COLORADO STATE PLANNING COMMISSION

AND THE

COLORADO WATER CONSERVATION BOARD

CADDOA RESERVOIR STUDY

SUMMARY OF ASSUMED OPERATION NO. 2

JANUARY 1938

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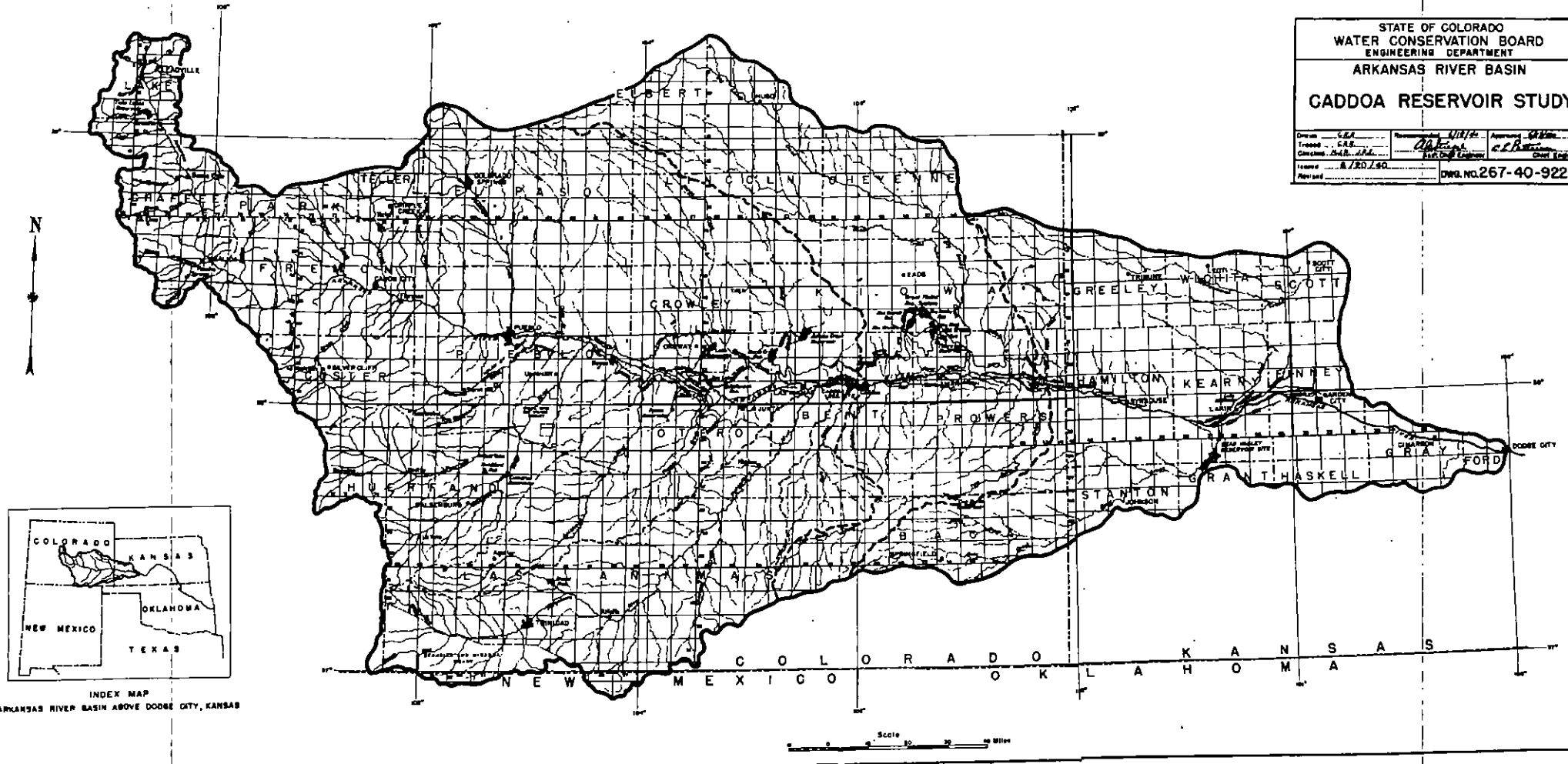

STATE OF COLORADO
WATER CONSERVATION BOARD
ENGINEERING DEPARTMENT

ARKANSAS RIVER BASIN

CADDOA RESERVOIR STUDY

Drawn C.E.A.	Recommended [illegible]	Approved [illegible]
Traced C.E.B.	Asst. Chief Engineer	Chief Engineer
Checked C.A.B. J.H.L.		
Issued 8/20/60		DWG. NO. 267-40-9221
Revised		

INDEX MAP
ARKANSAS RIVER BASIN ABOVE DODGE CITY, KANSAS

1 From U.S. Geological Survey state base maps - 1:500,000

COLORADO STATE PLANNING COMMISSION

and the

COLORADO WATER CONSERVATION BOARD

CADDOA RESERVOIR STUDY

SUMMARY OF ASSUMED OPERATION NO. 2

January, 1938.

Prepared and Published by the Colorado State Planning Commission and the Colorado Water Conservation Board as a report on Project No. 2694, conducted under the auspices of the Works Progress Administration.

(COPY)

JANUARY

TWENTY-SECOND

1938

Mr. Edward D. Foster, Director
Colorado State Planning Commission
130 State Office Building
Denver, Colo.

and

Judge Clifford H. Stone, Counsel
Colorado Water Conservation Board
205 State Capitol Building
Denver, Colorado

Gentlemen:

I am transmitting herewith a summary of the studies which have been completed with respect to the operation of the Caddoa Reservoir. The study covers the period 1914 to 1936, and indicates the benefit that would accrue to the State of Kansas, and the individual canals in Colorado from the Reservoir.

A discussion of the value of the reservoir from an economic standpoint to Colorado lands and to the Santa Fe Railroad in Colorado is included.

There are several detailed tables and graphs which are not submitted with the report. These are on file and available for inspection.

Sincerely yours,

ROYCE J. TIPTON. (Signed)

INTRODUCTION

In 1930 and 1931 a study of the proposed Caddoa reservoir was made by the state of Colorado in cooperation with the United States Corps of Engineers. The summary of the results of such study was published by the Corps in the "308" Report covering the Arkansas river.

In the 1930 and 1931 studies the operation of the reservoir was worked out on the basis of virtually pooling the water at the site of the reservoir and regulating it in accordance with an assumed ideal requirement for the irrigated lands in Colorado subject to benefit from the reservoir. Certain assumptions then were made as to the disposition of additional surplus water that would be made useable by the reservoir; one assumption that this water would go to the state of Kansas, and another that it would be used on new lands in Colorado. The published conclusions of the study did not indicate the benefit that would be derived by the individual canals in Colorado from the reservoir.

Under the present irrigation laws of Colorado and administrative procedure, the pooling of the water at the Caddoa reservoir probably could not be accomplished, since it would involve the storing at times of direct flow water.

Construction of the Caddoa reservoir by the Corps of Engineers has been approved, with the provision, however, that local interests shall furnish rights-of-way and take care of all damages resulting from the construction of the reservoir. It appears at the present writing that such rights-of-way and damages will amount to some $5,000,000.

Since the 1930 and 1931 studies were completed there have occurred several years of low water supply. The interstate situation between Colorado and Kansas also has changed in that a tentative agreement was entered into between the states

with respect to the disposition of the waters of the Caddoa reservoir if and when it is constructed, in which event the agreement is to become a stipulation in the pending case between Colorado and Kansas over the uses of the water of the Arkansas river.

For the above reasons another complete study has been made of the Caddoa reservoir. This study brings the former investigation up to date with respect to water supply; determines the benefit to be derived by the individual Colorado canals from the reservoir; determines the value of the reservoir from an economic standpoint; takes into consideration the terms of the tentative Kansas-Colorado agreement with respect to the allocation of benefits from the reservoir to the two states; and in the assumed operation of the reservoir, recognizes fully Colorado irrigation laws and administrative procedure.

The following discussion gives the conclusions of the study, together with a brief description of the methods used to arrive at those conclusions. Several voluminous detailed tables of water supply, reservoir operation, and crop statistics are not attached, but are available for inspection. This also is true of several graphs showing canal and reservoir operations and crop statistics plotted against water supply. A list of such tables and graphs is given at the end of the report.

It must be understood that certain assumptions were made as to irrigation requirements within the area to be served by the reservoir in order to arrive at a logical demand for supplemental water. The canals might operate differently than assumed if the reservoir were constructed. However, this would not materially affect the conclusions as to the amount of supplemental water made available by the reservoir. Also, the benefits derived by the Colorado canals from the reservoir could be distributed on a different basis than that assumed, providing the aggregate did not exceed the total benefit as arrived at in this study.

SUMMARY

1. It is concluded that for the period from 1914 to 1936 inclusive, the Caddoa reservoir would have made available to the states of Colorado and Kansas an average annual amount of 112,000 acre-feet of flood water not otherwise useable during that period, and that in accordance with the tentative agreement existing between Colorado and Kansas this 112,000 acre-feet would be divided equally between the two states.

In addition to the 112,000 acre-feet of flood water made useable by Caddoa, it is concluded an average annual saving of about 11,300 acre-feet of Kicking Bird water would have been effected, which would have been available for beneficial use in Colorado.

On the basis of the assumed operation of the reservoir, a total of 1,001,000 acre-feet would have spilled from the reservoir during the period under consideration, 1914 to 1936. Nominal shortages would have occured in some years prior to 1930 and more severe shortages since 1930.

2. It is the writer's conclusion that from the period 1895 to 1936 the most severe period with respect to water supply for the operation of the Caddoa reservoir would have been the period 1932 through 1935, and that the next most severe period would have been November, 1916, through May, 1921, inclusive. It is the writer's conclusion that the reservoir could have been operated from 1895 to 1913 inclusive, the beginning of the period covered by the present study, without material shortages, on the basis of the assumed requirements in the two states.

3. It is concluded that for the period 1914 to 1936, inclusive, the following canals would have received from Caddoa reservoir the mean annual amounts of water indicated in the following table:

Canal	Mean Annual Benefit 1914-1936 - 1000 acre-feet
Fort Lyon	25.9
Keesee Canal	2.1
Fort Bent Canal	4.7
Amity Canal	16.6
Lamar Canal	0.9
Hyde Ditch	3.1
Manvel Canal	2.3
X-Y Ditch	3.3
Graham Ditch	4.5
Buffalo Creek Ditch	2.5
Sisson Ditch	1.5
Total	67.4

The benefits from Caddoa reservoir could be more equitably distributed between the Fort Lyon canal and the canals below the reservoir in Colorado, by transferring from such canals to the Ft. Lyon about 60 second-feet of water from senior decrees. The Ft.Lyon would use water under such transferred decrees so long as there was sufficient water in Caddoa to replace the water now diverted under those decrees. By this procedure the mean annual benefit to the Ft. Lyon canal for a period, such as 1914 to 1936, would be increased about 8,000 acre-feet, with a corresponding decrease in the aggregate mean annual benefit to the other canals.

4. Based on the type of crops now raised in the Colorado area that would benefit from the reservoir, and the mean value of crops from 1923 to 1936, it is concluded that the Caddoa reservoir would increase the annual gross value of crops by at least ,300,000 or between $4 and $6 per acre-foot of additional water made available for such a period as 1914 to 1936.

Due to the character of the present water supply, a limited acreage of high priced row crops is raised within the area. For example, in Weld county,

where the water supply is no greater than in the area under discussion, but where it is controlled, the average gross crop value per year is practically double that in Bent and Prowers counties. If the reservoir were constructed, it is believed that there would be a change in the type of crop raised. If such a change materialized to the extent that the same type of crops were raised in Bent and Prowers counties as in Weld county, it is concluded the gross crop values would be increased about $600,000 a year for a period such as 1914 to 1936.

5. The annual cost of the reservoir would depend upon the repayment period and rate of interest. Based on a thirty-year repayment period and 4% interest rate and $25,000 for annual operation and maintenance, the annual cost during the period of repayment would be $314, 150 or about $2.55 per acre-foot of average annual benefit based on such a period as 1914 to 1936. If the repayment period were the same and the interest rate were 6%, the total annual cost would be about $388,250 or about $3.15 per acre-foot of benefit based on such a period as 1914 to 1936.

6. The following indicates the disposition of the flood water which flowed past the site of the reservoir from 1914 to 1936, inclusive, under the assumed operation of the reservoir.

VALUES IN 1,000 ACRE-FEET

Total Flood Water at Caddoa			4,165.0
Release to Kansas			
Net Benefit to Kansas	1,289.8		
April to October Release to bring useable water at State Line to 52,000 Acre-Feet	117.7		
River Losses, Lamar to Holly	62.6		
Total	1,470.1		
Less: April to October useable State Line Flow exceeding 52,000 Acre-Feet.	105.9	1,364.2	
Release to Colorado		1,288.6	
River Losses, Caddoa to Lamar		63.1	
Reservoir Evaporation		379.8	
Reservoir Spills		1,001.3	
Final Reservoir Content		68.0	
Total		4,165.0	4,165.0

7. The following indicates the disposition of the aggregate State Line flow from 1914 to 1936 under the assumed operation of the reservoir. The values include the estimated flow of Wild Horse Creek but not the Holly Drain.

VALUES IN 1,000 ACRE-FEET

Actual State Line Flow, 1914-1936			6,257.7
Saving of Bank Storage due to the 1921 flood			66.4
River Losses, Caddoa to Lamar		63.1	
Colorado Net Benefit			
Total Benefit	1,288.6		
Return Flow	385.9	902.7	
Final Reservoir Content		68.0	
Reservoir Evaporation		379.8	
New State Line Flow			
Kansas Release	1,364.2		
Reservoir Spills	1,001.3		
Remaining State Line Flow	2,545.0	4,910.5	
Total		6,324.1	6,324.1

GENERAL

The tentative agreement existing between the states of Colorado and Kansas with respect to the operation of the Caddoa Reservoir, provides essentially for the recognition of 52,000 acre-feet of water at the State Line during the April to October period, for use by the state of Kansas; 25,000 acre-feet at the State Line during the period November to March, inclusive, for the use of the state of Kansas; and 160,000 acre-feet of annual direct flow diversions by the Colorado canals below the site of the reservoir to represent status quo conditions.

The agreement provides essentially that after these amounts are delivered, all water over and above them made useable by the Caddoa reservoir shall be divided equally between the two states for use by their respective water users.

The agreement provides also that the reservoir can be used by either state for regulating and making more seasonable the water now being used by each state, but it does not indicate the maximum amount of the capacity of the reservoir that either state can use for this purpose. The above principles were taken into consideration in the present study of the operation of the Caddoa reservoir.

The water supply available for storage in the reservoir was taken as the recorded flow of the river at Lamar, less the estimated inflow to the river between the site of the Caddoa dam and that point, it being assumed in general that the requirements of the canals in Colorado below Lamar are satisfied from return flow.

In the main study it was assumed that the Colorado canals will divert exactly as they have in the past, during both the summer and the winter periods, and that the reservoir will not be used for the regulation of any of the water which has been so diverted.

The recorded flow at the State Line, excluding the Holly drain was then depleted by the amount of water assumed to be withheld in the Caddoa reservoir. The useability of the remaining supply at the State Line was determined by eliminating undivertible peaks and amounts of water which it was assumed would be in excess of the assumed ideal requirements. The remaining flow at the State Line was then increased by thirty percent of the releases of water from Caddoa reservoir for the benefit of Colorado lands, to represent return flow from such releases.

Kansas deficiencies were determined by applying to this remaining water supply at the State Line an assumed ideal requirement for Kansas lands, based on a base State Line delivery (excluding the Holly drain) of 130,000 acre-feet during the April to October period. An ideal requirement was assumed for the canals in Colorado, and the deficiency under these canals was determined by comparing the actual diversions with the assumed requirements. Releases were then assumed to be made from the reservoir to supply the estimated deficiencies in Colorado and Kansas as determined above.

Since the deficiencies in the two states were not necessarily the same in any one year, credits and debits were carried from one year to another in the assumed operation of the reservoir. In case of a shortage, the two states were brought to an equal basis, as far as the use of flood water was concerned, by the release, prior to the emptying of the reservoir, of an amount of water equal to the debit of the debtor state.

In the former study it was assumed there would be an exchange of direct flow water up stream even as far as the Bessemer canal. However, detailed studies indicated such direct flow water available for exchange would be very unfirm, going to one canal at one time and another at another time in order of priority. The exchange water would be so uncertain that no upstream canal could change its present irrigation program either as to the use of water or as to the planting of crops.

For this reason the present study contemplates that the area benefited shall not extend above the Fort Lyon canal, and that the benefit to this canal system shall be derived from the transfer to that system of the water formerly stored in the Great Plains reservoir by the Amity canal system. It was assumed that this water will be regulated in the existing Horse and Adobe Creek reservoirs, and in the Queens reservoir, which is one of the Great Plains reservoirs, the former operations of the Horse and Adobe Creek reservoirs being taken into consideration. In the assumed operation there will be supplied to the Amity canal from Caddoa reservoir an amount of water equivalent to that formely received from the Great Plains reservoir, in addition, of course, to sufficient additional water to take care of the assumed deficiency under that canal.

The period of years covered by the study includes four of the years of the highest run-off on the stream, namely, the years 1914, 1915, 1921 and 1923. There has been some question whether the reservoir, over a longer period, would operate with no more shortages than would have occurred had it operated only during the period covered by the study.

The writer made an investigation of this in the 1930 and 1931 study, and concluded that from 1895 to that time the most severe period was 1916 to May, 1921. Since that time there has occurred the recent period of drouth, during which time the shortages under the Caddoa reservoir would have been more severe than during the 1916 to 1921 period. However, it is still the writer's conclusion that from 1895 to 1913 the reservoir could have been operated on the basis of the assumed requirements in the two states without shortages any more severe than those which occurred in the 1916 to 1921 period. Attention is called to the fact that the years 1895, 1900, 1905, and 1907 were flood years, when there would have been substantial spills from the reservoir.

Following are summary tables indicating the benefits that would be derived from the Caddoa reservoir by the two states on the basis of the above assumed operation:

Column 3 Table No.1, representing Colorado benefits, indicates the amount of additional water that would have been supplied to canals below the reservoir, including the reservoir water which formerly went to the Amity canal, since under the assumed set-up the Fort Lyon canal would get the benefit from this water.

The benefit accruing to the state of Kansas was determined by deducting 52,000 acre-feet from the total amount of water supplied seasonably at the State Line. It may be noted from the summary at the end of the table that releases from the reservoir in an average annual amount of about 5,000 acre-feet would have been necessary to take care of the 52,000 acre-feet of useable water before charging Kansas for flood water.

COLORADO STATE PLANNING COMMISSION

SUMMARY
CADDOA RESERVOIR OPERATION NO. 2
1914 - 1936
UNIT: 1,000 ACRE-FEET

TABLE NO. 1

Year	Flood Water	Colorado Benefit	Kansas Benefit	April-Oct. State Line Flow Exceeding 52,000 Acre-Feet	Stipulation Release	River Loss Lamar to Holly	River Loss Caddoa to Lamar	Evaporation	Spills	** Shortage	Content of Reservoir Maximum	Content of Reservoir Minimum
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1914	444.8	38.1	78.0	5.1		15.6	5.2	19.2			322.1	2.5
1915	323.7	47.8	43.0	15.5			3.8	30.5	120.5		400.0	300.2
1916	82.4	85.9	78.0		7.5		1.8	31.6			411.4	262.7
1917	23.2	65.5	78.0		13.7		5.6	22.4			282.8	105.1
1918	26.9	71.0	31.3		14.8		0.7	9.9		27.0	114.8	0.0
1919	87.7	41.9	27.5		4.0		0.0	1.9		60.3	26.9	0.0
1920	54.5	23.5	43.7	14.1			0.0	1.7		66.7	25.2	0.0
1921	956.1	78.9	53.4	0.7			2.5	22.4	447.9		400.0	6.1
1922	16.9	107.9	78.0	6.5			2.3	29.7			381.3	173.2
1923	654.5	52.1	21.5		4.9		5.9	22.9	90.0		630.4	154.1
1924	177.4	92.3	78.0	3.2			4.2	40.6	342.9		680.0	250.5
1925	123.8	111.0	78.0	45.8			1.7	25.2			259.0	163.2
1926	25.3	44.1	78.0		6.9		0.8	18.8		48.9	214.9	82.2
1927	273.8	25.0	78.0		0.9	0.5	3.5	12.8		16.2	248.1	23.7
1928	186.3	50.2	43.0		15.8	2.2	3.4	24.0			368.7	225.6
1929	167.5	66.7	78.0		16.6		4.4	22.2			299.7	166.7
1930	87.0	52.7	69.5		11.8		0.9	22.2			279.0	149.0
1931	16.3	84.5	78.0		7.9		0.4	12.0		63.9	203.4	26.0
1932	8.9	2.5	28.7		*	1.4	1.9	1.6		205.5	28.9	0.0
1933	110.7	26.9	20.2		13.1	31.5	6.1	1.5		95.1	25.0	0.0
1934	23.5	3.7	13.5		*	8.6	5.7	1.0		276.6	10.3	0.0
1935	83.5	46.1	45.0	13.7			3.2	1.6		85.1	14.3	0.0
1936	210.3	70.3	71.5	1.3		2.8	0.6	4.1		17.5	76.2	0.0
Total	4,165.0	1,288.6	1,289.8	105.9	117.7	62.6	63.1	379.8	1,001.3	962.8		
Mean	181.1	56.0	56.1	4.6	5.1	2.7	2.7	16.5	43.5	41.9		

Mean Annual Saving of Kicking Bird Water. 11.3
Total 67.3

* Stipulation Release disregarded.
Note: Data for 1936 is for period - January 1st to September 30th.
** Does not include remaining shortage under Fort Lyon Canal.

Water Resources Survey,
January, 1938.

COLORADO STATE PLANNING COMMISSION

BENEFITS TO COLORADO AND KANSAS
CADDOA RESERVOIR OPERATION NO. 2
UNIT: 1,000 ACRE-FEET

TABLE NO. 2.

Year	Colorado Benefit	Cumulative Colorado Benefit	Release to Kansas	April-Oct. State Line Flow Exceeding 52,000 Acre-Feet	River Loss Lamar to Holly	Stipulation Release	Net Kansas Benefit Columns 4 plus 5-6-7	Cumulative Net Kansas Benefit	Kansas Debit Balance
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1914	38.1	38.1	88.5	5.1	15.6		78.0	78.0	39.9
1915	47.8	85.9	27.5	15.5			43.0	121.0	35.1
1916	85.9	171.8	85.3			7.3	78.0	199.0	27.2
1917	65.5	237.3	91.7			13.7	78.0	277.0	39.7
1918	71.0	308.3	46.1			14.8	31.3	308.3	0.0
1919	41.9	350.2	31.5			4.0	27.5	335.8	- 14.4
1920	23.5	373.7	29.6	14.1			43.7	379.5	5.8
1921	78.9	452.6	52.7	0.7			53.4	452.9	- 19.7
1922	107.9	560.5	71.5	6.5			78.0	510.9	- 49.6
1923	52.1	612.6	26.4			4.9	21.5	532.4	- 80.2
1924	92.3	704.9	74.8	3.2			78.0	610.4	- 94.5
1925	111.0	815.9	32.2	45.8			78.0	688.4	- 127.5
1926	44.1	860.0	84.9			6.9	78.0	766.4	- 93.6
1927	25.0	885.0	79.4		0.5	0.9	78.0	844.4	- 40.6
1928	50.2	935.2	51.0		2.2	15.8	43.0	887.4	- 47.8
1929	66.7	1,001.9	94.6			16.6	78.0	965.4	- 36.5
1930	52.7	1,054.6	81.3			11.8	69.5	1,034.9	- 19.7
1931	84.5	1,139.1	85.9			7.9	78.0	1,112.9	- 26.2
1932	2.5	1,141.6	30.1		1.4	*	28.7	1,141.6	0.0
1933	26.9	1,168.5	64.8		31.5	13.1	20.2	1,161.8	- 6.7
1934	3.7	1,172.2	22.1		8.6	*	13.5	1,175.3	3.1
1935	46.1	1,218.3	29.3	13.7			43.0	1,218.3	0.0
1936	70.3	1,288.6	73.0	1.3	2.8		71.5	1,289.8	1.2
Total	1,288.6		1,364.2	105.9	62.6	117.7	1,289.8		
Mean	56.0		59.3	4.6	2.7	5.1	56.1		

* Stipulation Release disregarded.

Note: Data for 1936 is for period - January 1st to September 30th.

Water Resources Survey,
January, 1938.

It may be noted that the average new-water received by each state for the period 1914 to 1936 would have been 56,000 acre-feet, and that Colorado would have received in addition for beneficial use about 11,000 acre-feet of water per year which was lost in the Great Plains system.

The following table indicates the amount of water flowing out of the state of Colorado into Kansas from 1914 to 1936 inclusive, and the estimated amount that would flow out of the state under the above assumed operation of the Caddoa reservoir. It may be noted from the table that in addition to the average amount of water available to Kansas, as represented in column 4 of Table No. 1, there would have been other amounts divertible which would have made a total average divertible amount during April to October of 126,100 acre-feet.

COLORADO STATE PLANNING COMMISSION

STATE LINE OUTFLOW - CADDOA RESERVOIR OPERATION NO. 2
1914 - 1936
UNIT: 1,000 ACRE-FEET

TABLE NO. 3

Year	APRIL TO OCTOBER: DIVERTIBLE: Divertible Water at State Line	DIVERTIBLE: Releases from Caddoa for Kansas	DIVERTIBLE: Total Divertible	UNDIVERTIBLE: Natural	UNDIVERTIBLE: Spills	UNDIVERTIBLE: Total Undivertible	NOVEMBER TO MARCH	Total Annual
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1914	96.7	88.5	185.2	8.4		8.4	33.9	130.6
1915	144.1	27.5	171.6	12.6	120.5	133.1	47.8	191.9
1916	48.3	85.3	133.6	1.0		1.0	44.1	92.4
1917	41.1	91.7	132.8	0.0		0.0	20.8	61.9
1918	39.9	46.1	86.0	0.0		0.0	18.3	58.2
1919	121.8	31.5	153.3	0.0		0.0	48.6	170.4
1920	107.5	29.6	137.1	9.2		9.2	46.7	154.2
1921	62.6	52.7	115.3	3.5	447.9	451.4	41.4	104.0
1922	72.1	71.5	143.6	0.8		0.8	45.9	118.0
1923	107.8	26.4	134.2	34.5	90.0	124.5	42.0	149.8
1924	73.7	74.8	148.5	0.0	342.9	342.9	54.5	128.2
1925	99.3	32.2	131.5	14.0		14.0	37.8	137.1
1926	45.1	84.9	130.0	0.0		0.0	28.4	73.5
1927	86.2	79.4	165.6	55.7		55.7	29.1	115.3
1928	41.5	61.0	102.5	2.6		2.6	35.8	75.3
1929	41.1	94.6	135.7	0.0		0.0	41.3	82.4
1930	61.4	81.3	142.7	13.3		13.3	39.4	100.8
1931	48.3	85.9	134.2	0.8		0.8	50.7	99.0
1932	13.7	30.1	43.8	1.8		1.8	18.4	32.1
1933	31.3	64.8	96.1	0.0		0.0	14.0	45.3
1934	3.7	22.1	25.8	0.0		0.0	12.0	15.7
1935	67.5	29.3	96.8	37.5		37.5	4.9	72.4
1936	80.5	73.0	153.5	51.0		51.0	9.3	89.8
Total	1,535.2	1,364.2	2,899.4	246.7	1,001.3	1,248.0	763.1	2,298.3
Mean	66.8	59.3	126.1	10.7	43.5	54.2	33.2	100.0

Note: Data for 1936 is for period - January 1st to September 30th.

Water Resources Survey,
January, 1938.

BENEFITS TO INDIVIDUAL CANALS IN COLORADO

The requirement of the individual canal systems in Colorado subject to benefit by the operation of Caddoa reservoir was determined by comparing the actual diversion of the canals with an assumed ideal requirement. Seasonable precipitation was taken into consideration in arriving at the ideal requirements. This process indicated non-seasonable diversions by the canals at times. In other words, during periods of large run-off the canals frequently divert excess quantities of water in anticipation of a shortage later in the season.

The greatest benefit would be derived from the Caddoa reservoir by using it not only to make flood water useable, but to regulate and make more useable the water which at times is diverted in excess of requirements. However, as indicated heretofore, it was assumed the canals would divert under their decrees exactly as in the past, since it would be impossible under our present administrative procedure to store the excess diversions made under direct flow decrees.

Only the deficiencies were taken into consideration, the sum of which, under the various canals, constituted the demand upon Caddoa reservoir. In assuming by this method past operation of the canals and supplying indicated late season deficiencies, there resulted in some years what appears to be an excess quantity of water for some of the canals. It is believed, however, that if Caddoa reservoir is constructed and operated over a period of years, a gradual change in the use of water by the canals served by the reservoir will result, which eventually will mean the storing of some water now diverted under direct flow decrees, and will result in a more efficient use of the water.

The following tables indicate the benefit that would be received by each of the canals from the Fort Lyon canal to Holly by the Caddoa reservoir, based on the above assumptions and the period 1914 to 1936 inclusive.

COLORADO STATE PLANNING COMMISSION

DISPOSITION OF KICKING BIRD WATER TO FORT LYON CANAL
CADDOA RESERVOIR OPERATION NO. 2
1914 - 1936
UNIT: 1,000 ACRE-FEET

Year	Additional Water Required by Fort Lyon Canal	Additional Water Supplied by Kicking Bird Canal		Remaining Water Required by Fort Lyon Canal
		Regulated by Horse Creek & Adobe Creek Reservoirs	Regulated by Queen's Reservoir	
(1)	(2)	(3)	(4)	(5)
1914	0	0	0	0
1915	0	0	0	0
1916	0	0	0	0
1917	96.2	73.2	23.0	0
1918	90.0	23.1	27.0	39.9
1919	40.9	40.9	0	0
1920	33.8	33.8	0	0
1921	80.4	48.6	14.5	17.3
1922	112.0	19.3	0	92.7
1923	51.2	27.8	0	23.4
1924	30.1	18.2	11.9	0
1925	132.7	13.4	38.1	81.2
1926	115.5	20.7	0	94.8
1927	79.2	23.9	0	55.3
1928	54.7	48.6	0	6.1
1929	72.9	24.1	0	48.8
1930	56.5	17.8	23.1	15.6
1931	195.7	13.1	0	182.6
1932	159.3	4.7	0	154.6
1933	119.1	3.8	0	115.3
1934	262.3	0.4	0	261.9
1935	152.9	0.9	0	152.0
1936	91.3	1.8	0	89.5
Total	2,026.7	458.1	137.6	1,431.0
Mean	88.1	19.9	6.0	62.2

Water Resources Survey,
January, 1938.

DIVERSIONS BY THE FORT LYON CANAL
CADDOA OPERATION NO. 2

UNIT: 1,000 ACRE-FEET

Year	Actual Diversions	Additional Water Supplied by Kicking Bird	Total
(1)	(2)	(3)	(4)
1914	303.1	0	303.1
1915	311.5	0	311.5
1916	180.0	0	180.0
1917	182.7	96.2	278.9
1918	186.4	50.1	236.5
1919	199.9	40.9	240.8
1920	256.4	33.8	290.2
1921	139.0	63.1	202.1
1922	166.4	19.3	185.7
1923	167.7	27.8	195.5
1924	153.5	30.1	183.6
1925	143.4	51.5	194.9
1926	202.8	20.7	223.5
1927	203.3	23.9	227.2
1928	169.3	48.6	217.9
1929	222.2	24.1	246.3
1930	189.4	40.9	230.3
1931	125.9	13.1	139.0
1932	155.6	4.7	160.3
1933	177.9	3.8	181.7
1934	94.6	0.4	95.0
1935	190.8	0.9	191.7
1936	229.0	1.8	230.8
TOTAL	4,350.8	595.7	4,946.5
MEAN	189.16	25.90	245.06

COLORADO STATE PLANNING COMMISSION

DISPOSITION OF CADDOA BENEFITS TO COLORADO CANALS
CADDOA RESERVOIR OPERATION NO. 2
CADDOA TO LAMAR, 1914 - 1936
UNIT: 1,000 ACRE-FEET

Year	Keesee Canal		Fort Bent Canal		Amity Canal		Lamar Canal		Total Caddoa to Lamar	
	Required	Supplied	Required	Supplied	Required	Supplied	Required	Supplied	Required	Supplied
1914	1.6	1.6	0.0	0.0	4.2	4.2	0.5	0.5	6.3	6.3
1915	1.9	1.9	1.2	1.2	12.0	12.0	2.2	2.2	17.3	17.3
1916	2.0	2.0	6.2	6.2	15.6	15.6	0.2	0.2	24.0	24.0
1917	1.9	1.9	5.3	5.3	21.5	21.5	0.4	0.4	29.1	29.1
1918	1.6	1.4	7.1	5.8	30.9	23.9	2.3	1.7	41.9	32.8
1919	4.2	0.4	10.9	1.8	38.4	10.5	1.7	0.3	55.2	13.0
1920	1.9	0.3	7.7	1.4	33.0	6.7	3.4	0.8	46.0	9.2
1921	2.3	2.3	4.3	4.3	14.3	14.3	0.0	0.0	20.9	20.9
1922	2.3	2.3	7.4	7.4	46.5	46.5	1.7	1.7	57.9	57.9
1923	2.2	2.2	7.5	7.5	18.9	18.9	0.4	0.4	29.0	29.0
1924	5.1	5.1	7.3	7.3	4.4	4.4	3.1	3.1	19.9	19.9
1925	7.5	7.5	9.9	9.9	29.0	29.0	1.0	1.0	47.4	47.4
1926	4.5	2.5	8.1	4.8	34.3	16.2	1.8	0.0	48.7	23.5
1927	2.4	1.3	4.4	2.9	19.4	10.8	1.9	1.5	28.1	16.5
1928	3.0	3.0	5.1	5.1	13.9	13.9	0.9	0.9	22.9	22.9
1929	3.4	3.4	6.3	6.3	21.0	21.0	0.6	0.6	31.3	31.3
1930	1.3	1.3	4.2	4.2	10.5	10.5	0.4	0.4	16.4	16.4
1931	2.8	1.9	17.7	9.1	78.3	32.1	10.9	3.3	109.7	46.4
1932	2.7	0.0	11.9	0.2	72.1	1.6	1.7	0.0	88.4	1.8
1933	2.6	1.2	5.4	3.0	35.4	14.0	0.0	0.0	43.4	18.2
1934	2.0	0.0	17.7	0.3	113.5	2.4	15.0	0.1	148.2	2.8
1935	2.3	1.6	9.6	4.6	46.2	18.3	1.2	0.2	61.3	24.7
1936	2.8	2.5	10.4	9.1	38.1	32.8	1.1	0.9	52.4	45.3
Total	64.3	47.6	175.6	107.7	753.4	381.1	52.4	20.2	1,045.7	556.6
Mean	2.80	2.07	7.63	4.68	32.76	16.57	2.28	0.88	45.47	24.20

Note: Data for 1936 is for period - January 1st to September 30th.

Water Resources Survey,
January, 1938.

COLORADO STATE PLANNING COMMISSION

DISPOSITION OF CADDOA BENEFITS TO COLORADO CANALS
CADDOA RESERVOIR OPERATION NO. 2
LAMAR TO HOLLY, 1914 - 1936
UNIT: 1,000 ACRE-FEET

Year	Hyde Ditch		Manvel Canal		A - Y Ditch		Graham Ditch		Buffalo Creek Ditch		Sisson Ditch		Total Lamar to Holly	
	Req'd.	Supp'd.	Req'd.	Supp'd.	Req'd.	Supp'd.	Req'd.	Supp'd.	Req'd.	Supp'd.	Req'd.	Supp'd.	Req'd.	Supp'd.
1914	3.0	3.0	3.2	3.2	2.7	2.7	4.5	4.5	2.2	2.2	1.1	1.1	16.7	16.7
1915	4.2	4.2	1.6	1.6	4.6	4.6	5.2	5.2	5.1	5.1	1.7	1.7	22.4	22.4
1916	6.3	6.3	3.1	3.1	5.0	5.0	7.2	7.2	4.0	4.0	3.3	3.3	28.9	28.9
1917	5.5	5.5	1.4	1.4	0.8	0.8	7.7	7.7	3.9	3.9	0.9	0.9	20.2	20.2
1918	5.4	4.5	1.9	1.5	2.5	1.8	4.0	3.2	2.4	1.8	3.8	3.2	20.0	16.0
1919	6.4	0.7	0.7	0.6	6.8	1.0	4.5	0.8	2.3	0.8	4.2	0.3	24.9	4.2
1920	5.4	1.4	0.6	0.2	8.0	1.4	5.2	1.0	2.9	0.2	2.1	0.1	24.2	4.3
1921	4.2	4.2	2.9	2.9	1.5	1.5	4.4	4.4	4.4	4.4	1.8	1.8	19.2	19.2
1922	4.6	4.6	4.7	4.7	7.1	7.1	5.9	5.9	7.8	7.8	2.9	2.9	33.0	33.0
1923	2.8	2.8	2.4	2.4	5.8	5.8	4.8	4.8	5.5	5.5	1.8	1.8	23.1	23.1
1924	3.6	3.6	4.6	4.6	3.4	3.4	6.0	6.0	6.2	6.2	2.6	2.6	26.4	26.4
1925	6.2	6.2	5.7	5.7	8.2	8.2	9.6	9.6	3.0	3.0	1.5	1.5	34.2	34.2
1926	3.5	2.1	4.0	2.2	3.8	1.9	5.7	3.3	0.6	0.4	0.0	0.0	17.6	9.9
1927	2.2	1.2	2.3	1.2	3.0	2.2	3.4	1.9	1.5	1.3	0.7	0.7	13.1	8.5
1928	2.2	2.2	2.5	2.5	4.3	4.3	4.1	4.1	0.2	0.2	1.2	1.2	14.5	14.5
1929	4.3	4.3	4.9	4.9	5.0	5.0	5.6	5.6	1.6	1.6	2.7	2.7	24.1	24.1
1930	2.0	2.0	3.1	3.1	2.4	2.4	4.1	4.1	1.0	1.0	1.2	1.2	13.8	13.8
1931	4.5	2.5	7.0	3.4	10.0	4.9	10.6	6.2	3.5	2.6	3.1	2.0	38.7	21.6
1932	6.3	0.2	5.0	0.0	7.8	0.2	9.8	0.3	1.2	0.0	3.3	0.0	33.4	0.7
1933	4.9	1.8	0.5	0.1	2.8	1.1	7.4	3.0	1.8	1.4	3.4	1.3	20.8	8.7
1934	6.7	0.1	6.8	0.0	9.4	0.1	9.2	0.5	2.1	0.0	3.7	0.0	37.9	0.7
1935	6.9	4.2	2.3	0.7	8.0	4.7	10.0	6.5	3.7	2.8	4.0	2.5	34.9	21.4
1936	4.5	4.1	4.0	3.6	7.7	6.7	7.4	6.8	1.5	1.2	2.8	2.6	27.9	25.0
Total	105.6	71.7	75.2	53.6	120.6	76.8	146.3	102.6	68.4	57.4	53.8	35.4	569.9	397.5
Mean	4.59	3.12	3.27	2.33	5.24	3.34	6.37	4.46	2.97	2.49	2.34	1.54	24.78	17.28

Note: Data for 1936 is for period - January 1st to September 30th.

Water Resources Survey,
January, 1938.

COLORADO STATE PLANNING COMMISSION

DIVERSION BY COLORADO CANALS
CADDOA RESERVOIR OPERATION NO. 2
CADDOA TO LAMAR, 1914 - 1936
UNIT: 1,000 ACRE-FEET

Year	Keesee Canal			Fort Bent Canal			Amity Canal			Lamar Canal			Total Caddoa to Lamar		
	Actual Diversions	Caddoa Benefit	Total	Actual Diversions	Caddoa Benefit	Total	Actual Diversions	Caddoa Benefit	Total	Actual Diversions	Caddoa Benefit	Total	Actual Diversions	Caddoa Benefit	Total
1914	3.0 2.9	1.6	4.6	23.4	0.0	23.4	129.2	4.2	133.4	39.1	0.5	39.6	194.7	6.3	201.0
1915	3.2 3.2	1.9	5.1	24.7	1.2	25.9	115.6	12.0	127.6	29.7	2.2	31.9	173.2	17.5	190.5
1916	3.9 3.9	2.0	5.9	20.1	6.2	26.3	121.3	15.6	136.9	37.7	0.2	37.9	183.0	24.0	207.0
1917	3.9 3.8	1.9	5.8	22.0	5.3	27.3	117.1	21.5	138.6	38.6	0.4	39.0	181.6	29.1	210.7
1918	4.3 4.7	1.4	6.2	16.0	5.8	21.8	100.6	23.9	124.5	36.3	1.7	40.0	159.7	32.8	192.5
1919	1.2 1.2	0.4	1.6	11.2	1.8	13.0	77.7	10.5	88.2	27.4	0.3	27.7	117.5	13.0	130.5
1920	4.8 4.8	0.3	5.1	14.4	1.4	15.8	89.9	6.7	96.6	40.2	0.8	41.0	149.3	9.2	158.5
1921	2.4 2.3	2.3	4.7	15.8	4.3	20.1	99.5	14.3	113.8	40.4	0.0	40.4	158.1	20.9	179.0
1922	4.9 5.2	2.3	7.2	17.0	7.4	24.4	100.2	46.5	146.7	34.5	1.7	36.2	156.6	57.9	214.5
1923	2.4 2.1	2.2	4.6	9.8	7.5	17.3	107.6	18.9	126.5	36.7	0.4	37.1	156.5	29.0	185.5
1924	0.0 0	5.1	5.1	18.8	7.3	26.1	135.5	4.4	139.9	36.1	3.1	39.2	190.4	19.9	210.3
1925	0.0 0	7.5	7.5	16.9	9.9	26.8	110.8	29.0	139.8	32.7	1.0	33.7	160.4	47.4	207.8
1926	0.0 0	2.5	2.5	15.9	4.8	20.7	103.4	16.2	119.6	37.4	0.0	37.4	156.7	23.5	180.2
1927	0.0 0	1.3	1.3	16.5	2.9	19.4	110.5	10.8	121.3	41.5	1.5	43.0	168.5	16.5	185.0
1928	0.0 0	3.0	3.0	15.0	5.1	20.1	104.0	13.9	117.9	36.0	0.9	36.9	155.0	22.9	177.9
1929	2.3 2.3	3.4	5.7	16.8	6.3	23.1	116.7	21.0	137.7	37.6	0.6	38.2	173.4	31.3	204.7
1930	4.5 4.5	1.3	5.8	16.6	4.2	20.8	108.9	10.5	119.4	40.4	0.4	40.8	170.4	16.4	186.8
1931	4.6 4.6	1.9	6.5	9.1	9.1	18.2	71.4	32.1	103.5	25.4	3.3	28.7	110.5	46.4	156.9
1932	4.6 4.7	0.0	4.6	15.6	0.2	15.8	59.7	1.6	61.3	32.8	0.0	32.8	112.7	1.8	114.5
1933	4.7 4.6	1.2	5.9	20.5	3.0	23.5	94.5	14.0	108.5	38.0	0.0	38.0	157.7	18.2	175.9
1934	5.5 5.4	0.0	5.5	11.1	0.3	11.4	33.8	2.4	36.2	20.8	0.1	20.9	71.2	2.8	74.0
1935	7.0 6.9	1.6	8.6	20.3	4.6	24.9	90.7	18.3	109.0	35.6	0.2	35.8	153.6	24.7	178.3
1936	5.4 5.4	2.5	7.9	14.3	9.1	23.4	102.9	32.8	135.7	38.5	0.9	39.4	161.1	45.3	206.4
Total	73.1 5.8 5.9	47.6	120.7	381.8	107.7	489.5	2,301.5	381.1	2,682.6	815.4	20.2	835.6	3,571.8	556.6	4,128.4
Mean	3.18	2.07	5.25	16.60	4.68	21.28	100.07	16.57	116.63	35.45	0.89	36.33	155.30	24.44	179.49

Note: Data for 1936 is for period - January 1st to September 30th.

Water Resources Survey,
January, 1938.

COLORADO STATE PLANNING COMMISSION

DIVERSIONS BY COLORADO CANALS
CADDOA RESERVOIR OPERATION NO. 2
LAMAR TO HOLLY, 1914 - 1936
UNIT: 1,000 ACRE-FEET

Year	Hyde Ditch			Manvel Canal			X - Y Ditch		
	Actual Diversions	Caddoa Benefits	Total	Actual Diversions	Caddoa Benefits	Total	Actual Diversions	Caddoa Benefits	Total
1914	1.0	3.0	4.0	1.8	3.2	5.0	9.9	2.7	12.6
1915	0.8	4.2	4.7	4.7	1.6	6.5	3.5	4.6	8.1
1916	0.2	6.3	6.5	5.8	3.1	8.9	8.5	5.0	13.5
1917	1.2	5.5	6.7	8.1	1.4	9.5	15.2	0.8	16.0
1918	0.9	4.5	5.4	8.4	1.5	9.9	13.1	1.8	14.9
1919	0.3	0.7	1.0	8.8	0.6	9.4	5.3	1.0	6.3
1920	1.6	1.4	3.0	12.5	0.2	12.7	3.1	1.4	4.5
1921	0.4	4.2	4.6	6.5	2.9	9.4	7.1	1.5	8.6
1922	3.9	4.6	8.5	3.7	4.7	8.4	5.0	7.1	12.1
1923	2.1	2.8	4.9	3.7	2.4	6.1	2.4	5.8	8.2
1924	3.4	3.6	7.0	2.4	4.6	7.0	9.1	3.4	12.5
1925	2.6	6.2	8.8	3.6	5.7	9.3	6.6	8.2	14.8
1926	3.4	2.1	5.5	3.8	2.2	6.0	12.1	1.9	14.0
1927	2.3	1.2	3.5	3.1	1.2	4.3	8.3	2.2	10.5
1928	3.5	2.2	5.7	4.0	2.5	6.5	4.9	4.3	9.2
1929	2.1	4.3	6.4	1.2	4.9	6.1	9.0	5.0	14.0
1930	4.2	2.0	6.2	2.7	3.1	5.8	10.0	2.4	12.4
1931	4.1	2.5	6.6	3.7	3.4	7.1	5.0	4.9	9.9
1932	2.7	0.2	2.9	4.0	0.0	4.0	8.0	0.2	8.2
1933	2.1	1.8	3.9	11.6	0.1	11.7	10.9	1.1	12.0
1934	2.4	0.1	2.5	3.2	0.0	3.2	8.0	0.1	8.1
1935	2.5	4.2	6.7	8.2	0.7	8.9	7.4	4.7	12.1
1936	3.1	4.1	7.2	4.1	3.6	7.7	3.0	6.7	9.7
Total	50.5	71.7	122.2	119.6	53.6	173.2	175.4	76.8	252.2
Mean	2.20	3.12	5.31	5.20	2.33	7.53	7.63	3.34	10.97

(Continued on following page)

DIVERSIONS BY COLORADO CANALS
CADDOA RESERVOIR OPERATION NO. 2
LAMAR TO HOLLY, 1914 - 1936
UNIT: 1,000 ACRE-FEET

(Continued from preceeding page)

Year	Graham Ditch			Buffalo Creek Ditch			Sisson Ditch			Total Lamar to Holly		
	Actual Diversions	Caddoa Benefits	Total	Actual Diversions	Caddoa Benefits	Total	Actual Diversions	Caddoa Benefits	Total	Actual Diversions	Caddoa Benefits	Total
1914	0.0	4.5	4.5	5.5	2.2	7.7	3.0	1.1	4.1	21.2	16.7	37.9
1915	0.1	5.2	5.3	1.3	5.1	6.4	1.1	1.7	2.8	11.2	22.4	33.6
1916	0.0	7.2	7.2	5.8	4.0	9.8	0.8	3.3	4.1	21.1	28.9	50.0
1917	0.0	7.7	7.7	9.5	5.9	13.4	6.8	0.9	7.7	40.8	20.2	61.0
1918	3.2	3.2	6.4	13.7	1.8	15.5	0.0	3.2	3.2	39.3	16.0	55.3
1919	4.4	0.8	5.2	10.9	0.8	11.7	0.0	0.3	0.3	29.7	4.2	33.9
1920	3.2	1.0	4.2	12.3	0.2	12.5	2.6	0.1	2.7	35.3	4.3	39.6
1921	0.9	4.4	5.3	2.8	4.4	7.2	0.9	1.8	2.7	18.6	19.2	37.8
1922	1.9	5.9	7.8	2.4	7.8	10.2	1.3	2.9	4.2	18.2	33.0	51.2
1923	0.5	4.8	5.3	1.2	5.5	6.7	1.0	1.8	2.8	10.9	23.1	34.0
1924	1.4	6.0	7.4	3.2	6.2	9.4	1.2	2.6	3.8	20.7	26.4	47.1
1925	0.7	9.6	10.3	9.2	3.0	12.2	4.2	1.5	5.7	26.9	34.2	61.1
1926	1.1	3.3	4.4	13.4	0.4	13.8	7.8	0.0	7.8	41.6	9.9	51.5
1927	0.4	1.9	2.3	7.4	1.3	8.7	3.6	0.7	4.3	25.1	8.5	33.6
1928	0.6	4.1	4.7	12.3	0.2	12.5	3.0	1.2	4.2	28.3	14.5	42.8
1929	1.8	5.6	7.4	11.1	1.6	12.7	1.0	2.7	3.7	26.2	24.1	50.3
1930	0.9	4.1	5.0	10.4	1.0	11.4	1.9	1.2	3.1	30.1	13.8	43.9
1931	0.0	6.2	6.2	10.9	2.6	13.5	2.3	2.0	4.3	26.0	21.6	47.6
1932	0.0	0.3	0.3	14.0	0.0	14.0	2.2	0.0	2.2	30.9	0.7	31.6
1933	0.0	3.0	3.0	12.5	1.4	13.9	0.7	1.3	2.0	37.8	8.7	46.5
1934	0.0	0.5	0.5	13.8	0.0	13.8	1.0	0.0	1.0	28.4	0.7	29.1
1935	0.0	6.5	6.5	13.6	2.8	16.4	1.3	2.5	3.8	33.0	21.4	54.4
1936	0.0	6.8	6.8	14.6	1.2	15.8	1.4	2.6	4.0	26.2	25.0	51.2
Total	21.1	102.6	123.7	211.8	57.4	269.2	49.1	35.4	84.5	627.5	397.5	1,025.0
Mean	0.92	4.46	5.38	9.20	2.49	11.70	2.13	1.54	3.67	27.28	17.28	44.56

Note: Data for 1936 is for period - January 1st to September 30th.

Water Resources Survey,
January, 1938.

The total benefit that would have accrued to the Colorado canals during the period 1914 to 1928, inclusive, was 1,050,000 acre-feet, or an average of 67,800 acre-feet per year. This is 860,000 acre-feet more than would have been received by Kansas under the assumed operation, resulting from reduction in the loss of Kicking Bird water by its use in the Fort Lyon's system of reservoirs rather than in the Great Plains reservoirs.

Another study was made to determine the amount of water diverted under direct flow decrees during the winter period, that could be stored in Caddoa reservoir without conflict with present administrative procedure. Only the water diverted during the months of December, January, and February, when the Colorado canal was diverting water for storage in Lake Meredith, and/or when there was an obvious surplus supply at Lamar, was considered as direct flow water storable in Caddoa. By this process it is estimated that the following amounts of water, diverted during the three-months winter period, could have been legally stored in Caddoa reservoir:

Season of:	Amount - Thousands of Acre-Feet
1925-26	19.0
1926-27	13.1
1927-28	17.0
1928-29	26.2
1929-30	22.0
1930-31	10.0
1931-32	16.5
1932-33	13.0
1933-34	2.8
1934-35	0.0
1935-36	16.1
1936-37	10.0
Total 12 years	165.7
Mean	13.8

No data were available to determine these quantities prior to the season 1925-26. Under the assumed operation of Caddoa reservoir the last spill would have occurred in 1924. Assuming that 13,800 acre-feet of winter water could have been stored during the winter season of 1924-1925, which is the mean

quantity for the 1925 to 1937 period, the total winter water which could have been stored since the last spill would have been 179,500 acre-feet. Assuming that the direct flow diversion during the period December to February, inclusive, has little benefit, the shortages since 1930 would have been reduced by the 179,500 acre-feet. The nominal shortages in the earlier years could have been entirely eliminated by storing water otherwise diverted in December, January and Ferruary for use during the irrigation season.

By comparing the benefits that would accrue to Fort Lyon canal and the benefits that would accrue to the other canals under the above assumed operation, it may be noted that the shortages of the Fort Lyon canal would not be relieved in the same degree as the shortages of the other canals.

Another study was made to determine whether it would be practicable to distribute more equitably the benefit of the Caddoa reservoir throughout the area in Colorado subject to benefit by its operation. The most feasible means for doing this appears to be the transfer of some of the early direct flow water used below Caddoa reservoir to the Fort Lyon canal, the water available under such early decrees to be used by that canal during those periods when sufficient water is available in Caddoa reservoir to replace the water now diverted under the early decrees to lands below the reservoir. It was found that the transfer of about 60 cubic feet per second of early water to the Fort Lyon would bring all the canals subject to benefit by the operation of Caddoa reservoir to a fairly equal basis.

If this were done, the mean annual benefit to the Fort Lyon's system from the operation of the Caddoa reservoir between the period 1914 to 1936 would be increased by about 8,000 acre-feet, with a corresponding decrease in the benefit to the canals below Caddoa.

VALUE OF SUPPLEMENTAL WATER TO THE AREA IN COLORADO SUBJECT TO BENEFIT BY THE OPERATION OF CADDOA RESERVOIR

The area in Colorado subject to benefit from the Caddoa reservoir lies wholly within Bent and Prowers counties. A detailed study was made of crop production in those counties from 1923 to 1936, inclusive. Crop production was then compared to the water supply. By this process it was determined that supplemental water with the type of crops that are raised at present in those two counties is between $4.00 and $6.00 per acre-foot per year in terms of increased gross crop production.

If a more dependable water supply were made available to the area, a change in type of crops would take place which it is estimated would result in a value of water of between $8.00 to $10.00 per acre-foot per year in terms of gross crop production.

The study indicated the outgoing car loadings of the Santa Fe railroad would be increased by from 1,200 to 1,600 cars per year per 100,000 acre-feet of additional supplemental water made available. The following is a brief explanation of the manner in which the above conclusions were reached:

The production of the seven principle crops, namely: corn, wheat, oats, barley, dry beans, sugar beets and alfalfa, raised in the two counties for each of the years 1923 to 1936 was determined from statistics gathered by the Colorado Cooperative Crop Reporting Service. The mean value for each crop for the period was then applied to the annual production and the gross value of the crops produced in the two counties was determined. The mean value of the crop was used in order to eliminate the effect of fluctuating prices. The final result called "measure of crop values" became a measure of crop production constituting a device whereby bushels and tons could be combined.

Another set of values was worked out, based on the average acreage planted to each of the principal crops, the mean value of the crops and the per-acre production for each year of the period, This eliminated the changes

in planting which might have taken place from influences other than water supply. However, it was found that the major changes that took place in the acreage of various crops was due more to water supply than to any other factor.

The two sets of values representing "measure of crop value" were plotted year by year against water supply. Several combinations were worked out, one taking the diversions from April to October as the water supply; another taking the annual diversions; another taking the April to October diversions plus the November to October precipitation; and another taking the November to October diversions plus the November to October precipitation. Two graphs resulting from the above processes are submitted herewith.

Plate No. 1 shows the "measure of crop values", based on actual acreage of crops and average unit prices, plotted against the November to October diversions plus the November to October precipitation. The protracted drought since 1930 unduly affected the planting so that not only was the unit production down during the years since 1930, but the acreages were less than normal.

Attention is called to the relative position of the years 1929, 1930 and 1931, which it is believed represent fairly the relationship between the gross value of crops in the two counties, and the water supply. The water supply during the years 1929 and 1930 was fairly good. There was not much change in acreage of the principal crops planted in those two years and in 1931. The water supply during 1931, based on the November to October diversions plus the total November to October precipitation, was about 260,000 acre-feet less than it was during the years 1929 and 1930. The gross value of crops in 1931 was about $2,000,000 less than in 1930 and $1,600,000 less than 1929. The water supply during the year 1934 was even less than in 1931, being about 330,000 acre-feet less than it was during 1929, and about 375,000 acre-feet less than in 1930. The gross value of crops in 1934, based on the

PLATE NO. 1

MEASURE OF CROP VALUES vs. TOTAL NOV-OCT DIVERSIONS & PRECIPITATION

BASED ON ACTUAL ACREAGE & AVERAGE UNIT PRICE

BENT & PROWERS COUNTIES

1924 — 1936

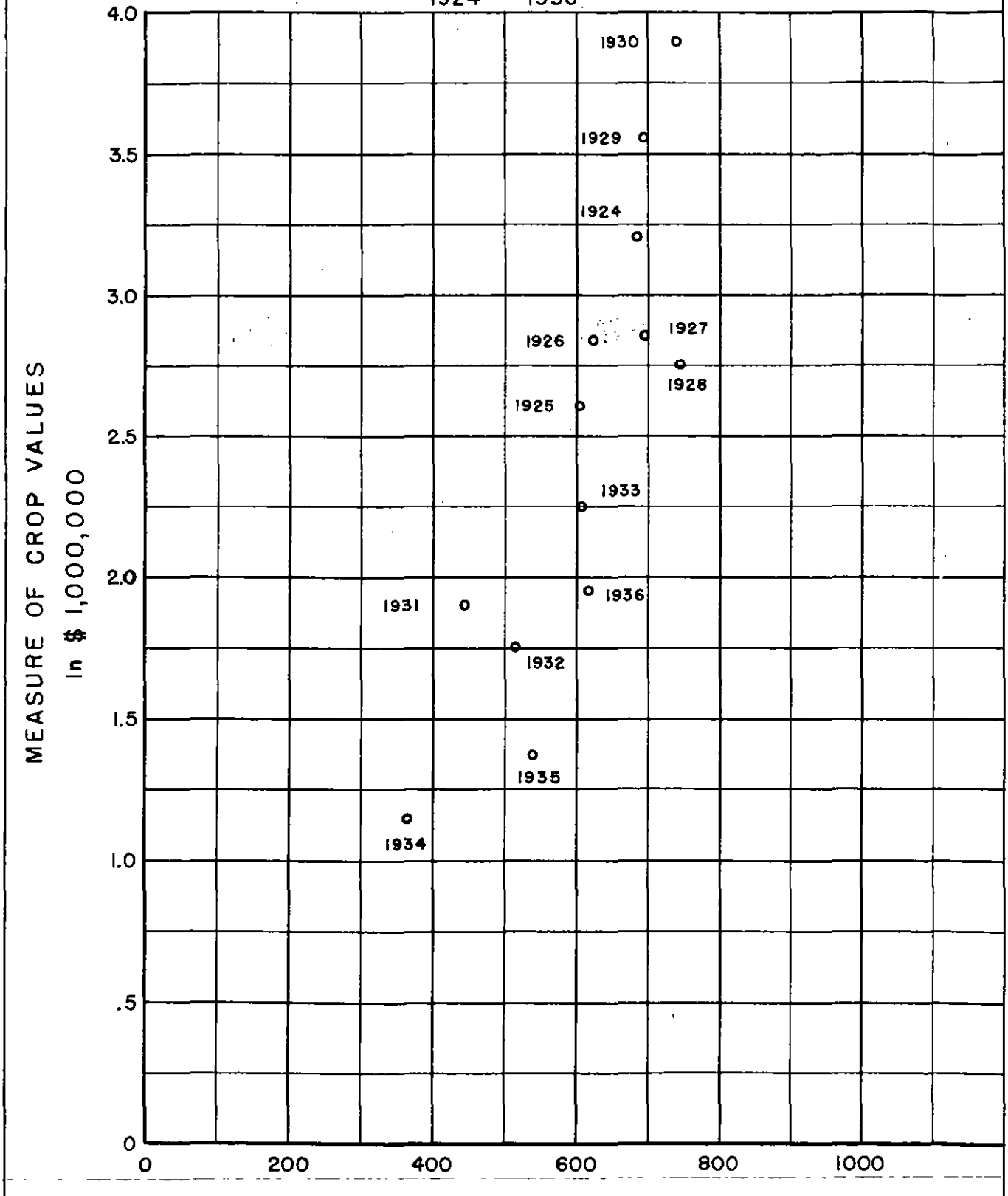

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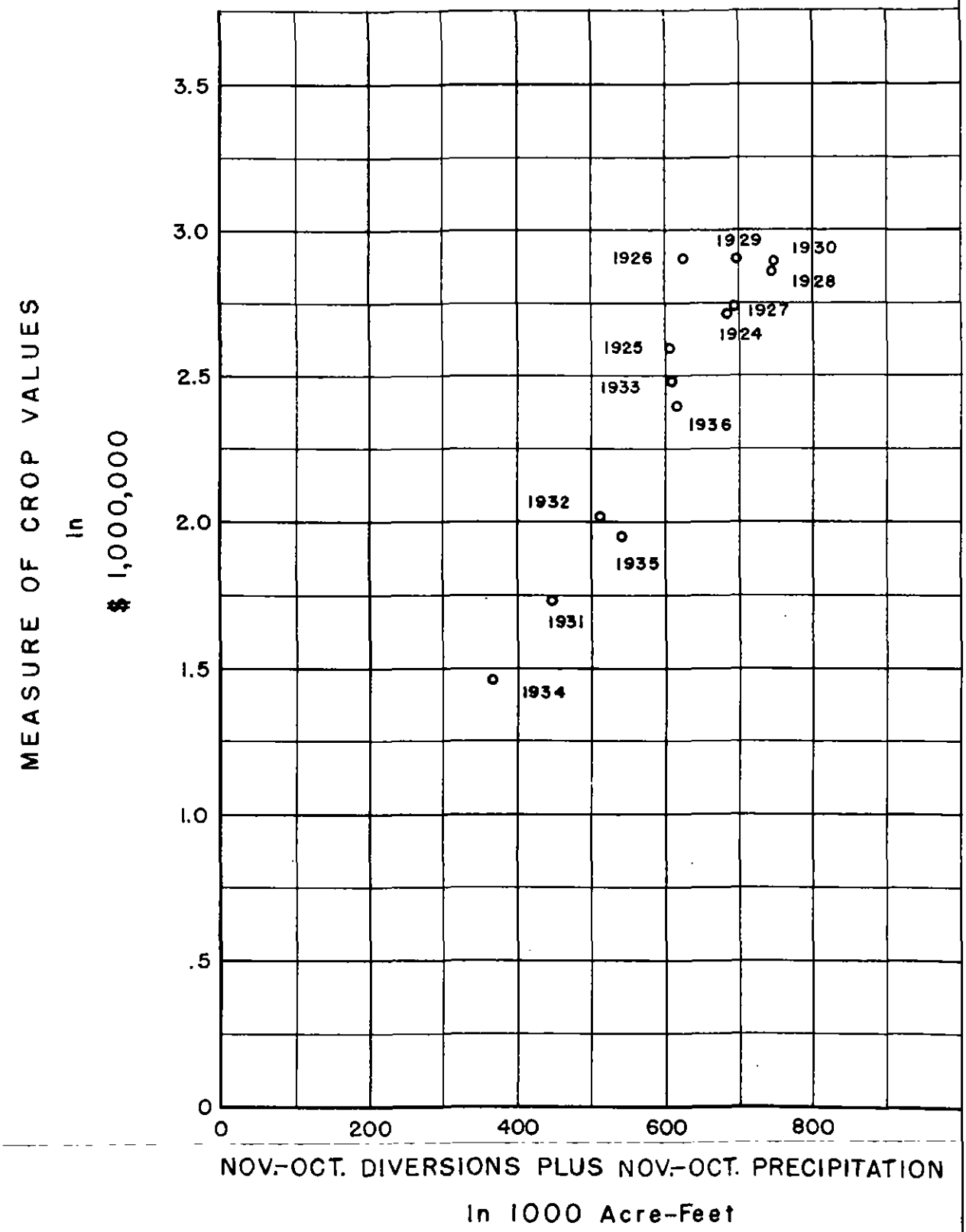
PLATE NO. 2

MEASURE OF CROP VALUES vs. NOV.-OCT. DIVERSIONS & PRECIPITATION

BASED ON MEAN ACREAGE & AVERAGE UNIT PRICE

BENT & PROWERS COUNTIES

1924 — 1936



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average unit prices for the period, was $1,148,000, or about $2,700,000 less than in 1930, and about $2,400,000 less than in 1929.

Plate No. 2 shows the "measure of crop values" based on the mean acreage of the principal crops for the period 1923 to 1936, inclusive, and the average unit price of crops for that period, plotted against the November to October diversions plus the November to October precipitation. In this graph there is eliminated entirely the influence of variable acreage of the various crops. The value used is an index of crop production per acre.

The close correlation between water supply and crop production may be noted by this plate. If the acreage devoted to the six principal crops was the average for the period under consideration, it is estimated from this plate that the value of additional water supply for the area is about $4.00 per acre-foot per year in increased gross production of crops.

However, due to the character of the water supply, the acreage of high priced row crops raised in the area is low. A comparison was made of the type of crops raised in Bent and Prowers counties and the crops raised in Weld county. The total water supply available for use in Weld county is not any more per acre than it is in Bent and Prowers counties, but it is practically all controlled and subject to use when most needed. As a result, for the period 1923 to 1936, inclusive, of the total acreage of principal crops in Weld county, there was an average of about 28% in row crops; while for the same period the average percentage of row crops in Bent county was about 6% and in Prowers county about 7%. This is shown in the following table:

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COLORADO STATE PLANNING COMMISSION

TABLE SHOWING PER CENT OF ACREAGE OF ROW, CEREAL AND FORAGE CROPS

1923 - 1936

Year	BENT COUNTY			PROWERS COUNTY			WELD COUNTY		
	% Row Crops	% Cereal Crops	% Forage Crops	% Row Crops	% Cereal Crops	% Forage Crops	% Row Crops	% Cereal Crops	% Forage Crops
1923	5.8	46.1	48.1	4.7	43.8	51.5	23.2	43.8	33.0
1924	8.6	38.1	53.3	10.6	32.0	57.4	38.3	30.4	31.3
1925	8.5	43.5	48.0	9.0	43.0	48.0	13.9	45.4	40.7
1926	2.7	45.6	51.7	5.7	40.4	53.9	26.7	41.4	31.9
1927	5.7	39.3	55.0	3.6	36.4	60.0	30.4	37.2	32.4
1928	4.1	43.4	52.5	3.5	41.0	55.5	25.3	42.8	31.9
1929	5.5	42.1	52.4	9.2	37.8	53.0	29.0	38.3	32.7
1930	9.0	38.0	53.0	8.1	38.8	53.1	31.9	41.0	27.1
1931	8.4	40.9	50.7	11.0	38.3	50.7	34.2	36.2	29.6
1932	4.1	44.5	51.4	6.2	43.9	49.9	28.9	41.6	29.5
1933	10.1	38.4	51.5	11.1	40.0	48.9	30.6	43.3	26.1
1934	8.0	26.1	65.9	7.7	24.6	67.7	31.8	41.3	26.9
1935	3.2	18.2	78.6	6.1	24.0	69.9	24.5	52.4	23.1
1936	5.5	30.0	64.5	4.4	39.4	56.2	26.5	51.5	22.0
Total	89.2	534.2	776.6	100.9	525.4	775.7	395.2	586.6	418.2
Mean	6.4	38.1	55.5	7.2	37.4	55.4	28.2	41.9	29.9

Row Crops: Sugar Beets. (Includes Potatoes for Weld County)
Cereal Crops: Corn, Wheat, Oats, Barley and Dry Beans.
Forage Crops: Alfalfa.

Water Resources Survey,
January, 1938.

The value of the crops raised in Weld county for the period 1923 to 1936, inclusive, was determined by using the average unit prices for the 14-year period, applying those prices to the actual production of the principal crops. It was found that the average gross value of the crops produced in Weld county for the period was $12,768,700, or about $40.00 per acre per year. The average value of the crops produced in Bent and Prowers counties for the same period, based on the same average unit prices, was about $23.00 per acre per year.

The growing season in Bent and Prowers counties is about one month longer than it is in Weld county. With a controlled water supply, available for use when needed, it is reasonable to suppose that the same type of crops would be grown in Bent and Prowers counties as in Weld county, which would almost double the gross crop value per year. If this change in type of crop materialized, the value of supplemental water to the area would practically double.

Detailed studies in connection with the Colorado-Big Thompson trans-mountain diversion, which is to serve the northern Colorado area, indicate that the value of supplemental water for that area in terms of increase in gross crop production is not less than $10.00 per acre-foot per year.

Since for the period 1914 to 1936, inclusive, it is estimated there would be made available to the Colorado canals by the Caddoa reservoir about 67,300 acre-feet of additional water per year, it is estimated this water would result in an increased gross value of crops produced, based upon present acreages and types of crops, and based upon average unit prices prevailing between 1923 and 1936, of $280,000 to $400,000. If the operation of the reservoir would bring about a change in types of crops, approaching the types raised in Weld county, it is estimated the increased value of crops resulting from the operation of the Caddoa reservoir in the Colorado area would amount to between $500,000 and $600,000 per year.

Plate No. 3 shows the annual number of cars hauled from the area over the Santa Fe railroad from 1924 to 1936 inclusive, plotted against the November to October diversions plus the November to October precipitation. Attention is called to the fairly close correlation between the two sets of values for the period 1924 to 1931, inclusive. The car loading for the years 1932, 1933, 1935 and 1936 are not in line with the points on the graph representing the other years. A full analysis has not been made to determine the reason for this. It may have been due to the general economic conditions during the depression, which resulted in lesser shipments of the crops that were raised, and it may have been due in part to increased trucking.

If it could be assumed that the period 1924 to 1931 was a fairly representative period, and discounting somewhat the very high car loadings in 1929 and 1930, the graph indicates that the car loadings would be increased by about 1,300 cars per each 100,000 acre-feet of additional water made available.

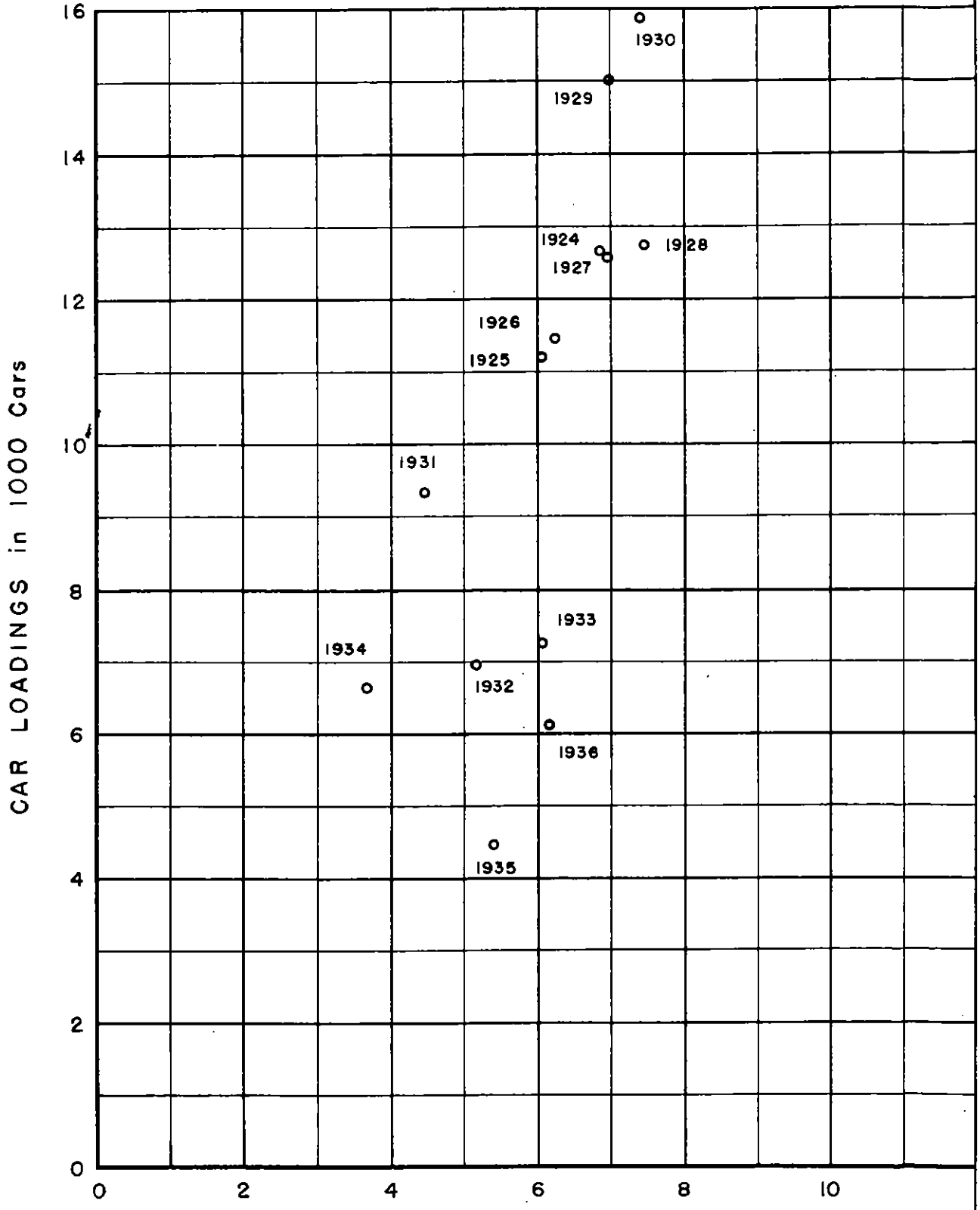
The very marked drop in car loadings from the two-year period of 1929 and 1930 to the year 1931 may be noted. The car loadings in 1931 were about 5,700 less than in 1929, and about 6,600 less than in 1930, while water supply in 1931 was about 250,000 acre-feet less than in 1929 and about 300,000 acre-feet less than in 1930. A more detailed analysis should be made of this phase of the problem to determine more conclusively the relation between car loadings and water supply.

No study was made of the economics of Caddoa reservoir with respect to the area in Kansas, since the basic data necessary for this study were not available. However, it is thought that such a study should be made by the officials of the state of Kansas.

In addition to the direct benefit which would accrue to the irrigators by the operation of Caddoa reservoir, material indirect benefit would result to

PLATE NO. 3

CAR LOADINGS vs. TOTAL NOV.-OCT. DIVERSIONS & PRECIPITATION
BENT & PROWERS COUNTIES
1924 — 1936



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all other types of business in the area. An increase in crop production in the Colorado area of some $280,000 to $600,000 per year would materially benefit all utilities, the sugar companies and all other retail and wholesale businesses. This indirect benefit has not been evaluated, but it is so material that all businesses within the area should aid in financing the reservoir.

Other benefits that would result from the operation of the reservoir which have not been definitely evaluated are flood protection, which would extend from the site of the reservoir to Hutchinson, Kansas and the possibility of settling the controversies between Kansas and Colorado over the waters of the Arkansas river.

ANNUAL COST OF CADDOA RESERVOIR

If the cost of construction of the Caddoa reservoir to the water users is assumed at $5,000,000 and the annual operation and maintenance cost at $25,000, the following table indicates the annual cost of the reservoir under various assumptions as to interest rate and repayment period, necessary to amortize the $5,000,000.

Repayment Period	Interest Rate	Amortization Sum	O. & M.	Total An. Cost	Average Cost per Ac.-ft.*
20 yrs.	4%	367,908.75	25,000	392,908.75	3.18
20 yrs.	6%	435,922.80	25,000	460,922.80	3.74
25 yrs.	4%	320,059.80	25,000	345,059.80	2.80
25 yrs.	6%	391,133.60	25,000	416,133.60	3.37
30 yrs.	4%	289,150.50	25,000	314,150.50	2.55
30 yrs.	6%	363,244.55	25,000	388,244.55	3.15

* For a period such as 1914 to 1936.

List of Tables and Graphs not attached, but available for study if desired. Years 1914 to 1936 unless otherwise stated.

Tables -- Reservoir Data

1. Estimated Inflow between Caddoa and Lamar, Colorado.

2. X Values between Caddoa and Holly, Colorado.

Tables - Reservoir Data. (Continued)

3. Estimated Water-Supply under Proposed Caddoa Reservoir, Operation No. 2.

4. Surplus and Deficiencies at State Line, Caddoa Reservoir, Operation No. 2.

5. Caddoa Reservoir, Operation No. 2.

Graphs - Reservoir Data.

1. Caddoa Reservoir, Operation No. 2.

2. Outflow at Colorado-Kansas State Line, With and Without Caddoa Reservoir.

3. Diversions by the Fort Lyon Canal (1912 - 1936)

4. Diversions by the Amity Canal. (1912 - 1936)

Tables - Crop Data. (1923 - 1936)

Bent, Prowers and Weld Counties.

1. Per Cent of Acreage in Row, Cereal and Forage Crops.

2. Acreage and Production of Winter and Spring Wheat.

7.

Bent and Prowers Counties.

1. Annual Production and Crop Values (Irrigated) using unit pric
14 year average.

2. Table of Crop Values, Car-loadings and Water Diversions.

Bent County.

1. Crop Values using Mean Acreage Base.

2. Crop Values using Unit Price 14 year Average.

3. Acreage and Production.

4. Per Acre Production.

5. Acreage of Seven Principal Crops.

Prowers County.

1. Five Tables the same as for Bent County.

Weld County.

Five Tables the same as for Bent and for Prowers Counties.