UNITED STATES
DEPARTMENT OF THE INTERIOR
Harold L. Ickes, Secretary

BUREAU OF RECLAMATION
John C. Page, Commissioner

RECONNAISSANCE REPORT ON REPUBLICAN RIVER BASIN

COLORADO, NEBRASKA
and
KANSAS

March 1940

Project Investigations Report No. 41.

SYNOPSIS

A storage development is needed above Wray on the North Fork of the Republican River to provide supplemental water for 3,420 acres of irrigated lands. By development of the available water supply at this site, a new irrigation development of 2,000 acres may be served. Flood control would be of minor importance. A report on this project is being prepared.

Buffalo Creek, a north side tributary entering the Republican River near Haigler, has an annual winter flow of about 4,500 acre-feet, that could be conserved with a storage development on that creek, for use by lands on that stream and in the main valley immediately adjacent.

The Arikaree Drainage Basin presents about the only opportunity for new irrigation developments in the State of Colorado. Such a development would fill a real need in assuring a reliable feed supply for livestock on a surrounding dry farm and grazing area. Storage is required for irrigation and flood control. The most favorable reservoir site on this stream appears to be the Beecher Island site, since it will allow irrigation of most lands in Colorado and afford flood protection for lower lands.

The South Fork of the Republican River presents a similar opportunity for a new irrigation development in the State of Kansas where it is most needed. The most favorable reservoir site on this stream appears to be the Hale site, since it will allow project

return flows to be used on more favorable lands.

Storage is needed in the Frenchman Creek Basin to supplement existing irrigation, and for new irrigation developments, which are limited by the available water supply.

Developments in the Beaver-Sappa Drainage Basin will be limited by the available water supply. Lack of water precludes development in Kansas.

A large storage capacity at the Harlan County site for extensive flood protection would submerge a possible irrigation development on Prairie Dog Creek below the Woodruff Dam site. Developments requiring storage at the Harlan County site appear to be more desirable. Storage in the Almena or Clayton Reservoir sites would permit irrigation of about 10,000 acres in Kansas, but such storage would be very costly and submerge the towns at these sites. The benefits do not justify such expenditure and destruction.

In the Republican River Valley below the Wray development near Haigler and above Culbertson, about 10,000 acres can be developed with the aid of reservoirs near the mouth of the Arikaree and South Fork, which reservoirs would also protect the Republican River Valley so heavily damaged by the 1935 flood.

Between Red Willow Creek and the Harlan County Dam site about 28,500 acres are suitable for development, with the aid of storage on Medicine Creek and possibly also on Red Willow Creek. Diversion dams in Republican River are costly, and pumping from

the stream will probably prove preferable in some instances to utilize uncontrolled stream flow and return flow.

Between the Harlan County Dam site and Scandia, Kansas, about 54,000 acres of valley lands and about 9,000 acres of table lands can be developed with the aid of a reservoir on the main Republican River at the Harlan County site. The reservoir could also provide flood protection for lands and improvements which suffered heavy damage in the 1935 flood.

With the aid of storage development, about 90,000 acres can be developed on the Scandia Project in the Republican River Valley between Scandia and Clay Center, Kansas. Storage for this area may be provided at the offstream White Rock Reservoir site and enable some power production. The Scandia Reservoir site on the Republican River would provide both irrigation and needed flood control. The White Rock Project would utilize the White Rock Reservoir for the irrigation of 75,000 acres of upland area southwest of Scandia. If this project were built, the Scandia Project would need to be reduced to 45,000 acres and the Scandia Reservoir would be required for that area.

Ground water developments in the Republican River Valley below McCook appear to have favorable irrigation possibilities. Valley fills are largely sand with some clay and gravel strata. Several wells are in operation and yield one to three second-feet. Wells are 50 to 70 feet deep, with static water levels from 20 to

40 feet below the surface and pumping levels 15 to 20 feet lower. A limited amount of this type of irrigation can be developed without artificial recharge of under ground basins. However, with a heavy draft on ground waters, water levels may drop beyond an economic pumping limit. With gravity irrigation developments on higher lands, return flows would assure a substantial recharge to ground water basins, depleted by pumping. With further investigations of irrigation developments in the valley below McCook, ground water developments should be carefully studied.

Available information indicates that irrigation construction costs may be about the same as repayment ability for an irrigation development, with storage provided in a dual reservoir for complete flood control of the Republican River at the Harlan County site. In other instances, construction costs will exceed repayment ability, whether reservoirs be built for irrigation alone or for the dual purposes of irrigation and flood control. Power values exist on some of the projects but they are not sufficient to assist materially in improving economic feasibility. Stabilization of dry land agriculture by means of irrigation adds an intangible but significant value to irrigation in the western part of the drainage basin.

Storage developments will add recreational opportunities and bird life refuges of material value but not of sufficient value to be significant in considering feasibility.

TABLE OF CONTENTS

RECONNAISSANCE OF THE REPUBLICAN RIVER BASIN

General

A reconnaissance survey of the Republican River Basin has been made primarily to determine the potential irrigation developments of the entire basin, and the related incidental developments of power, flood control, navigation, wild life, and recreation.

A number of the potential projects principally irrigation and flood control, have been investigated at different times by various agencies and individuals and several multiple-use projects have been proposed. The available information indicates incidental developments of power to be of importance, while navigation, wild life, and recreation are minor.

The Republican River Basin lies in Colorado, Nebraska, and Kansas, with existing and contemplated irrigation developments in all three states. To avoid expensive litigation as a result of possible conflicting uses of water in the various states, further developments for irrigation should be preceded by a three-state compact or other similar agreement on use of water.

Numerous irrigation developments using natural stream flows were attempted during the dry years of the early nineties, most of which were abandoned because of an insufficient sustained water supply, excessive costs, or an increasing rainfall with less demand for irrigation. Following the dry years since 1930, the

interest in irrigation has increased.

Acknowledgment is made to the United States Engineers, whose "308" report, House Document 195, 73d Congress, 2d Session, was drawn on freely, and who made available unpublished factual information from recent studies.

Description of Basin

The Republican River heads in the table lands of Eastern Colorado, flows northeast and east about 250 miles through Nebraska, entering Kansas near Superior, and thence scutheast to its confluence with the Smoky Hill River at Junction City, Kansas, at which point the Kansas River is formed. The total watershed area is 24,955 square miles. Its principal tributaries and their drainage areas are:

North Fork Republican River	1,998	square miles
Arikaree River	1,918	" "
South Fork Republican River	2,726	" "
Frenchman Creek	3,765	" "
Red Willow Creek	742	" "
Medicine Creek	874	" "
Beaver Creek (1)	3,789	" "
Prairie Dog Creek	1,007	" "
Total-	16,819	" "

(1) Includes 1,622 square miles in Sappa Creek drainage area.

The north side tributaries, the North Fork of the Republican River, Frenchman, Red Willow, and Medicine Creeks drain sand hill areas; these streams are perennial, and supply most of the base flow of the Republican River. The south side tributaries of the basin are intermittent, with flashy run-off after storms.

It is on these streams that most of the disastrous floods have originated, causing damage downstream as far as Kansas City, on the Kansas River.

The elevation of the basin ranges from about 1,100 feet at Junction City, Kansas, to about 5,500 feet on the headwaters of the South Republican near Bovina, Colorado. The Republican River flows through a valley, which, throughout most of its course, has a width of two or three miles, with bordering uplands rising 100 to 200 feet above the valley floor. The main valley and those of its principal tributaries are bordered by a definite system of terrace benches.

Climate

The basin marks the change from semiarid to sub-humid climatic conditions. Average annual precipitation is about 21 inches, ranging from 28.3 inches at Clay Center, Kansas, in the east, to 17 inches at Arriba, Colorado, in the west, but declines to amounts one-third less in dry periods.

The average number of days between the last killing frost in the spring and the first in the fall varies from about 175 in the eastern part of the basin to about 145 days in the west. The average annual growing season may be 20 to 30 days longer. Average annual temperatures range from 45 to 48 degrees.

Crops

The principal crops grown in the basin under normal moisture conditions are corn, small grain, alfalfa, and grass hay.

Since 1931 crops have either failed or yielded poorly, and three years of severe drought have occurred.

Under average conditions, yields under irrigation and dry farming in the Republican River Valley are:

Crop	Unit	Average Yield Irrigated	Dry-Farmed
Corn	Bu.	30 - 70	15 - 20
Wheat	"	20 - 40	10 - 14
Oats	"	35 - 70	20 - 26
Potatoes	"	175	80
Alfalfa	Ton	3 - 3.5	1.5 - 2.0

Irrigation

Present irrigation developments depend almost without exception on unregulated stream flow. The North Fork of the Republican River and Frenchman Creek are the most important streams, and their irrigation season flows are over appropriated. Junior rights are short of water much of the time, and it is not uncommon for the older rights to be short during a dry season. Return flow is an important factor in the water supply in the Republican River Valley at present and can be expected to increase in importance with any further irrigation development.

Throughout the basin isolated areas of from a few hundred to about 2,000 acres of bottom and terrace lands are found, some of which have been irrigated. In the event cheap power can be furnished during the irrigation season, it is probable some of these areas may become attractive pumping projects.

Several irrigation wells are in operation in the basin, mostly in the Republican Valley below McCook, Nebraska. Yields of one to three second-feet are secured. Wells are from 50 to 70 feet deep, with static water levels from 20 to 40 feet below the surface. A limited amount of this type of development can be expected without storage regulation.

Water Rights

Active water rights cover about 38,000 acres of irrigated land distributed throughout the basin. In addition there are several inactive rights and filings. The following hydropower plants have water rights that might be affected by future irrigation developments:

Plant	Stream	Location	Installed Capacity (kw.)
Wray (1)	North Fork	At Wray, Colorado Sec.6, T. 1 N., R.43 W.	-
Krotter-Palisade	Frenchman Cr.	Near Palisade, Nebr. S.35, T.5 N., R. 34 W.	264
Oliver Bros. (2)	Frenchman Cr.	2 mi.below Wauneta,Neb. S.7, T.5 N., R. 35 W.	-
Wauneta Light and Power Company	Frenchman Cr.	Wauneta, Nebraska S.11, T. 5 N., R. 36 W.	125
Williams & Enders	Frenchman Cr.	Near Enders, Nebraska S.5, T.5 N., R. 37 W.	40
Imperial	Frenchman Cr.	5 mi.S.W. of Imperial, Nebraska S.25, T.6 N., R.39 W.	245
So.Nebr.Power Co.	Republican R.	Near Superior, Nebraska S.34, T.1 N., R.7 W.	785
Kansas Power & Light Co. (3)	Republican R.	Clay Center, Kansas	900

(1) Used occasionally to grind grain for stock feed - water right 50 second-feet.
(2) Small plant for farm use.
(3) Not used since 1935.

With further studies, the status of existing water rights should be determined.

Water Supply

Available run-off records pertinent to basin water supplies are given in discussion of individual basins.

consecutive days at McCook, Nebraska, from 1914 to 1939:

Year	Precipitation in Inches: Annual	Apr.-Sept.	Extended Dry Periods, March-Sept, Inc. During which 1/2" or less of Precipitation fell in 20 consecutive Days. Mar.	Apr.	May	June	July	Aug.	Sept.
1914	18.24	15.06							
1915	30.95	26.37							
1916	15.35	13.14							
1917	16.19	13.83							
1918	19.09	14.21							
1919	15.61	10.22							
1920	18.35	13.71							
1921	-								
1922	13.99	11.50							
1923	28.41	22.41							
1924	15.63	8.64							
1925	20.16	16.66							
1926	17.30	13.76							
1927	22.65	16.69							
1928	23.81	18.92							
1929	20.57	15.55							
1930	38.26	26.55							
1931	19.77	10.02							
1932	16.43	13.58							
1933	21.14	17.22							
1934	16.26	12.14							
1935	20.29	17.35							
1936	13.70	11.80							
1937	15.10	9.82							
1938	19.10	17.02							
1939		11.08							
Average	19.85	15.08							

Water Requirements

The average consumptive use of water during the growing season in the basin is estimated at about 2.3 feet or 28 inches per year. With an average precipitation in dry periods of from 12 inches in the western end to 20 inches in the eastern end, about 20% of which may be lost through run-off and deep percolation, there is a deficiency of 18 inches to 12 inches of water for plant use. Farm deliveries will vary throughout the basin with precipitation occurring during the growing season. Sandy soil types, particularly in the western part of the basin result in relatively high percolation and transportation losses. An average annual diversion requirement of fully 3.5 acre-feet per acre is generally needed in the area west of Culbertson, Nebraska, and may decrease to 2.5 acre-feet per acre, or even less, in the eastern part of the basin.

Diverted waters in excess of consumptive use requirements produce substantial dependable return flows fully utilized in the irrigation season but still largely escaping for lack of reservoirs to conserve such waters in the non-irrigation season.

Irrigation is needed only to supplement rainfall. About 75% of the annual precipitation occurs from April through September; however, in most every year one or more dry periods of 20 days or more can be expected. The following table shows the annual and April to September inclusive, precipitation and extended dry periods during which one-half inch or less of precipitation fell in 20

Existing Irrigation Development

The "308" report of the United States Engineers reports the irrigated area in the basin at 32,680 acres. A summary of the irrigated area including areas irrigated from wells in 1939, as obtained from available information follows:

State	Drainage Basin	Irrigated Areas in Acres	
Colorado	North Fork Republican River and tributaries	1,680	
	South Fork Republican River and tributaries	6,800	
	Arikaree	120	8,600
Nebraska	Republican River including North Fork	8,100	
	Frenchman Creek including Stinking water creek	16,680	
	Miscellaneous streams	4,170	28,950
Kansas	South Fork Republican River	200	* 200
	Total		37,750
	Total in round numbers		38,000

*Some small additional areas in Beaver and Sappa Valleys

Irrigation Possibilities

Possible irrigation developments are presented by sub-drainage basins and convenient sections along the main stem of the Republican River. Not all of the irrigated acres listed can be provided with supplemental water, since reservoir sites are lacking above these areas. A summary of the possible developments by sub-basins follows:

Sub-Drainage Basin	Area - Acres		
	(1) Arable	Irrigated	Total
North Fork Republican River	-	3,420	3,420
Arikaree River	6,400		6,400
South Fork Republican River	17,000	200	17,200
Frenchman Cr. below Enders Dam Site, including Republican River Valley between Culbertson and Red Willow Creek	42,000	15,520	57,520
Beaver - Sappa Creeks	24,000	400	24,400
Prairie Dog Creek	16,000	400	16,400
Main Stem Republican River			
Haigler to Culbertson	13,000	1,560	14,560
Red Willow Creek to Republican City	32,000	(2) 500	32,500
Republican City, Nebraska, to Scandia, Kansas	63,000	(2) 500	63,500
Below Scandia, Kansas	90,000	-	90,000
White Rock Project	75,000	-	75,000
Total	378,400	22,500	400,900

(1) Lands meeting requirements for successful irrigation, except as availability of water is not assured.

(2) About 1,000 acres of irrigated land, in Republican Valley below Red Willow Creek, served mostly by individual pumps and was not measured in each section of the river separately.

North Fork Republican River Drainage Basin

This basin comprises the Republican Valley from the headwaters of the North Fork of the Republican River to its confluence with the Arikaree River near Haigler, Nebraska.

Most all of the valley lands are irrigated. The irrigated area comprises 3,420 acres; 1,180 acres lying in Colorado, and 2,240 acres in Nebraska. Natural flow is not sufficient to supply irrigation demands during the latter part of the irrigation season. Much water escapes in winter.

Storage can be provided in the Wray Reservoir site a few miles above Wray, Colorado, to provide supplemental water for the irrigated land and for 2,000 acres additional.

This area is being investigated by the Bureau of Reclamation as the North Republican Project, and a report thereon is in preparation. Storage is to be provided in the Wray Reservoir site, at a cost of about $800,000 for the larger plan. There have been no floods on this stream, stream flow being substantially uniform.

Buffalo Creek Drainage Basin

Buffalo Creek, a north side tributary entering the Republican River between Haigler and Parks has a dependable annual run-off of about 8,000 acre-feet. Summer flows are over appropriated. Storable flows from November through April average about 4,500 acre-feet. Storage can be provided in the Buffalo Creek Reservoir site, located a short distance above the mouth of the stream.

There are a few thousand acres of scattered valley lands above the dam site, but no storage site was found to provide a reliable water supply for these lands.

There are about 525 acres of irrigated lands and about 200 acres of arable lands below the dam site along Buffalo Creek. Arable lands can be reached by a diversion from the creek at a moderate cost. Water not required for use in this basin can be used on lands in the Republican River Valley immediately adjacent. A new development of about 1,500 acres can be obtained.

Arikaree Drainage Basin

The Arikaree River is subject to flashy flows, from early spring to fall, which may vary from a few second feet to several thousand in a few hours. It generally has flows at Haigler, Nebraska, of from about 10 to 50 second-feet during fall and winter months, 20 to 70 second-feet from March through June and from zero to about 30 second-feet from July through October. Run-off of the Arikaree River near Haigler, for the period of record, with estimated run-off at the Beecher Island and Idalia sites is given in the following table:

Year	Run-off of Arikaree River in Acre-Feet		
	(1) Near Haigler Drainage Area 1,920 Square Miles	* Beecher Island Dam Site, Drainage Area, 1,740 Square Miles	* Idalia Dam Site Drainage Area 1,570 Square Miles
1929-1930	20,700	18,200	15,300
1930-1931	13,000	11,400	9,600
1931-1932	-	-	-
1932-1933	24,200	21,200	18,100
1933-1934	15,000	13,200	11,200
1934-1935	91,700	80,300	68,300
1935-1936	16,000	14,000	11,900
1936-1937	12,300	10,800	9,200
1937-1938	28,000	24,600	20,800
1938-1939	10,600	9,300	7,900
Average	25,500	22,600	19,100
Average exclusive of 1934-1935	17,500	15,300	13,000

(1) Record from Geological Survey and Nebraska State Engineer. Contains some wastes from Pioneer Canal.

* Estimated.

Most of the run-off given in the foregoing table is available for future irrigation use. A small amount of upstream depletion may result from small reservoirs for recreation and stock water, and from small irrigation developments contemplated in the Water Facilities program of the Department of Agriculture.

Storage is essential for development, not only for irrigation but also to provide flood protection for local areas if developed, and benefits thereof would extend into the Republican Valley in Nebraska. The best sites so far found are as follows:

Arikaree Reservoir Site

Assumed Elevation	Reservoir Capacity	Valley Width at Dam Site
110	0 acre-feet	100 feet
120	165 "	1,950 "
140	3,100 "	2,100 "
160	10,900 "	2,400 "
180	24,500 "	2,800 "
200	45,500 "	3,600 "
220	75,000 "	4,500 "
230	94,000 "	4,700 "

Borings have not been made at this site.

Idalia Reservoir Site

Elevation	Reservoir Capacity	Valley Width at Dam Site
3710	0 acre-feet	500 feet
3720	366 "	2150 "
3760	10,800 "	3450 "
3780	42,000 "	4300 "
3850	300,000± "	6700 "

This site was surveyed by the United States Engineer Department. Borings are not available at this site.

Beecher Island Reservoir Site

Elevation	Reservoir Capacity	Valley Width at Dam Site
3530	300 acre-feet	1,600 feet
3550	4,400 " "	3,500 "
3570	16,500 " "	4,300 "
3590	42,300 " "	5,100 "
3610	84,500 " "	5,900 "
3630	146,600 " "	7,800 "
3650	231,200 " "	8,500 "

This site was surveyed by the United States Engineer Department. Borings by United States Engineers indicate Pierre Shale is found at depths of about 15 feet in the left abutment, about 40 feet in the right abutment, and about 8 feet at stream level.

There are several thousand acres of scattered arable valley lands along the Arikaree above the Idalia Dam site. Canals to service these shoestring areas would be relatively costly, if built for permanency. No reservoir sites have been found to provide a reliable water supply for these areas. Soils are light and sandy. Railroad shipping facilities are at a distance of 25 to 30 miles. Water available for these lands can be used to better advantage on other lands.

Below the Idalia Dam site the arable valley lands are as follows:

Colorado		
	Between Idalia and Beecher Island Dam sites, about 1/3 within Beecher Island Reservoir site	1,000 acres
	Below Beecher Island Dam site	3,800 "
	Subtotal-	4,800 "
Kansas		600 "
Nebraska		1,000 "
	Total-	6,400 "

Some of this land is very sandy and upon more detailed land classification may be eliminated. Lands at higher levels cannot be practicably substituted.

Arable lands can be reached by canals diverting from the Arikaree at a moderate cost.

There appears to be little difference in storage costs in the three reservoir sites. Rough computations, with consideration to return flow, indicate about 3,000 acres can be irrigated with storage at the Idalia Reservoir site and about 3,800 acres with storage at the Beecher Island site. The Beecher Island site appears to be the most favorable at this time, since it will intercept more run-off, ensure greater flood control and will allow irrigation of as much land in Colorado as storage in the upper sites.

This basin presents the most likely possibilities in the entire Republican River Drainage Basin for new irrigation developments in Colorado. Indications are a dual purpose reservoir may cost about $6,000,000.

While a storage development would stabilize agriculture on a surrounding dry farm area of some extent by assurance of a feed supply for live stock, available information indicates storage costs may be materially beyond repayment ability, even in a dual purpose reservoir for flood control and irrigation.

South Fork Republican River Drainage Basin

The South Fork of the Republican River is subject to flashy flows, from early spring to fall, which may vary from a few

second-feet to several thousand in a few hours. It has flows near Benkelman, Nebraska, generally of from 10 to 80 second-feet during fall and winter months, 20 to 200 second-feet from March through June, and from nothing to about 200 second-feet from July through October. Run-off of the South Fork of the Republican River near Benkelman, for the period of record, with estimated run-off at the Hale Dam site is given in the following table:

Year	Run-off of South Fork Republican River (In acre-feet)	
	(1) Near Benkelman Drainage Area 2,726 Sq. Miles	* Hale Dam Site Drainage Area 2,000 Sq. Mi.
1930-1931	49,700	26,900
1931-1932	52,600	28,500
1932-1933	50,900	27,500
1937-1938	61,000	29,300
1938-1939	23,900	12,900
Average	49,500	25,000

(1) From Geological Survey and Nebraska State Engineer
* Estimated.

Most of the run-off in the foregoing table is available for future irrigation use. A small amount of upstream depletion may result, from small reservoirs for recreation and stock water and from small irrigation developments, contemplated under the Water Facilities program of the Department of Agriculture.

Storage is essential for development, not only for irrigation but also to provide flood protection for local areas if developed, and benefits thereof would extend into the Republican

Valley in Nebraska. The best sites so far found are as follows:

Hale Reservoir Site

Elevation	Reservoir Capacity	Valley Width at Dam Site
3550	0 acre-feet	400 feet
3555	0 " "	3,000 "
3560	150 " "	3,900 "
3580	6,290 " "	4,900 "
3600	32,800 " "	5,700 "
3620	84,560 " "	6,800 "
3640	171,800 " "	8,700 "
3660	302,340 " "	11,000 "
3680	485,775 " "	14,000 "

This site was surveyed by United States Engineer Department. Borings by United States Engineers indicate Pierre Shale at a depth of about 65 feet across the valley and at a greater depth in the abutments. Overburden is sand, sandy clay, or a gravelly sand.

St. Francis Reservoir Site

Survey or borings are not available, but the site appears to have about the same reservoir capacity, and valley widths at the dam site, as the Hale site.

There are about 6,800 acres of irrigated valley lands along the South Fork and its tributaries above the Hale Dam site. This area comprises most of the valley lands, and depends on unregulated streamflows, with wild hay as the principal crop. The only reservoir sites found for use on these lands were on the head waters of the main stream or tributaries, but due to a meager run-off at these points, these sites are of little value for irrigation or flood control purposes.

Arable and irrigated lands lie below the Hale and St. Francis Dam sites as follows:

Location	Land Areas in Acres			
	Below Hale Dam Site		Below St. Francis Dam Site	
	Irrigated	Arable	Irrigated	Arable
Dam site to St. Francis, in Kansas	200	11,000	200	(1) 7,000
Below St. Francis in Kansas		5,500		5,500
Nebraska		500		500
Total	200	17,000	200	13,000

(1) Area that can be reached by a diversion near reservoir dead storage level, arable area would be materially less for a diversion from the river below the dam.

Some of this land is very sandy and upon more detailed land classification may be eliminated.

Arable lands above St. Francis can be reached by canals diverting from the South Fork at a moderate cost.

Arable lands below St. Francis lie in long narrow strips. Canals to service these areas would be relatively costly if built for permanency. The water available for these lands can be used to better advantage on the area above St. Francis, except as return flow from areas above St. Francis would be usable below.

Rough computations with consideration to return flow indicate an area of about 5,000 acres can be irrigated from either reservoir site.

Available information indicates the Hale Reservoir site to be the better at this time, since it will allow a larger irrigation development on higher lands and permit use of return flow on more favorable lands.

While a storage development would stabilize agriculture on a surrounding dry farm area of some extent by assurance of a feed supply for livestock, and would assure a greater variety and increased yields of cash crops, since railroad shipping facilities are available at St. Francis, available information indicates reservoir costs may be materially beyond repayment ability in a dual purpose reservoir for flood control and irrigation. Indications are a dual purpose reservoir will cost about $7,000,000.

Frenchman Creek Drainage Basin

Frenchman Creek drains a sand hill area and has a very uniform run-off. It has sustained flows at Hamlet, Nebraska, of from 90 to 115 second-feet during fall and winter months, 90 to 130 second-feet from March through June and from 70 to 100 second-feet from July through October. Stinking Water Creek, a tributary with a drainage area of 1,200 square miles, joins Frenchman Creek near Palisade, and has flows about 1/3 as large at its mouth as Frenchman Creek at Hamlet. Run-off for the period of 1931 through 1939, of Frenchman Creek near Culbertson, and at Hamlet with the estimated run-off at the Enders, Harvey, and Palisade Dam sites is given in the following table:

Year	Run-off in Acre-Feet				
	Frenchman Creek				Stinking Water Creek
	(1) At Culbertson: Drainage Area 3,753: Sq.Mi.	(1) At Hamlet: Drainage Area 2,386: Sq. Mi.	(2) At Enders Dam Site, Drainage Area 2,240 Sq.Mi.	(2) At Harvey Dam Site, Drainage Area 2,140 Sq.Mi	(2) at Palisade Dam site, Drainage Area 1,113 Sq.Mi.
1930-1931:	85,700	72,700	64,700	59,000	23,500
1931-1932:	84,200	70,900	63,100	58,000	22,900
1932-1933:	89,500	73,600	65,500	60,500	23,800
1933-1934:	85,500	76,200	66,400	62,500	24,600
1934-1935:	124,900	80,200	79,800	65,800	26,000
1935-1936:	82,700	74,000	65,800	60,700	24,000
1936-1937::	67,600	65,300	58,100	53,500	21,100
1937-1938:	83,700	68,800	61,100	56,500	22,100
1938-1939::	67,800	61,100	54,400	50,100	19,800
Average	85,700	71,400	64,300	58,500	23,000

(1) Records taken by Nebraska State Engineer and Geological Survey.
(2) Estimated.

Run-off from November through April is available for storage, providing proper arrangements are made for the Frenchman Creek power plants below the reservoir sites. Storable run-off is estimated at about 31,000 acre-feet at the Enders site, about 28,000 acre-feet at the Harvey site, and about 12,000 acre-feet at the Palisade site. About 46,000 acre-feet are divertible to the Blackwood site.

A small amount of upstream depletion may result from small developments for recreation, stock water, and irrigation, which might be constructed under the Water Facilities program of the Department of Agriculture.

Irrigation shortages of from 5,000 to 10,000 acre-feet exist most every year. Storage is essential for future irrigation development and desirable for supplemental irrigation. Little flood control is required, since flows are very uniform and little damage has resulted from maximum flows. The best sites so far found, are as follows:

Enders Reservoir Site

Elevation	Reservoir Capacity	Valley Width at Dam Site
3040	0 acre-feet	50 feet
3050	500 "	700 "
3060	2,000 "	780 "
3080	9,000 "	1,100 "
3100	27,500 "	1,850 "
3120	58,000 "	2,350 "
3140	108,000 "	3,050 "

This site was surveyed by the United States Engineer Department. Borings by United States Engineers indicate foundation material to be mostly sand to depths greater than 150 feet.

Harvey Reservoir Site

Elevation	Reservoir Capacity	Valley Width at Dam Site
3145	210 acre-feet	- feet
3155	1,205 "	400 "
3165	3,555 "	500 "
3175	7,655 "	600 "
3185	14,680 "	650 "
3190	20,000 "	1,800 "
3200	34,500 "	2,300 "
3205	43,825 "	2,700 "

This site was surveyed by the United States Engineer Department. Boring records are not available at this site.

The capacity of this reservoir is limited to about 30,000 acre-feet for economical dam construction. The Imperial Hydro Electric Power Plant, with an installed capacity of 245 kw. and a head of about 15 feet, is located in the upper end of the reservoir site at an elevation of about 3,200.

Palisade Reservoir Site

No survey is available at this site. A 12,000 acre-foot reservoir would require a dam about 42 feet high with a crest length of about 2,500 feet, and a length at its base of 950 feet.

Blackwood Creek Reservoir Site

This reservoir site is located in Blackwood Creek some five miles north of Culbertson. The site has been surveyed for private parties but the data have not become available. A dam about 2,500 feet long and about 70 feet high would be required for a reservoir capacity of 40,000 acre-feet. Blackwood Creek has little flow and the major supply would be through a five-mile extension of the Culbertson Canal, having a capacity of about 150 second-feet, and about 33 miles long diverting from Frenchman Creek below its confluence with Stinking Water Creek. A storage development at this site would avoid interference with power plants in Frenchman Creek.

With the development of the Harvey or Enders Reservoir sites, it would be necessary to purchase the hydropower plants since the Krotter-Palisade plant with an installed capacity of 264 kw. operates under a head of ten feet and uses the entire flow of Frenchman Creek. There are several thousand acres of scattered valley lands along Stinking Water Creek both above and below the Palisade Dam site, and about 500 acres of irrigated lands lying principally below the dam site. Water available for arable lands can be used to better advantage on lower lands in the Frenchman Valley.

About 3,480 acres of irrigated lands lie along Frenchman Creek above the Enders Dam site. No reservoir sites were found to provide a reliable supplemental water supply for these lands.

There are 15,520 acres of irrigated lands, and about 12,000 acres of arable valley lands lying in the Frenchman Valley below the Enders Dam site, along Blackwood Creek and in the Republican River Valley between Culbertson and Red Willow Creek. Of the 15,520 acres of irrigated lands, 2,890 are irrigated from the Republican River. About 2,000 acres of arable valley lands are light and sandy. Arable lands lie in five separate tracts to be served by five separate distribution systems, and are listed as follows:

Hamlet Unit	1,960	acres
Follette and Krotter Canal Extension	3,440	"
Blackwood Creek Unit	1,640	"
Farmers Canal Extension	2,800	"
Meeker Canal Extension	1,640	"
Total (round numbers)	12,000	"

The Hamlet Unit can be serviced by a diversion from Frenchman Creek. Other areas require enlargement and extension of existing canals. Canal enlargement and extension may be relatively expensive for the Blackwood Unit. Other areas can be reached at a moderate cost.

An arable area of a few thousand acres of table lands lying south of Palisade can be reached by a canal diverting from Frenchman Creek below Enders Dam site. The canal would be costly.

Water available for this area can be used to better advantage on other lands.

About 30,000 acres of excellent arable table lands between Blackwood and Red Willow Creeks can be reached by an enlargement and extension of the Culbertson Canal. Since the valley lands can use the available water supply it does not appear desirable to develop this area.

With consideration to return flow, rough computations indicate with storage at various reservoir sites, after allowing for a supplemental supply of 10,000 acre-feet, the following new irrigation developments can be made:

Reservoir Site	Allowable New Irrigation Development
Harvey	7,000 acres
Enders	8,000 "
Palisade (On Stinking Water Creek)	3,500 "
Blackwood Creek	11,000 "

Further study is necessary to determine the most favorable plan of development with these reservoir sites.

The cost of a dual purpose reservoir providing a limited amount of flood protection on Frenchman Creek or Blackwood Creek may exceed $1,500,000.

While a storage development would assure greater variety and increased yields of cash crops, available information indicates storage costs may be somewhat beyond repayment ability of the benefited lands even with a reservoir for flood control and irrigation.

Beaver Creek Drainage Basin

This basin comprises the drainage area of Beaver and Sappa Creeks.

These creeks are subject to flashy flows, from early spring to fall, which may vary from a few second-feet to several thousand in a few hours. They generally have flows near Beaver City, Nebraska, of from nothing to a few second-feet. Flood flows of several thousand second-feet may occur during spring and summer months, during and shortly after storms. Run-off of Beaver Creek near Beaver City, and near Ludell, Kansas; and of Sappa Creek near Beaver City, and near Oberlin, Kansas, for a period of record is given in the following table:

Year	Run-off in Acre Feet			
	Beaver Creek		Sappa Creek	
	(1) Near Beaver City, Nebraska Drainage Area 1,964 Sq. Mi.	(2) Near Ludell Kansas-Drainage Area 1,390 Sq. Mi.	(1) Near Beaver City, Nebraska Drainage Area 1,492 Sq. Mi.	(2) Near Oberlin, Kans. Drainage Area 1,070 Sq. Mi.
1929		(3) 3,620		(3) 5,600
1929-1930		3,970		12,500
1930-1931		5,620		16,500
1931-1932		(4) 2,360		3,540
1937-1938	16,320		19,250	
1938-1939	12,510		15,190	

(1) Records by Geological Survey.
(2) Records by Kansas Division of Water Resources.
(3) Period, March 18 through September 1929.
(4) Period, October 1931 through June 1932.

Most of the run-off given in the foregoing table is available for future irrigation use. A small upstream depletion may

result from small reservoirs for recreation and stock water, and from small irrigation developments, contemplated under the Water Facilities program of the Department of Agriculture.

Storage is essential for future irrigation development and for flood protection of new areas if developed, and desirable for existing improvements with benefits entending into the Republican Valley. The best sites so far found are as follows:

Beaver City Reservoir Site
on Beaver Creek

Elevation	Reservoir Capacity	Valley Width at Dam Site
2160	0 acre-feet	25 feet
2170	0 " "	650 "
2180	490 " "	2,200 "
2190	2,430 " "	2,400 "
2220	34,900 " "	3,100 "
2240	91,230 " "	3,200 "
2250	135,530 " " estimated	4,300 "
2260	193,300 " " "	-

This site was surveyed by the United States Engineer Department. Borings by the United States Engineers indicate shale is found at depths of 20 to 30 feet across the bottom, at about 65 feet in the left abutment and at about 100 feet in the right abutment. Material overlying the shale is generally sand or a sandy loam. A branch line of the Burlington Railroad traverses the site and an improved oiled highway crosses it.

Herndon Reservoir Site
on Beaver Creek

This site has not been surveyed. The dam and reservoir sites appear to have about the same physical proportions as the Beaver City site. A branch line of the Burlington Railroad traverses the site. A meager water supply makes this site of little value for irrigation development.

Sappa Creek Reservoir Site

Elevation	Reservoir Capacity	Valley Width at Dam Site
2140	0 acre-feet	20 feet
2145	0 " "	200 "
2155	0 " "	2,200 "
2175	4,000 " "	3,100 "
2180	7,360 " "	4,300 "
2200	41,360 " "	5,050 "
2220	15,990 " "	5,500 "
2235	200,000 " "	5,900 "

This site was surveyed by the United States Engineer Department. Borings by the United States Engineers indicate shale is found at depths of about 30 feet across the bottom and at depths varying to about 60 feet in the left abutment. A soft fractured limestone is found near the surface in the right abutment.

Norcatur Reservoir Site on Sappa Creek

Assumed Elevation	Reservoir Capacity	Valley Width at Dam Site
0	0 Acre-feet	15 feet
20	0 " "	240 "
40	4,500 " "	2,220 "
60	26,000 " "	2,670 "
80	67,000 " "	3,205 "
100	134,000 " "	4,030 "

Information from a rough reconnaissance survey. Elevation assumed.

Oberlin Reservoir Site on Sappa Creek

This site was not surveyed. A cursory examination indicates this reservoir site to be of similar physical proportions to the Norcatur Reservoir site; valley widths at the dam site are about the same. The available water supply at this site makes it of little value for an irrigation development.

There are several thousand areas of scattered arable valley lands along Beaver and Sappa Creeks lying between creek meanders, above the Beaver City and Sappa Creek Dam sites. Canals to serve these areas would be relatively costly if built for permanency. In view of the meager water supply available at possible storage sites, water available for these lands can be used to better advantage on lands below the Beaver Creek and Sappa Creek sites.

Below the Beaver City and Sappa Creek Dam sites, to the Republican River, there are about 24,000 acres of arable and about 400 acres of irrigated valley lands. Run-off at these sites is about equal.

Arable lands can be reached by canals diverting from the creeks at a moderate cost.

There appears to be little difference in storage costs in the Beaver City and Sappa Creek Reservoir sites; both are required to develop the available water supply. Rough computations with consideration to return flow indicate about 9,000 acres can be irrigated.

Available information indicates storage costs in reservoirs for flood control and irrigation to be materially beyond repayment ability. Costs of dual purpose reservoirs may exceed $5,000,000 at each site.

Prairie Dog Creek Drainage Basin

Prairie Dog Creek near Woodruff, Kansas, ordinarily flows from nothing to a few second-feet, but may increase up to several thousand second-feet during, and shortly after storms. Run-off of Prairie Dog Creek near Woodruff for the period of record is given in the following table:

Year	Run-off, Prairie Dog Creek (1) near Woodruff, Kansas, Drainage Area 937 square miles.
March 13 - September 1930	25,500 acre-feet
1929-1930	31,700 " "
1930-1931	34,100 " "
1931-June 1932	24,100 " "

(1) Record from Kansas State Division of Water Resources.

Run-off at the Almena Dam site will be practically the same as at Woodruff, and somewhat less at the Clayton site.

Most of the run-off in the foregoing table is available for future irrigation use.

Construction of small upstream reservoirs for stock water and recreation, and small irrigation developments would cause a minor depletion.

Due to the flashy and undependable flows of this stream, storage is essential for irrigation and flood protection of developed low lands. Benefits would extend downstream to the Republican River Valley in Nebraska. The best sites so far found are as follows:

Clayton Reservoir Site

This site has not been surveyed. A cursory examination indicated little difference in the physical proportions of the dam site or reservoir capacity, as compared to the Almena site. The Rock Island Railroad and a paved state highway traverse the reservoir site. The town of Clayton would be submerged.

Almena Reservoir Site

Elevation	Reservoir Capacity	Valley Width at Dam Site
2135	0 acre-feet	100 feet
2140	194 " "	2,100 "
2160	21,000 " "	7,400 "
2180	103,000 " "	12,500 "

Information taken from the Norton Quadrangle sheet of the Geological Survey. The Rock Island Railroad, a branch line of the Burlington Railroad, and a paved highway traverse the reservoir site. The town of Almena would be submerged at an elevation of 2160.

Woodruff Reservoir Site

Elevation	Reservoir Capacity	Valley Width at Dam Site
2015	0 Acre-feet	100 feet
2020	665 " "	1,700 "
2030	5,700 " "	2,650 "
2040	16,700 " "	2,900 "
2050	36,600 " "	3,200 "
2060	68,800 " "	3,300 "
2063	81,233 " "	3,350 "
2070	- " "	3,400 "

This site was surveyed by the United States Engineers. Borings are not available at this site. A branch line of the Burlington Railroad and a paved state highway crosses the reservoir site at elevation 2045.

There are several thousand acres of arable valley lands lying between creek meanders along Prairie Dog Creek, above Norton, Kansas. Canals to service these areas, if built for permanence,

would be costly. Water available for these areas can be used to better advantage on lands below Norton.

There are about 16,000 acres of arable and about 400 acres of irrigated valley lands along Prairie Dog Creek between Norton, Kansas, and the Republican River. Lands lie below reservoir sites as follows:

1/

Reservoir Site	Valley Lands Lying Below Reservoir Sites Between Norton, Kansas, and Republican River - In Acres				
	Kansas		Nebraska		Total
	Irrigated	Arable	Irrigated	Arable	
Clayton	-	11,600	400	4,400	16,400
Almena	-	9,600	400	4,400	14,400
Woodruff	-	1,600	400	4,400	6,400

Man-made improvements make storage costs materially more in the Clayton or Almena sites, than in the Woodruff site.

Rough computations indicate about 7,000 acres can be irrigated from the Woodruff site. Return flows would largely escape. With consideration to return flow, an area of about 10,000 acres could be irrigated with storage in the Almena site. This area would be somewhat reduced with storage in the Clayton site.

The Woodruff site appears to be most favorable at this time, since reservoir costs may be materially less and project return flow would be available for use lower in the Republican River Valley. The cost of a dual purpose reservoir at this site may exceed $3,500,000.

Storage costs in a reservoir for irrigation and flood control appear to be beyond repayment ability, considering increased crop income from irrigated crops, with a reliable water supply.

Republican River Valley - Haigler to Culbertson

The Republican River is subject to occasional flood flows from early spring to fall, which may rise to several thousand second-feet for a few hours. At Max, Nebraska, it generally has flows of from 100 second-feet to 500 second-feet from November through February, of from 100 second-feet to several thousand second-feet from March through the middle of June, and from nothing to several thousand second-feet from the middle of June through October. Run-off of the Republican River near Max for the period of record is given in the following table:

Year	Run-off in acre-feet (1) Republican River near Max Drainage Area 7,190 Sq.Mi.
1930-1931	105,000
1931-1932	102,000
1932-1933	161,000
1933-1934	93,300
1934-1935	484,000
1935-1936	119,800
1936-1937	90,700
1937-1938	127,000
1938-1939	70,500
Average	150,000
Average exclusive of 1935	108,600

(1) Records by Geological Survey and Nebraska State Engineer

Run-off at Max is substantially the same as near Culbertson immediately above the confluence with Frenchman Creek,

Little of this water is in use as the stream is usually dry when water is wanted for irrigation. A minor, upstream depletion would come from small reservoirs that may be constructed by the Department of Agriculture in the Water Facilities program. Development of the Wray, Beecher Island, and Hale Reservoir sites, together with the Water Facilities program, might reduce stream flows by about 30,000 acre-feet annually.

Storage is essential for further development, not only for irrigation, but, also to provide flood protection for existing improvements and new developments in the Republican River Valley. Storage sites for flood control and irrigation are confined to the Arikaree and South Fork as unfavorable topography for dam sites, and man-made improvements would make storage costs prohibitive on the main stem of the Republican River. Storage to irrigate 2,000 acres can be obtained in the Wray Reservoir site on North Fork. Reservoir sites other than those listed for upstream basins are as follows:

Arikaree River

Pioneer Reservoir Site

Elevation	Reservoir Capacity	Valley Width at Dam Site
3300	0 acre-feet	50 feet
3310	0 " "	70 "
3320	500 " "	1,450 "
3340	6,500 " "	2,300 "
3360	26,500 " "	3,500 "
3380	61,000 " " Est.	3,550 "

The dam site materially widens above 3380. Information was taken from "308" report. Boring records are not available at this site.

South Fork Republican River

Benkelman Reservoir Site

Elevation	Reservoir Capacity	Valley Width at Dam Site
2990	0 acre-feet	200 feet
3000	2,000 " "	4,300 "
3020	18,500 " "	5,200 "
3040	59,000 " "	6,000 "
3050	88,000 " " Est.	6,300 "

Information taken from the "308" report. Records of borings are not available. This site is of little value for irrigation development in this section of the valley, as only a small amount of land can be irrigated from it. Storage can be provided for lower lands in more favorable reservoir sites. A reservoir for irrigation may cost $2,500,000 at this site.

There are about 13,000 acres of arable and about 1,560 acres of irrigated valley lands lying in strips 1/2 to one mile wide, as follows:

Haigler to Benkelman

Irrigated	860		Acres
Arable	5,000		"
Subtotal-		5,860	"

Benkelman to Culbertson

Irrigated	700		"
Arable	8,000		"
Subtotal-		8,700	"
Total-		14,560	"

Some of this land is very sandy and upon a more detailed land classification may be eliminated. Lands farther down in the valley could be substituted.

Lands above Benkelman can be reached by canals diverting from the Arikaree or Republican Rivers at a moderate cost. Lands below Benkelman are scattered. About 4,000 acres can be served by an extension of a canal serving lands north of the river above Benkelman at a moderate cost. Canals to service the remaining lands will be costly, if permanent diversion dams are provided.

Shortages for the present irrigated lands occur for short periods generally in July and August but are not serious. Diversions are generally not shut down to supply senior rights in the vicinity of Culbertson, since small stream flows do not reach Culbertson during dry periods. A storage development of about 2,000 acre-feet would assure a supplemental irrigation supply, and can be obtained with development of the Wray and Buffalo Creek Reservoir sites.

Rough computations indicate about 5,000 acres can be developed with a reservoir at the Pioneer site on the Arikaree River. The Pioneer site appears to be the most favorable reservoir site on the Arikaree for the development of this section, since it will allow a larger irrigation development and can control more flood producing area.

A storage development on South Fork at the Benkelman site would be of little value, since it could only serve a small area of irrigable land for which canal construction would be costly.

Since railroad transportation is closely available and present irrigated lands produce about as much feed, as can be consumed by livestock on surrounding areas, new irrigation developments will generally produce cash crops.

Available information indicates storage costs in reservoirs for irrigation or in a dual purpose reservoir for flood control and irrigation may be materially beyond repayment ability.

The Pioneer project comprising an arable area of 13,400 acres in this portion of the valley was investigated by the United States Engineers, their findings are published in the "308" report. Forty-five thousand acre-feet of reservoir capacity was to be provided in the Pioneer Reservoir site. Non-irrigation season flows of the North Fork of the Republican River were to be diverted to the

Pioneer Reservoir. Estimated costs were $188 per acre. Reservoir costs were estimated at $1,799,400.

In the event a reservoir is built at the Wray site, large enough to develop the available water supply, a diversion from North Fork would not be desirable. Water available for new developments at the Pioneer or Wray sites can serve the same lands in the Republican River Valley.

Republican River Valley, Red Willow Creek to Republican City

This section of the Republican Valley includes Red Willow and Medicine Creeks. Average daily flows of the Republican River at Culbertson, or Red Willow Creek at Red Willow near its mouth, and of Medicine Creek near its mouth at Cambridge, follow:

Stream	Station	Average Flows in Second-Feet		
		Oct. through February	Mar. through June	July thru September
(1)		80 to 500	100 to 1,200 (2)	10 to 650
Republican R.	Near Culbertson	10 to 50	30 to 90	0 to 30
Red Willow Cr.	" Red Willow	30 to 150	30 to 150	0 to 100
Medicine Cr.	" Cambridge			

(1) Includes flow of Frenchman Creek near Culbertson. The Meeker canal diversion is just below this station, and diverts about 40 second-feet when available.

(2) During drought seasons flows may drop to 10 second feet early in June.

Run-off of the Republican River near Culbertson, Red Willow Creek near Red Willow, and Medicine Creek near Cambridge are given for the period 1930, through 1939. Run-off for missing years is estimated:

Year	Run-off in Acre-Feet		
	(1) Republican River at Culbertson, incl., Frenchman Cr. Drainage Area 11,660 Sq. Miles	(2) Red Willow Creek Near Red Willow Drainage Area 742 Square Miles	(3) Medicine Creek Near Cambridge Drainage Area 864 Sq. Miles.
1929-1930	190,100	21,100	59,600
1930-1931	179,600	24,500	45,300
1931-1932	164,900	* 15,800	* 38,000
1932-1933	287,900	* 18,300	* 44,000
1933-1934	153,500	* 13,300	* 32,000
1934-1935	687,000	* 44,000	*106,000
1935-1936	190,400	* 16,200	* 39,000
1936-1937	149,500	* 15,800	* 38,000
1937-1938	216,500	* 19,400	46,600
1938-1939	141,100	* 16,800	40,500
Average	235,600	20,500	48,900
Average exclusive of 1934-1935-	185,600	17,900	42,500

(1) From Nebraska State Engineer and Geological Survey when not estimated.
* Estimated.
(2) Drainage area is 110 square miles less at Red Willow Dam site.
(3) Run-off is about the same at Medicine Creek Dam site.

In addition to the run-off at the gaging stations in the preceding table, an average annual flow of 162,000 acre-feet enters the river in this section of which about 60,000 acre-feet is from the drainage areas above dam sites on Beaver, Sappa, and Prairie Dog Creeks, and may be largely utilized on these creeks. Muddy Creek, a tributary from the North procudes an average annual run-off of about 3,000 acre-feet from fairly uniform base flow. Other run-off occurs mostly after occasional storms.

An irrigated area of about 4,000 acres lies along the Republican River below the gaging stations, 3,000 acres of which lies above Red Willow Creek. Irrigated lands use most of the summer flow during dry years.

A run of the river power plant of the Southern Nebraska Power Company at Superior has an active water right for 400 second-feet. The flows of the Republican River from October through June without the flows of Red Willow or Medicine Creeks can generally supply this demand, with much greater flows from March through June. In the months of July to September, return flow from the irrigation development with the water from these creeks would probably fully equal the present natural flow therefrom, except at time of floods. Consequently storage on these creeks would not injure the right of the Superior plant.

With development of small irrigation projects a minor upstream depletion would occur.

Future irrigation developments above Max may reduce stream flows by 30,000 acre-feet annually, and on Frenchman Creek at Culbertson by about 20,000 acre-feet annually, making a total annual upstream depletion at Culbertson of about 50,000 acre-feet.

The Republican River flood of May and June 1935, reached its maximum discharge in this section of the valley; peak discharges were as follows:

Culbertson	(1)	245,000	second-feet
Cambridge, below Medicine Creek		280,000	" "
Bloomington		260,000	" "

In Nebraska, (1) 94 lives were lost and property damage amounted to about $7,500,000. A large portion of these losses occurred in this section of the valley. Property damage was principally to railroads, highways, and bridges. About two-thirds of the houses in Cambridge, population 1,203, were affected by the flood. Considering the amount of damage done, flood protection should be provided, if it can be obtained at a justifiable cost. No other flood exceeded 30,000 second-feet since 1880.

Storage is essential for further irrigation, except for a limited amount from wells, and for flood protection. Unfavorable dam site topography and man-made improvements, make storage costs prohibitive on the main stem of the Republican River. Reservoir sites are confined to tributaries; the only sites found were on Red Willow and Medicine Creeks.

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(1) Geological Survey Water Supply Paper 796-B.

The following reservoir sites were found on Red Willow Creek:

Red Willow Reservoir Site

Elevation	Reservoir Capacity	Valley Width at Dam Site
2490	0 acre-feet	100 feet
2500	370 "	280 "
2520	5,100 "	1,300 "
2540	20,800 "	1,600 "
2560	50,500 "	2,200 "
2580	97,000 "	2,600 "
2600	165,000 "	6,500 "
2620	257,000 "	7,000 "
2630	314,000 "	7,300 "

This site was surveyed by the United States Engineer Department. Borings by the United States Engineers indicate foundation material to be mostly sand to depths greater than 30 feet.

Osburn Reservoir Site

This site has not been surveyed. The dam site appears to be about as wide as the Red Willow site, and the reservoir capacity somewhat less.

There are about 100 acres of irrigated and several thousand acres of scattered arable valley lands above the Red Willow Dam site. Canals to serve arable lands would be costly. Water available for these arable lands can be used to better advantage on land below the Red Willow Dam site and on lands in the Republican River Valley.

There are about 2,900 acres of arable lands along Red Willow Creek between the Red Willow Dam site and the Republican River, that can be reached by diversions from the creek at a moderate cost.

The only reservoir site found on Medicine Creek was the Medicine Creek site.

Medicine Creek Reservoir Site

Elevation	Reservoir Capacity	Valley Width at Dam Site
2304	0 acre-feet	75 feet
2317	0 " "	170 "
2320	775 " "	1,300 "
2340	8,150 " "	1,400 "
2360	26,400 " "	1,500 "
2370	41,070 " "	1,600 "
2380	61,345 " "	2,150 "
2400	127,100 " "	3,450 "
2420	235,700 " "	5,350 "
2430	307,700 " "	6,600 "

This site was surveyed by the United States Engineer Department. Borings by the United States Engineers indicate hard shale is found at about 60 feet below creek bottom, overburden being generally sand or a silty clay loam.

The Gold Coin Mills have a flour mill on Medicine Creek near Cambridge with an installed hydro-capacity of 100 hp., which has not been used since 1935.

There are several thousand acres of arable lands lying principally between creek meanders in a relatively narrow valley above the Medicine Creek Dam site. Canals to irrigate these lands would be expensive. Water available for these lands can be used to better advantage on lands in the Republican Valley.

About 600 acres of arable valley lands lie between the Medicine Creek Dam site and the Republican River, 300 acres on each side of the creek. Ditches diverting from Medicine Creek can

serve these lands at a moderate cost.

There are about 500 acres of irrigated and about 28,500 acres of arable valley lands, in this section of the Republican River Valley. The location of these lands follows:

Location of lands	Land Area in Acres	
	Irrigated	Arable
South of the Republican River:	-	6,500
North of the Republican River:	500	5,900
Between Red Willow and Medicine Creeks		
Between Medicine Creek and Republican City		16,100
Total -	500	28,500

Lands south of the Republican River lie in three long narrow tracts opposite Cambridge, Arapahoe, and Oxford, and can be reached by diversions from the Republican River. Canals to service these areas would be relatively expensive. Pumping from the river for small areas may prove attractive, if irrigation developments are provided for lands north of the river, since return flow will then provide sustained river flows during late summer months. Some irrigation developments may be made from wells.

Lands north of the Republican River can be reached by diversions from the river and Red Willow and Medicine Creeks at a moderate cost.

Sand and gravel valley fills present an opportunity for irrigation from wells in this section of the Republican River Valley. Several irrigation wells are in operation. Wells are

from 50 to 70 feet deep, with static water levels from 20 to 40 feet below the surface and yield 1 to 3 second-feet with draw downs of 15 to 20 feet. The major recharge of the ground water basins occurs during heavy spring run-off. With a heavy draft on this source of supply, water levels may drop beyond an economic pumping limit, and artificial means of recharge may be required. Return flow from irrigation developments on higher lands could supply a substantial recharge. Consumptive use would deplete lower river flows by about 1.3 acre-feet per year for each acre irrigated from this source.

The Red Willow and Medicine Creek Reservoir sites appear to be the most favorable at this time, there being little difference in storage costs. Both are required to develop the available water supply which could serve an irrigation development of about 30,000 acres. Upon a more detailed study it may be found that a storage development at the Medicine Creek site with the unregulated flows of the Republican River and Red Willow Creek, or a limited amount of storage in both reservoir sites may present the most economical development for these lands.

A dual purpose reservoir on Red Willow Creek may cost about $2,000,000 and on Medicine Creek about $2,500,000.

The availability of railroad shipping facilities, improved highways, and creameries, indicate cash crops and dairy products will be the principal source of income.

Available information indicates storage costs may be somewhat beyond repayment ability in dual purpose reservoirs for flood control and irrigation.

An attempt was made between 1891 and 1894 to irrigate 8,000 acres north of the Republican River, between Cambridge and Arapahoe. The project was operated seven years during which time a maximum of 700 acres was irrigated. Water shortages and financial difficulties were given as the reason for abandonment. The United States Engineers investigated the portion of this project between Cambridge and Arapahoe, the results of which are published in the "308" report. The irrigable area was reduced to 6,700 acres, and three plans to irrigate the area were presented. Plan 1 proposed a direct diversion from Medicine Creek with no storage involved. Plan 2 proposed a diversion from Medicine Creek with 10,000 acre-feet of storage provided in the Medicine Creek Reservoir. Plan 3 proposed to supplement plan 1, with a direct flow diversion from the Republican River. The estimated costs for the three plans were as follows:

Plan 1 - $40.80 per acre
Plan 2 - 168.30 " "
Plan 3 - 50.10 " "

Dry years following these studies indicate no major irrigation development should be contemplated without a storage development.

Republican River Valley, Republican City, Nebraska, to Scandia, Kansas

Flows of the Republican River at Bloomington, Nebraska, vary from about 100 second-feet to about 600 second-feet from November through February. Flows may increase to several thousand second-feet for short intervals from March through June and may drop to about 10 second-feet in the latter part of the summer in dry years. Run-off of the Republican River near Bloomington, since 1930, is given as follows:

Year	Runoff of Republican River (1) Near Bloomington, Nebraska. Drainage area 21,040 Sq. Mi.
1929-1930	563,000 acre-feet
1930-1931	489,000 " "
1931-1932	361,000 " "
1932-1933	419,000 " "
1933-1934	302,000 " "
1934-1935	1,002,000 " "
1935-1936	380,000 " "
1936-1937	364,000 " "
1937-1938	444,000 " "
1938-1939	343,000 " "
Average	467,000 " "
Average exclusive of 1935	408,000 " "

(1) Records from Geological Survey.

Run-off is practically the same at the Harlan County Dam site, ten miles above Bloomington.

Little of this water is in use for irrigation, as the stream may be about dry when most needed for irrigation. Developments above may reduce annual stream flows as follows:

Main Republican River	90,000	acre-feet
Beaver and Sappa Creeks	15,000	" "
Prairie Dog Creek (1)	10,000	" "
Total-	115,000	" "

(1) This project would be largely submerged by a reservoir at the Harlan County site at an elevation of 1940.

With possible upstream development an average annual flow of about 293,000 acre-feet would be available for irrigation use, providing downstream power plants listed on page 6 are subordinated in right so as to permit stream depleting developments above them.

Storage is required for irrigation, with the exception of a limited amount of irrigation from ground water pumping, and for flood protection of existing improvements and low lying lands if developed. Benefits from a storage development on the main stem of the Republican River would extend down stream to the Kansas River. The best sites so far found are as follows:

Harlan County Reservoir Site

Elevation	Reservoir Capacity	Valley Width at Dam Site
1875	0 acre-feet	200 feet
1879	0 " "	230 "
1890	3,500 " "	4,700 "
1900	19,300 " "	4,900 "
1910	57,300 " "	5,100 "
1920	112,800 " "	7,200 "
1930	194,100 " "	9,100 "
1940	309,300 " "	10,500 "
1960	628,000 " "	11,000 "
1980	1,079,600 " "	11,400 "

This reservoir site was surveyed by the United States Engineers. Borings by United States Engineers indicate soft shale is found at about 15 feet below the valley floor.

Several miles of railroad and improved highway would require reconstructing. Republican City population 417, would be submerged between elevations 1910 and 1940; and the town of Alma, population 1235, between elevations 1940 and 2000. This site is being studied by the United States Engineer Department, as an alternate to the Scandia or Milford Reservoir sites for flood control on the Republican River. The Milford site is located near the mouth of the stream and would have no value for irrigation developments.

Rope Creek Reservoir Site

Elevation	Reservoir Capacity	Valley Width at Dam Site
1958	0 acre-feet	50 feet
1980	154 " "	560 "
2000	1,984 " "	950 "
2020	6,304 " "	1,200 "
2040	16,194 " "	2,150 "
2060	34,384 " "	3,350 "

This site was surveyed by the Bureau of Reclamation. An off channel storage site on Rope Creek that can be supplied by a diversion from the Republican River near Edison. Rope Creek Dam site has a maximum height of 108 feet, top elevation 2068, and a length of 3,700 feet, about 1200 feet of which will be dike less than 50 feet high. The cost of the storage dam and reservoir has been estimated at $1,966,000 or about $57 per acre-foot. (From the Bostwick Project report).

There are about 63,000 acres of arable valley and table lands in this section of the Republican River and about 500 acres of irrigated lands lying mostly north of the river in Nebraska. Arable lands are segregated as follows:

Location	Arable Land in Acres		
	Nebraska	Kansas	Total
Valley lands along Republican River			
North & east of River	34,000	3,000	37,000
South & west of River	15,000	2,000	17,000
Table lands, lying on divide between Republican River and White Rock Creek		9,000	9,000
Totals -	49,000	14,000	63,000

The available water supply is materially greater than needed for the arable lands in this section. Excess water can be used on lower lands.

Arable lands can be reached by diversions from the Republican River at a moderate cost.

The Harlan County Reservoir site appears the more favorable at this time since it could provide flood control and develop the available water supply. A dual purpose reservoir for irrigation and a limited amount of flood control at this site may cost in excess of $4,500,000; a dual purpose reservoir providing complete flood control would cost about $22,000,000.

Cash crops and dairy products would be the principal source of income. A storage development would assure feed for dairy stock and increase crop yields. Available information indicates storage costs may be about repayment ability in a dual purpose reservoir, providing complete flood control.

A project called the Lower Republican River Project lying in this section of the valley was investigated by the United States Engineers; their findings are published in the "308" report. Storage was to be provided in the Harlan County reservoir site. Under plan 1, an area of 50,000 acres of valley land was to be irrigated at an estimated cost of $116 per acre. Under plan 2, an area of 34,000 acres was to be irrigated at an estimated cost of $134 per acre. It is doubtful if enough reservoir capacity was allowed for silt accumulation, in which event costs will be far in excess of those estimated.

The project was further investigated by the Bureau of Reclamation as the Bostwick Project, and a preliminary report was released in June 1938. A project area of 35,000 acres of irrigable land was considered, similar to plan 2 of the United States Engineer. A 34,000 acre-foot reservoir on Rope Creek supplied by a feeder canal diverting from the Republican River near Edison, Nebraska, was substituted for the reservoir at the Harlan County site. An incidental power development was considered, with an average annual production of 8,500,000 kw.-hrs. of secondary power for the period 1931 through 1938. The power plant was located immediately below the dam. Penstock connections were to be made directly with the feeder canal and with the reservoir. The maximum effective head is about 105 feet. Annual charges with a 40-year repayment period without interest were

estimated at $5 per acre after deducting benefits from the sale of power.

White Rock Project

Storage is essential for the irrigation development of this project. The best storage sites so far found are as follows:

Harlan County Reservoir Site

A limited amount of storage may be obtained in this site, the amount depending on requirements for flood control and irrigation requirements on upper lands.

White Rock Reservoir Site

Elevation	Reservoir Capacity	Valley Width at Dam Site
1474	0 acre-feet	50 feet
1490	452 " "	1,700 "
1500	4,425 " "	6,700 "
1510	16,370 " "	8,150 "
1520	39,795 " "	9,150 "
1530	77,095 " "	10,450 "
1540	130,495 " "	11,500 "
1550	203,595 " "	17,000 "

Surveys by Paulette and Wilson of Topeka and Salina, Kansas. An off channel reservoir site on White Rock Creek, two miles above the Republican River. Can be supplied by a relatively expensive canal about 15 miles long diverting from the Republican River near Superior, Nebraska, at an existing power plant diversion dam.

The project comprises an arable area of about 75,000 acres, mostly table lands, lying south and west of the Republican River in Republic, Cloud, and Jewell Counties, Kansas. Soils are generally a sandy loam.

Project lands can be reached by a relatively expensive canal diverting from the Republican River near Superior, Nebraska,

if storage is obtained in the Harlan County Reservoir site, and at a moderate cost by a canal diverting from the White Rock Reservoir site at elevation 1530.

Available information indicates storage can be obtained at less cost in the White Rock Reservoir site. Water not required for irrigation on the project can be used for power production, some of which could be used for irrigation on lower lands in the Republican River Valley, a head of about 55 feet below dead storage level being available. With possible upstream depletion power production would be of little value.

Even with the diversified crops that could be grown under intensive irrigation farming, storage costs appear to be materially beyond repayment ability.

Irrigation district No. 1 of Republic, Cloud, and Jewell Counties, Kansas applied for a P. W. A. loan and grant to construct this project. The total reservoir capacity was to be 203,600 acre-feet, of which 126,500 acre-feet was live storage, 91,000 acre-feet being allocated to irrigation. The feeder canal was to have a capacity of 4,000 second-feet. A power development was contemplated. Water not required for irrigation was to be passed through a power plant integral with the dam and to operate under an average head of 56 feet. Power production was estimated at 7,000,000 kw.-hrs. of firm power and 8,000,000 kw.-hrs. of dump power.

The estimated cost of the project was $8,000,000. Annual costs to the district are estimated at $400,000 to be repaid by the sale of water and electric power. Water was to sell for $3 an acre-foot. It is thought actual costs of this project will be higher than estimated, as no allowance was made for a lateral or drainage system.

Solomon Valley Diversion

There are several thousand acres of arable table lands in the Solomon River Drainage Basin, in Jewell County, Kansas. These lands lie west of the White Rock Project, generally at a higher elevation.

The Harlan County Reservoir site is the lowest storage site, that lies at a high enough elevation to serve this area. Economic storage capacity is limited in a dual purpose reservoir for flood control and irrigation at this site, and storage capacity available for irrigation can be largely used by irrigation developments in Nebraska. Water available for these lands can be used to better advantage on the White Rock Project or on lands in the Republican River Valley below Scandia, since storage can be provided at lower reservoir sites.

Republican River Valley below Scandia, Kansas.

The Republican River at Scandia, Kansas, has flows varying from about 100 second-feet to 600 second-feet from November through February, increasing to several thousand for short intervals from

March through June, and may drop to about 15 second-feet in summer months during dry years. Run-off of the Republican River at Scandia for the period of record, follows:

Year	Run-off of Republican River (1) Near Scandia, Kansas Drainage Area 22,930 Sq. Mi.
1928-1929	501,000 acre-feet
1929-1930	563,000 " "
1930-1931	546,000 " "
1931-1932	516,000 " "
1932-1933	491,000 " "
1933-1934	316,000 " "
1934-1935	1,214,000 " "
1935-1936	434,000 " "
1936-1937	436,000 " "
1937-1938	529,000 " "
1938-1939	451,000 " "
Average	545,000 " "
Average exclusive of 1935	478,000 " "

(1) Record by Geological Survey.

Little of this water is in use at present. The Kansas Power and Light Company have a power plant at Clay Center with a 900 kw. installation that has not been used since 1935. Possible upstream irrigation developments may deplete the flow at Scandia, as follows:

Above Harlan County Dam site	115,000 acre-feet
Republican River, Republican City to Scandia	85,000 " "
Subtotal	200,000 " "
White Rock Project	170,000 " "
Total-	370,000 " "

Without development of the White Rock Project an average annual run-off of 278,000 acre-feet is available for use on this project, which, with consideration to return flow, would allow an irrigation development of about 110,000 acres. With development of the White Rock Project an average annual flow of about 108,000 acre-feet is available for use, which would allow an

irrigation development of about 45,000 acres. Return flows from the White Rock Project would reach the Republican River a few miles above Concordia, and would allow for a little additional development. These flows would occur below possible reservoir sites.

Storage is essential for irrigation developments of any appreciable size, for flood protection of existing improvements and a large area of low lying land if developed.

Benefits thereof would extend downstream to the Kansas River in Kansas. The best storage sites so far found are as follows:

Harlan County Reservoir Site

Some storage may be obtained at this site above the needs of upper lands.

White Rock Reservoir Site

An off channel storage site that could be used if not required for development of the White Rock Project.

Scandia Reservoir Site

Elevation	Reservoir Capacity	Valley Width at Dam Site
1440	0 acre-feet	800 feet
1460	29,320 " "	7,400 "
1480	148,000 " "	7,900 "
1500	408,000 " "	9,000 "
1520	884,000 " "	14,300 "

Information taken from the Concordia quadrangle sheet of the Geological Survey. Topography limits a dam to a maximum elevation of about 1,520 at this site. About 13 miles of the Missouri Pacific Railroad lies in the reservoir site below elevation 1520. The town of Republic City, population 396 would be largely submerged at that elevation.

There are about 90,000 acres of arable valley lands along the Republican River from Scandia to about seven miles below Clay Center. Some of this land is very sandy, and upon a more detailed land classification may be eliminated. Land farther down the valley can be substituted.

Arable lands can be reached by canals diverting from the Republican River at a moderate cost.

With upstream developments, requiring a dual purpose reservoir at the Harlan County site for flood control and irrigation, the White Rock Reservoir site appears to be more favorable than the Scandia site. Without development of the Harlan County site for upstream irrigation and flood control, more study is required to determine the most favorable reservoir site.

Kansas City, with a population of 536,000, is within trucking distance and railroad shipping facilities are close at hand. Consequently, a storage development would assure a wide variety of cash crops. However, indications are storage costs in reservoirs at available sites will be materially beyond repayment ability.

Power Development

To insure a reasonable life, for reservoirs on the Republican River or its major tributaries, except North Fork and Frenchman Creek, large capacities are required for silt accumulation.

Because of the large amount of dead storage required at the reservoir sites, heads are available at the dams, which could be used for secondary power production from irrigation releases. On Frenchman, Red Willow, and Medicine Creeks, the irrigation diversions are several miles below the storage dams, and more head can be developed by power diversions at dead storage level, to a point above the upper irrigation diversions. Information available at this time indicates little opportunity for firm power production without interfering with possible irrigation developments. A limited amount of seasonal power could be used for irrigation pumping. No power lines traverse the valley.

Wild Life and Recreation

Storage dams would create lakes with a large water surface area throughout the year. Such a lake presents an ideal opportunity for aquatic wildlife, boating, swimming, and adjacent parks or picnic grounds. That such a need exists is evident, from the number of small reservoirs that have been constructed by various communities throughout the basin for these purposes.