to use all of the water which may flow within its boundaries. From the 15th of February to the 1st of December, each state is granted the right to the unrestricted use of all waters within its boundaries if the Interstate gage indicates flows in excess of 100 cu. ft., per second. If the flow of the Interstate gage is less than 100 cu. ft., per second, New Mexico is granted an amount equal to one-half the flow at the Hesperus gage on the preceding day; provided that, whenever the flow of the river is so low that the greatest beneficial use of its waters may be secured by distributing all of its waters successively to the lands in each state, in alternating periods, the State Engineers of the two states can so rotate the water for such periods and for such times as they may jointly determine.

An unusual provision indicates great confidence on the part of New Mexico in the good faith of her sister state. It is provided that, "a substantial delivery of water under the terms of this article shall be deemed a compliance with its provisions and minor and compensating irregularities in flow or delivery shall be disregarded."

The rotation provision of the compact eventually became the subject of litigation in the Supreme Court of the United States. As I stated earlier, the Supreme Court has tried to avoid establishing a set of principles for the adjudication of interstate controversies, but a few very important such principles were established in the case of Hinderlider vs LaPlata and Cherry Creek Ditch Company which involved an interpretation of the LaPlata River Compact. This case is perhaps the compact's major claim to fame.

The principles established are as follow:

1-No state can claim the exclusive right to the use of all waters within its boundaries; there must be an equitable apportionment of the benefits of the interstate stream between the states affected.

2-The appropriators and users of water in a state are represented by the state under which their claims arise, and are bound by the limitations which may be imposed upon the state either by Supreme Court decree or by interstate compacts.

3-States have the unquestioned authority to agree upon the division and use of the waters of an interstate stream, even if such division and use may have the effect of disturbing or destroying the rights of individual appropriators which had theretofore been recognized by the laws of either state.

LaPlata River is a tributary of the San Juan which in turn is a tributary of the Colorado, therefore, LaPlata water apportioned to New Mexico under this compact is a part of the water allocated to New Mexico under the Upper Colorado River Compact and to the Upper Basin by the Colorado River Compact of 1922. Thus the LaPlata is affected by three compacts.

Costilla Creek Compact

The Costilla Creek Compact was signed at Santa Fe in 1944 by Thomas McClure as Commissioner for New Mexico. Colorado and New Mexico are the signatory states. Costilla Creek crosses and recrosses the Colorado-New Mexico line three times and its waters are used by irrigators in the two states through a complex distribution system. Although the discharge of this stream amounts to an average annual supply of only about 20,000 acre-feet, the waters have been the subject of bitterstrife and controversy. The principal objectives of the Costilla Compact are to provide for the equitable division and apportionment of the use of the creek's waters and to provide for the integrated operation of the existing irrigation facilities on the stream in the two states. One of the prime sources of controversy was the storage of water in Costilla Reservoir in New Mexico for use in Colorado. The compact provides for the allocation of storage benefits of this reservoir between the states, and for the supplying of water to rights in New Mexico and Colorado in accordance with the relative priorities of these rights. The control of water under this compact is accomplished by a watermaster appointed by the New Mexico State Engineer.

Canadian River Compact

The Canadian River Compact among the states of New Mexico, Texas and Oklahoma, was signed at Santa Fe in 1950. John H. Bliss, then State Engineer, was appointed by the Interstate Stream Commission to negotiate this compact and signed for the State of New Mexico. This compact which was negotiated subsequent to the construction of Conchas Dam and Reservoir and the Arch Hurley Conservancy District, apportions the beneficial consumptive use of the waters of the Canadian River by limiting conservation storage which may be constructed in each of the states. The article most affecting the rights of New Mexico is Article IV which states:

"(a) New Mexico shall have free and unrestricted use of all waters originating in the drainage basin of Canadian River above Conchas Dam.

(b) New Mexico shall have free and unrestricted use of all waters originating in the drainage basin of Canadian River in New Mexico below

Conchas Dam, provided that the amount of conservation storage in New Mexico available for impounding of these waters which originate in the drainage basin of Canadian River below Conchas Dam shall be limited to an aggregate of 200,000 acre-feet."

"(c) The right of New Mexico to provide conservation storage in the drainage basin of North Canadian River shall be limited to the storage of such water as at that time may be unappropriated under the laws of New Mexico and of Oklahoma."

The compact defines the term conservation storage as that portion of the capacity of reservoirs available for the storage of water for release for domestic, municipal, irrigation and industrial uses and excludes any portion of the reservoirs allocated solely to flood control, power production, and sediment control.

The average annual flow of the Canadian River at Logan, New Mexcio near the New Mexico-Texas state line is about 275,000 acre-feet. This large and somewhat erratic water supply has remained undeveloped and unused to this time primarily because there is very little irrigable acreage below Conchas Dam along the Canadian or its tributaries other than the acreage which has already been developed by the Arch Hurley Conservancy District. The Interstate Stream Commission is at this time engaged in a study of the feasibility of developing the waters of the Canadian below Conchas for industrial use. It is possible that development for such use may make feasible some irrigation as a by-product.

Pecos River Compact

The Pecos River Compact was signed in Santa Fe in December, 1948. The signatory states are New Mexico and Texas. John H. Bliss signed for the State of New Mexico and is still serving as our Pecos River Commissioner. The Major purposes of the compact are to provide for the equitable division and apportionment of the use of the waters of the Pecos River and to facilitate the construction of works for the salvage of water and the more efficient use of water in the Pecos River Basin in New Mexico and Texas. Beneficial consumptive uses of the waters of the Pecos River in New Mexico deplete the stream by an average of about 500,000 acre-feet per annum.

Under the compact it is New Mexico's obligation not to deplete the flow of the Pecos River by man's activities below the flow that would have occurred under the conditions of usage existing in 1947 in New Mexico. The effect of these conditions of usage and the natural conditions on the river, was determined by an Engineering Advisory Committee established to implement the compact negotiations. The records for the period 1938 to 1947 were found by the Advisory Committee to represent well the conditions existing on the river in 1947.

The compact provides that the inflow-outflow method shall be used to determine whether or not New Mexico is meeting its obligations under the compact. In applying the method this general procedure is followed: The river in New Mexico is divided into five reaches in each of which the tributary flood inflows are determined by a comparison of the inflow and outflow hydrographs. The flood inflow is added to the quantity of water entering the reach and this total is compared with the total quantity of water leaving that reach to determine whether depletions over and above the 1947 condition have occurred. In order for New Mexico to fulfill its commitments the three-year running average of the algebraic sum of the departures from the 1947 condition in these five reaches must not be negative. There is no compact provision for the accrual of debits or credits, although it is recognized that natural variations from the normal may occur over periods of several years duration.

New Mexico's obligation is confined to depletions by man's activities. Diminution of flow by encroachment of salt cedars or by deterioration of the channel of the stream is an interstate obligation and problem. Determination of such increased nonbeneficial consumptive uses is a function of the Engineering Advisory Committee which reports to the Commission.

The compact imposes an obligation on both states to cooperate in water salvage programs. The most pressing water salvage project on the Pecos River is in the delta area above McMillan Reservoir. This reservoir serves the Carlsbad Irrigation District. Legislation authorizing a substantially nonreimbursable water salvage project in this area has recently been introduced in the Congress. The introduction of this legislation is a culmination of at least a year's negotiation between the two states in arriving at a mutually satisfactory project.

The compact provides that water salvaged shall be allocated 43% to Texas, and 57% to New Mexico. Water salvaged in the McMillan delta project will be available for first use by the Carlsbad Irrigation District. This District will bear New Mexico's share of the operation and maintenance cost of the project.

There are no storage limitations set forth in the compact, and both states are obligated to cooperate in the construction of facilities of mutual benefit.

Rio Grande Compact

The Rio Grande Compact among New Mexico, Texas and Colorado was signed in Santa Fe in 1938. Mr. Tom McClure, then State Engineer for New Mexico, signed for New Mexico. John Bliss served as his engineering advisor and played an important role in the negotiation of this compact.

The purpose of this compact is to provide an equitable apportionment among the three signatory states of the waters of the Rio Grande above Fort Quitman, Texas. The mechanism used for apportioning the water is a relatively inflexible version of the inflow-outflow method. The equities developed in the river by each state were defined by a study of the pre-compact conditions of flow which existed in each State. On the basis of this study schedules establishing the outflow which must be maintained with a given index inflow were drawn to define the obligations of each of the upstream states. Colorado's oblication to deliver water at Lobatos near the Colorado-New Mexico state line is established by index inflows indicated by gages on tributaries to the Rio Grande in Colorado and by a gage on the main stem of the Rio Grande at Del Norte, Colorado. New Mexico's obligation to deliver water to Elephant Butte Reservoir is established by the flow of the river at Otowi gage, located on the Rio Grande near Espanola and just below the confluence of the Chama River and the Rio Grande.

Otowi gage is some 80 miles below the Colorado-New Mexico line and it might seem that New Mexico is granted the unrestricted use of the river in the reach above Otowi and below the Colorado line. The compact, however, provides that the schedule is subject to appropriate adjustments for any depletion in New Mexico of the natural run-off at Otowi gage.

As I have said, the mechanism for apportionment of the water is basically the inflow-outflow method, but the Rio Grande index gages are located at points rather widely separated on the main stream, and tributary inflows between these gages are not separately determined as in the Pecos Compact. Because of this, long term climatological changes which might affect the relationship of tributary inflows to main stream discharges could result in inequities affecting adversely either the upstream or downstream states. For example, if the ratio of the precipitation in the Rio Grande Basin above Otowi gage to the precipitation in the basin below the gage becomes greater than it was during the period of record, the Middle Rio Grande Valley in New Mexico would receive an inequitably small portion of the available water supply. We have recently made a climatological study to determine whether this might have happened. While New Mexico's ability to meet its commitments under the compact seems to follow climatological changes fairly closely, there is as yet no good evidence that the Middle Valley has been adversely affected by such changes.

Prior to 1949 the gage at San Marcial was used to measure New Mexico's water deliveries and the schedule was based on the nine months water supply excluding the months of July, August and September when erratic tributary inflows usually occur. Since 1949 the gage below Elephant Butte Dam, corrected for changes in storage in Elephant Butte Reservoir, has been used to measure New Mexico's deliveries and the schedule is based on the 12 months water supply. This change was made because of the relative inaccuracy of the gage at San Marcial and also to take into account the tributary inflow from the relatively heavy summer precipitation in the Middle Valley.

These numbers provide a concept of the water supply and the effect of this schedule: The average annual flow of the Rio Grande at Otowi is 1,300,000 acre-feet. At this flow the present schedule requires a delivery to Elephant Butte reservoir of 897,000 acre-feet.

It is of interest that in this new schedule, bank storage in Elephant Butte Reservoir becomes a factor. When the reservoir is full water seeps into the reservoir banks and is stored there. As the reservoir is drained the water stored in the banks returns to the reservoir and is available for use. It seems possible that a generally declining reservoir during the period upon which the new schedule is based may have affected the accuracy of the correlation of the San Marcial and Elephant Butte effective supply gages. During most of the period since the establishment of the new schedule, the reservoir has remained at consistently low levels and little or no water has become available from bank storage. Furthermore, as storage is increased from the minima of the last few years, water will be withdrawn to bank storage and the outflows measuring New Mexico's deliveries may be correspondingly decreased.

Under historic conditions substantial departures from the average relationship between index inflow and outflow sometimes occurred. For this reason the compact made provision for the accrual of debits or credits by the upstream states. These debits and credits are computed annually. Colorado's limit for accrued debits is 100,000 acre-feet and New Mexico's limit is 200,000 acre-feet. The accrued debits of these states cannot exceed these amounts unless the excess is offset by hold-over storage. Neither New Mexico nor Colorado can acquire, in any one year, a credit in excess of 150,000 acre-feet and New Mexico may not be charged in any one year a debit in excess of 150,000 acre-feet.

Storage rights were carefully defined and limited in drafting the compact. The priority of the storage right of Elephant Butte Reservoir over later upstream storages is carefully guarded. Within the physical limitation of the storage capacity of reservoirs constructed after 1929, New Mexico must retain water in storage at all times to the extent of its accrued debit. In January of any year the Commissioner for New Mexico may demand of Colorado, and the Commissioner for Texas may demand of Colorado and New Mexico the release of stored water up to the amount of the accrued debits of Colorado and New Mexico, or up to an amount sufficient to bring the quantity of usable water in Elephant Butte Reservoir to 600,000 acre-feet by March 1st.

If less than 400,000 acre-feet are stored in Elephant Butte Reservoir, neither Colorado nor New Mexico may increase the amount of water stored in reservoirs constructed after 1929, unless the average annual release of water from Elephant Butte has exceeded 790,000 acre-feet per annum, the normal project release. If, however, New Mexico or Colorado have credits in the water stored in Elephant Butte, they may relinquish these credits for the right to increase storage in their own reservoirs.

In the event of spill of water from Elephant Butte Reservoir all of the debits of Colorado and New Mexico are cancelled. Also, in any year in which the aggregate debits of Colorado and New Mexico exceed the unfilled capacity of Elephant Butte Reservoir, the debits are reduced proportionately to an aggregate amount equal to the minimum unfilled capacity. This provision assumes that if Colorado and New

Mexico had delivered the debit water, the amount of the debits over and above the minimum unfilled capacity would have been spilled.

On the other hand, if Colorado and New Mexico have credit water in Elephant Butte Reservoir at the time of spill, these credits are reduced by the amount of spill plus the amount of increase in storage in Colorado and New Mexico up to the time of spill. This provision is based on the fact that Colorado and New Mexico have no storage rights in Elephant Butte, and therefore, the first water spilled must be theirs.

The Rio Grande compact also foresaw the San Juan-Chama diversion. Article X provides that if water is imported into the Rio Grande Basin, the State having the right to the use of the imported water shall be given credit therefore in the application of the schedules.

The Rio Grande compact contains an anomaly which is probably unique. The compact does not, in fact, apportion the waters between New Mexico and Texas, but rather between the water users in New Mexico above Elephant Butte on one hand and the water users in Texas and New Mexico below Elephant Butte on the other hand. This fact creates a serious administrative problem for the New Mexico Interstate Stream Commission and the State Engineer. It makes it impossible for the State Engineer to administer Rio Grande waters in New Mexico in accordance with the well established doctrine of priority. When the State Engineer as compact commissioner acts to effectuate the compact, he must bear in mind the interests of users both above and below the reservoir. When litigation arises the attorneys for New Mexico are in the strange position of opposing some of their own clients.

In spite of the detailed definition of storage rights contained in the compact, it is silent on the subject of storage for flood and silt control. Through the wisdom of the Compact Commissioners, the compact has been operated as though the term "storage" applied only to conservation storage and storage for flood and silt control beyond the storage limitations set forth in the compact has been permitted.

Article XIII of the compact provides that the Commission may, by unanimous consent, review provisions of the compact which are not substantive in character and which do not affect the basic principles of the compact. Any changes to which the Commissioners might agree, except changes in gaging stations, must be ratified by the legislatures of the respective states and consented to by the Congress. While this article seems to restrict changes to those not basic in nature, it seems reasonable to suppose that changes which are substantive in nature could be made if ratified and approved.

A motion passed at the recent meeting of the Rio Grande Compact Commission provides that the Engineer Advisors will undertake to study, in the light of the experience of the past 16 years, the operational procedures and the methods of computation required to carry out in a practical manner the intent of the Rio Grande Compact, and make recommendations to the Commissioners. It is my hope that this motion is a harbinger of a new spirit on this troubled river.

Conclusion

Your Chairman, Dr. Stucky, has asked me to comment if possible on the economic effects of these compacts on the State of New Mexico. First, it is difficult to express water supply in terms of dollars. Perhaps a reasonable value for the direct and indirect benefits from water being used in agriculture is about $40 per acre-foot, but this value may vary greatly among agricultural enterprises and may vary even more among the various types of use, including domestic and industrial uses. The interstate compacts profoundly affect our economy because they determine and control our water supply. It is difficult to assess this affect accurately because it would be necessary to visualize conditions as they might have existed if the compacts had not been consummated. These conditions would depend upon a number of physical, economic, political, and social factors. One can reasonably suppose that without the compacts the delay of projects necessary for flood protection and the full development of our water supply would have been greatly extended by opposition in the Congress from representatives of states competing with us for this water supply. One can also reasonably suppose that we would have been engaged to a greater extent in prolonged and expensive litigation in Federal District Courts and in the Supreme Court of the United States. Additional delay would have resulted from the uncertainty about what the final judgment of these courts might be.

Despite the apparent impossibility of arriving at compacts which are equitable in all their provisions, and despite the frustrations which arise from living under these compacts, it is my opinion that our compacts have greatly improved the economy of New Mexico by serving to secure our water supply and our way of life on these rivers.

IRRIGATION DEVELOPMENTS BY THE BUREAU OF RECLAMATION IN NEW MEXICO

By

Leon W. Hill*

The Bureau of Reclamation operates in the 17 Western States and its activities are governed by what is known as the Federal Reclamation Laws. In the early history of our country Congress recognized the importance of widespread ownership of lands, and to carry out this objective, the homestead laws were enacted which provided free lands to settlers. In adopting this policy to arid lands of the west irrigation was essential. Consequently, Congress went a step farther and enacted the Reclamation Act of 1902 providing for reclaiming arid lands of the west by constructing irrigation works. Costs of such works have to be repaid over a period of years without interest.

To facilitate administration of the Reclamation Program the Commissioner established seven regional offices. The Regional office in Amarillo, Texas is responsible for work in Texas, Oklahoma, New Mexico east of the Continental Divide, that portion of Colorado drained by the Rio Grande, and a small portion of Southern Kansas. Each Region establishes such additional offices as are needed. For example, the Rio Grande Project office is located in El Paso, Texas, and we have a Middle Rio Grande Project office in Albuquerque.

In briefly describing reclamation developments in New Mexico I will omit the Rio Grande Project because it will be handled by Mr. Moser, representing Mr. W. F. Resch, Manager of the Rio Grande Project. Dr. Stucky also advised me that the Upper Colorado River Project, and particularly the San Juan Chama Diversion Project, will be the subject of a subsequent presentation and, therefore, my remarks will not extend to these proposed developments. Since the College is located on the Rio Grande Project you are, no doubt, familiar with how the Bureau of Reclamation operates and, therefore, I will limit my presentation largely to a description of the Bureau's projects and will try to answer any specific questions you may have during the discussion period.

The next project upstream in which the Bureau of Reclamation is interested is the Middle Rio Grande. A comprehensive

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plan for the Middle Rio Grande Valley resulted from investigations conducted by both the Bureau of Reclamation and the Corps of Engineers. The plans of the respective agencies were coordinated by Secretarial agreement between the Departments of Army and Interior, which assigned to the Bureau of Reclamation rehabilitation of El Vado Reservoir, rehabilitation of the Conservancy District's irrigation and drainage systems, acquisition of the outstanding bonds of the District, and channel rectification from the head of Elephant Butte Reservoir throughout the Middle Valley, including the Espanola and Hot Springs reaches. To accomplish this work by the Bureau of Reclamation, Congress authorized an expenditure of approximately 30 million dollars. The first reach of the river to be channelized extends from Elephant Butte Reservoir to San Marcial, a distance of about 35 miles. Channelization consisted of constructing a low flow channel of 2000 cu. ft. per second capacity, and a cleared floodway of about 1000 feet in width. Dirt excavated form the channel section farms a levy to protect the channel during flows in the floodwqy. Other minor segments of the river have been cleared and improved, and currently channel work is underway in the Espanola area. The next segment of the river to be channelized reaches from San Marcial to San Acacia and the first contract on this section of the work is scheduled for award soon. In addition, most of the drainage rehabilitation and extension has been accomplished and the work on El Vado Reservoir and diversion headings has been completed or is near completion. Priority has been given to channelization and drainage rehabilitation so as to salvage as much irrigation water as possible to alleviate the current water shortages.

Although it is the Bureau's policy to have completed irrigation projects operated by water user organizations, the Bureau did assume the operation and maintenance of the Middle Rio Grande Conservancy District works February 1, 1955 with the exception of El Vado Dam and Reservoir. Under terms of our contract with the Middle Rio Grande Conservancy District the Bureau will operate and maintain the project during the construction period with funds advanced by the District. The contract further provides that on completion of the rehabilitation and construction work the District will resume operation and maintenance.

Although not in the State of New Mexico, you are probably also interested in the San Luis Valley Project. The Bureau constructed the Platoro Dam and Reservoir on the Conejos River to regulate and provide a late season water supply for some 80,000 acres of land in the Conejos Water Conservancy

District. The reservoir has a capacity of 60,000 acre-feet and the structure cost about $3,800,000, which is allocated 60 percent to irrigation and 40 percent to flood control. Before the dam and reservoir could be placed in operation, Colorado was alleged to be incurring water indebtedness under the Rio Grande Compact, and consequently this structure since completion has been operated for flood control only. The Bureau has also completed and is processing a report on the Wagon Wheel Gap Dam and Reservoir, and is currently completing a reconnaisaance report on the Closed Basin Drain.

The Carlsbad Project on the Pecos River is one of the first in reclamation developments. Initially this project consisted of McMillan and Avalon dams and reservoirs and irrigation and drainage works to serve approximately 25,000 acres. As the capacity of these reservoirs was lost through sedimentation, Alamogordo Dam and Reservoir, located above Fort Sumner, New Mexico, was constructed to provide replacement storage. The spillway is currently being enlarged and this work is scheduled for completion in June of 1956. As you know, McMillan Reservoir has been subject to considerable leakage, particularly along the escarpment along the east side. To alleviate this situation approximately 10,000 feet of levy was constructed to dike off the worst sink holes through a cooperative program with the State Engineer's office, the Carlsbad Irrigation District, and the Bureau participating. The Bureau operated the Carlsbad project for many years, but operation and maintenance was assumed by the Carlsbad Irrigation District October 1, 1949. The District has been doing an excellent job including an extensive replacement and improvement program. The Carlsbad Irrigation District has repaid all of the initial cost of the project and have been making regular payments since 1946 on Alamogordo Dam and Reservoir.

The next Bureau project upstream on the Pecos is the Fort Sumner Project. The work for this project consisted of constructing a new concrete diversion dam, lowering and lining the Main Canal, and the installation of a hydraulic turbine pumping plant, rehabilitation of part of the distribution system and rehabilitating and extending the drainage system. These works provide irrigation to 6500 acres of land, and the project works cost $2,432,000, which the Fort Sumner Irrigation District will repay in 80 annual installments. This project is also operated and maintained by the District.

The Bureau has constructed two projects on the Canadian River in New Mexico. The largest is the Tucumcari Project, which consists of canals, laterals and drains to serve 42,000 acres of irrigated land. The system cost approximately 16 million dollars, of which the District is required to repay approximately $5,900,000 over a 40 year repayment period with repayment to begin in 1959 following a five year development period. Water is supplied the Tucumcari Project from Conchas Reservoir which was constructed by the Corps of Engineers. The project is operated and maintained by the Arch Hurley Conservancy District.

Upstream on the Canadian in the vicinity of Maxwell, New Mexico, is the Vermejo Project. Project works consist of a series of offstream reservoirs, canals, laterals and drains to serve 7300 acres of irrigated lands. These works cost approximately $2,800,000 of which the water users will repay $2,107,000 over a period of approximately 78 years. The project was completed last year and the works are operated and maintained by the Vermejo Conservancy District.

Statistics relating to acreages and gross crop value on irrigation developments by the Bureau of Reclamation in New Mexico follows:

Crop Summary
1955 Census of Region 5

Project	Irrigable Area	Net Acres in Cultivation	Gross Crop Value	Average Gross Crop Value per Cultivated Acre
	Acres	Acres	$	$
Rio Grande	159,650	142,694	32,446,623	227.37
Carlsbad	25,055	23,289	3,695,724	158.69
Tucumcari	42,214	38,677	1,869,467	48.33
Ft. Sumner	6,500	5,732	464,416	81.02
Middle Rio Grande	121,680	66,887	4,192,452	62.68
Vermejo	7,379	-	-	-

Aside from the investigations of the San Juan Chama Diversion Project, the Bureau has recently completed a number of reconnaissance reports on small projects on the upper Canadian River and is currently conducting investigation of the Pecos Basin in cooperation with the Pecos Compact Commission and the State of New Mexico. Investigations in the Pecos Basin are primarily for the purpose of determining ways and means of salvaging and conserving the limited water supply. In this connection, Congress now has under consideration a bill which would authorize channelization work above McMillan Reservoir area similar to that previously described on the Rio Grande.

I have given you a birdseye view of reclamation projects in New Mexico and will attempt to answer any specific questions you may have during the discussion period.

Water Supply and Costs in Operation of Rio Grande Project

By

Theodore H. Moser*

History and Development

Before beginning a discussion of the water supply and costs in operation of the Rio Grande Project, I would like to trace briefly, for those that aren't familiar with it, some of the history and development of the Project.

Irrigation in this area was initially begun by the Indians, possibly many years before the first Spanish explorers arrived. Recorded history of the valley began with its discovery by the Spanish explorers under Coronado in 1540, who reported Indians cultivating the land and bringing water to it by irrigation ditches. In the upper Rio Grande Indian Pueblos were, of course, numerous and communal life was well established at the time of Coronado's explorations.

Irrigation by Spaniards was begun on a small scale with the establishment of the Guadalupe Mission in what is now Juarez, Mexico, in 1659, although efforts to start a mission at this location were first begun in 1632 and some writers refer to a church at Cinecue, three miles east of El Paso, in 1626. Settlements in the immediate vicinity of Juarez and El Paso continued to flourish as they were a stopping station between the east coast of Mexico and the colonization that was taking place along the Rio Grande further north in New Mexico.

Colonization around El Paso was given a big boost as a result of the Pueblo Indian revolt in 1680. The Indians, under the leadership of Pope', rebelled and drove the Spaniards and Christianized Indians south to the El Paso area, and it was 12 years before the Spanish reoccupied the territory to the north.

It was not until about 1840 that the American settlers began to arrive and they also practiced irrigation. All of these early attempts at irrigation consisted of community ditches drawing from the normal flow of the Rio Grande by means of temporary diversion works.

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Further up the river, rapid development of irrigation occurred in the San Luis Valley in southern Colorado between 1880 and 1890. During this period, most of the large canal systems and other irrigation works that exist there today were built. This upstream expansion of irrigation in southern Colorado, in addition to that which had also taken place in central New Mexico, absorbed the normal summer flow of the Rio Grande, causing it to be dry in this area for longer and more frequent periods. As a result of this shortage of water, storage was first considered abuut 1890. Several local and smaller storage projects were proposed, but conflicting interests prevented the culmination of any of them.

Soon after the passage of the Reclamation Act of June 12, 1902, the formation of the Rio Grande Project was first considered. Investigative surveys were begun in 1903 and a feasibility report was made the next year. The Rio Grande Project was approved by the Secretary of the Interior on December 2, 1905. Also in 1905 the Reclamation Act was extended to that portion of Texas lying along the Rio Grande and in 1906 the act was extended to the whole state. A contract was entered into with the Elephant Butte and El Paso Valley Water Users' Associations in 1906 for construction of storage and diversion works on the Rio Grande.

A treaty with Mexico, providing for the distribution of Rio Grande waters, was signed on May 21, 1906, wherein it was provided that Mexico was to receive 60,000 acre-feet of water annually except during periods of water shortages, such as we have experienced the last 5 years, when they were to receive a proportionate percentage of the normal usage.

The first construction work on the Rio Grande Project began in 1906 with the construction of Leasburg Diversion Dam and 6 miles of the Leasburg Canal. This was completed in 1908 and the first water was delivered through Project works to three old community ditches, one of which is now the Las Cruces Lateral that flows through the City of Las Cruces and just west of the college.

The construction of Elephant Butte Dam was authorized by Congress on February 25, 1905. Pre-construction work began in 1908, although preparatory surveys had begun as early as 1903. Actual construction on the dam proper didn't begin until 1912. Storage was first available in 1915 with completion and dedication of the dam being in 1916.

Considering the equipment available in those early days, the construction of Elephant Butte Dam was quite an engineering feat. It was one of the highest dams at that time, rising 301 feet above its base. It was one of the first dams built by the Bureau of Reclamation, and at the time it was built, created the largest artificial lake in the country having an initial capacity of 2,638,000 acre-feet. Even though built 40 years ago, the reservoir is still one of the five largest built by the Bureau of Reclamation, being surpassed only by the reservoirs behind Hoover, Grande Coulee, Shasta, and Hungary Horse Dams.

In 1917 and 1918 the Water Users' Associations, which had been created in 1906, were succeeded by the Elephant Butte Irrigation District and the El Paso County Water Improvement District No. 1, and contracts were entered into with the Government for the construction of the distribution canals and laterals and the drainage system in addition to the completion of the diversion works. During the period from 1912 to 1930, the construction of most of the canal and lateral system and the drainage system was in progress. Altogether, the Project now operates and maintains about 600 miles of canals and laterals and 470 miles of wasteways and drains. If all of these could be placed end to end in one continuous ditch, it would extend from here to Omaha, Nebraska.

Caballo Dam, located 25 miles downstream from Elephant Butte, was first conceived as a flood control structure, but additional capacity was provided to allow for year-round generation of power at Elephant Butte. It was completed in 1938 and has a total capacity of 340,000 acre-feet, 100,000 of which have been reserved for flood control by the International Boundary and Water Commission in connection with the Rio Grande Rectification program between the United States and Mexico.

Construction of the power plant at Elephant Butte began in 1938. The rated capacity of the plant is 27,000 kva. 14 substations and 500 miles of transmission lines are also part of the power system.

Cost and Repayment

Before any of these features of the Project were approved for construction, it was necessary to determine that they were economically justified. Under Reclamation laws the cost of irrigation and power projects must be reimbursed to the Government over a period of years and contracts guaranteeing this repayment, except for certain non-reimbursable items authorized by Congress, were worked out and signed.

To date the cost of Elephant Butte Dam has been $5-1/2 million, only a small fraction of what it would cost if it were built at today's prices, and the cost of the power plant, to date, has been about $1-1/2 million. These costs are being repaid by power revenues, except for $1 million set aside as non-reimbursable to cover the allocation of a portion of the water to Mexico under the Treaty of 1906. Caballo Dam, costing a little less than $2-1/2 million, is also being repaid out of power revenues, except for $1-1/2 million paid by the Federal Government, through the International Boundary and Water Commission, for flood control features.

The cost of the irrigation and drainage systems was $10-1/2 million, and is being repaid by the water users at the rate of about $1.40 per acre per year. Repayment for the irrigation and drainage systems would have been completed in 1967 except that the Secretary of the Interior under Congressional authorization, has granted a moratorium each of the last two years due to the extreme water shortage and the resulting financial plight of the farmers of the valley. To date 71 percent of the water users' obligation has been repaid.

Physical Aspects and Organization of Rio Grande Project.

The water-right acreage under the Rio Grande Project is 155,000 acres extending 60 miles up the river north of Las Cruces and 80 miles below Las Cruces. The maximum width is only about 4-1/2 miles. You can see that the Project is long and narrow, which makes the distribution of the water quite difficult at times.

Geographically, the Project is divided into five units separated by short river canyon sections. These are the Elephant Butte Reservoir, Caballo Reservoir, and the agricultural areas in the Rincon, Mesilla, and El Paso Valleys.

For operational purposes the Project is divided into three branches--the Power and Storage Branch at Elephant Butte, the Las Cruces Branch for the irrigated area above El Paso, and the Ysleta Branch, located at Ysleta, Texas, for that portion of the Project below El Paso. Project headquarters are in El Paso.

The water users are organized into two districts--the Elephant Butte Irrigation District with offices in Las Cruces for the portion of the Project in New Mexico, and the El Paso County Water Improvement District No. 1 with offices in El Paso for the Texas portion of the Project.

Watershed and Runoff

The drainage area of the Rio Grande above Elephant Butte contains approximately 26,000 square miles. It is long and relatively narrow, extending into the San Luis Valley in southern Colorado, a total distance of 470 miles above Elephant Butte Reservoir.

For the fifty-year period from 1895 to 1944, the flow in the Rio Grande at San Marcial at the head of Elephant Butte Reservoir averaged about 1,100,000 acre-feet annually. Since 1944 the runoff into Elephant Butte has averaged 518,000 acre-feet annually, and for the last 3 years has been only 245,000 acre-feet, or 22% of the 50-year average before 1944. Since the construction of Elephant Butte Dam, water has flowed over the uncontrolled spillway of the dam only once and that was in 1942.

Storage in Elephant Butte has been low for the last 6 years and reached an all-time low of 9,900 acre-feet in August 1954, just 0.45 of 1 percent of its total capacity. The greatest amount of storage this spring in both Elephant Butte and Caballo was 241,000 acre-feet before water was released for irrigation on March 18th. As of today, April 5, 1956, there is only about 180,000 acre-feet left in storage in both reservoirs.

Earlier predictions for an appreciable runoff this year are apparently not going to materialize. The latest prediction by the Weather Bureau for flow into Elephant Butte for the current water year is 460,000 acre-feet; however, it may be considerably below that amount.

Because of the extreme shortage of water in recent years, deliveries to the water users have been on an allotment basis since 1951, with the amount being considerably less than the normal requirement. The total allotment for last year was only 5 inches of water, about 14% of the normal requirement. The initial allotment last year was 2-1/2 inches while the initial allotment this year is 4 inches with no guarantee of delivery after June 15th. Any increase in the allotment that might be made during the year is dependent on runoff into Elephant Butte from the snow pack in the mountains or from spring and summer rains on the watershed. All in all, the outlook for this year is extremely poor unless relief comes in the form of rains of near-flood proportions.

Supplemental Ground Water Supply

The average amount of water applied to the land in order to grow crops in the Rio Grande valley is about 3.0 feet. In order to supplement storage water, the water users of the Project, at their own expense, have drilled about 1700 irrigation wells at a total cost of approximately $12 million. It is only because of these wells that agriculture in the valley has been able to survive the last few years. However, this is probably only a temporary solution since the water table has already dropped an average of 5 to 10 feet throughout most of the Project and the salinity of the well water in the lower end of the Project appears to be increasing. Some wells have already required lowering in order to get enough water. Some have been abandoned because of high salinity and others are approaching the limit where continued use will be detrimental to the land.

Crops and Farm Income

The effect of the drought, plus the cotton acreage limitations, reduced the total farm revenue for farms on the Rio Grande Project nearly 22% last year over the amount received the year before. The total gross income for last year's crops was a little over $32 million. Last year's total was a 45% drop from the record high of $59 million in 1952.

Cotton, the big money crop on the Rio Grande Project, accounted for 79% of the income and 61% of the total acreage last year. Because of reduced acreages, smaller yields and lower prices, it was responsible for most of the drop in farm income from the year before. Medium staple cotton dropped from about $29 million in 1954 to about $21 million last year. The yield dropped from 1.85 bales per acre to 1.54 bales and the cash value dropped from $383 per acre to $309. Long staple cotton suffered an even greater reduction because of a substantial drop in price as well as a drop in yield. The price dropped from an average of 67½ cents per pound in 1954 to 53½ cents in 1955, and the yield dropped from 1.04 bales per acre to 0.85. This brought about a 35% reduction in the cash value per acre, dropping from $366 to $236.

The second most valuable crop was alfalfa with almost 35,000 acres planted. The yield last year, 3.6 tons per acre, was the same as the year before but the price ran a little higher, averaging about $93 per acre, an increase of about $4 per acre.

The third most valuable crop was pecans, which yielded $358 per acre. The pecan acreage of almost 4,200 acres is largely on the Stahmann Farms near here. The crop that brought the highest gross revenue per acre last year was dry onions, grossing $904 an acre on 542 acres. Other vegetables and fruits brought fairly high returns also. The average of all crops harvested was $227 last year as compared with $289 in 1954.

It should be remembered that these figures are gross income from crops. Not only have labor, seed and material costs risen in the last few years, but irrigation water cost the farmers considerably more money last year, due to the fact that on the average over 2-1/2 feet of water had to be supplied by the farmer himself from his own or his neighbor's well at an estimated cost of $5 to $15 an acre-foot. This added cost cut deeply into the revenue the farmer received from his crop.

The total gross income last year was the lowest since 1945 and, considering the reduced buying power and added expense, it made 1955 one of the poorest years on record.

In spite of the present period of water stress, however, the history of the Project to date is encouraging as reflected by the value of the crops produced since 1915 of $712 million.

Operation and Maintenance Costs

The cost of operation and maintenance of the irrigation and drainage facilities of the Project is advanced to the United States each year by the Irrigation Districts. Due to reduced incomes, increased costs, and water shortage, the farmers, through their irrigation districts, have asked for and received a reduction in the operation and maintenance budget of the Bureau of Reclamation, operating the Rio Grande Project. O&M charges have been reduced from about $6.50 per acre in 1954 to about $4.50 per acre this year. This reduction has meant a major curtailment of the rehabilitation program, that is, replacement of old structures such as checks and bridges, which in some instances have reached an age of forty years or more, as well as a reduction in the extent of the regular maintenance work. In spite of the small amount of Project water delivered, though, the system still has to be maintained to keep it from deteriorating. Also, the ditches have to be kept clean to handle the well water that is conveyed through the system.

In comparing the cost of maintaining and operating this Project with other projects that have been financed with Federal funds, some of which are operated by the Bureau of Reclamation and some by the irrigation districts, for the year 1954, the last year that complete figures are available, the Elephant Butte District of the Project ranked 77th and the El Paso District ranked 91st, out of 117 projects compared on cost per irrigated acre. On the basis of the ratio of O&M cost to gross crop value, however, both Districts of the Project ranked with the very best, with the Elephant Butte District 9th and the El Paso District 17th.

Future Conditions

In closing, I would like for you to think for a minute about what the future might hold in store for the irrigated lands of this valley. Some people think that if we could just get one good runoff "we would be back on our feet". Others, like Dr. Nelson Sayre, director of the ground water studies for the U. S. Geological Survey, feel that it might take five or six above-normal years in a row to bring this Project back to its 1949 condition. After 13 years of below-average inflow to

Elephant Butte, we are still hoping for improvement in the amount of runoff.

However, there are other factors that need to be considered besides runoff. Evaporation and seepage losses take a large percentage of the water that we do get. The evaporation off the surface of Elephant Butte, for example, amounts to about 6 feet of water a year. To try to reduce this amount at Elephant Butte and other reservoirs, experiments are being conducted by the Bureau of Reclamation and other agencies, both in this country and abroad, to try to reduce evaporation losses by use of a thin film over the surface of the water, using cetyl alcohol, or other chemicals which do not have an adverse effect on water, such as creating objectionable tastes or odors or an adverse effect on the biological balance of the reservoirs.

We have also begun reconnaissance studies to determine the feasibility of lining a section of the river or providing a lined conveyance channel outside the river from Leasburg Dam to El Paso to reduce seepage losses and reduce evaporation losses by cutting down the time for transporting the water. In this same connection we are also investigating the cost and the benefits of lining all the major canals and laterals on the Project. Such programs would have to be approved by the farmers before firm reports could be prepared for submission to Congress. The studies haven't progressed far enough yet to know how much it will cost or just how much water it would save.

Other studies, such as changes in methods of irrigation to conserve water, finding new crops that take less water, improving means of increasing rainfall, and finding economical methods of desalting water, still require much research and study. Such studies, as you well know, are being undertaken in virtually all the universities and colleges through out the West.

Irrigated farming is the backbone of the economy of this area. The future of the irrigated farm is the future of the Southwest and most assuredly of the Rio Grande Project area.

THE COLORADO RIVER STORAGE PROJECT
and
PARTICIPATING PROJECTS

By

Ralph Charles*

The Colorado River Basin

Description of the Area

1. The Colorado River rises in Colorado and Wyoming and flows southwest some 1,400 miles to enter the Gulf of California. It drains 242,000 square miles-- one-twelfth of the continental United States.

2. From the high mountain peaks, it traverses mountain valleys, flows through the spectacular canyons of the Upper Basin, and finally meanders through low, broad, alluvial plains of the Lower Basin.

3. Because of the difficulty of development, the Upper Basin is relatively underdeveloped when compared with the Lower Basin. Eastern Utah, Southern Wyoming, and Western Colorado are estimated to contain one-fourth of the undeveloped coal resources of the United States. Vast deposits of oil shale and bituminous sandstone, as well as great beds of phosphate rock are as yet undeveloped.

4. Present development of hydroelectric power also presents a contrast between the basins. In the Upper Basin there is less than 100,000 kilowatts of installed capacity, while in the Lower Basin the Hoover, Parker, and Davis Dam power plants, together with Pilot Knob, those on the Salt River, and a few other smaller developments, aggregate roughly two million kilowatts of installed capacity.

5. In irrigation development, some two million acre-feet of water are depleted in the Upper Basin as

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compared to seven million acre-feet in the Lower Basin. Likewise, the Upper Basin has about two million acre-feet of storage developed as compared to thirty-seven million in the Lower Basin.

6. Bureau of Reclamation projects provided the basis for Lower Basin development. Construction of Hoover Dam provides control of floods, and permits releases as needed for power development, municipal purposes, and irrigation of lands in the Lower Colorado River, Imperial, and Coachella Valleys. More than a dozen cities in the vicinity of Los Angeles get their domestic water supply from the Colorado River Aqueduct. Most of the project costs are paid from firm power, and the vast industrial expansion of the Pacific southwest has been made possible by low-cost dump power from Hoover Dam.

Division of Water

1. The Colorado River Compact, signed November 24, 1922, apportions the waters of the Colorado River system between the Upper and Lower Basins. It provides that the Upper Basin States, Colorado, New Mexico, Utah, and Wyoming, will not cause the flow of the river at Lee Ferry to be depleted below an aggregate of 75,000,000 acre-feet for any period of 10 consecutive years.

2. The Compact also provides for a division of the surplus waters--those in addition to the 15,000,000 acre-feet average that was allotted--after October 1, 1963.

3. There is not complete agreement among the States regarding the interpretation of the Compact and its associated documents (the Boulder Canyon project Acts, the California Self-Limitation Act, and the several contracts for the delivery of water from Lake Mead).

4. Before approval of the Boulder Canyon Project Act of 1928, California signed, at the President's insistence, the Self-Limitation Act which limited the amount to be used by California to 4,400,000 acre-feet.

5. The Upper Colorado River Basin Compact, signed October 11, 1948, allocates 50,000 acre-feet of water to Arizona, and apportions the remainder of the available water, 51.75 percent to Colorado, 11.25 percent to New Mexico, 23.00 percent to Utah, and 14.00 percent to Wyoming.

6. In this Compact, the State of Colorado assents to storage and diversion of water in Colorado for use in New Mexico.

<u>Water Supply</u>

1. In its virgin condition, based on the 1897-1943 record, it is estimated the Colorado River would have carried an average of 17,720,000 acre-feet of water annually into Mexico. The annual flow would have varied from about 5,000,000 acre-feet to 25,000,000 acre-feet.

2. Under the Mexican Treaty, Mexico would have received about 1,500,000 acre-feet annually, leaving an average, based on this record, of 16,200,000 acre-feet for consumption in the United States.

3. Present water uses in the United States are estimated to deplete the virgin water supply at the International Boundary by about 7,120,000 acre-feet annually, leaving an average of about 9,100,000 to meet future uses.

4. On the basis of the longer term records now available, 1897 through 1955, some engineers believe it may be difficult to deliver 75,000,000 acre-feet at Lee Ferry in each 10 consecutive years, as required by the Compact, if 7,500,000 acre-feet of depletions occur in the Upper Basin.

5. Studies have been made of 143 potential projects in the basin and 20 transmountain diversions. Development of only the within-basin potential projects, 6,000,000 acre-feet; the present depletion, 7,000,000 acre-feet; and expansion of present projects, 4,000,000 acre-feet, would make a total of about 17,000,000 acre-feet of depletion annually, more water than is available.

Authorized Project

1. The Secretary is authorized to construct, operate, and maintain the following initial units consisting of dams, reservoirs, power plants, transmission facilities, and appurtenant works; Curecanti, Flaming Gorge, Navajo (dam and reservoir only) and Glen Canyon.

2. The Secretary must re-examine Curecanti, determine that it is economically justified, and so certify to Congress and the President before its construction can be undertaken.

3. The Secretary is also authorized to construct, operate, and maintain the following 11 participating projects: Central Utah (initial phase), Emery County, Florida, Hammond, LaBarge, Lyman, Paonia, Pine River Extension, Seedskadee, Silt, and Smith Fork.

4. In further investigations, priority shall be given to completion of planning reports on 20 participating including the following New Mexico projects: San Juan-Chama, Navajo, and Animas-LaPlata.

5. Irrigation repayment contracts shall be entered into which, except for the Paonia and Eden projects, provide for repayment of the obligations assumed thereunder with respect to any project contract unit over a period of not more than 50 years exclusive of any development period authorized by law.

6. As to Indian lands within, under or served by any participating project, payment of construction costs within the capability of the land to repay shall be subject to the Leavitt Act.

7. For a period of 10 years from the date of the authorizing law, no water from any participating project shall be delivered for the production on newly irrigated land of any "excess" basic commodity.

Basin Fund

1. The authorizing act sets up a separate fund in the Treasury to be known as the Upper Colorado River Basin Fund.

2. All reimbursable appropriations and all revenues collected in connection with the operation of the Colorado River Storage project shall be paid into the Basin Fund and shall be available without further appropriation for operation, maintenance, replacement, or other authorized payments.

3. Revenues in the Basin Fund in excess of operating needs shall be paid annually into the Treasury to return: (a) the costs of each unit, project or feature allocated to power, within a period of 50 years; (b) the costs of each unit, project or feature allocated to municipal water; (c) interest on the unamortized balance of the power and municipal water investment - and interest shall be a first charge; and (d) the costs of each storage unit allocated to irrigation within a period not exceeding 50 years.

4. Revenues in the Basin Fund in excess of the amounts needed to pay operation and maintenance, and to return the cost of power, municipal water, and irrigation storage, shall be apportioned as follows: Colorado, 46 percent; Utah, 21.5 percent, Wyoming, 15.5 percent; and New Mexico, 17 percent.

5. The Secretary must comply with the Compacts, the Boulder Canyon Project Acts, and the Treaty with the United Mexican States. In the event he fails, any State may maintain an action in the Supreme Court of the United States to enforce compliance.

Costs of the Project

1. The Act authorizes the appropriation of not to exceed $760,000,000, a compromise figure that may not have too great a significance in view of the time element involved in project construction.

2. Much of the costs allocated to irrigation must be repaid by revenues from power. An illustration of

the approximate amount of such repayment by the initial phase is shown in Table 1.

3. The amount of revenue available for repayment assistance and the rate at which it becomes available depend upon a myriad of variable factors, including the construction schedule for both the storage plan and the participating projects, as well as the amount of water available for power production. A study made to illustrate what might occur under one annual construction and operational schedule gave results shown in Table 2.

TABLE 1
Illustration of Irrigation Cost Allocation and Repayment Requirements

Project	Allocation to Irrigation	Repayment by Irrigation	Assistance Required from Power		State Total Assistance
LaBarge	1,506,000	495,000	1,011,000)	Wyo.	30,211,000
Seedskadee	20,945,000	4,785,000	16,160,000)		
Lyman	9,508,000	2,255,000	7,253,000)		
Silt	2,954,000	1,020,000	1,934,000)		
Smith Fork	3,009,000	1,045,000	1,964,000)		
Paonia	6,315,000	2,414,000	3,901,000)	Colo.	14,320,000 1/
Florida	5,853,000	1,711,000	4,142,000)		
Pine River Ext.	4,524,000	2,045,000	2,479,000)		
Emery County	8,673,000	3,715,000	4,958,000)		
Central Utah	114,619,000	15,191,000	99,428,000)	Utah	104,386,000
Hammond	2,072,000	370,000	1,702,000	N. M.	1,802,000 1/
Subtotal	179,978,000	35,046,000	144,932,000		
Eden	7,287,000	1,500,000	5,787,000		
Navajo	31,765,000	---	31,765,000		
Flaming Gorge	27,810,000	---	27,810,000		
Glen Canyon	45,266,000	---	45,266,000		
Curecanti	79,650,000	---	79,650,000		
Subtotal	184,491,000	---	184,491,000		
Total	371,756,000	36,546,000	335,210,000		

1/ 4% of the Pine River project allocated to New Mexico

TABLE 2
Estimate of Repayment Assistance
Initial Phase
(Thousands of Dollars - Cumulative)

Year of Operation	Assistance Available 1/ Credits in Basin Fund		Assistance Required 1/ Credits in Basin Fund	
	Total	New Mexico	Total	New Mexico
25	72,398	12,308	29,002	504
50	230,998	39,269	85,244	1,404
75	347,443	59,005	121,035	1,802
100	582,097	98,956		

1/ Exclusive of net irrigation revenues and net power revenues available from participating projects.

San Juan-Chama Project

Present Status

1. A project report, recognizing the informal comments received from the States of Colorado, Texas and New Mexico, has been completed and sent to the Secretary of the Interior with the recommendation that he forward it, together with the report of the proposed Navajo Indian Project, to the Governor of New Mexico for resolution of certain policy questions.

Plan

1. The imported water would be used in the Rio Grande and Canadian River Basins as follows:

Supplemental irrigation		136,700 A.F.
Tributary units	39,800	
Middle Rio Grande Conservancy	25,000	
Elephant Butte Irrigation District	71,900	
Municipal and industrial water supply		55,800 A.F.
Replacement of miscellaneous basin depletions		42,500 A.F.
Total		235,000 A.F.

2. The plan conforms to the limitations of the authorizing act and involves (a) the collection and diversion features in the San Juan River Basin consisting of three storage dams, five diversion dams, and about 48.93 miles of main conduit; (b) the regulation and storage features consisting of Heron No. 4 dam and reservoir on Willow Creek; and (c) the water-use features providing for use of imported waters as follows: (1) new depletions by 45,145 acres in tributary areas, (2) supplemental water for 81,610 acres in the Middle Rio Grande Conservancy District; (3) supplemental water for 98,700 acres in the Elephant Butte Irrigation District; (4) additional municipal water for Albuquerque; and (5) replacement of basin depletions amounting to 20,000 acre-feet annually for watershed improvement programs and 15,000 acre-feet of pumping, plus losses of 7,500 acre-feet.

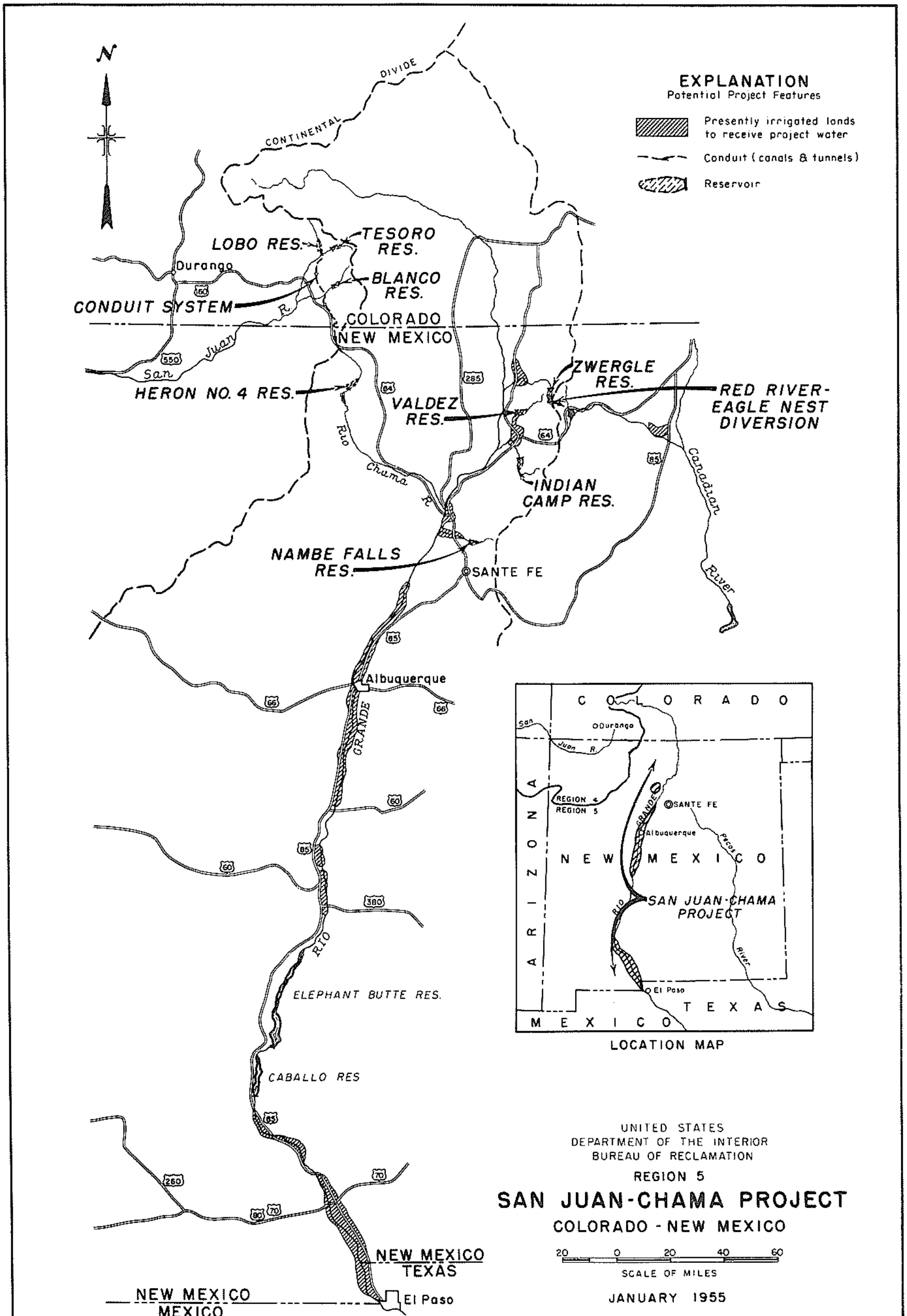
Construction Costs

Navajo Dam Allocation		$ 800,000
Pagosa Division		103,708,000
Lobo Dam and Reservoir	10,307,000	
Tesoro Dam and Reservoir	9,044,000	
Blanco Dam and Reservoir	9,060,000	
Diversion Dams (5)	653,000	
Conduits	74,205,000	
Permanent Property	439,000	
Rio Chama Division		8,254,000
Heron No.4 Dam and Reservoir	7,680,000	
El Vado Outlet Works	574,000	
Rio Arriba Division		21,937,000
Cerro Unit	5,377,000	
Taos Unit	11,692,000	
Llano Unit	1,748,000	
Pojoaque Unit	1,567,000	
Cimarron Creek Unit	1,553,000	
Recreational developments		360,000
Stream measurement facilities		110,000
Total construction expenditure		$135,169,000
Interest during construction on municiapl and industrial water costs		728,000
Total construction costs		$135,897,000

Allocations and Repayment

Allocation of construction costs

	Total	Non-reimbursable	Reimbursable	Repayment
Irrigation	$87,531,000		$ 87,531,000	$21,290,000
M&I water	27,503,000		27,503,000	27,503,000
Basin depletions	20,393,000		20,393,000	6,600,000
Recreation	360,000	$360,000	- -	- -
Stream measurement	110,000	110,000	- -	- -
Colorado R.Basin Fund	- -	- -	- -	80,034,000
Total	$135,897,000	$470,000	$135,427,000	$135,427,000


N
EXPLANATION
Potential Project Features
Presently irrigated lands to receive project water
Conduit (canals & tunnels)
Reservoir
CONTINENTAL DIVIDE
LOBO RES.
TESORO RES.
BLANCO RES.
Durango
CONDUIT SYSTEM
COLORADO
NEW MEXICO
San Juan R.
HERON NO. 4 RES.
ZWERGLE RES.
RED RIVER-EAGLE NEST DIVERSION
VALDEZ RES.
Rio Chama R.
INDIAN CAMP RES.
Canadian River
NAMBE FALLS RES.
SANTE FE
Albuquerque
GRANDE
RIO
ELEPHANT BUTTE RES.
CABALLO RES
NEW MEXICO
TEXAS
NEW MEXICO
MEXICO
El Paso
160
550
84
285
64
85
66
60
380
260
80
70
COLORADO
Durango
San Juan R.
REGION 4
REGION 5
SANTE FE
GRANDE
Albuquerque
Pecos River
ARIZONA
NEW MEXICO
RIO
SAN JUAN-CHAMA PROJECT
El Paso
TEXAS
MEXICO
LOCATION MAP
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
REGION 5
SAN JUAN-CHAMA PROJECT
COLORADO - NEW MEXICO
20 0 20 40 60
SCALE OF MILES
JANUARY 1955

Irrigation

Rio Arriba Division

	Cerro	Taos	Llano	Pojoaque	Cimarron Creek
Irrigable area (acres)	11,820	20,550	5,690	2,440	4,645
Consumptive use requirement (acre-feet per acre)	1.95	2.06	2.38	2.30	1.97
Average annual diversion requirement (acre-feet per acre)	2.24	2.46	3.77	2.72	3.03
Average annual payment capacity (per acre per year)	$7.18	$7.11	$11.43	$11.54	$13.36
Amortization capacity available for payment of San Juan-Chama Project costs (per acre per year)	$4.16	$4.31	$2.19	$8.92	$5.89
Project O&M costs (per acre per year)					
Joint works	$0.80	$0.57	$1.65	$0.32	$1.62
Unit works	$2.22	$2.23	$4.06	$2.30	$2.67

Rio Medio Division

Water right lands (acres)	121,680
Irrigable area (acres)	81,610
Consumptive use requirement (acre-feet per acre)	2.37
Average annual crop irrigation requirements (acre-feet per acre)	2.03
Average annual payment capacity (per acre per year)	$10.05
Amortization capacity available for payment of San Juan-Chama Project costs (per acre per year)	$0.61
Project O&M costs (per acre per year)	$0.30

Rio Abajo Division

Irrigable area (acres)	98,700
Average annual farm delivery requirement (acre-feet per acre)	3.35
Average annual payment capacity (per acre per year)	$20.70
Amortization capacity available for payment of San Juan-Chama Project costs (per acre per year)	$1.79
Project O&M costs (per acre per year)	$0.71

Municipal and Industrial Water Supply

Deliveries to Albuquerque, New Mexico, assumed to be 6,000 acre-feet per year initially, and 50,000 acre-feet from 1990 on.
Average annual water charge per acre-foot delivered. (based on a uniform rate over a 50-year period with 2-½ percent interest$29.50).

Ground Water: Its Importance to the Economy of New Mexico

By

C. S. Conover*

It goes without saying that water and its availability are one of the principal factors in the expanding economy of New Mexico. However, it is not so well recognized or known that ground water, as well as surface water, plays a major role in the economy. Also, in the long run, the most efficient use of our water resources will require increasing attention to the interrelation of surface and ground waters and their development as an integrated water supply.

An estimate of the water use in New Mexico for 1955 shows that ground water is used for irrigation on about 66 percent of the irrigated land, or on about 576,000 acres of a total of 873,000 acres. About 13,000 acres of the 576,000 are lands normally furnished surface water but which now are furnished ground water also. Usually it is considered that ground water, when applied to lands normally furnished surface water, is supplemental to the surface water supply. However, because of drought and the interrelation of the waters, such is not always the case. For example, in the Rincon and Mesilla Valleys on the Rio Grande, where until about 1948 ground-water irrigation virtually did not exist, there were in 1955 some 1,700 irrigation wells which furnished all but a few inches of the total irrigation supply. At present, therefore, in the Rincon and Mesilla Valleys the surface water applied to the irrigated lands is supplemental to the ground-water supply. This situation calls for more than a casual consideration of the pumping of ground water, as it will have far-reaching effects on both the economy and the hydrology of the area.

The importance of ground water to New Mexico is further emphasized by the fact that, of the total quantity of municipal water used, 92 percent comes from wells, The 92 percent is used by 87 percent of the population that is furnished public water. That the proportion of ground water used is greater than the proportion of the population using ground water is interesting, for it means that--contrary to the situation in many other States-- the per-capita use of ground water from municipal systems is greater than that of

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surface water. This is because many of the towns using surface water are located where they have access to streams having only limited flows, and also because most of the towns using surface water are in the northern part of the State where the climate is cooler. Where possible some towns that normally use surface water, such as Santa Fe, have drilled wells as a supplemental supply. It is interesting to note that in 1955 Santa Fe used nearly twice as much ground water as surface water, whereas prior to about 1951 only surface water was used. Albuquerque, the largest city in the State, pumped about 26,000 acre-feet of ground water in 1955, an amount sufficient to irrigate 10,000 acres of farmland or to flood the area within the city limits to a depth of about 8 inches. Presently, though municipal use of water is large, it represents only about 5 percent of the water use in the State.

The third important use of water is for industry, although present industrial use of water is only about 1 percent of the total water use in the State. Industrial use now is confined primarily to the refining of petroleum and potash. The need and value of water for industry is emphasized by the potash mines in the vicinity of Carlsbad; there pipelines as much as 35 miles in length have been laid from the potash refineries to the High Plains in Lea County to obtain adequate quantities of fresh water. In addition, appreciable quantities of the saline ground water available locally are used for certain processing. The estimated use of water in New Mexico in 1955 is given in table 1.

Table 1.--Summary of estimated water use in New Mexico, 1955

Irrigation	Acres	Percent	Ac.-ft/yr	Mgd.
Ground water and surface water	131,000	15	-	-
Ground water	445,000	51	1,350,000 1/	1,200
Surface water	293,000	33	778,000	694
Sewage	4,000	1(-)	12,000	11 2/
Total	873,000	100	2,140,000	1,905
Municipal	**Population**	**Percent**	**Mgd**	**Percent**
Ground water 3/	505,000	87	94.6	92
Surface water	75,000	13	8.6	8
Total	580,000	100	103.2	100
Industrial	**Fresh (Mgd)**	**Saline (mgd)**	**Total (mgd)**	**Percent**
Ground water	17.3	3.7	21.0	79
Surface water	1.5	4.2	5.7	21
Total	18.8	7.9	26.7	100
Summary	**Ground water (mgd)**	**Surface water (mgd)**	**Total (mgd)**	**Percent**
Irrigation	1,210	695	1,905	94
Industrial	21	6	27	1
Municipal	95	8	103	5
Sub Total	1,326	709	2,035	100
Rural	9	1	10	
Total (State)	1,335	710	2,045	
Percent	65	35	100	

1/ Including that supplemental to surface water.

2/ Estimated 10 mgd ground water, 1 mgd surface water.

3/ Includes government installations.

The value in dollars and cents of ground water to New Mexico is difficult to assess. Without ground water, the population of the State probably would have become fixed long ago at a level lower than at present. However, for talking purposes, it may be assumed that irrigation water is worth $10 an acre-foot, municipal water 25 cents per 1,000 gallons, and industrial water 50 cents or more per 1,000 gallons. The latter figure is set high because of the high cost of getting water for some of the principal industrial users. In other terms, the water is worth about 0.7 cent per ton, 6 cents per ton, and 12 cents per ton for the three uses, respectively. Water is still our best buy. Using the above figures, the present annual value of ground water to New Mexico is $13,500,000 for irrigation, $8,600,000 for municipal use, and $3,800,000 for industrial use, a total of about $26,000,000.

The present use and value of the ground water to the State are only a part of the picture that must be known before the potential value of this resource to the economy of the State can be appraised. A study of the increase in development in the past, coupled with evaluation of its effects on the water supply; an inventory of the volume of ground water in storage and of the recharge to and discharge from this supply; and additional knowledge of basic hydrogeologic principles are needed to appraise the ground-water potential of the State. Needless to say, in such a large State with such a varied geologic and hydrologic environment, an accurate answer is difficult to obtain and in addition requires appreciable time. Also, as the availability of water and the need for it vary with time, owing to changes in precipitation and demand, all estimates are subject to continued reappraisal.

Collection and appraisal of basic information on the Nation's water resources are one of the responsibilities of the U. S. Geological Survey. Studies of the ground-water conditions in various areas of the State are being made in cooperation with the State Engineer, the New Mexico Bureau of Mines, various counties and municipalities, the Department of Defense, and other Federal agencies. The program with the State Engineer consists of evaluation of the ground-water resources, generally in irrigated and other areas where water demands are appreciable. The program with the New Mexico Bureau of Mines, in which the State Engineer also is a participant, consists primarily of areal investigations of the occurrence of ground-water, generally on a county basis. Presently 37 ground-water studies are being conducted in the State by the Survey. Those studies in cooperation with the State agencies are listed in table 2. Additional studies will be started as others become completed. The scope of the studies ranges from short reconnaissance investigations of the occurrence of water, such as at Crow Flats, Otero County, through general county or basin studies to intensive evaluation of special problems such as the feasibility of diverting brine inflow from the Pecos River at Malaga Bend south of Carlsbad. Reports on ground-water studies prepared by the Geological Survey are released to the public in the open file and published by the State Engineer, the New Mexico Bureau of Mines, or the Geological Survey itself.

As a sign of the times, it is of interest to point out the two studies being made to determine means of alleviating salinity conditions, east of Roswell and Malaga Bend. Also, investigation of the availability of nonpotable water in an area in the Tularosa Basin is being made for the Department of Defense, and a general report on the saline waters of New Mexico is planned next year. The latter report will summarize the availability of saline water as a resource for use as is or for conversion to potable water by methods now under study as a part of the Interior Department's Saline Water Conversion Program.

Table 2.--Cooperative ground-water studies by the Geological Survey in New Mexico, 1955-56

Study	Cooperating agency
Water levels and artesian pressures in observation wells in New Mexico	State Engineer
Ground-water conditions in the Animas Valley Hidalgo County, N. Mex.	State Engineer
Geology and ground-water resources of Torrance County, N. Mex.	Bureau of Mines and State Engineer
Geology and water resources of the Santa Fe area, New Mexico.	Bureau of Mines and State Engineer
Feasibility of diverting brine inflow along Malaga Bend of the Pecos River and disposing of it by evaporation in a nearby depression, Eddy County, N. Mex.	Pecos River Commission
Geology and ground-water conditions in the area between Lake McMillan and Carlsbad Spring, Eddy County, N. Mex.	Pecos River Commission
Occurrence of saline water in the San Andres limestone east of Roswell, Chaves County, N. Mex.	State Engineer and Pecos Valley Artesian Conservancy District
Ground-water conditions in the structural basins west of Tucumcari, N. Mex.	State Engineer, Bureau of Mines and city of Tucumcari
Progress report on ground-water resources of northern Lea County, N. Mex.	State Engineer
Geology and ground-water conditions in southern Lea County, N. Mex.	Bureau of Mines and State Engineer
Progress report on ground-water resources of Mimbres Valley, Luna County, N. Mex.	State Engineer
Ground-water conditions in the Playas Valley Hidalgo County, N. Mex.	State Engineer
Geology and ground-water conditions of Grants-Bluewater area, Valencia County, N. Mex.	State Engineer

Table 2.--Cooperative ground-water studies by the Geological Survey in New Mexico - Continued

Study	Cooperating agency
Geology and water resources of the Carlsbad area, Eddy County, N. Mex.	City of Carlsbad and State Engineer
Geology and ground-water resources of Quay County, N.Mex.	Bureau of Mines and State Engineer
Geology and ground-water conditions in Grant County, N. Mex.	Grant County Comm. and State Engineer
Geology and water resources of Guadalupe County, N. Mex.	State Engineer
Progress report on Chaves-Eddy County Ground -water Basin, N. Mex.	State Engineer
Water resources and geology of the Hondo Valley, Lincoln County, N.M.	State Engineer
Reconnaissance of ground-water conditions in the Sunshine Valley area, Taos County, N. Mex.	State Engineer
Geology and ground-water occurrence in the Gallup area, McKinley County, N. Mex.	City of Gallup and State Engineer
Geology and ground-water resources of the Albuquerque area, N. Mex.	City of Albuquerque and State Engineer
Ground-water conditions in the McMillan delta area, Eddy County, N. M.	Pecos River Commission
Geology and ground-water conditions in eastern Valencia County, N.M.	Bureau of Mines and State Engineer
Hydrologic atlas of northern Lea County, N. Mex.	State Engineer
Reconnaissance of ground-water conditions in Crow Flats area, Otero County, N. Mex.	State Engineer

One of the important programs with the State Engineer is that of continuing evaluation of changes in ground-water storage as represented by changes in water levels in observation wells. At present water levels are measured annually in some 1,700 wells in 18 main areas of development. Such records, however, are not now being obtained in some important areas--for example, the Rincon and Mesilla Valleys.

The amount of land irrigated by ground water in New Mexico has increased appreciably in the last few years, from about 140,000 acres in 1940, to 320,000 acres in 1950, and to about 576,000 acres in 1955. Ground-water irrigation is practiced in about 20 major areas. Part of the increase, some 130,000 acres since 1940, represents lands previously served exclusively by surface water, such as those in the Rincon and Mesilla Valleys and some in the Carlsbad area.

Much of the ground-water development has occurred in areas where the recharge is small, such as the High Plains of Lea and Curry Counties, the Mimbres Valley near Deming, and the Animas Valley southwest of Lordsburg. However, the volume of water contained in ground storage in these areas is very large, and development over a long period will be possible if this valuable resource is used wisely and efficiently. For instance, fairly reliable information indicates that some 25,000,000 acre-feet of water is stored in the Ogallala formation in Lea County. The hydrologic conditions in Lea County are such that essentially all water pumped is taken from storage. At present most water in Lea County is being used for irrigation. Appreciable development for irrigation began in 1948, and to date water levels have lowered about 25 feet locally where pumping is concentrated. However, in areas distant from pumps, water levels have declined only a few feet. Because of the slow rate of movement of ground water, long-term development is favored by conservative pumping which allows time for water to move from distant areas to the pumped wells. Under present controls established in Lea County by the State Engineer, a minimum safe life of development of 40 years appears assured. Increased conservation of water, and increased industrial use of water, would maintain the economy at a high level for many years.

In contrast to areas where water essentially is being mined, there are certain areas in the State, particularly along the Rio Grande in places such as the Rincon and Mesilla

Valleys, where ground-water reservoirs are or can be replenished from surface-water supplies. In such areas efficient utilization of the ground-water resource revolves around the long-term availability of surface water taking into account the need of downstream users, the capture of water being wasted by native vegetation, and maintenance of soil-moisture salinity at a safe level. In other words, in such stream valleys the total water supply must be considered as a unit, ground water plus surface water. Full integration of the ground-water and surface-water use in stream valleys apparently could increase measurably the amount of water dependably available for beneficial use. The ground-water reservoir in the Rio Grande Valley is very large when compared with present surface reservoirs constructed in the State. For instance, in the middle Rio Grande Valley, it is estimated that nearly half a million acre-feet of ground water is stored within 100 feet of the surface under each area of valley floor equivalent to a township (36 square miles); in other words, there is more water stored under 5 townships than can be stored in Elephant Butte reservoir. Underground storage generally has the advantage of being relatively immune to direct evaporation losses, a major item in surface reservoirs in this dry country. Because of the large underground storage, utilization of the ground as a regulating reservoir would result in a firmer supply, during droughts, than could be obtained through man-made surface reservoirs alone.

Full utilization of the ground-water reservoir in the Rio Grande Valley would result in an appreciable lowering of water levels during droughts. This would have a three fold effect: (1) waste of water by water-loving plants would be measurably reduced, resulting in an effective increase in water supply; (2) the quality of the ground water would deteriorate temporarily, owing to cessation of drain flow; and (3) nearly all water users would of necessity use ground water to secure a dependable water supply.

In considering the water potential of the State, mention is made many times of the total precipitation as a measure of potential water supply. Using 13.9 inches as the average precipitation for the State, it might be stated that the potential water supply is 90,000,000 acre-feet. However, the real potential is only a very small fraction of this, as evapotranspiration must take its toll. If it were not for the fact that prcipitation comes mainly in showers of short duration and in snow, evapotranspiration would claim all the precipitation. We must therefore content ourselves with essentially the water that appears as runoff to the streams and as recharge to the ground-water bodies. This amount is only a small fraction of the precipitation, on the order of 5 percent. Of this amount, nature takes a further toll in the form of evaporation from streams and surface reservoirs and evapotranspiration from areas of shallow water table where dense growths of native vegetation exist. The remaining 95 percent includes the soil moisture that benefits mankind by maintenance of range, forest, and cropland. There are two main areas in New Mexico where large areas of native vegetation exist, the delta areas of Elephant Butte Reservoir and McMillan Reservoir. The Bureau of Reclamation has spent considerable sums in salvaging water in the Elephant Butte delta by construction of a river channel and drains. The Pecos River Commission is proposing a similar project in the McMillan delta to salvage about 25,000 acre-feet of water annually. Further, in considering the water available for development in the State, allowance must be made for downstream users such as Texas and Arizona.

Considering the future, it has been estimated that the population of New Mexico will increase by more than 50 percent by 1975. The need for water will undoubtedly increase by a greater percentage, as the tendency is for continued increase of per-capita use of water. Though our water supplies are limited and generally are fully utilized at present, the future is not exactly bleak. Much can be done and undoubtedly will be done to assure the continuing availability of water. Solution to many of the water problems revolves around economics. As water becomes more scarce, it becomes more valuable, and certain conservation and developmental measures can be undertaken in the future which at the present may be uneconomical. Measures that need to be considered in evaluating and providing for our water supply in the future are: Reduction of nonbeneficial use by native vegetation, such as in the middle Rio Grande Valley and along the Pecos; conservation of present supplies by increasingly efficient use of water, such as by using closed conduits in irrigation; utilization of nonpotable water for certain industrial processes, such as water flooding of oil fields; reclaiming waste waters such as sewage in certain areas for other uses; substitution of low-water-requirement industries for irrigation in some areas; utilizing additional water supplies, such as water from the San Juan and ground water in areas presently undeveloped; utilizing underground storage to conserve surface waters; and conversion of saline water for municipal and industrial use. There also remain the possibilities, which as yet are only remote, of artificially increasing the precipitation and increasing the percentage of runoff.

Solution to these problems will not come easily or in a short time and will require a consistent, continuous effort to collect and interpret water facts. Further, effective solution will depend upon concentrated effort on the part of many agencies and individuals, actively supported by the public.

STREAMFLOW INVESTIGATIONS OF THE U. S. GEOLOGICAL SURVEY IN NEW MEXICO

By

Wallace T. Miller*

The water resources investigations conducted by the Geological Survey are made by authorization of the Congress under the organic act of 1879. Since 1894, Congress has annually appropriated funds for investigating the water resources, and since 1902 each appropriation bill has had in it the following:

".....for gaging streams and determining the water supply of the United States, investigating underground currents and artesian wells, and methods of utilizing the water resources".

Since 1929 the appropriation acts have provided that a part of the appropriation shall be made available for matching on a 50-50 basis the cooperation offered by States or municipalities for general water resources investigations.

The water resources investigations of the Survey are conducted by the Water Resources Division through its three operating branches -- Surface Water, Ground Water, and Quality of Water--and the Technical Coordination Branch, a staff branch.

The Surface Water Branch collects, compiles, analyzes, and evaluates basic data relating to the source, quantity, movement, availability for utilization, and hydraulic and hydrologic characteristics of the nation's streams and other surface water resources.

In New Mexico there are 178 gaging stations operated by the Geological Service located on streams, canals and reservoirs, These stations are operated for or in cooperation with the following agencies:

Soil Conservation Service - - - - - - - - -	1
Bureau of Reclamation - - - - - - - - - - -	23
Corps of Engineers - - - - - - - - - - - -	16
Fish and Wildlife Service -- - - - - - - -	4
Bureau of Indian Affairs - - - - - - - - - -	7

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State Engineer of New Mexico and Interstate Streams Commission	104
Rio Grande Compact Commission	10
Costilla Creek Compact Commission	14
Pecos River Commission	15
U. S. Federal Base Stations	17
Total	211

The difference of 33, between 211 and 178, is accounted for by the fact that a number of gaging stations receive partial support from more than one agency.

In addition to the operation of these gaging stations the New Mexico Surface Water District is engaged in four other related projects.

1. Compilation and evaluation of records

This project involves reviewing, revising, filling in gaps, and summarizing and publishing all available streamflow records through the water year 1950 in one volume. It has been a tremendous project, in that early discharge records have been reviewed in the light of modern reporting standards. Records collected by other agencies but not previously published by the Survey have been included after having been reviewed. Part 9, Colorado River basin, was published in 1954; Part 7, Arkansas River basin, has recently been received from the printer. Part 8, Western Gulf of Mexico basins, of which the Rio Grande is a part, is being reviewed at this time. The review for the New Mexico portion will be completed about two years from now, but it is not known when the printed report will be available. These compilations will save a tremendous amount of time of those who use the data.

2. Flood-frequency analyses

This project involves the compilation of annual peak discharges and the computation of the probable frequency of occurrence of discharges of various magnitudes. These studies will provide flood-frequency data useful in the design of highways, bridges, dams, and levees, and in determining the feasibility of establishing residential, farming or industrial activities within a flood plain. By these studies it will be possible to predict losses from flooding as well as to provide data for adequate designs, and at the same time ensure that overdesigns may be avoided.

This district's part of the Colorado River basin report has been completed; our part of the Canadian River basin has been computed and is now being checked. The Rio Grande and Pecos River basin studies probably will not be started for two years, although some work will be done in connection with the compilation report.

3. Highway program

This project is operated in cooperation with the Bridge Design Section of the State Highway Department and consists of the operation of 75 crest-stage gages, indirect determination of peak discharges, reports on the magnitude and frequency of floods, and site reports on hydrologic and hydraulic characteristics of stream channels. The basic data collected and the studies made under this program will ensure sound planning and economical design of bridges and culverts. The cost of these studies is small when compared to the overall cost of the bridges and culverts; savings resulting from more economical designs based on the information obtained will more than pay for the program.

4. Drought Studies

The Surface Water Branch is engaged in a study of the drought that persists in the Southwest and is preparing a report on it. This work is being done in Tucson, Arizona, by a staff engineer.

The question often is asked, "Why continue operating gaging stations? Won't three, five, or ten years of record suffice?" A good answer is, "If you were a farmer or fruit grower in an area subject to killing frosts, would you say that five to ten years of weather records would be all you need?".

Water is our most important natural resource. It is a unique resource - and fortunately so - in that it is a renewable resource. But replenishment varies from time to time and from place to place. In some areas the supply received in any one year may be insufficient to meet the demands, while in others too much is received.

Because of the variations in streamflow, the value of a program depends to a large extent on the continuity and adequate areal coverage of basic field observation. Because of time variations in streamflow, a gaging-station record becomes progressively more valuable as it increases in length. When a long record is interrupted, even for only a few years, it loses a great deal of its value, for during that period floods or droughts might occur that would pass unmeasured. Records of extreme occurrences are of great importance to engineers designing or operating water-works facilities. Because of areal variations in streamflow, proper distribution of stream-gaging stations is necessary. Runoff is influenced by factors such as topography and geology. They are basin characteristics and do not vary with time, but may vary greatly from one basin to another.

Flood-frequency studies show very clearly that records of 50 or 60 years cover too short a period of time to be used with certainty to predict the recurrence interval for 100 or more years. Often in such studies a peak discharge will plot high in discharge, indicating that the recurrence interval is much greater than the period of record. A streamflow record 10 years long may contain a 50-year, a 100-year, or even a greater flood. When gaging-station records are analyzed on an areal basis, results will allow prediction of the 50-year flood with acceptable accuracy.

Residents of the Mesilla Valley are vitally interested and concerned with the flow of the Rio Grande. Figure 1 (refer to hydrographs) shows the annual runoff in thousands of acre-feet of three stations on the Rio Grande for the period 1931 to 1955. The lower one (Black) is for Lobatos, which shows the inflow to New Mexico; the upper (blue) is for Otowi, which is the inflow station for the Middle Valley and the index for scheduled deliveries to Elephant Butte; the third, or center (red), is for San Marcial, The difference between the hydrographs for Otowi and San Marcial reflects the use of water between those two points. The runoff at Otowi was greater than downstream at San Marcial in all years shown on the graph except the two high years 1941 and 1942.

The 5-year moving average for each station is superimposed on the hydrograph. This moving average smooths out extreme annual variations and indicates trends more clearly than the conventional hydrograph. The second chart (fig. 2) shows the ratio of the 5-year moving average to the average or mean for the same period, 1931-55. It emphasizes the fact that lower flows have prevailed since 1943 than during the 12-year period 1931-1942.

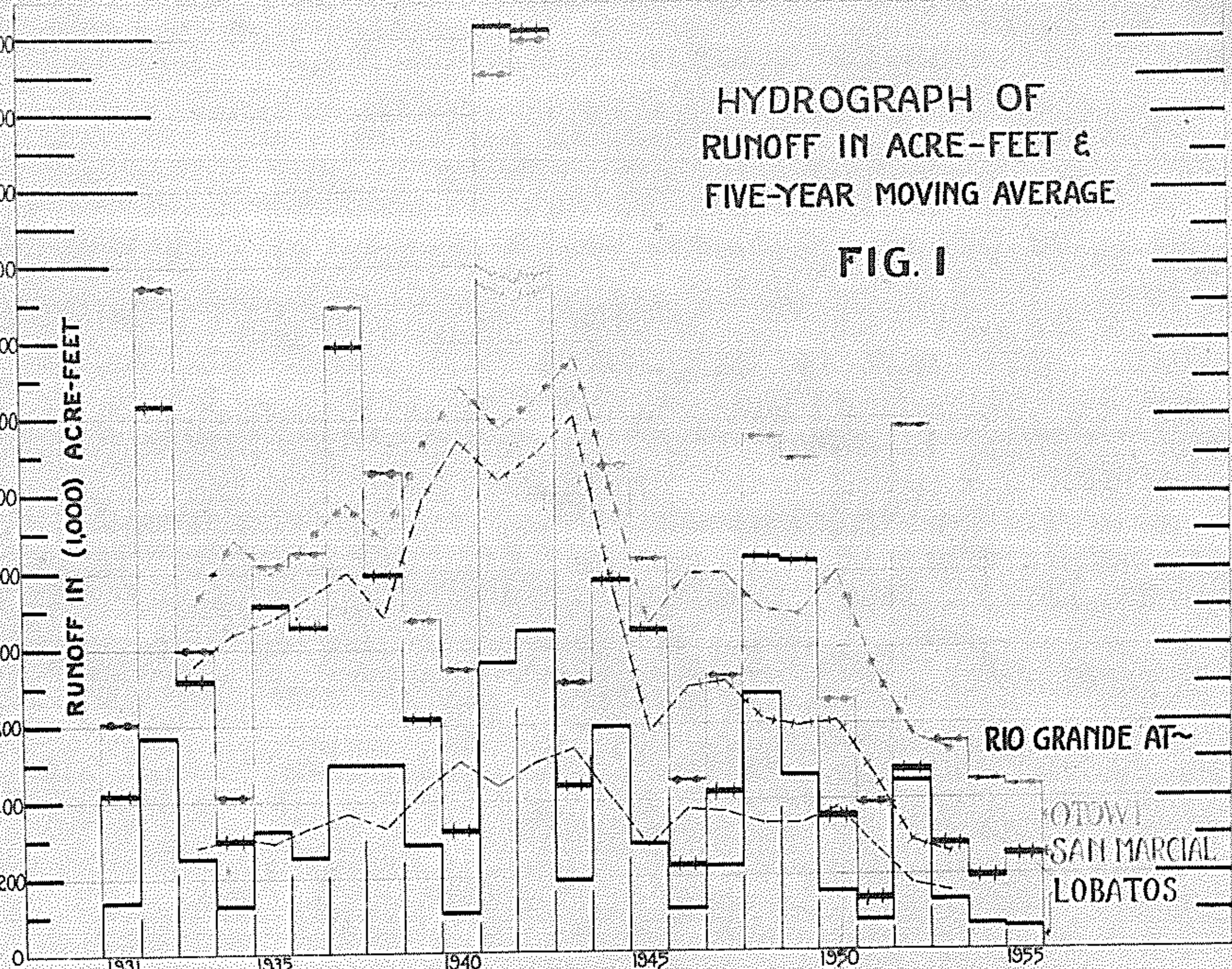

HYDROGRAPH OF
RUNOFF IN ACRE-FEET &
FIVE-YEAR MOVING AVERAGE
RUNOFF IN (1,000) ACRE-FEET
RIO GRANDE AT~
OTOWI
SAN MARCIAL
LOBATOS
1931
1935
1940
1945
1950
1955

FIG. 1

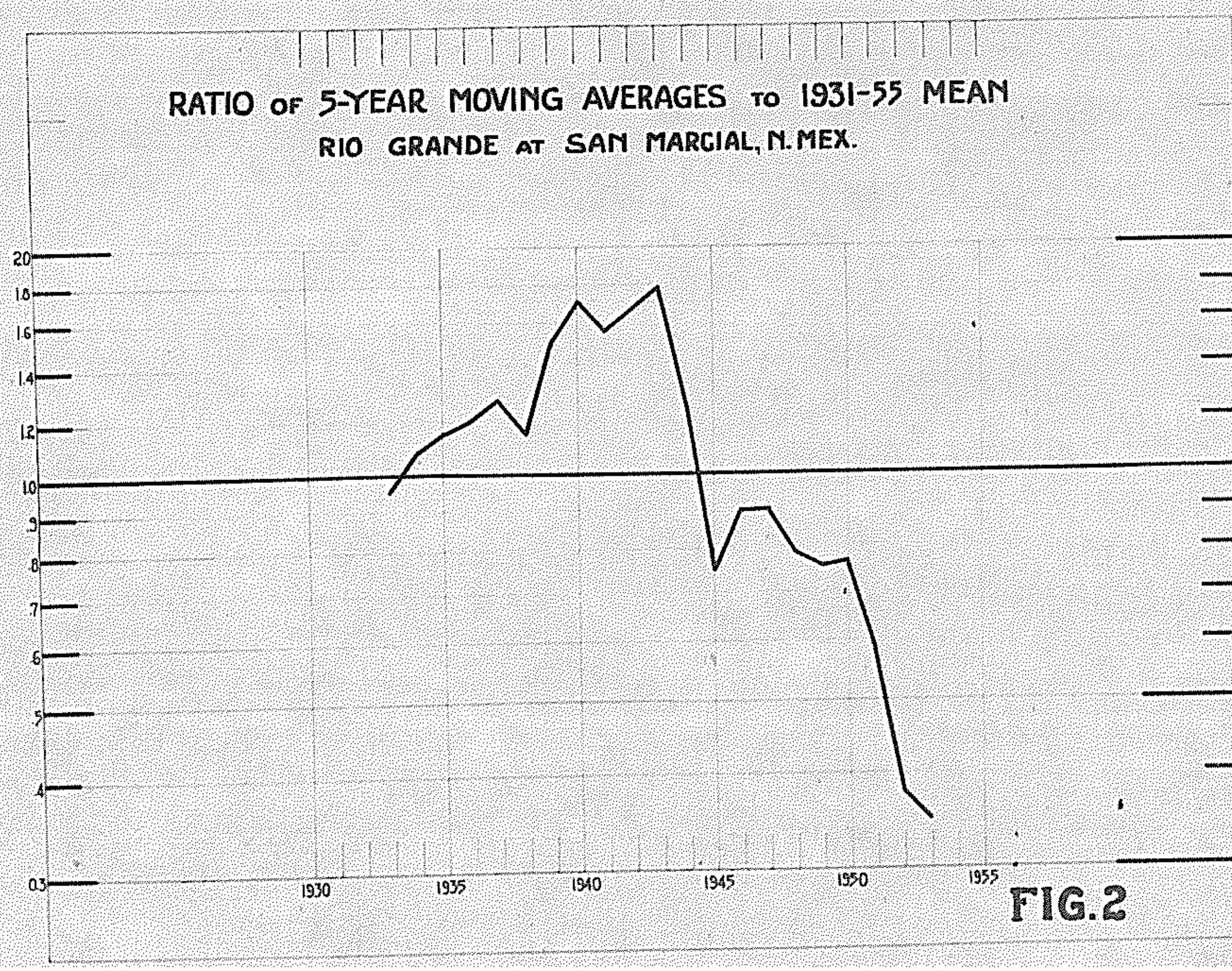
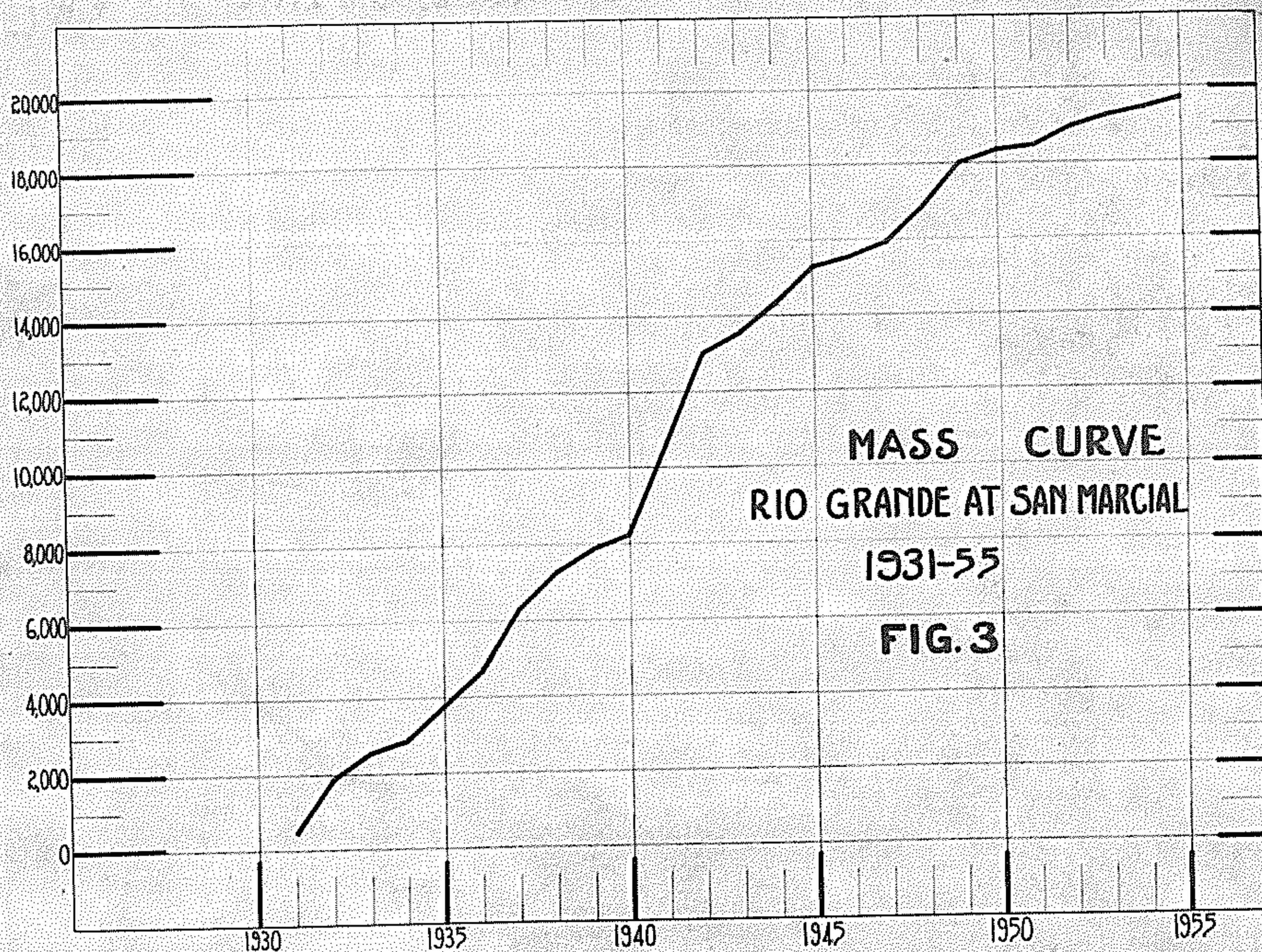
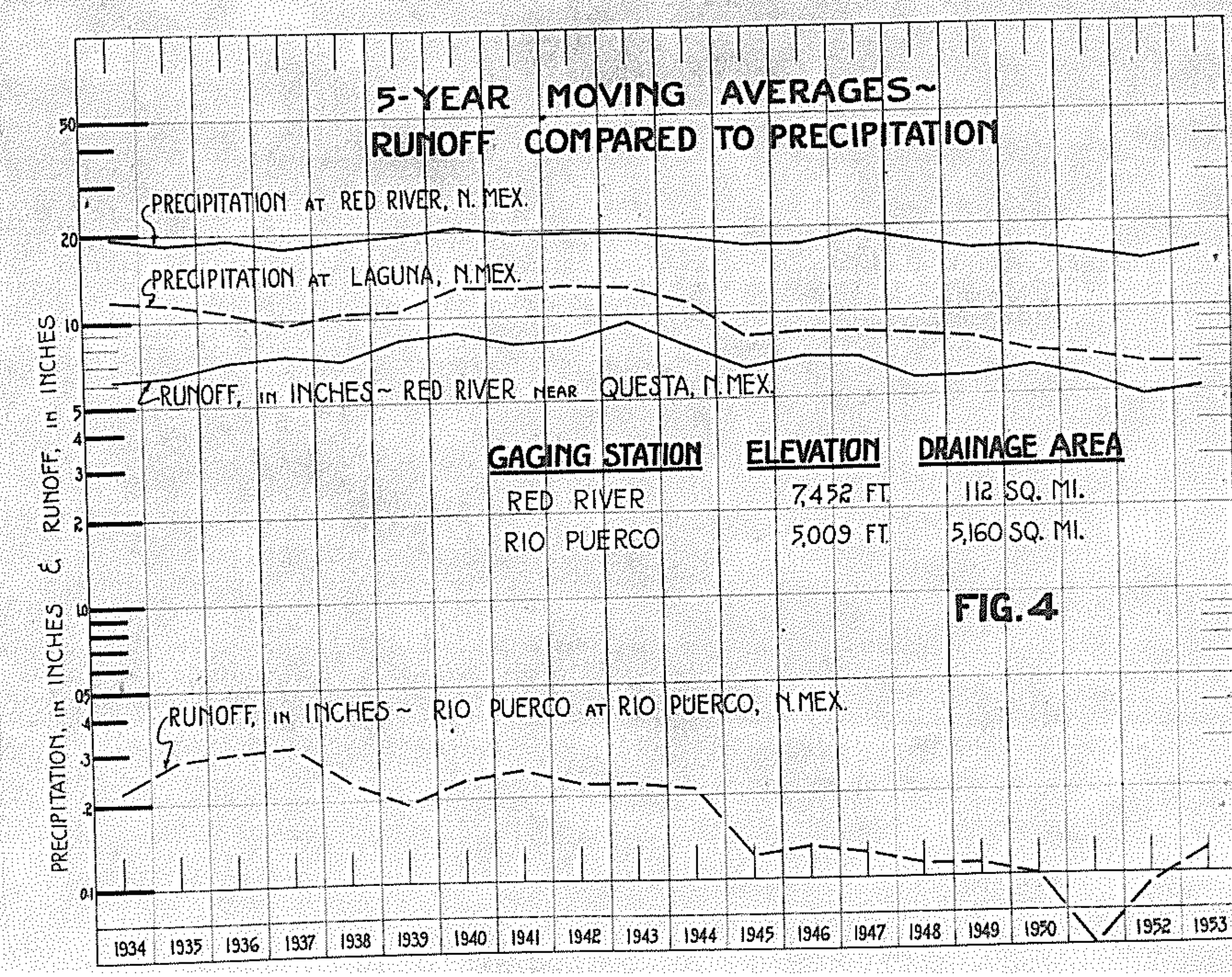

RATIO OF 5-YEAR MOVING AVERAGES TO 1931-55 MEAN
RIO GRANDE AT SAN MARCIAL, N. MEX.
1930
1935
1940
1945
1950
1955

FIG. 2


MASS CURVE
RIO GRANDE AT SAN MARCIAL
1931-55
FIG. 3
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1930
1935
1940
1945
1950
1955


5-YEAR MOVING AVERAGES~
RUNOFF COMPARED TO PRECIPITATION
PRECIPITATION AT RED RIVER, N. MEX.
PRECIPITATION AT LAGUNA, N. MEX.
RUNOFF, IN INCHES~ RED RIVER NEAR QUESTA, N. MEX.
GAGING STATION ELEVATION DRAINAGE AREA
RED RIVER 7,452 FT. 112 SQ. MI.
RIO PUERCO 5,009 FT. 5,160 SQ. MI.
FIG. 4
RUNOFF, IN INCHES~ RIO PUERCO AT RIO PUERCO, N. MEX.
PRECIPITATION, IN INCHES & RUNOFF, IN INCHES
50
20
10
5
4
3
2
1.0
0.5
.4
.3
.2
0.1
1934
1935
1936
1937
1938
1939
1940
1941
1942
1943
1944
1945
1946
1947
1948
1949
1950
1952
1953

The third chart (fig. 3) is a mass diagram, or mass curve, of the annual runoff at San Marcial for the same period. You will note the effect of the high years of 1941 and 1942, and that since 1946, except for a respite in 1948 and 1949, the runoff has been below average, being particularly noticeable since 1950.

The fourth chart (fig. 4) shows the difference between precipitation and runoff on a high, rugged wooded drainage area and one at a lower elevation with less vegetation and much less rugged terrain. All factors have not been considered but the chart does show that the unit runoff per unit of rainfall is much higher from a mountainous area.

We all agree that the demand for water is increasing. The best estimates available are that 200,000 m.g.d. are being used in the United States. This is an average of about 1,200 gallons per day for each man, woman and child. It is estimated that the total use will amount to about 350,000 m.g.d. in 1975. Of this amount, 215,000 m.g.d. will be used for industry, 110,000 m.g.d. for irrigation, and 25,000 m.g.d. for municipal and rural water supplies. Supplemental irrigation by pumping directly from streams and shallow wells in the normally humid eastern and southern portion of the country has increased three-fold since 1940.

Available water supplies may be increased by constructing more surface-water reservoirs to impound flood flows which now cannot be used; transporting water from areas with a surplus to areas of scarcity; improving irrigation practices so as to use water more effectively and economically; water salvage measures such as the elimination or reduction of non-beneficial use areas; reduction of pollution; greater reuse of water, which may mean that some measures must be taken to reduce the salinity; use of air to air cooling instead of the commonly-used water to air systems which waste a large amount of water even when recirculated.

The ultimate development of the water resources of a basin requires the cooperation and coordination of all interests. It cannot be done successfully by any one agency. The problem of each area must be considered independently of other sections of the country and the overall program adjusted to the particular needs of that area in the light of its own present and future problems. Such a comprehensive program can be successful only if local interests, through their proper agencies, can have a voice in planning such a program.

THE WORK OF THE CORPS OF ENGINEERS

IN NEW MEXICO

By

Robert C. Woodson*

The work of the Corps of Engineers in New Mexico involves both Civil and Military installations. For the purpose of this seminar the discussion will be limited to the Civil Works program.

The Civil Works program is primarily concerned with water resources development. It is comprehensive in scope. The principal activities in the State of New Mexico relate to flood and sediment control, major drainage, water conservation for domestic, industrial, and irrigation use, pollution abatement, fish and wildlife conservation, and recreational development of multiple-purose reservoirs constructed for flood control and allied purposes. Navigation is not considered feasible in the State. These functional activities are coordinated with the work of other Federal, State, and local agencies carrying out related programs to avoid any unnecessary duplication of work and to insure that the improvement proposed will satisfy all needs to the fullest extent.

One of the primary responsibilities of the Corps of Engineers is to initiate emergency action before and during floods,whether of a localized nature or of major national concern, especially when local agencies normally responsible are unable to cope with the situation. The Congress, through general and special laws, has authorized the expenditure of certain funds for rescue work, flood fighting, and the repair and restoration of levees and other flood control structures damaged or destroyed by floods. Close cooperation is maintained with local interests by periodic inspection of their levee systems to detect possible future failures, and in addition, maintenance methods are suggested to improve the degree of flood protection.

The water development program of the Corps of Engineers is logically on a watershed basis, and since New Mexico includes portions of several different watersheds there are as many

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development programs in the State. The Continental Divide passes entirely through New Mexico from north to south. About one-sixth of the State is on the western slope of the Divide, in the watershed of the Colorado River. This watershed is under the jurisdiction of the Los Angeles District, which is in the South Pacific Division of the Corps of Engineers. The part of the State east of the Continental Divide is all in the Southwestern Division of the Corps of Engineers. This part is further divided into three districts. The Albuquerque District includes the watersheds of the Canadian River and a very small part of the Purgatoire River, both of which are tributary to the Arkansas River; and the Rio Grande and its major tributary, the Pecos River, which drain the entire central portion of the State. Also included is the small closed basin of the Mimbres River in south central New Mexico. Tributaries of the Arkansas River, including the watersheds of the North Canadian and Cimarron Rivers, lie in the northeast section, and together with tributaries of the Canadian and Red Rivers which rise in New Mexico but which enter the main stems below the New Mexico-Texas State line, comprise that part of New Mexico under the jurisdiction of the Tulsa District. A relatively small part of southeastern New Mexico lies in the watersheds of the Colorado (Texas) and Brazos Rivers. These watersheds are under the jurisdiction of the Fort Worth District.

RIO GRANDE WATERSHED

The Rio Grande drainage area above the New Mexico-Texas State line is about 38,960 square miles, of which about 31,480 square miles lie in New Mexico. The principal tributaries of the Rio Grande, lying wholly within New Mexico, are the Rio Chama, Rio Galisteo, Jemez Creek, Rio Puerco, and Rio Salado. The main stem and tributaries of Rio Grande in New Mexico are either entrenched in deep canyons or are confined to alluvial valleys that vary in width from one-fourth to four miles, and in length from a few miles to more than 100 miles. There are three notable valleys along the main stem: Espanola (upper) Valley, about 30 miles long; Middle Valley, about 165 miles long; and Lower Valley, about 110 miles in length. Within these valleys are some of the State's most densely populated areas, including Albuquerque, Belen, Socorro, Truth or Consequences, and Las Cruces. Industries, transportation and communication facilities, and highly developed agricultural areas are also concentrated along the Rio Grande.

Over the past years, deposition of large quantities of sediment brought down by floods on tributaries has caused a gradual building-up of the Rio Grande channel through the valley reaches. At the present time in Espanola and Middle Valleys the stream bed is as high as, and in many locations, higher than the adjacent valley floor. As a result, the developed areas in the valleys are subject to damage from major floods on Rio Grande. Also the accumulation of sediment in the stream bed has encouraged and promoted the growth of native vegetation which pirates vast quantities of water.

In 1943, the Corps. of Engineers water resources development program was initiated in the Rio Grande watershed in accordance with Section 4 of the Flood Control Act of 1941. After four years of intensive study, in coordination with the Department of the Interior, Department of Agriculture, Federal Power Commission, the Rio Grande Compact Commission, the States of Colorado, New Mexico, and Texas, Middle Rio Grande Conservancy District, and other interested Federal and State agencies, a comprehensive plan was developed for the basin. The plan of development provided generally for flood control and major drainage, sediment control, rehabilitation of the Middle Rio Grande Conservancy District, power development, recreational development, fish and wildlife development, watershed improvement program, improvement of Indian lands, and other collateral improvements.

The flood control phase of the comprehensive plan which was authorized by the Flood Control Act of 1948, provides for flood and sediment control reservoirs on the Rio Chama and Jemez Creek; Rio Grande Floodway through the Espanola and Middle Valleys, including levee rehabilitation and channel rectification in the vicinity of Truth or Consequences; and the Bluewater Floodway.

The following is a brief description of the individual projects, their present status, and relationship to the comprehensive plan of development.

Project Completed

THE JEMEZ CANYON DAM AND RESERVOIR is the first unit to be completed of the flood control phase of the comprehensive plan for the Rio Grande basin in New Mexico, which was authorized by the Flood Control Act of 1948. The dam is located on Jemez Creek about 2 miles above its confluence with the

Rio Grande, near the town of Bernalillo in Sandoval County. Bernalillo is 17 miles north of Albuquerque. The structure is an earthfill dam, 780 feet long, rising to a height of 136 feet above the stream bed. Flood releases are regulated by a gate-controlled conduit, 13 feet in diameter. The dam is protected against overtopping by an uncontrolled off-channel spillway 400 feet long, located about a mile to the south of the dam. An earthen levee about 2,900 feet long prevents backwater from entering the Santa Ana Indian Pueblo which is near the upstream end of the reservoir area. The primary purpose of the project is to provide a reservoir to trap sediment and for the detention and regulation of floods on Jemez Creek, thereby aiding in the prevention of flood damages and aggradation in the Middle and Lower Valleys of the Rio Grande. The reservoir controls the runoff from an area of about 1,034 square miles. The storage capacity at spillway crest is about 120,000 acre-feet, 73,000 of which is reserved for flood control use and 47,000 for deposition of sediment.

Construction was initiated in May 1950, and completed in October 1953. The cost of the project was $4,055,627, which is about $2,800,000 less than the original estimate. The flood control and other benefits which will accrue to the flood control phase of the comprehensive plan, of which the Jemez Canyon Dam and Reservoir is an integral part, are estimated at $5,200,000 annually.

Jemez Canyon Reservoir will be emptied as soon as practicable after each flood and as it will be dry 70 percent of the time, it will afford no opportunity for water-associated recreational activity. However, an overlook shelter, and other public use facilities including picnic tables, barbecue pits, and comfort stations have been provided.

Project Under Way

THE RIO GRANDE FLOODWAY authorized by the Flood Control Act of 1948 will be located along three separate reaches of the Rio Grande. In downstream order, the first reach will extend through the Espanola Valley, the second reach through the Middle Valley from Cochiti to the upstream end of Elephant Butte Reservoir, and the third reach will be between Elephant Butte Dam and the upstream end of Caballo Reservoir.

The project will include rehabilitation and enlargement of existing levees and construction of supplemental levees where necessary. Also, it will include the construction of levee protection works and channel dredging. The ultimate objective is a deeper, stabilized channel that will safely pass floods that cannot be controlled by upstream reservoirs and provide a solution to the problem created by the rising water table throughout the valley.

In accordance with an agreement reached between the Secretary of the Army and the Secretary of the Interior in 1947, it is the responsibility of the Corps of Engineers to construct and rehabilitate levees and provide the necessary bank and levee protection works. Channel rectification, dredging, and the rehabilitation of existing drainage and irrigation facilities is the responsibility of the Bureau of Reclamation.

About 30 miles of the channelization program under the direction of the Bureau of Reclamation has been completed in the San Marcial area and planning and some construction is under way for the remainder.

Construction of the first phase of the Rio Grande Floodway, consisting of a system of levees to protect the city of Albuquerque and its environs, was initiated in May 1954 by the Corps of Engineers. This levee system when completed will afford protection to the city from floods up to 42,000 cubic feet per second on Rio Grande. The levee will have a total length of about 27 miles, of which about 18 miles will be built along the east bank of the river to protect the principal business and industrial sections of the city as well as a large segment of the residential district. Another 9 miles will be constructed along the west bank of the river to protect an urban and suburban area located on the west side. The levee will have an average height of 10 feet, a crown width of 12 feet, and 1 on 2.5 side slopes. Flexible-type levee protection works will be provided in the critical areas that are vulnerable to scour and cutting during floods. This phase will be substantially complete by July 1956.

The estimated cost of construction of the levees protecting Albuquerque (first phase of the floodway) is $3,529,000. The average annual benefits expected to accrue to the Albuquerque Unit are included in the benefits of $5,200,000 which are expected to accrue annually to the entire flood control phase of the comprehensive plan.

Authorized Projects

THE CHAMITA RESERVOIR PROJECT (ABIQUIU AND LOW CHAMITA DAMS) was authorized by the Flood Control Act of 1948 as a unit in the flood control phase of the comprehensive plan for the Rio Grande basin in New Mexico. The authorized plan originally provided for a high dam on Rio Chama in Rio Arriba County, 5 miles upstream from its confluence with the Rio Grande and about 6 miles northwest of Espanola. However, as a result of additional studies a more economical plan which will effect a savings of $8,800,000 has been substituted for the authorized plan. The adopted plan consists of Low Chamita Dam and Abiquiu Dam. Low Chamita Dam will be located at the site of the authorized high Chamita Dam and Abiquiu Dam, a high structure, will be located near the town of Abiquiu on Rio Chama about 25 miles upstream from the Chamita site. Together these reservoirs will control 3,126 square miles of drainage area and will have a total controlled storage of 700,000 acre-feet, as contemplated in the authorizing legislation. Since the Abiquiu project is the upstream dam, it will be constructed first in order to provide the greatest initial benefit from the substitute plan.

The Abiquiu Dam will control 2,147 square miles of drainage area or about two-thirds of the total project drainage area. It will be an earthfill structure about 1,500 feet long which will rise 325 feet above stream bed. It will be the fourth highest earth dam in the world and the second highest earth dam to be built by the Corps of Engineers. Two outlets, one gated at stream bed level and one ungated at a higher elevation, will be provided in the stucture for regulation of discharges from the reservoir. The initial controlled storage below the ungated outlet will be 562,000 acre-feet; however, upon completion of Low Chamita Dam, which is scheduled for construction after the completion of Abiquiu Dam, the entrance to the ungated outlet works of the Abiquiu Dam will be lowered, thereby reducing the controlled storage from 562,000 acre-feet to 449,000 acre-feet, so that the total controlled storage in the two reservoirs will not exceed 700,000 acre -feet. The uncontrolled storage capacity made available by the modification of the outlet works of Abiquiu Dam, after the construction of Low Chamita Dam, will be utilized for temporary detention of floodwaters which will be automatically released through the uncontrolled outlet. The estimated cost of Abiquiu Dam is $13,290,000.

The Low Chamita Dam, with a capacity of 251,000 acre-feet, also will be an earth-fill structure. It will be about 5,700 feet long and rise 153 feet above stream bed. It will be operated in conjunction with the Abiquiu Dam for flood and sediment control during flood periods. The estimated cost of Low Chamita Dam is $14,700,000.

The total estimated cost of the two dams is $27,990,000. Benefits from the two dams will be realized on Rio Chama and on Rio Grande throughout the Espanola, Middle, and Lower Valleys. By far, the greatest benefit will accrue in the Middle Valley, particularly in the vicinity of Albuquerque, where high value property subject to flood damage is concentrated. Although damage from spills from Elephant Butte Reservoir will be eliminated, only a very small percentage of the total benefits will accrue to the valley downstream from Elephant Butte Dam. The flood control and other benefits which will accrue to the flood control phase of the comprehensive plan, of which Chamita Reservoir Project (Abiquiu and Low Chamita Dams) is an integral part, are estimated at $5,200,000 annually. Construction of the Abiquiu Dam will be initiated during Fiscal Year 1956.

THE BLUEWATER FLOODWAY would be located on Bluewater Creek in Valencia County, about 2 miles north of the town of Bluewater. This authorized improvement is an element of the comprehensive plan of development for the Rio Grande and tributaries in New Mexico.

Floods on Bluewater Creek inundate large areas of valuable agricultural land in the Bluewater-Toltec Irrigation District, causing considerable damage to rich farmland used for commercial truck farming. During major floods many acres of land have been totally destroyed by bank cuttings.

Flood protection would be provided by the construction of a small earth-fill dam about 8 feet high, which would divert flood flows through an excavated channel about 8,300 feet long, and discharge them into adjacent lava beds north of the irrigation district. A concrete box culvert would be provided for passing flows under U. S. Highway 66 and the Atchison, Topeka and Santa Fe Railway.

The estimated cost of the project is $323,300, of which about $75,000 would be the amount required from local interests toward construction of the concrete culvert under the highway and railroad, and for rights-of-way and relocation of public utilities. The average annual benefits that would be derived from the prevention of flood damages by the construction of the project are estimated to be about $38,100.

THE ALBUQUERQUE DIVERSION CHANNELS PROJECT was authorized by the 1954 Flood Control Act to alleviate the flood condition at Albuquerque, Severe flooding has been experienced frequently in urban and suburban Albuquerque as a result of flash floods in the numerous intermittent streams and arroyos which originate near or on the steep slopes of the Sandia Mountains east of the city and flow westward across the highly developed residential and business districts to the Rio Grande. The problem is becoming more acute because of rapid expansion of the city and the extension of subdivisions into the tributary flood plains.

The plan of improvement would provide for the construction of two large diversion or collection channels and appurtenant works to be located on high ground east of and, in general, parallel to Rio Grande. One channel would run north, with a capacity increasing from 5,300 cubic feet per second to 42,000 cubic feet per second, intercept flows from the numerous arroyos which enter Rio Grande north of U. S. Highway 66, and divert them into Rio Grande through a drop structure to be located near Alameda. The other channel would intercept flows from the arroyos which enter Rio Grande south of U. S. Highway 66 and divert them into Rio Grande through a drop stucture and outfall channel to be located a short distance from Tijeras Canyon. The flows from Tijeras Canyon would be diverted into the latter outfall by means of a short diversion dike and channel. The capacity of the south diversion channel would increase from 1,500 cubic feet per second at its upper end to 5,400 cubic feet per second at the junction with the diversion dike from Tijeras Canyon. At that point the capacity would be increased to 20,000 cubic feet per second to accommodate the combined flows of the south diversion channel and Tijeras Canyon Arroyo.

The diversion channels would be trapezoidal and would be excavated for about two-thirds of the total depth. The upper one-third would be formed by levees. The channels would be paved where necessary with concrete and riprap. Both of these channels would provide protection against floods

Considerably greater than have been known to occur. The dike intercepting Tijeras Canyon is designed to control floods equal to the largest of record and to afford partial protection against greater floods.

Local Interests have organized the Sandia Conservancy District to cooperate with the Federal Government in the construction of the project, and to construct complementary works and supervise flood plain zoning as required. The total project cost is estimated to be $10,287,000. The Federal share would be $7,500,000, and that of local interests, $2,787,000, including an initial cash contribution of $170,000. Average annual benefits have been estimated at about $1,199,400. Preconstruction planning is now under way.

Survey Under Way

RIO GRANDE AND TRIBUTARIES, SOCORRO AND VICINITY. A review of the report on Rio Grande and tributaries, House Document No. 243, 81st Congress, 1st Session, with respect to flood protection at Socorro and vicinity was directed by the Senate Public Works Committee by resolution adopted September 8, 1950. The town of Socorro is located on the west bank of the Rio Grande directly in the path of several tributary arroyos that rise in the Socorro Mountains a few miles west of the town. Investigations and studies of damages caused by flash floods on these arroyos have been initiated. It is estimated that the report will be completed during Fiscal Year 1957.

Survey Authorized

RIO GRANDE AND TRIBUTARIES, LAS CRUCES AND VICINITY. A further review of House Document No. 243 was directed by the Senate Public Works Committee by resolution adopted July 20, 1954, to determine if flood protection could be provided at Las Cruces and vicinity which is also subject to severe flooding from arroyos and streams tributary to Rio Grande. Recent requests of local interests at nearby State College to investigate a similar flood problem have resulted in combing the studies of flood problems in this locality with those for Las Cruces into a single report. Initiation of this investigation is contingent upon appropriation of funds.

Flood Control Operation of Projects Constructed by Other Agencies

THE PLATORO RESERVOIR PROJECT is located about 80 miles above the mouth of the Conejos River, a tributary which enters the Rio Grande just above the New Mexico-Colorado State line. Regulation of floods on the Conejos River directly affects Rio Grande flows in New Mexico.

The Platoro Dam was constructed by the Bureau of Reclamation and put into operation in September 1951. The project is a dual-purpose dam and reservoir for flood control and irrigation, and is designed to control the runoff from about 40 square miles of mountainous drainage area. The reservoir has a total storage capacity of 60,000 acre-feet, of which 54,000 acre-feet is allocated for joint irrigation and flood control use and the remaining 6,000 acre-feet is allocated for inviolate flood control use. The joint storage is operated for flood control in accordance with forecasts of runoff computed from precipitation indices, snow surveys, and other water-shed conditions. The inviolate flood control storage of 6,000 acre-feet is the capacity required to control the summer and fall floods.

The project is operated and maintained by the Bureau of Reclamation; however, operation regulations of the reservoir for flood control are prescribed by the Secretary of the Army in accordance with Section 7 of the Flood Control Act of 1944.

Although Platoro Reservoir has been operated for flood control only twice, substantial benefits have accrued to the project. The peak discharge during the May 1952 flood was reduced by about 1,200 cubic feet per second at the Mogote gage on Conejos River in Colorado, and by about 500 cubic feet per second on Rio Grande at Otowi, New Mexico. It is estimated that this operation reduced damages by about $90,000 in Colorado and $50,000 in New Mexico.

PECOS RIVER WHATERSHED

The Pecos River watershed in New Mexico drains an area of about 25,470 square miles. The principal tributaries to the Pecos River in New Mexico are Salt Creek, Rio Hondo, Rio Feliz, and Rio Penasco. The larger towns in the watershed, Las Vegas, Santa Rosa, Fort Sumner, Roswell, Artesia, and

Carlsbad, are located in the valleys of either the main stem or its tributaries.

Several municipalities, together with about 25,500 acres of irrigated cropland, and many diversion structures are located in the flood plains of Pecos River and tributaries. It is estimated that a repetition of floods which have occurred during and since 1904 would cause damages of about $41,000,000 under present conditions of development on the Pecos River and major tributaries. There are no existing flood control projects constructed by the Corps of Engineers in the watershed.

There are many diversion and storage dams on Pecos River and tributaries constructed by others for the purpose of regulating and utilizing stream flow to provide water for irrigation. However, the supply, generally insufficient except in time of floods, is a limiting factor to the development of the watershed. The use of water, and water rights have been the subject of litigation for years, and until recently, basin-wide development of the resource was hampered by the lack of agreement between the States on the division and use of waters of the Pecos River and tributaries.

In 1949, a compact which provides for apportionment of Pecos River waters and contains provisions to permit and facilitate full development of the river became effective. Since that time the Corps of Engineers in cooperation with the State and other Federal agencies has carried on an extensive investigation of problems and needs in the watershed. At the present time two interim survey reports have been completed in accordance with directives contained in the Flood Control Acts of 1938, 1939, and 1950, and submitted to Congress for consideration. As an initial step in a plan of water resources development for the Pecos River watershed, Congress by the 1954 Flood Control Act authorized the construction of three flood control improvements in New Mexico: Los Esteros and Alamogordo Reservoirs project on the main stem, Two Rivers Reservoir Project on Rio Hondo, and the Artesia Diversion Channel. These projects are briefly described in the following paragraphs.

Authorized Projects

THE LOS ESTEROS AND ALAMOGORDO RESERVOIR PROJECT was authorized by the Flood Control Act of 1954 for flood protection on the Pecos River in New Mexico and Texas. However, the act provided that no appropriations shall be made for constuction until satisfactory arrangements have been made by the State of New Mexico for the transfer of irrigation storage from the existing Alamogordo Reservoir to the authorized Los Esteros Reservoir.

The project provides for Los Esteros Dam to be built on the Pecos River about 7 miles above Santa Rosa, and for the modification of the existing Alamogordo Reservoir. Los Esteros Reservoir would be used for both irrigation and flood control while Alamogordo Reservoir would be used for flood control.

The main section of the Los Esteros Dam would be of earth fill, about 1,865 feet long and would rise 218 feet above stream bed. In addition to the main dam, a dike would be built across a low saddle about 4,000 feet east of the east or left abutment. This saddle dike would be 1,420 feet long with a maximum height of 12 feet.

The capacity of Los Esteros Reservoir would amount to 587,000 acre-feet with 60,000 acre-feet available for storage of sediment, 250,000 for irrigation, and 277,000 for flood control. It would control 2,479 square miles of drainage area. The outlet through the main dam would be controlled by two 54-inch diameter valves, permitting a release of 2,290 cubic feet per second when the pool reaches spillway crest level. An open-cut, uncontrolled spillway would be constructed between the main dam and the saddle dike, about 1,000 feet from the left abutment.

The Los Esteros-Alamogordo project would afford protection against floods larger than any of record. In addition, more irrigation water would be provided because spills would be less frequent and the life of the conservation storage pool would be greatly extended. It is estimated that the existing Alamogordo Reservoir will lose its effectiveness for conservation in about 40 years because of sediment depletion; whereas, the irrigation pool in the Los Esteros Reservoir would not even be encroached upon at the end of 40 years of operation.

The benefits expected to accrue amount to about $428,000 annually. The total estimated cost of the project is $7,060,000. Preconstruction planning has been initiated.

<u>THE TWO RIVERS RESERVOIR PROJECT</u> is designed to prevent damages at Roswell and vicinity by controlling floods on Rio

Hondo. The project was authorized for construction by the Flood Control Act of 1954. It consists of two dams, Diamond A Dam on Rio Hondo and Rocky Dam on Rocky Arroyo. The two dams would create a common reservoir to be known as the Two Rivers Reservoir.

Diamond A Dam would be an earth-fill structure about 4,994 feet long and 106 feet high, with a gated 6-foot diameter outlet. Rocky Dam also would be of earth fill, about 2,924 feet long and 120 feet high, with an uncontrolled 3-foot diameter outlet. In addition, there would be four uncontrolled spillways, with a total length of about 2,375 feet, in natural saddles on the rim of the reservoir.

The project would control 1,084 square miles of drainage area, 1,009 square miles of which are in the Rio Hondo watershed, and 75 in the Rocky Arroyo watershed. The common reservoir formed by the two dams would have a capacity of 207,500 acre-feet at spillway crest elevation, which is a little more than twice the amount needed to store the maximum flood of record.

The Two Rivers Reservoir project would reduce to non-damaging proportions such large floods as occurred on Rio Hondo in 1937, 1941, and in October 1954. In addition to affording protection to the city of Roswell and to Walker Air Force Base, the project would also reduce damages on the Pecos River. The project would cost $6,171,200, of which $121,200 would be non-Federal. The average annual benefits are estimated at about $307,290. Preconstruction planning has been initiated.

THE ARTESIA DIVERSION CHANNEL was authorized by the 1954 Flood Control Act. It consists of a diversion channel on Eagle Creek upstream from Artesia, to convey flood flows from Eagle Creek into Tumbleweed Draw, a tributary which enters the Pecos River about 4 miles downstream from Artesia.

An earth levee about 5.7 miles long with a maximum height of about 10 feet would be the principal feature of the diversion works. The borrow area would be graded to provide a channel for low flows, and the capacity of Tumbleweed Draw would be increased to accommodate diverted flood flows.

The project would protect the city of Artesia and irrigated land in the vicinity from floods on Eagle Creek up to 38,000 cubic feet per second, which is about 35 percent greater than the estimated discharge of the flood of July 1911, the maximum known to have occurred. The average annual benefit expected to accrue is $81,800. The estimated cost of the project is $760,000, of which $170,000 would be non-Federal. Preconstruction planning has been initiated.

Survey Under Way

PECOS RIVER AND TRIBUTARIES, CARLSBAD AND VICINITY. A final report, as authorized by the 1938 Flood Control Act, on the flood control problems in the Pecos River watershed remains to be completed. The major consideration will be an improvement for the protection of Carlsbad, which has experienced severe damage from floods on Pecos River, and on Dark Canyon, a tributary to Pecos River, also Hackberry Draw, a tributary to Dark Canyon. Completion of this investigation is scheduled during Fiscal Year 1956.

Survey Authorized

RIO FELIX AND RIO HONDO AND TRIBUTARIES. As a result of the disastrous floods which occurred in the Pecos River basin in 1954, a review of reports previously submitted on the Pecos River and tributaries was authorized by Congress. The purpose of this review is to determine the feasibility of flood control improvements on Rio Felix and tributaries, and additional improvements on Rio Hondo and tributaries. A preliminary examination has been completed and additional studies will be initiated as soon as funds are made available.

EMERGENCY FLOOD CONTROL WORK

During flood emergencies the Corps of Engineers assists local interests in flood fighting and rescue work to protect life and property. Upon specific request of local interests, the Corps of Engineers repairs damaged flood control works, under various statutory authorities, when such work is determined to be sound from an engineering and economic standpoint and funds are available.

The major portion of emergency work performed by the Corps of Engineers in the Rio Grande basin has been on the main stem, particularly in the Middle Valley. About 190 miles of levees were constructed by the Middle Rio Grande conservancy District during the period 1930 to 1935. Floods occurring in 1937, 1941, 1942, 1948, 1949, and 1952 damaged these levees at numerous points and an extensive program of repair and rehabilitation by the Corps of Engineers has been necessary to prevent complete failure. When Rio Grande flows begin to endanger the levees, vulnerable reaches are kept under continuous observation in order that preventive measures may be initiated at the earliest possible moment. In addition to the duties of observation, patrols participate in effecting emergency repairs, since a general failure of these levees would cause damage to property valued at about $460,000,000.

At the request of local interests about $1,374,000 has been expended in the Middle Valley since 1942 by the Corps of Engineers in performing emergency work, including levee raising, installation of log and brush protective mats, timber pile dikes, rock revetments, flexible-type steel jetties, reconstruction and repair of levees, construction of diversion dikes, and channel straightening. In addition, the Corps of Engineers prepared plans and specifications during 1949 and 1950 for emergency repairs constructed by the State of New Mexico.

COLORADO RIVER BASIN

An area of approximately 20,000 square miles in New Mexico, or that part of the State lying west of the Continental Divide, is drained by three tributaries of the Colorado River; namely: Gila, LIttle Colorado and San Juan Rivers.

The Gila River drains an area of about 5,600 square miles in the southwestern part of the State. The area is extremely rugged and much of it is set aside as a national forest. The more important industries are mining and farming. Scattered tracts of irrigated land, totalling about 11,000 acres, are located along the Gila River and its tributary, San Francisco River. The principal towns are Lordsburg and Mogollon.

The Little Colorado River drains about 4,700 square miles in the west central part of the State. Livestock raising, mining, and lumbering are the most important industries. Rainfall is insufficient for crop production and because of the short water supply and topographic limitations, only about 8,800 acres are under irrigation at the present time. The principal town is Gallup, which is on a tributary, the Puerco River.

The San Juan River, the second largest tributary of the Colorado River, drains an area of about 9,700 square miles in the northwestern part of the State. The principal industries in the area are farming, mining, oil, gas and helium production, and refining. About 38,000 acres of land are presently irrigated in the watershed in New Mexico. The principal towns are Farmington, Aztec, Bloomfield, and Shiprock. Parts of the urban areas of Shiprock and Blanco and about 27,000 acres of land are in the flood plain.

There are no existing Corps of Engineers projects in the Colorado River basin in New Mexico and none is under construction. The Bureau of Indian Affairs, in a feasibility report dated January 1955, recommended the Navajo Project. This project, principally for irrigation, includes the Navajo Dam on the San Juan River in New Mexico. This project is proposed as a participating project of the recently authorized Colorado River Storage Project. The Navajo Reservoir would have an initial storage capacity of 1,450,000 acre-feet and, if operated for flood control in accordance with recommendations of the Corps of Engineers, would control the maximum flood of record at the dam site, and reduce flood damages on the San Juan River in New Mexico by an estimated $39,000 annually.

There has been no emergency flood control work performed by the Corps of Engineers in the Colorado River basin in New Mexico.

<u>Preliminary Examinations and Surveys Authorized</u>

Pertinent information about presently authorized reports on preliminary examinations and surveys for the Colorado River basin is given in the following tabluation:

Area under investigation	Type of report	Completion date by District Engineer
Little Colorado River, Arizona and New Mex. in vicinity of Gallup, New Mexico	Survey report on flood control	Dependent upon future appropriation of funds
Colorado River & Tributaries above Lee Ferry, Arizona	Revised preliminary examination report	Dependent upon future appropriaion of funds
Animas River, Colorado and New Mexico	Interim survey report on flood control	Dependent upon future appropriation of funds
Gila River and tributaries, Arizona and New Mexico	Comprehensive survey report on flood control	Dependent upon future appropriation of funds

ARKANSAS RIVER BASIN

In northeastern New Mexico, an area of approximately 16,910 square miles drains to the Mississippi River as a part of the Arkansas River system. The Canadian River, the North Canadian River, and the Cimarron River are the principal streams in the area; the latter two are locally known as Corrumpa Creek and the Dry Cimarron River, respectively. Each of these streams is locally important and each increases in size and importance as it flows eastward.

The Cimarron and North Canadian Rivers rise in foothills areas. In New Mexico they are not dependable sources of water; development along them is comparatively minor and improved areas are widely scattered. The principal towns are Clayton, Folsom, and Des Moines. Flash floods on these streams are problems which are now under consideration.

The Candian River rises in the lofty Sangre de Cristo Range of the Rocky Mountains near Raton Pass at the northern boundary of New Mexico. From its source at about 8,000 feet elevation, it flows southward through an ever-widening valley for about 64 miles where it enters a deep, narrow canyon. Except for a short reach where the canyon floor is relatively broad, the river continues southward confined between canyon walls, for nearly 100 miles, to its confluence with the Conchas River. From this point, the river flows eastward in a deep canyon for a little more than 100 miles to the eastern boundary of the State. Major tributaries which enter the Canadian River in New Mexico, in downstream order, are Cimarron (not the Dry Cimarron mentioned above), Mora, and Conchas Rivers, and Ute Creek. The principal towns are Raton, Springer, Tucumcari, and Cimarron.

The only completed Corps of Engineers project in the Arkansas River basin in New Mexico is Conchas Dam and Reservoir, described hereinafter. There are no projects or emergency flood control work under construction or authorized for construction at this time.

Project Completed

CONCHAS DAM AND RESERVOIR is located in San Miguel County on the Canadian River just below its confluence with the Conchas River. The drainage area above the dam is about 7,409 square miles.

Construction of Conchas Dam was approved by the President of the United States as a part of the Works Relief Program under the Emergency Relief Appropriation Act of 1935; subsequently, the project was authorized by the Congress in 1936. Construction of the dam was assigned to the Corps of Engineers, and under the provisions of the Flood Control Act of June 22, 1936, operation and maintenance of the dam and reservoir were also delegated to the Corps of Engineers.

Conchas Reservoir has a total storage capacity of 566,000 acre-feet for flood control and irrigation. Approximately 370,000 acre-feet are available for irrigation and sediment storage up to the crest of the uncontrolled spillway notch provided for flood control regulation. At this elevation, a 9,600 acre lake extends up the Canadian River valley for a distance of 14 miles and up the Conchas River valley 11 miles. About 279,000 acre-feet of storage is provided for irrigation uses and the remaining 91,000 acre-feet below the irrigation outlet is for deposition of sediment. The reservoir has a flood control storage of 196,000 acre-feet between the crests of the flood regulation notch and the uncontrolled emergency spillway. The reservoir is the prime source of water supply for the Arch Hurley Conservancy District in the vicinity of Tucumcari, New Mexico.

Within this District, where maximum productivity is just now being attained, there are about 42,000 acres of irrigable land.

Both the Corps of Engineers and the State of New Mexico have participated in the development of recreational facilities in the vicinity of Conchas Lake. The Federal Government conveyed to the State by easement deed, a tract on the south shore containing 1,487 acres. On this tract the State has remodeled and enlarged an existing lodge and has provided such other accommodations as cabin sites, a boat repair building, a minnow stand, comfort stations, fireplaces, tables, floating docks, and living quarters for the operating personnel. On the north shore the State has provided a minnow stand, a general store, a floating dock, fireplaces, and tables. In addition, the Corps of Engineers has provided a water supply system consisting of a treatment plant, an elevated storage tank and distribution facilities, a system of roads, floating docks, tables, fireplaces, and comfort stations. All recreational facilities are supervised and maintained by the State. The store and lodge are operated on a concessionaire basis.

Since Conchas Dam became operative in 1939, three floods of consequence have occurred on the Canadian River in New Mexico; in May and September, 1941, and September, 1942. During these floods the operation of Conchas Dam resulted in reductions in stages at Logan, New Mexico, about 45 miles downstream from the dam, ranging from 3.0 to 7.2 feet.

Surveys Under Way

ARKANSAS, WHITE AND RED RIVER BASINS REPORT. Studies of water and land resources and their potential development for the portions of the Arkansas and Red River watersheds in New Mexico have been completed in connection with a comprehensive investigation of the Arkansas, White and Red River Basins, Arkansas, Louisiana, Oklahoma, Texas, New Mexico, Colorado, Kansas, and Missouri. This investigation was authorized by the Flood Control Act of 1950.

The President of the United States requested that the interested Federal agencies organize an inter-agency committee to conduct the investigation. The Arkansas-White-Red Basins Inter-Agency Committee was organized for this purpose in July 1950. As presently constituted, the Committee includes one member each from the Department of the Army, Department of the Interior, Department of Agriculture, Department of Commerce, Department of Labor, Department of Health, Education and Welfare, and the Federal Power Commission, and a representative of the Governor of each of the eight states named above. The Division Engineer, Southwestern Division, who represents the Department of the Army, is chairman ex officio of the Committee.

Regional and basin-wide public hearings have been conducted by the Committee to determine the desires of local interests. The water and land resources, needs, and problems of the area have been carefully studied and inventoried in considerable detail by agencies and interests concerned. Studies of possible solutions and formulation of an integrated comprehensive plan of development for the three-basin area are now completed as a result of this coordinated action.

The report presents a long-range plan for coordinated development and conservation of the water and related land resources of the AWR basin. It includes projects and programs which might be developed by the Federal Government, State and local governments, or private interests. The report will not serve as an authorizing document for any Federal project or program, but instead will provide the Congress with a framework within which it may consider future separate recommendations for individual project or program authorizations. The Corps of Engineers plans to prepare supplemental reports to substantiate recommendations for future authorizatinn of specific projects in the three-basin area.

RED RIVER BASIN

A very small portion of the State, comprising 891 square miles in northern Curry County and western Quay County, is drained by the Red River which empties into the Mississippi River near Marksville, Louisiana. The New Mexico part of the Red River basin is semi-arid, sparsely settled, and used primarily for grazing of livestock.

The Corps of Engineers has no existing projects on Red River in New Mexico, and none is under construction or authorized for construction, including emergency flood control work.

Surveys Under Way

Studies in connection with the Arkansas, White and Red River Basins Report, described in the Arkansas River Basin section of this paper, include studies of the Red River basin in New Mexico.

BRAZOS AND COLORADO (TEXAS) RIVER BASIN

A small portion of the east-central part of the State, consisting of about 3,830 square miles, lies in the basins of the Brazos and Colorado Rivers of Texas. Of this, 2,670 square miles is in the Brazos Basin and 1,160 is in the Colorado Basin. Both of these streams head in New Mexico and flow in a southeasterly direction across Texas to the Gulf of Mexico.

The area is characterized by low relief and poorly-defined drainage patterns, and because of this only a small part of the precipitation over the area ever reaches the streams as surface runoff. Urban communities in the basins include Clovis, Portales, Lovington, and Hobbs, and except for these the area is sparsely settled. Livestock raising, limited irrigated farming, and petroleum production and refining are the principal industries.

A survey report recently submitted to Congress served as a basis for authorization for a number of projects on the Brazos River; however, all of these would be in Texas as no water resource development was recommended in New Mexico. The Corps of Engineers has performed no emergency flood control work in either watershed in New Mexico.

Survey Under Way

A survey report has been authorized on the Colorado (Texas) River basin, including that part of the basin which is in New Mexico. Completion of this report is dependent upon future appropriations of funds by Congress.

SUMMARY

The following tabulation gives the estimated total cost of the major elements of the water resources development program of the Corps of Engineers in New Mexico which has been authorized or constructed to date, and the estimated annual charges and benefits assignable to those projects.

COSTS AND BENEFITS

1955 Price Levels

Project	Total First Cost	Amounts made Available To Date	Annual Charges	Annual Benefits
Conchas Dam	$15,488,909	$15,488,909	Not estimated	
Jemez Dam	4,055,627	4,055,627)		
Abiquiu Dam	13,290,000	879,000)	$1,314,600	$1,716,900
Low Chamita Dam	14,700,000	266,000)		
Rio Grande Floodway (Albuquerque Unit)	3,529,000	3,529,000	174,100	304,000
Albuquerque Diversion Channels	10,287,000	60,000	433,100	1,199,400
Bluewater Floodway	323,300	0	13,900	38,100
Los Esteros-Alamogordo Reservoirs	7,060,000	50,000	280,000	428,000
Two Rivers Reservoir	6,171,200	50,000	260,415	307,290
Artesia Diversion Channel	760,000	25,000	28,600	81,800
TOTALS	*$75,665,036	$24,403,536	**$2,504,715	**$4,075,490

* Includes $3,288,200 non-Federal Costs
** Exclusive of Conchas Dam

HYDROLOGIC ASPECTS OF PLANNING FLOOD CONTROL WORKS IN NEW MEXICO

By

John T. Martin*

1. General. -First I would like to give the items which the Corps of Engineers consider as hydrology, namely:

a. Watershed	f. Humidity
b. Weather	g. Evaporation
c. Precipitation	h. Wind
d. Snowfall	i. Stream flow characteristics
e. Temperature	j. Runoff
k. Sediment	

In the planning of flood control projects these items have varying signifigance depending upon the nature of the project. Due to the limited time, I will confine my talk to certain of these items which are more directly related to the economic feasibility of a flood control project.

2. Stream Flow Characteristics Including Channel Capacities. We study the stream pattern of the watershed and the nature of the stream flow; that is, the relationship of peak flow to volume. In other words, are the floods of a flashy type with relatively high peaks and small volume, or of a type which may be produced by snow melt runoff of comparatively low peaks and large volume? Also pertinent to the economic analysis are the minimum channel capacities in a selected damage reach or at a location of concentrated flood damage.

3. Runoff.- In many instances in New Mexico, there are no stream flow records or too short a period of record upon which to base the economic studies. We determine which is better related to the flood damages, the flood volume or the peak discharge. In many cases in New Mexico, due to the lack of edfined channels and the influence of man made barriers, the flood damages are found to be better related to the flood volume. In order to evaluate flood control projects as to economic feasibility, the Corps of Engineers estimates the probable recurrence of floods. When sufficient stream flow records are not available a hypothetical flood history is estimated, generally from rainfall records. In doing this, it is

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recognized that such a flood history may have had floods occuring when actually there were no floods and may not have floods indicated when actually there were floods and the accuracy of this procedure is dependent on how well this condition averages over a long period of time.

4. Infiltration.-To provide tools for estimating this hypothetical flood history and for the project design floods, it is necessary to make a study of the watershed characteristics to determine average and minimum infiltration or rainfall loss rates. The average loss rates are used in computing a flood history, while the minimum loss rates are used to compute the design floods so that these flood estimates are conservatively high. The infiltration rates are generally based on a study of precipitation and stream flow records on the other watersheds with similar runoff characteristics.

5. Unit Hydrograph.- The unit hydrograph method is used by the Corps of Engineers primarily for the determination of flood peak discharge. Mr. F. F. Snyder's method is generally used and, by the way he is an employee in the office, Chief of Engineers, his method is basically the same as Mr. Sherman's method which you may be familiar with as published in certain texts. As for rainfall loss rates, unit hydrograph coefficients have to be transferred from one watershed to the other by a study to determine similar watershed characteristics.

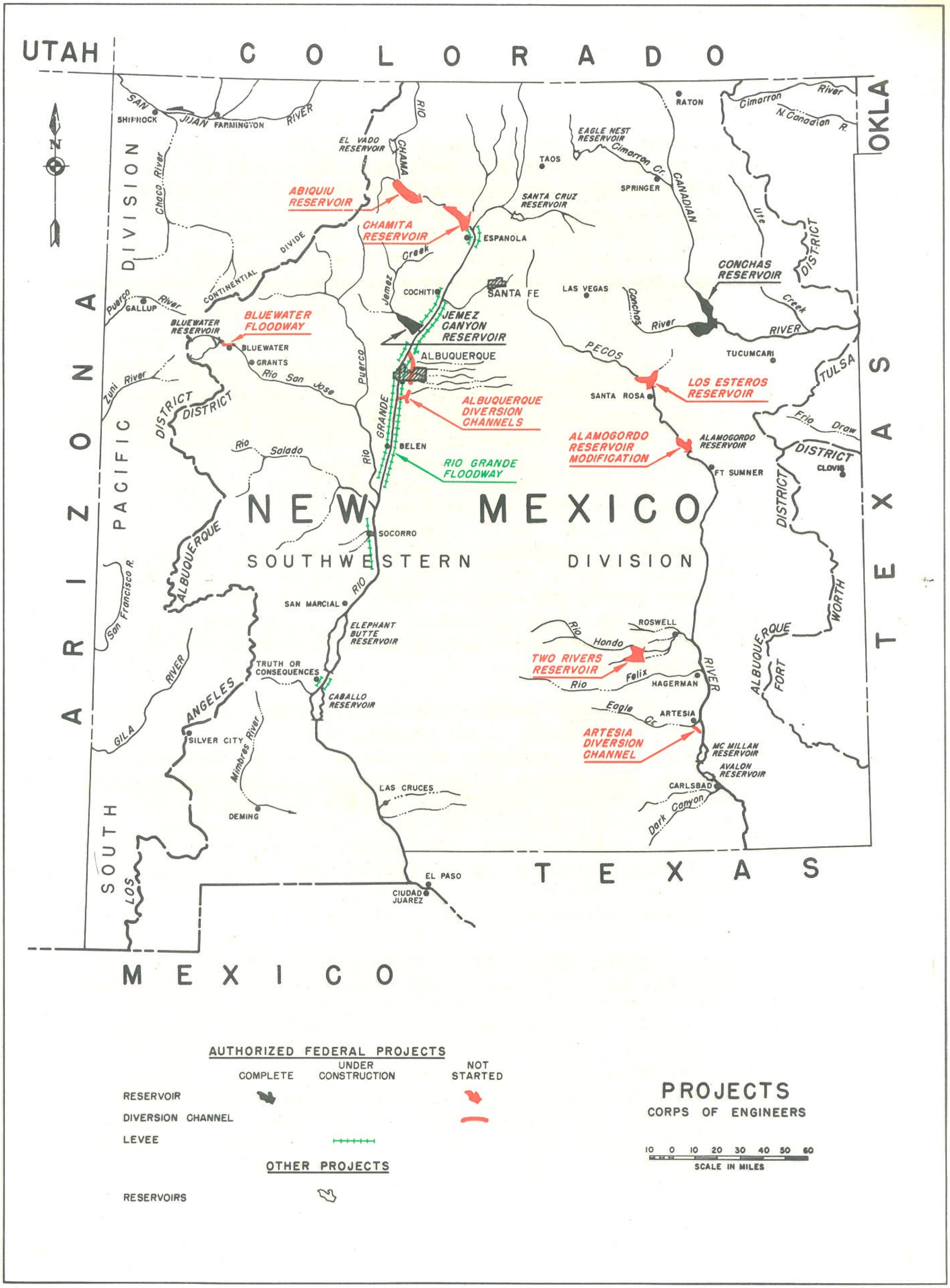
6. Standard Project Flood.- The Corps of Engineers uses what I like to call a yard stick for the design of flood control projects. This yard stick is called the standard project flood or maximum probable flood. In some cases the flood volume is the major consideration, while in others such as leveed floodways or diversion channels the peak discharge is a major consideration. The standard project flood is estimated by a study of the major storms of record in the general vicinity which could have just as well occurred over the watershed under study. Then the storm is selected for transposition which would give either the maximum peak or the maximum volume from the watershed as desired. After the storm is selected it is moved over the watershed under study and rotated to fit the new topography and the storm precipitation is adjusted, up or down, for the difference in inflow barrier. The basis for the adjustment for this difference in elevation is determined along the path of the moist air inflow for the storm. The percent adjustment per increment of inflow barrier change has been provided by the U. S. Weather Bureau. The minimum in-

filtration rates are applied to the standard project storm rainfall and the rainfall excess is applied to the unit hydrographs for the watershed to determine the standard project flood hydrograph. The flood control project is designed for any degree of protection up to the standard project flood, depending on economic justification. In general a concentrated locality of flood damage such as an urban area where loss of life may be involved it is found economically feasible to provide protection against a flood equal to the standard project flood.

7. Spillway Design Flood.- The Corps of Engineers for many years has cooperated with the U. S. Weather Bureau in a storm study program of all the major storms. The Corps prepares the storm studies and submits them to the Weather Bureau for review and comments. On reservoir projects, the Corps of Engineers provides a spillway adequate to pass the flood which would result from the estimated maximum possible precipitation over the watershed. In the planning of such a project, the Corps submits a description of the watershed and the major storms which have occurred in the general vicinity to the U. S. Weather Bureau and requests the maximum possible precipitation to be used. This criteria for the design of the spillway has a considerable effect on the economic feasibility of the reservoir project.

8. Sediment.- Another consideration in reservoir projects in New Mexico which has a considerable affect on the economic feasibility is the provision of sediment reserve storage. In addition to the storage allocations required for flood control and other water uses, a sediment storage allocation equal to the estimated reservoir depletion during the economic life of the project is provided. In connection with leveed floodways and diversion channel projects, aggradation or degradation may materially increase the maintenance costs of the project which in turn affect the economic feasibility.

9. Coordination with Other Projects.- In the planning of reservoir flood control projects in New Mexico it is considered very essential to make the necessary operation studies to determine the effect of the project on irrigation and other water supplies. It is also necessary to coordinate the flood control regulation with the regulations provided by other projects in the same watersheds. In the planning of levees, floodways, and diversion projects consideration is given to the restriction to the flood plain and to the probable increase of flood depths on other land. In the case of diversion projects, sometimes it is necessary to pass certain flows on down the natural water coarse and just divert the flood flow. Further, such projects may cause damaging aggradation or degradation at another project or location.


UTAH
COLORADO
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ARIZONA
TEXAS
TEXAS
MEXICO
NEW MEXICO
SOUTHWESTERN DIVISION
SOUTH PACIFIC DIVISION
ALBUQUERQUE DISTRICT
FORT WORTH DISTRICT
TULSA DISTRICT
LOS ANGELES DISTRICT
CONTINENTAL DIVIDE
SHIPROCK
FARMINGTON
SAN JUAN RIVER
EL VADO RESERVOIR
RIO CHAMA
ABIQUIU RESERVOIR
CHAMITA RESERVOIR
ESPANOLA
TAOS
EAGLE NEST RESERVOIR
Cimarron Cr.
RATON
Cimarron River
N. Canadian R.
SPRINGER
SANTA CRUZ RESERVOIR
CANADIAN
Ute Creek
CONCHAS RESERVOIR
Conchas River
RIVER
Creek
SANTA FE
LAS VEGAS
COCHITI
Jemez Creek
JEMEZ CANYON RESERVOIR
ALBUQUERQUE
BLUEWATER FLOODWAY
BLUEWATER RESERVOIR
BLUEWATER
GRANTS
Rio San Jose
Puerco River
GALLUP
Chaco River
Zuni River
Puerco
PECOS
TUCUMCARI
LOS ESTEROS RESERVOIR
SANTA ROSA
ALBUQUERQUE DIVERSION CHANNELS
ALAMOGORDO RESERVOIR MODIFICATION
ALAMOGORDO RESERVOIR
FT SUMNER
Frio Draw
CLOVIS
BELEN
RIO GRANDE FLOODWAY
Rio Salado
Rio Grande
SOCORRO
SAN MARCIAL
ELEPHANT BUTTE RESERVOIR
San Francisco R.
GILA RIVER
ROSWELL
Rio Hondo
TWO RIVERS RESERVOIR
Rio Felix
HAGERMAN
RIVER
TRUTH OR CONSEQUENCES
CABALLO RESERVOIR
Eagle Cr.
ARTESIA
ARTESIA DIVERSION CHANNEL
MC MILLAN RESERVOIR
AVALON RESERVOIR
SILVER CITY
Mimbres River
CARLSBAD
Dark Canyon
LAS CRUCES
DEMING
EL PASO
CIUDAD JUAREZ
AUTHORIZED FEDERAL PROJECTS
COMPLETE
UNDER CONSTRUCTION
NOT STARTED
RESERVOIR
DIVERSION CHANNEL
LEVEE
OTHER PROJECTS
RESERVOIRS
PROJECTS
CORPS OF ENGINEERS
10 0 10 20 30 40 50 60
SCALE IN MILES

Problems of the Elephant Butte Irrigation District

By

John L. Gregg*

The Elephant Butte Irrigation District is located in the New Mexico portion of the Rio Grande project (New Mexico-Texas), a Bureau of Reclamation project situated in south central New Mexico and in West Texas. The district contains a gross area of 100,000 acres of which 90,000 acres have a first class water right. An additional 70,000 acres of water right land are located in the Texas portion of the Rio Grande Project, principally below El Paso, Texas. The Elephant Butte Irrigation District is the water users' organization formed for the purpose of cooperating with the United States government in connection with project management. The District has the authority to contract with the government and represents the water users in all matters relating to water supply. This discussion pertains mainly to the Elephant Butte Irrigation District, but certain data appearing below are applicable to the entire Rio Grande Project.

The present problems and difficulties facing the Elepant Butte Irrigation District originate from the current water shortage which is caused primarily by a prolonged drouth in the Upper Rio Grande Basin of Colorado and New Mexico, aggravated by the failure of the Rio Grande Compact to operate effectively and to cause the delivery of that portion of river flow to which the irrigated area below Elephant Butte Reservoir is entitled.

The average annual flow of the Rio Grande past San Marcial, at the head of Elephant Butte Reservoir, for the period 1895 to 1955, inclusive, is about one million acre feet. During the thirteen year period from 1943 to 1955, inclusive, the average annual flow past San Marcial has been only 550,000 acre feet. Eight years of this latter period (1943, 1946, 1947, 1950, 1951, 1953, 1954, 1955) have produced annual flows far below the long time average, ranging from a minimum of 113,000 acre feet in 1951 to a maximum of 434,000 acre feet in 1947; while only three years (1944, 1949, and 1952) equalled the 61 year average. The remaining two years (1945 and 1948) of the thirteen

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year period approached the average. The year 1951 produced the least flow past San Marcial during the period of record, amounting to only 113,000 acre feet. The past three years (1953, 1954 and 1955) have been extremely low, flows ranging from 218,000 acre feet in 1954 to 264,000 acre feet in 1955, as recorded at San Marcial, The year 1956, from all indications, will be no better than 1955. The significance of these figures is that the surface water supply difficulties of the District actually began in 1943, but were masked for several years by reason of the heavy carryover of stored water from 1941 and 1942 when river flow was far above normal; and that the most acute portion of the thirteen year period of low flow began in 1953 and apparently still continues. Spring inflow for 1956 from snowmelt, upon which we depend for the major part of our water supply under normal conditions, has been very disappointing, amounting to only 13,000 acre feet as of this date. Storage today is 181,700 acre feet, or only twenty percent of average storage at this time of the year for the past 21 years.

The impact of drouth conditions, as well as other factors, upon this District is shown by allotments of water available for delivery to the land during the past few years:

1951 - 1.75 acre feet per acre of water right land
1952 - 2.75 " " " " " " " "
1953 - 1.90 " " " " " " " "
1954 - Six inches per acre of water right land
1955 - Five inches " " " " " "
1956 - Four inches " " " " " " to date

Normal use of water per acre ranges from three to three and one half acre feet per acre delivered to the land.

Another factor in the adverse water supply situation facing the Elephant Butte Irrigation District, and which has greatly aggravated the effects of douth, has been the failure of the Rio Grande Compact to operate properly and to protect our water supply to the extent of assuring us that we shall receive our share of whatever flow appears in the Rio Grande. The Rio Grande Compact is an agreement among, Colorado, New Mexico and Texas relative to the division of the flow of the Rio Grande among the three states. It became effective in 1939 after ratification by the three state legislatures, the Congress, and approval by the President. Operation actually began on January 1, 1940. The basis for the division of the water was historical flow of the Rio Grande, and certain tributaries, during certain periods of time that were considered representative of conditions along the river immediately prior to the period of litigation and of negotiation which led to the signing of the compact. The Rio Grande Compact provides that the obligation of Colorado to deliver water to New Mexico shall be determined by the flow of the river at Del Norte, Colorado, above the irrigated area of the San Luis Valley, plus the flow of the Conejos River, a tributary of the Rio Grande in Colorado. Based upon a schedule developed from inflow-outflow data for the representative period referred to above, combined flow at the above points determines Colorado's obligation to deliver water to New Mexico. Similarly, the obligation of New Mexico to deliver water to Elephant Butte for the use of the Rio Grande Project is determined by flow passing the Otowi gauging station, located a short distance below the junction of the Chama and the Rio Grande in New Mexico, which flow is related to an inflow-outflow schedule based upon data for the representative period referred to above. The area below Elephant Butte Reservoir, consisting of Rio Grande Project lands, was placed under the jurisdiction of the State of Texas for compact administration purposes. This area agreed to limit its annual releases from storage to an average of 790,000 acre feet, including water due Mexico under the provisions of the treaty of 1906.

The manner in which the Rio Grande Compact has operated is best shown by cumulative figures compiled as of December 31, 1955. On that date, New Mexico had failed to make deliveries of water to Elephant Butte Reservoir to the extent of 477,000 acre feet, and had accumulated a debit under the Compact to that extent over a period of years. As of the same date, Colorado had failed to make deliveries to New Mexico to the extent of 287,000 acre feet and had an accumulated debit of that amount. The Rio Grande Project had an accumulated under-release (below an average of 790,000 acre feet per year) of 1,742,000 acre feet which reflects both the effects of the drouth and the failure of upstream areas to make required deliveries, as well as the careful use of water made on the Rio Grande Project. In 1951, after a period of unsatisfactory experience under the Rio Grande Compact, the State of Texas, acting for the Rio Grande Project area below Elephant Butte, filed suit in the Supreme Court of the United States against the State of New Mexico for the purpose of compelling New Mexico to comply with the Compact. Various violations were cited such as illegal storage and release of water, and the accumulation of a debit in excess of permissible limits, and, among other things, the Court was asked to appoint a Federal Watermaster to supervise the distribution of water on the Rio Grande in New Mexico in order to assure delivery to the area below Elephant Butte. The State of New Mexico immediately raised the issue of the indispensability of the United States as a party to the suit on the grounds that Pueblo Indians, who are wards of the government, living in the Middle Rio Grande Conservancy District in the vicinity of Albuquerque, would be affected by the Texas demands and, therefore, the United States has an interest in, and should be a party to, the suit. Hearings and oral arguments have been held, and numerous briefs have been written by both sides, but the suit has not yet progressed beyond this point and the Supreme Court is still in the process of deciding whether or not the United States is an indispensable party to the suit. If the decision is in the affirmative, the case will be dismissed because the United States cannot be joined in a suit without its consent. If the decision is in the negative, the case will proceed to trial. At the present time, the Special Master appointed by the Court to hear the case has recommended that the United States be not considered an indispensable party to the suit, but the Court is awaiting comments from the Department of Justice before making its decision.

The Rio Grande Compact is of great importance to the area below Elephant Butte because it is our only guarantee that we shall receive our share of water that is available in the Rio Grande. As additional storage facilities are constructed above us, and as greater demands are made upon the stream in northern New Mexico and southern Colorado, the Compact will become increasingly important as a source of protection for our water supply. We are, in effect, situated in the lower end of a river basin, since practically all water appearing in the Rio Grande in Colorado and New Mexico is fully used in the area extending from the San Luis Valley, in Colorado, to Fort Quitman, located eighty miles southeast of El Paso. No substantial amount of outflow occurs from this area into the Lower Rio Grande Valley of Texas. Because of our location, we are vulnerable to upstream encroachments upon our water supply and some method of protecting ourselves must be made available. The Rio Grande Compact offers that protection if it can be made an effective instrument.

STREAM FLOW STUDIES IN THE MESILLA VALLEY

By

Frank Bromilow*

INTRODUCTION

All of the work described in this paper was done by members of the staff of the Civil Engineering Department of New Mexico College of Agriculture and Mechanic Arts. The work was financed by the Elephant Butte Irrigation District and under the terms of our contract with them, the results obtained are the exclusive property of the District.

A short description of the physical characteristics of the irrigation system of the valley is necessary in order to see the reasons for the projects undertaken and the relation they bear to each other.

DESCRIPTION OF VALLEY

The Mesilla Valley is approximately 50 miles in length from Leasburg Dam at the north to Courchesne Gap at the south. There are about 78,000 acres under irrigation, of which about 69,000 acres are in New Mexico and 9,000 are in Texas. There are three main canals which carry water from the river. These are:

- Leasburg Canal which irrigates about 37% of the valley
- Mesilla East Side Canal which irrigates about 21% of the valley
- Mesilla West Side Canal which irrigates about 42% of the valley.

A small area, known as the Picacho Area, near the northern end of the valley and west of the river, is irrigated by Leasburg water which reaches the area through a metal flume over the river. This area of 4305 acres, or about 5½% of the valley, was used for a number of special studies because of its size and the ease with which the amount of water delivered to it could be measured.

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1952 STUDIES

The first study undertaken began in September of 1952. It consisted of a collection and study of data available from:

United States Bureau of Reclamation
United States Weather Bureau
International Boundary Commission

Such data as flows, diversions, rainfall, deliveries to the land, wastes and evaporation were collected, tabulated and graphed to make them available for easy reference. The period 1936 through 1951 was considered. This report was completed and submitted in January 1954. Present plans call for bringing it up to date through 1955 this year.

1953 STUDIES

The second study was undertaken during the irrigation season of 1953. This study was made on the Picacho Area and was conducted in order to find the distribution of the water over that section of the project.

A continuous water stage recorder was installed at the inlet of the Picacho Flume. Flow measurements were made at the same location from time to time during the summer. From the quantities measured and the water stage recorder values it was possible to develop a relationship between quantity of flow and stages. This relationship was then used to compute the total flows from the charts produced by the recorder. This technique proved to be satisfactory and has been used on all of the work done on this project.

Analysis of the results of the study including estimates of the probable losses by evaporation and transpiration indicated that a considerable portion of the water was not accounted for in our calculations. The conclusion reached was that either a large amount of water was being lost through seepage or that the ditch riders estimates of deliveries to the land were wrong.

1954 STUDIES

In 1954 the study of the Picacho Area was repeated to check the conclusions reached in 1953. Examination of this information confirmed the previous conclusion.

In addition, three other studies were undertaken in 1954. The first was an analysis of that part of the Picacho Area served by Lateral A. A weir was built and a recorder installed near the entrance of the Lateral. This recorder showed a total flow for the season of 480 acre feet. Part of this flow came from the Lateral system, and part from a privately owned pump. From the shape of the lines on the recorder graph, it was possible to separate the pump flow from the river water. Our calculations indicated that 200 acre feet was pump flow and 280 acre feet was river water. The ditch riders' estimate for deliveries of water to Lateral A was 271 acre feet.

The second study of this season was a soil study of the Lateral A area. Holes were drilled or dug adjacent to the Lateral and measurements made to locate the water table. This work was carried on by students in the departments of Agricultural Engineering and Civil Engineering. The conclusions reached from this study were that silt in the ditch bottom provided a good seal and reduced seepage losses. Scour of this silt by high velocity flows would increase losses. It was decided to recommend to the Irrigation District that a study be made of the Picacho Area during 1955 in an attempt to locate areas where high losses occurred regularly.

A small amount of preliminary work was done during this season on ground-water observations. Mr. Fields, of the department of Mechanical Engineering made observations on his well in Mesilla Park and compared the results with the level of water in the park drain near by. No important numerical values were obtained, but as a result of the information gathered it was decided that an investigation of ground-water levels was needed.

1955 STUDIES

The field work during the 1955 irrigation season was divided into three main studies. These were:

Seepage study in Picacho Area.
River flow study
Ground-water investigation

As a result of the conclusions reached in the 1954 soil study, an intensive investigation of the soils in the bottom of the canals in the Picacho Area was made. The entire canal system was examined visually and 32 samples of the canal bottom material were obtained on which permeability tests were run in the laboratory. In addition, a piece of equipment was developed from which measurements of seepage losses in place could be made.

A laboratory experiment was developed in which silt was allowed to deposit itself on a sample of sand and the change in the seepage losses was measured. It was found that as little as 0.2#/sq. ft. of silt settling on a sample cut the seepage by 97%, but the silt film dried, cracked, and was washed away by the next flow.

The conclusions reached in this study were that the first few inches of soil in ditch bottom offer most of the resistance to seepage and are saturated. Soil below this level is not saturated so that the distance to water table has no effect on seepage losses. Another conclusion was that the amount of loss from any section of canal varied greatly depending on conditions of flow and on previous history of flow.

The study of flow in the river was accomplished by means of gauging stations installed as follows:

Leasburg Cable
Mesilla Bridge (Mar 21 - Apr 5)
Highway 28 Bridge
Anthony Bridge
Vinton Bridge (June 10 on.)
Courchesne

Flows obtained in these stations were combined with data available on drain returns, wasteway flows, and arroyo flows to produce calculated values for losses from various reaches of the river. The results obtained in this study were:

1. The river is a perched water table

2. Rainfall during the irrigation season on the Mesilla Valley has a considerable effect on apparent losses from the river

Staten, Glen	Experiment Station
Stephens, W. P.	Agricultural Economics
Stucky, H. R.	Agricultural Economics
Sullivan, Darrell	Horticulture
Tejada, Jacob	Extension Service
Thomas, John W.	Agricultural Economics
Triviz, A. E.	Extension Service
Valentine, K. A.	Animal Husbandry
Vandecaveye, S. C.	Agronomy
Watts, J. G.	Biology
Williams, B. C.	Agronomy
Yager, Thomas U.	Soil Conservation Service

Students

Ales, Don	Agricultural Education
Arizo, Ted	Animal Husbandry
Biad, Victor	Civil Engineering
Binns, Eddie	Civil Engineering
Chavez, A. E.	Animal Husbandry
Davis, William R.	Civil Engineering
DeOliviera, Ralph	Animal Husbandry
Flowers, R. N.	Civil Engineering
Geer, Hunter L.	Agricultural Economics
Gonzales, M. E.	Agricultural Economics
Gross, Louis	Civil Engineering
Hix, Marvin	Agricultural Engineering
Hodge, John	Geology
Hogsett, Ted C.	Civil Engineering
Jenkins, Lloyd	Civil Engineering
Jones, David	Civil Engineering
Livingston, Leon	Civil Engineering
Lujan, Lawrence	Geology
Mayfield, Bob	Agricultural Economics
Miller, Wallace T.	Engineer
Moreno, Louis	Electrical Engineering
Naul, B. D.	Agricultural Economics
O'Brien, Walt	Geology
Parra, James	Civil Engineering
Pilley, Claude	Civil Engineering
Rivera, Luther	Agricultural Engineering
Robinson, Phil	Geology
Sanders, B. K.	Civil Engineering
Saunders, Gary	Geology
Shelley, Thomas R.	Agricultural Engineer
Stallings, Jack	Agricultural Engineer
Vance, Howard	Agricultural Engineer
Vigil, Lawrence D.	Civil Engineering
Wheeler, Wayne	Agronomy
Wicker, Clabe	Civil Engineering
Wilkes, Lambert H.	Agricultural Engineer

Others

Alberson, Ken	Soil Conservation Service, USDA
Duesberg, Peter	El Paso, Texas
Elmendorf, Harold B.	Soil Conservation Service
Fletcher, Joel E.	Soil Scientist, Tucson
Freudenthal, L. E.	Farmer
Gilman, Virgil	Extension Service, USDA
Gregg, John L.	Elephant Butte Irrigation District, Las Cruces
Hall, Dale	State Engineer's Office
Hardaway, George	U. S. Forest Service, Albuquerque, N.M.
Hedges, Frank R.	Soil Conservation Service
Hill, Leon	Bureau of Reclamation
Jordan, D.	State Engineer's Office
Moser, Theodore H.	Bureau of Reclamation
Putman, Lewis T.	State Engineer's Office
Redmond, J. L.	Corps of Engineer's Office, Albuquerque, N.M.
Reynolds, S. E.	State Engineer's Office
Thomas, Merton G.	Agricultural Engineer, Iowa
Worthen, C. H.	Bureau of Reclamation
Young, R. A.	Soil Conservation Service

3. Low flows in the river should be avoided since the per cent of water losses under these conditions is a maximum.

The ground-water study consisted entirely of a review of data available. This data was plotted to give a picture of ground-water conditions in the valley. The general pattern for the ground-water is as follows:

1. The slope of the water table down the valley is 4½ ft. per mile

2. The slope of the water table from the west into the valley is 3½ ft. per mile

3. The slope of the water table from the east into the valley adjacent to the Organ Mountains is 15 ft. per mile

4. There is no data available on the water table on the east side of the valley from Berino south to Courchesne.

A typical example of the weakness of the information presently available on ground-water conditions in the Mesilla Valley is shown by the available data on the underground flow through the Pass at Courchesne. Borings were made by a Mexican commission in 1897 which indicated that the depth to rock was 86 ft. Underground flow measurements were made by Slichter in 1907 which indicate that there is no flow at a depth of 42 ft. below the surface. However, the method used by Slichter is one that is now not acceptable.

CONCLUSION

The study for the current season has had to be reduced to a continuation of the river study. The well-publicized shortage of engineers made it impossible to obtain the manpower for any other work. We hope to be able to conduct a more extensive study of one reach of the river and the relation it bears to the water table next year if we can find the manpower and if funds are then available.