Special Report

Republican River Basin Water Management Study

Colorado, Nebraska, Kansas

February 1985

Department of the Interior
Bureau of Reclamation

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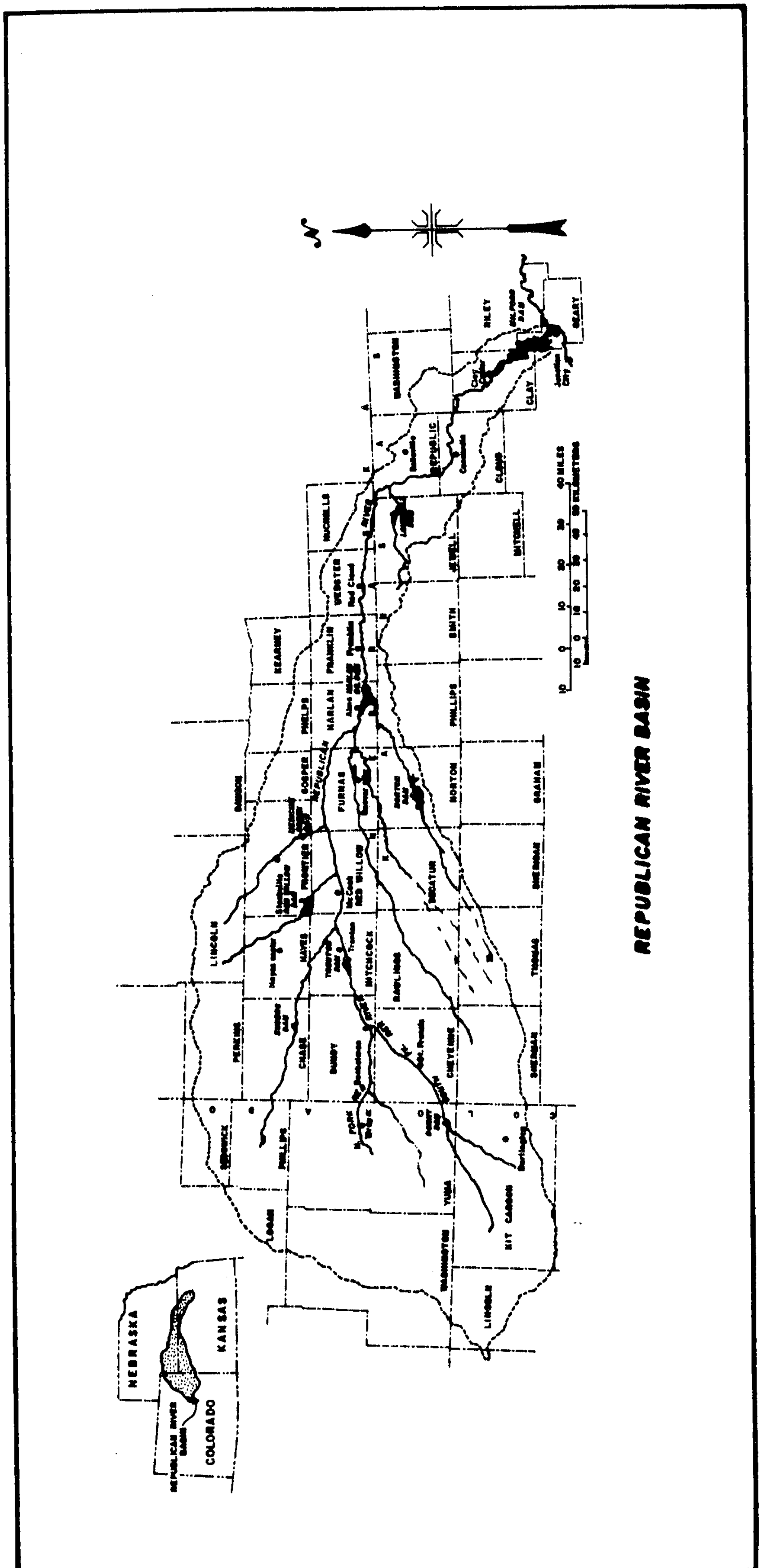
REPUBLICAN RIVER BASIN
NEBRASKA
KANSAS
COLORADO
40 MILES
50 KILOMETERS

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HYDROLOGY - Volume 1

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- Ground-Water Reconnaissance of the Upper Republican River Basin above Harlan County Dam, Nebraska
- Ground-Water Reconnaissance of the Republican River Basin from Harlan County Dam, Nebraska to Milford Dam, Kansas

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- Assessment of Changes in Precipitation Regime of the Republican River Basin (Kansas State University, January 1983)

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- Reservoir Analysis Final Working Paper, Republican River (Fish and Wildlife Service, June 1982)
- Evaluation of Existing Use of Fish and Wildlife Resources, Final Working Paper, Republican River Basin (Fish and Wildlife Service, August 1983)
- Instream Flow Analysis - Republican River Basin, February 1984

ECONOMIC AND SOCIAL ASSESSMENT - Volume 7

- Socioeconomic Conditions
- Crop Enterprise Budgets
- Economic and Social Impacts

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Electrical Terms and Factors for Converting English Units to Metric Units

(International System, SI, units)

Electrical Terms

1 kilovolt	equals	1 thousand volts
1 kilowatt	equals	1 thousand watts
1 megawatt	equals	1 million watts
1 gigawatt	equals	1 billion watts

Factors for Converting English Units to Metric Units

Multiply English units	by	To obtain metric units
	Length	
inch (in)	* 2.54	centimeter (cm)
	*25.4	millimeter (mm)
	* 0.0254	meter (m)
foot (ft)	* 0.3048	meter (m)
yard (yd)	* 0.9144	meter (m)
rod	* 5.0292	meter (m)
mile (mi)	* 1.609344	kilometer (km)
	Area	
acre	4.04686×10^3	square meter (m^2)
	0.404686	1/ hectare (ha)
	0.404686	square hectometer (hm^2)
	0.004047	square kilometer (km^2)
square mile (mi^2)	2.589988	square kilometer (km^2)
	Volume	
gallon (gal)	3.785412	2/ liter (l)
	3.785412	cubic decimeter (dm^3)
	3.785412×10^{-3}	cubic meter (m^3)
million gallons (10^6 gal)	3.785412×10^3	cubic meter (m^3)
	3.785412×10^{-3}	cubic hectometer (hm^3)
cubic foot (ft^3)	28.31685	cubic decimeter (dm^3)
	2.831685×10^{-2}	cubic meter (m^3)
cubic foot per second-day (ft^3/s-day)	2.446576×10^3	cubic meter (m^3)
	2.446576×10^{-3}	cubic hectometer (hm^3)
acre-foot (acre-ft)	1.233482×10^3	cubic meter (m^3)
	1.233482×10^{-3}	cubic hectometer (hm^3)
	1.233482×10^{-6}	cubic kilometer (km^3)
	0.123348	3/ hectare-meter (ha.m)

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Multiply English units	by	To obtain metric units
	Flow	
cubic foot per second (ft^3/s)	28.31685	liter per second (l/s)
	28.31685	cubic decimeter per second (dm^3/s)
	2.831685×10^{-2}	cubic meter per second (m^3/s)
gallon per minute (gpm)	6.309020×10^{-2}	liter per second (l/s)
	6.309020×10^{-2}	cubic decimeter per second (dm^3/s)
	6.309020×10^{-5}	cubic meter per second (m^3/s)
million gallons per day (mgd)	43.81264	cubic decimeter per second (dm^3/s)
	4.381264×10^{-2}	cubic meter per second (m^3/s)
4/cubic foot per square foot per day (ft^3/ft^2d)	3.527778×10^{-6}	cubic meter per square meter per second (m^3/m^2s)
	Velocity-Speed	
mile per hour (mi/h)	4.470400×10^{-1}	meter per second (m/s)
	Mass	
ton (short)	9.071847×10^{2}	kilogram (kg)
	0.907185	tonne (t)
	Temperature	
degrees Fahrenheit (°F)	$(°F-32)\frac{5}{9}$	degrees Celsius (°C)
degrees Celsius (°C)	$(°C \times 1.8)+32$	degrees Fahrenheit (°F)

1/The unit hectare is approved for use with the International System (SI) for a limited time.
2/The unit liter is accepted for use with the International System (SI).
3/The unit hectare-meter (ha·m) is not approved for use with the International System (SI) at the present time.
4/Hydraulic conductivity-permeability.

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CHAPTER I--INTRODUCTION

The Republican River is located along the Kansas-Nebraska border and drains portions of three states. The drainage area is approximately 24,900 square miles, of which 7,700 square miles are in Colorado, 9,700 square miles are in Nebraska, and 7,500 square miles are in Kansas. The river is formed by the junction of the Arikaree and North Fork Republican Rivers near Haigler, Nebraska. From Haigler, the river flows in an easterly direction to Junction City, Kansas, where it joins the Smoky Hill River to form the Kansas River. The watershed has an approximate length of 430 miles. The principal tributaries downstream from the confluence of the Arikaree and North Fork Republican Rivers are South Fork Republican River and Frenchman, Blackwood, Driftwood, Red Willow, Medicine, Sappa, Prairie Dog, and White Rock Creeks.

Four Reclamation (Bureau of Reclamation) water resource development divisions of the P-SMBP (Pick-Sloan Missouri Basin Program) are included in the study area. These include the Upper Republican, Frenchman-Cambridge, Kanaska, and Bostwick Divisions. The Upper Republican Division contains Bonny Dam and Reservoir, which is operated and maintained primarily for flood control. The State of Colorado purchased the conservation space in Bonny Reservoir for fish, wildlife, and recreation use. The other divisions primarily supply irrigation water.

The Frenchman-Cambridge Division includes the Frenchman Valley, H&RW, and Frenchman-Cambridge Irrigation Districts serving approximately 64,600 acres of irrigated land. Water supply and recreation are provided from four major reservoirs. The Kanaska Division includes the Almena Irrigation District, which includes approximately 5,200 irrigated acres with a water supply from Keith Sebelius Lake and ground-water wells. The Bostwick Division serves approximately 53,400 irrigated acres and includes the Bostwick Irrigation District in Nebraska and the Kansas-Bostwick Irrigation District. Water is supplied by Harlan County Lake and Lovewell Reservoir. The potential Scandia Unit, Kansas would also be included in the Bostwick Division.

The surface water area of the basin is nearly 41,000 acres. Over 40,000 acres are contained in reservoirs larger than 40 surface acres. Major reservoirs include Bonny (Colorado); Swanson Lake, Enders, Hugh Butler Lake, Harry Strunk Lake (Nebraska); Keith Sebelius Lake (Kansas); Harlan County Lake (Nebraska); and Lovewell Reservoir and Milford Lake (Kansas). All the reservoirs are Reclamation facilities, except Harlan County and Milford Lakes, which are Corps of Engineers facilities. Several of these reservoirs have experienced extreme water level fluctuations and long-term surface area declines in the past several years.

This report summarizes reconnaissance level investigations initiated in October 1977 in the Republican River Basin.

STUDY PERIOD

The surface water operations study period is 1949 to 1978. This period was selected due to availability of existing information. Comprehensive weather data for the entire basin is not available earlier than 1949. This study period appears adequate because it begins in an average year, contains a drought and a wet period, and ends in an average year.

PURPOSE AND GOALS

The purpose of this water management study was to identify existing and future uses of the limited water supply and associated land and environmental resources throughout the basin to determine ways to efficiently use the remaining available water.

Basic goals of the study were:

1. Identify water resource problems and water needs in the basin. These included multiple water uses such as municipal and industrial, irrigation, flood control, recreational, fish and wildlife, water quality, and environmental needs.

2. Define the causes of the declining water supplies for the existing reservoirs.

3. Define future water supply capability in the basin.

4. Develop alternative management plans, including both structural and nonstructural solutions, for the most effective use of present and projected water resources.

Investigations of structural methods to optimize water supplies considered canal automation, transbasin diversions, and canal and lateral lining.

Nonstructural conservation methods involved changes in reservoir operation, selective removal of streambank vegetation, and changes in irrigation techniques. Effects of no further well development and advances in farm conservation, tillage, and crop rotation practices, as well as possible precipitation changes were evaluated. Aerial photographic surveys were used to inventory land use and water resources.

5. Evaluate and document the economic, social, and environmental impacts associated with these alternative management plans.

AUTHORITY

The Republican River Basin Water Management Study was proposed by Reclamation because surface water supplies for existing projects within the upper portion of the basin have decreased within the last 10 years, while a demand for further development exists in the lower portion of the basin. The study was authorized by the Federal Reclamation Laws (Act of June 17, 1902, Stat. 388) and all Acts amendatory and supplementary thereto. The study was initially funded in fiscal year 1978 by Public Law 95-96 dated August 7, 1977.

PREVIOUS INVESTIGATIONS

Previous investigations conducted by Reclamation in the Republican River Basin include:

1946, June	Frenchman-Cambridge Unit, Comprehensive Plan
1951, February	Frenchman-Cambridge Division, Definite Plan Report
1953, June	Bostwick Division, Nebraska-Kansas, Definite Plan Report, Part 1
1954, April	St. Francis Unit (now Armel Unit), Definite Plan Report
1956, April	Bostwick Division, Nebraska-Kansas, Definite Plan Report, Part 2
1957, April	Almena Unit, Kansas, Definite Plan Report
1957, October	Red Willow Dam and Reservoir and Associated Works, Feasibility
1959, February	Nelson Buck Unit, Reconnaissance
1964, March	North Republican Unit, Concluding Report
1966, January	Phillipsburg-Smith Center Unit, Investigations Status Report (M&I water from Harlan County Dam, Bostwick Division)
1966, April	Scandia Unit, Kansas, Reconnaissance Report
1967, February	Nelson Buck Unit, Feasibility
1968, June	Scandia Diversion Damsite, Feasibility Geologic Report
1974, February	Colorado State Water Plan, Water for Tomorrow, Phase I
1974, April	Oberlin Unit, Appraisal
1974, August	Colorado State Water Plan, Legal and Institutional Considerations, Phase II
1974, October	Kansas State Water Plan Studies, Phase I
1976, December	Frenchman-Cambridge Irrigation District, Rehabilitation and Betterment Program
1977, January	Frenchman Unit, Appraisal Report
1977, March	Armel Unit, Concluding Report
1978, July	Frenchman Unit, Rehabilitation and Betterment Program, Concluding Report
1979, December	Kansas State Water Plan Studies, Phase II
1982, April	Courtland Unit, Bostwick Division, Kansas, Inventory of Remaining Subsurface Drainage Requirements, Special Report

PUBLIC INVOLVEMENT AND COORDINATION WITH PARTICIPATING AGENCIES

Public input information for this report is the same as that for the Solomon River Basin Water Management Study completed in 1984. The Solomon River Basin is an adjoining basin. The primary areas of concern in both basins are:

1. The causes of decline in the surface water supply.

2. The outlook for future water supplies for municipal, industrial, recreational, and fish and wildlife uses.

3. The alternatives available.

Local, state and Federal agencies have assisted Reclamation in addressing these concerns.

The Kansas State University, Department of Civil Engineering investigated changes in precipitation to determine potential impacts on watershed yield in the Republican River Basin.

The Colorado Division of Wildlife, Nebraska Game and Parks Commission, Kansas Fish and Game Commission, and Fish and Wildlife Service participated in the environmental assessment of the basin.

Study progress and interim results were presented to the Southwest Nebraska Irrigators Association and the Republican River Compact Administration. The membership of the Compact Administration consists of the State Engineer, Colorado; the Director, Department of Water Resources, Nebraska; and the Chief Engineer-Director, Division of Water Resources, State Board of Agriculture, Kansas. In addition, interim study results were reviewed by members of the Engineering Committee for the Compact Administration.

The Geological Survey made a reconnaissance hydrogeologic study, OF-81-531, of the Republican River Basin in Nebraska in July 1981. They completed a similar study, OF-82-79, of the Kansas portion of the basin in 1982.

The Bureau of Reclamation, with its ongoing responsibility for planning and operations, has maintained contacts with virtually all water-using entities in the basin. These contacts, either for this investigation or for other purposes, have led to an understanding of the basin's water-related problems and needs.

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CHAPTER II--GENERAL DESCRIPTION

PHYSICAL CHARACTERISTICS

Topography and Drainage

The western three-fourths of the upper basin (figure 1) lies in the High Plains Section of the Great Plains Physiographic Province (Fenneman, 1931). This section is characterized by flat to gently rolling plains which are mildly dissected by the valleys of major streams. The eastern fourth of the upper basin lies within the Plains Border Section. In this section, dissection of the plains becomes more pronounced with steeper valley walls. The land surface slopes in an easterly direction from an elevation of 5650 feet near the headwaters of the Arikaree River to 2000 feet near Harlan County Dam with an average gradient of 14.5 feet/mile.

The uplands are dotted with many depressions ranging from a few feet to several thousand feet in diameter and depths from shallow to 40 feet. After a heavy rain, these depressions may retain water for weeks or months. The major topographic feature of the upper basin is the sandhills located in the northwest section. The sandhills are sand dunes that have been stabilized by a cover of grass. Local relief between dune troughs and crests ranges from 50 to 150 feet. During periods of high ground-water levels small lakes may form in the troughs of the dunes.

All of the lower basin (figure 2), except the portion southeast of Clay Center, Kansas, lies within the Border Section of the Great Plains Physiographic Province. This area is characterized by plateaus that are submaturely to maturely dissected (Fenneman, 1931). The area southeast of Clay Center lies in the Osage Plains Section of the Central Lowland Physiographic Province. This area has gently rolling uplands with entrenched streams. The lower Republican River valley in Nebraska is approximately 300 feet below the undissected uplands and in Kansas, it is 200-250 feet below the uplands. The Republican valley slopes in a southeasterly direction from an elevation of 2000 feet at Harlan County Dam to 1150 feet at Milford Dam with an average gradient of 5.2 feet/mile.

The drainage pattern of the Republican River Basin is dendritic, which is characterized by irregular branching of tributaries. This implies that the underlying strata is relatively flat, and there is a lack of structural controls such as faults and folds.

Soils

The soils of the Republican River Basin are very productive and are used primarily for growing both dryland and irrigated crops. The following is a general description of the major soil areas in the basin.

The alluvial soils along the Republican River and its tributaries are deep and lie on nearly level flood plains. The major portion of this group is well drained, but both poorly and excessively drained soils are common.

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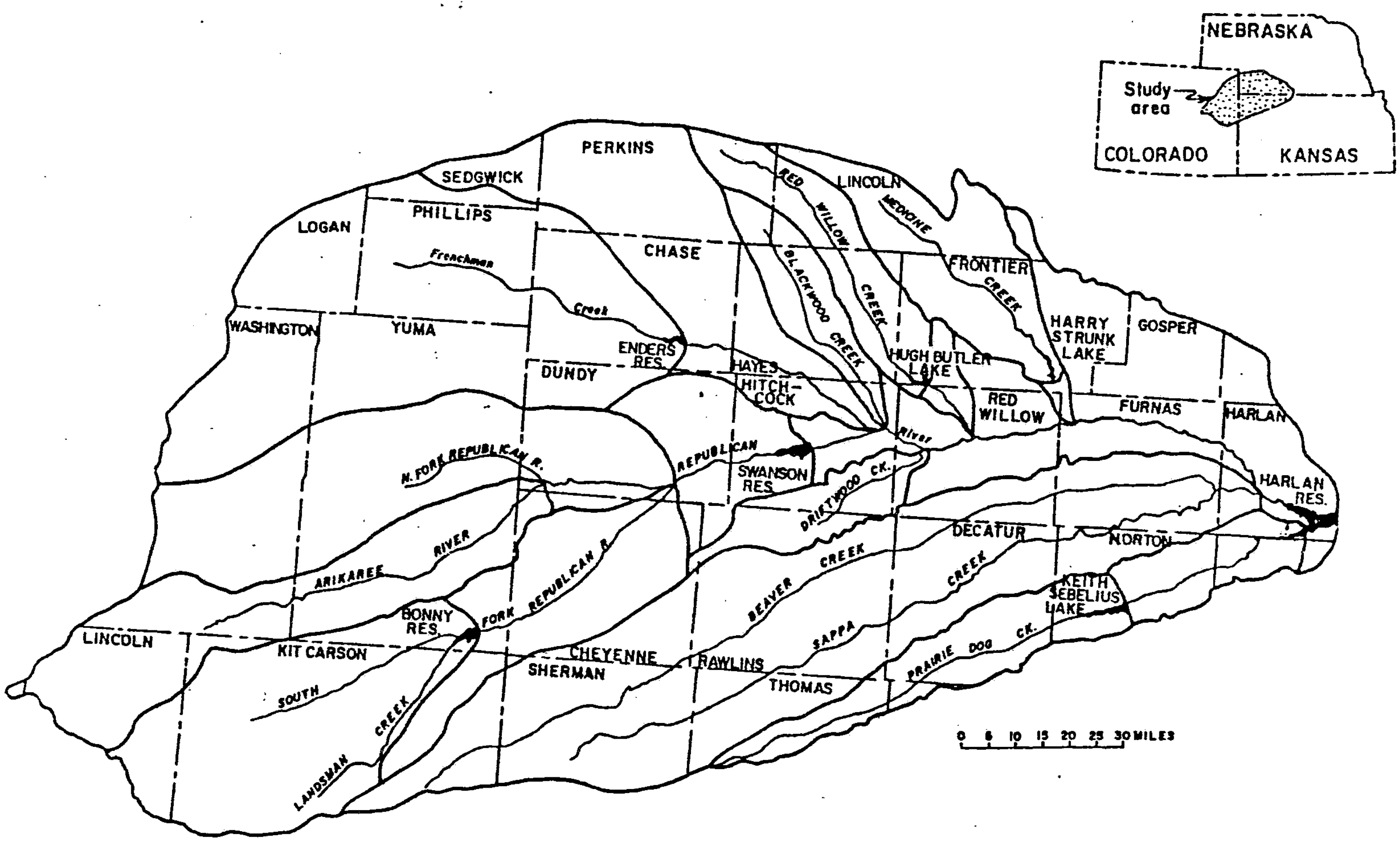

FIGURE 1 – Upper Republican River Basin divided into subbasins

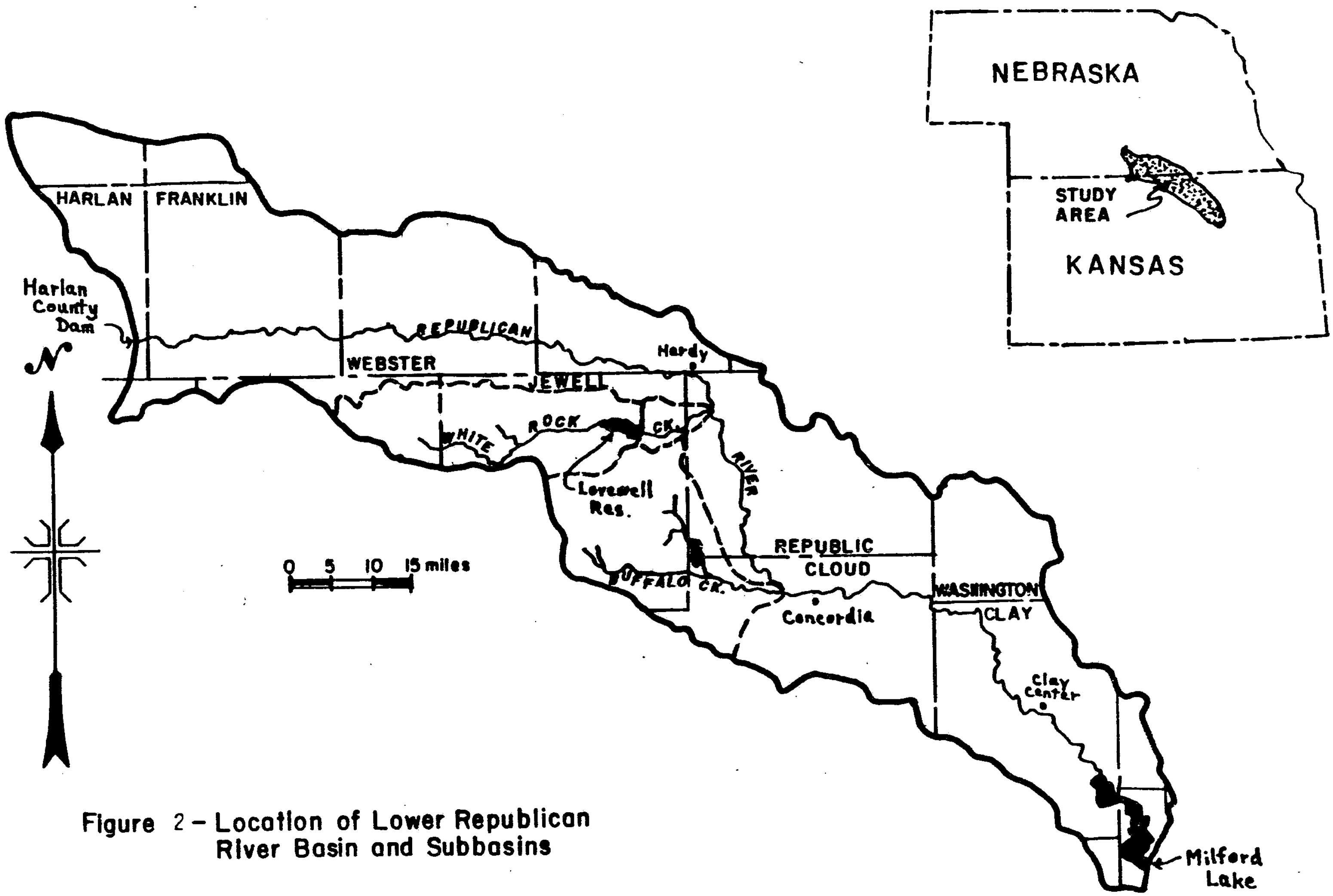

Figure 2 - Location of Lower Republican River Basin and Subbasins

Between the alluvial flood plains and the uplands are deep, near level to sloping well-drained soils formed in colluvial and eolian silts on terraces and footslopes. These soils are medium textured, but are generally more calcareous in their subsoils than are the soils on the uplands. Some moderately deep soils in this group occur in the western most portion of the basin as well as the north-central portion of the Kansas counties.

The loessial soils of the uplands are the most important both in areal extent and productivity. This group is comprised primarily of deep, nearly level to strongly sloping, well-drained silty soils. Generally, these soils are found in the eastern two-thirds of the Nebraska portion and to a smaller extent the northern portion of Kansas. Particularly in the Colorado portion and some of Perkins and Chase Counties of Nebraska are soils which contain dark fine-textured buried soils in their profiles.

Another important soils group includes the soils which are normally associated with the term "sandhills." These soils are generally deep, gently sloping to very steep, excessively drained, sandy soils formed in eolian sands on uplands. This group occupies two major areas: the first being Dundy County and the southwestern portion of Chase County and the second being Lincoln County, Nebraska, from Highway 83 west. Between these two sandhill areas is a group of soils which includes both deep and shallow, nearly level to gently sloping, well-drained loamy and silty soils formed in weathered sandstone and loess on uplands.

The soils in the lower reaches of the basin tend to be somewhat finer textured than the soils in the western portion. These uplands generally have a thin mantle of loess on the divides and are moderately deep over calcareous shales and sandstones.

Climate

The Republican River Basin has a subhumid to semiarid continental climate. The variable weather is typical of the interior of a large land mass in the temperate zone: light rainfall, low humidity, hot summers, and cold winters. Rapid weather changes are caused by invasions of larger masses of warm, moist air from the Gulf of Mexico; hot, dry air from the southwest; cool, dry air from the Pacific Ocean; and cold, dry air from Canada.

There is a large variation in precipitation from year-to-year and station-to-station within the basin (table 1). The mean annual precipitation varies from nearly 18 inches in the western part of the basin to 30 inches in the eastern part. Seventy-seven percent of the annual precipitation falls during the growing season (April through September).

Table 1.--Precipitation summary for representative climatological stations

Station	1920-1978 mean annual (in)	Maximum annual (in)	Minimum annual (in)
Wray, CO	17.63	30.36	7.29
McCook, NE	20.15	38.26	9.69
Alma, NE	21.42	37.75	11.73
Red Cloud, NE	24.14	40.42	11.94
Clay Center, KS	29.68	53.86	13.88

Table 2 summarizes the annual, maximum, and minimum mean monthly temperatures for the 1920-1978 period.

Table 2.--Temperature summary for representative climatological stations

Station	1920-1978 mean annual temperature (°F)	Maximum mean monthly temperature (°F)	Minimum mean monthly temperature (°F)
Wray, CO	51.2	81.8	10.8
McCook, NE	52.3	84.6	13.3
Alma, NE	52.8	86.8	10.1
Red Cloud, NE	52.6	87.6	10.0
Clay Center, KS	55.5	89.6	13.2

Figure 3 depicts average monthly temperatures, last and first killing frost dates, and frost-free days for the five stations.

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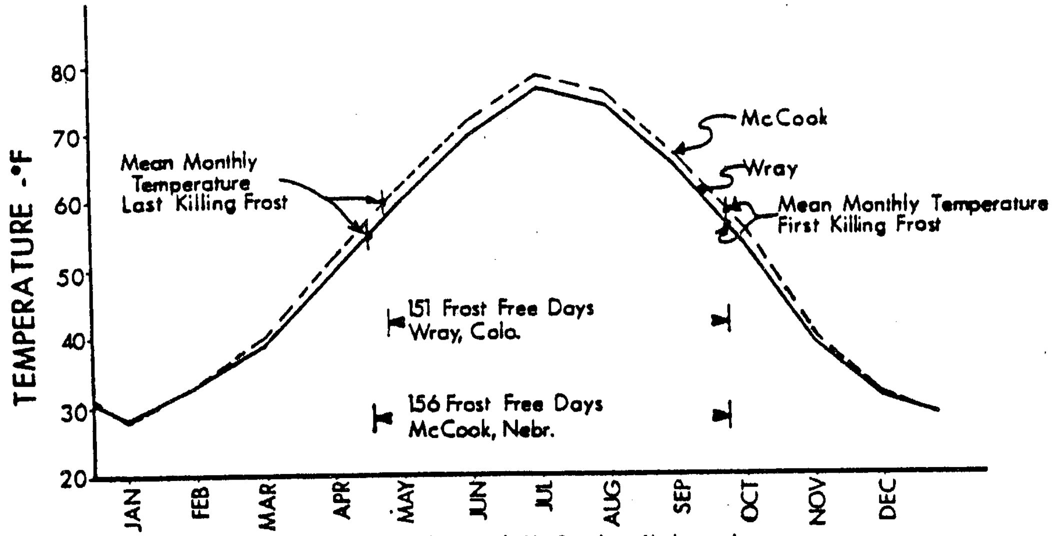
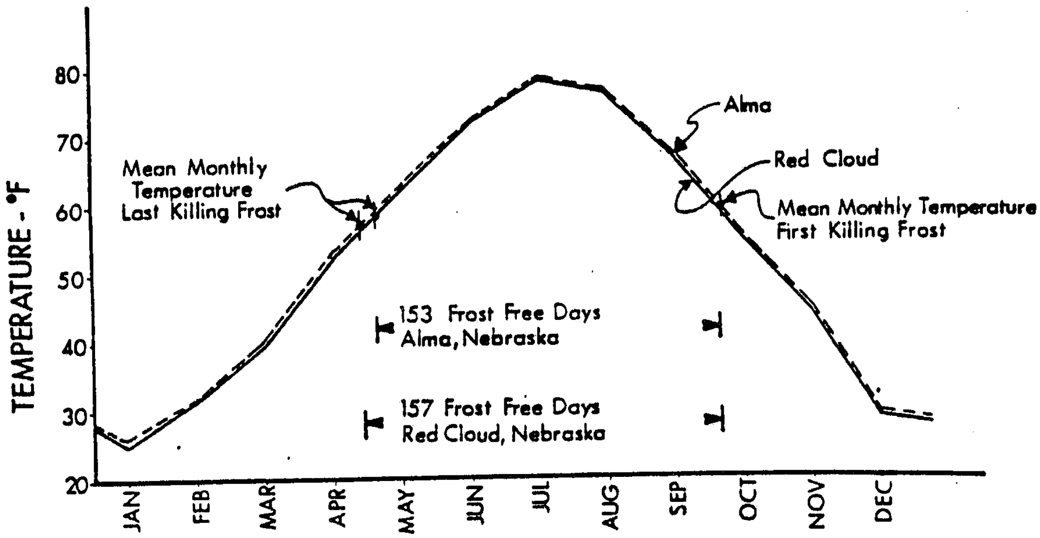
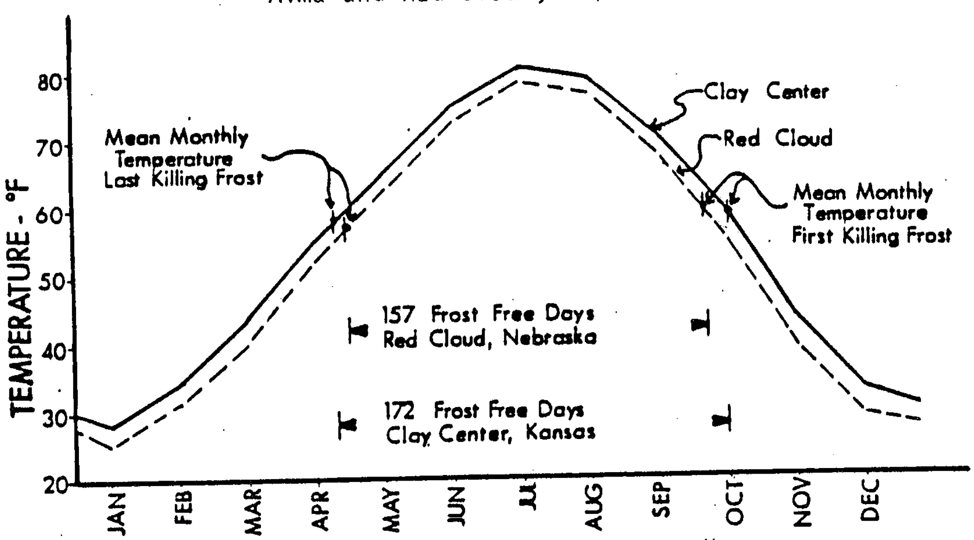


Wray, Colorado and McCook, Nebraska



Alma and Red Cloud, Nebraska



Red Cloud, Nebraska and Clay Center, Kansas

Figure 3.--Average Monthly Temperature

Geology

Upper Republican Basin

The major geologic formations are the Ogallala Formation, alluvium, and eolian deposits that make up the aquifer system. The base for the aquifer system is comprised of the Niobrara Formation, Pierre Shale, and White River Group.

The Niobrara Formation and the Pierre Shale of late Cretaceous age, and the White River Group of Tertiary age are relatively impermeable consolidated deposits, which restrict the downward movement of water from the overlying aquifer system. The Niobrara and Pierre Shale are of marine origin. The Niobrara Formation (the aquifer base in the eastern part of the upper basin) consists of massive chalk beds, chalky shales and limestones, and thin beds of bentonite. The Niobrara Formation has a thickness of approximately 650 feet in Phillips County, Kansas. The Pierre Shale (the aquifer base in the western part of the upper basin) lies conformably on the Niobrara Formation. It is a thinly bedded shale with thin beds of bentonite and numerous concretionary zones. The Pierre Shale in the Frenchman Creek area is more than 2,000 feet thick. The Niobrara Formation and Pierre Shale slope to the east with an average gradient of 14.7 feet/mile. The White River Group (Brule and Chadron Formations) of Oligocene age, lies unconformably on the Pierre Shale in the northwestern portion of the upper basin. It appears to be of fluviatile origin and consists of siltstone, clay, and localized channel deposits of sand and gravel that may or may not be cemented. Although the deposit is considered impermeable, minor amounts of water could be obtained from unconsolidated sand and gravel deposits within the formation. It has a maximum thickness of ± 450 feet.

The semiconsolidated Ogallala Formation of Pliocene age is the major source of ground water due to its areal extent, accessibility, and extent of saturation. The formation is present throughout the upper basin, except where major streams have eroded through it to the bedrock. The Ogallala is believed to have been formed by eastward flowing streams whose sediment filled pre-existing valleys in the bedrock. Eventually, lateral constraints were eliminated, and the streams coalesced to form a broad alluvial plain. The formation consists of a poorly sorted mixture of clay, silt, sand, and gravel that is loosely cemented; the material becomes coarser or less cemented in the lower part (McGovern and Coffin, 1963). Also present are beds of soft limestone, bentonite, and volcanic ash. The top of the formation consists of a few feet of a dense, sandy limestone known as the "Algal limestone." Maximum thickness is about 500 feet in the northern Medicine Creek subbasin in Nebraska. Depth to the top of the formation varies from 0 to 200 feet, averaging less than 100 feet. The surface of the Ogallala slopes to the east with an average gradient of 12 feet/mile.

Pleistocene loess deposits (wind deposited silt and clay) are present throughout the upland areas and valley walls. These deposits, varying in thickness from 0 to 200 feet, lie above the water table and yield little water.

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Sand deposited by the wind during the Pleistocene and Holocene epochs is present in the northwest section of the upper basin with a maximum thickness of 170 feet. These deposits are an important element of the aquifer system because of their high permeability, which allows rapid recharge to the underlying Ogallala Formation.

The next most important sources of ground water are alluvium and terrace deposits of Holocene age. They are found in the valleys and under the flood plains of the larger streams and are comprised of varying mixtures of clay, silt, sand, and gravel. Thickness of these deposits varies from 0 to 90 feet.

Lower Republican Basin

The principal aquifer system in the lower basin is comprised of alluvium and terrace deposits and the Ogallala, Grand Island, and Dakota Formations. The base of the aquifer system consists of Pierre Shale, the Niobrara and Wellington Formations, and the Chase Group.

The alluvium and terrace deposits of recent and Pleistocene age are a major source of municipal and irrigation water. They are made up of unconsolidated clay, silt, sand, and gravel that have been deposited in the valleys and flood plains of the major streams. The deposits generally become more coarse with depth. Thickness of the alluvium ranges up to 130 feet. The terrace deposit thickness ranges up to 125 feet.

Covering the uplands of the lower basin are undifferentiated deposits, consisting loess, volcanic ash, and gravels formed locally by weathering or stream action. Where saturated, these deposits will provide small to moderate amounts of water for domestic and stock wells. Thickness ranges up to 100 feet.

The Grand Island Formation is a major source of irrigation water in northeastern Jewell and northwestern Republic Counties, Kansas. It consists of coarse sand and medium-to-coarse gravel interbedded with silty clay deposited during the Pleistocene age in a former channel of the Republican River (Dunlap, 1982). Thickness ranges up to 120 feet.

The Ogallala Formation is found in the Nebraska portion of the lower basin. It is comprised of sandstone and siltstone interbedded with sand, gravel, and clay and has various degrees of cementation by calcium carbonate and silica. Thickness ranges over 100 feet and thins in an easterly direction. The base of the formation slopes to the southeast with an average gradient of 7 feet/mile.

Underlying the Ogallala and forming a relatively impermeable base are the Pierre Shale and Niobrara Formation. These formations were deposited in a marine environment during the late Cretaceous age. The Pierre is a dark-gray fissile shale, and the Niobrara consists of chalky shale and limestone. The Niobrara has a thickness of about 400 feet in Harlan County, Nebraska, and thins in an easterly direction.

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Underlying the Niobrara Formation in the northern part of the lower basin, in descending stratigraphic order, are the Carlile Shale, Greenhorn Limestone, and Graneros Shale. They crop out at the surface in the central portion of the lower basin. Of these formations, the Greenhorn Limestone has the most potential for yielding small quantities of water for domestic purposes. Maximum total thickness of these deposits is about 430 feet.

The Dakota Formation is one of the principal aquifers in the vicinity of Cloud and Clay Counties (Kansas) for supplying municipal, domestic, and stock wells. Thickness ranges up to 350 feet. The quality of water varies from good-to-bad with a better quality generally obtained where the formation crops out or is near the surface. Water obtained from the Dakota Formation in most of northwestern Cloud County, Kansas contains high chloride concentrations, 250 p/m (parts per million) or higher (Fader 1968, pg 14). Walters and Bayne (1959) reported that samples obtained from the Dakota Formation in Clay County, Kansas show chloride concentrations below 250 p/m.

The Wellington Formation and Chase Group underlie the Dakota Formation to the north and crop out at the surface in Clay County, Kansas. Total thickness of these deposits ranges up to 480 feet. Small-to-moderate amounts of water for domestic and stock use may be obtained from several formations within the Chase Group. Better quality water can be obtained where the formations are not deeply buried.

ENVIRONMENT

Vegetation

The basin encompasses the Steppe and Prairie Divisions of Bailey's ecoregions. General environmental conditions found in these two divisions are shown in table 3.

Table 3.--General environmental conditions associated with the Steppe and Prairie Divisions

Division	Temperature	Rainfall	Vegetation	Soils
Prairie	Variable	Adequate all year except during dry years, maxi mum in summer	Tall grass, parklands	Prairie soils Chernozems (Mollisols)
Steppe	Variable winters cold	Rain 19.7 in/yr	Short grass, shrubs	Chestnut, brown soils and Sierozems (Mollisols and Aridosols)

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Figure 4 shows where the irrigation lands and reservoirs lie in relation to Bailey's ecoregions. The Steppe and Prairie Divisions can be divided into separate provinces, which contain the various species of the Great Plains. The grama-buffalo grass prairie (3113) is part of the Great Plains-short grass prairie province. The bluestem-grama prairie (2533), wheatgrass-bluestem-needlegrass prairie (2532), and the bluestem prairie (2531) are all part of the tall grass prairie province. Over 90 percent of the area in the basin is used for agricultural purposes with over 50 percent cropland and less than 1 percent in forest land. The balance of the land is pasture and rangeland, farmsteads, wildlife areas, water, and miscellaneous areas.

Principal crops grown in the basin include corn, grain sorghum, wheat, soybeans, and alfalfa hay. The pastureland consists of introduced grasses and legumes on smaller tracts of mostly irrigated soils. Rangeland, which is dominated by climax communities of native grasses and associated forbs, is used for grazing livestock. Forested land occurs mainly along river bottoms in narrow bands. Common species are cottonwood, boxelder, green ash, willow, and oaks.

Field shelterbelts and farmstead windbreaks include species such as Rocky Mountain juniper, eastern redcedar, russian olive, locusts, elms, ponderosa pine, and various shrubs. All of these areas are important for their ability to trap snow and soil, stabilize stream courses and streambanks, and provide wildlife habitat and forage, and to provide shade and shelter to livestock. Significant areas of forest land have been cleared for agricultural purposes in the last three decades. Decreased numbers of farmsteads and increased farming intensity have been among the factors contributing to forest land decline.

Fish and Wildlife

There are nearly 17,000 acres of wildlife habitat adjacent to the river, its tributaries, and ponds. The ponds include small structures built for livestock watering, irrigation reuse, erosion control, fish and wildlife, and local flood control. In 1978, it was estimated that approximately 9,000 ponds, averaging 1.4 acres in size, were in the basin.

The most sought after fish in the river basin are the trout, stocked near Wray, Colorado, and the channel catfish in Nebraska and Kansas. Other fish in the streams and reservoirs sought by anglers in the basin include smallmouth and largemouth bass, flathead catfish, white bass, walleye, black bullhead, white and black crappie, and carp. Most of the fishing pressure in the basin occurs in public areas on or adjacent to the reservoir lands.

Ring-necked pheasant, bobwhite quail, cottontail rabbits, and fox squirrels are the most important small game species hunted in the basin. Limited numbers of sharp-tailed grouse and prairie chickens are also pursued. Waterfowl hunted in the area consists mainly of mallards and Canada geese followed by green-winged and blue-winged teal, American widgeon, gadwall, wood duck, pintail, ring-necked duck, redhead, canvasback lesser scoup,

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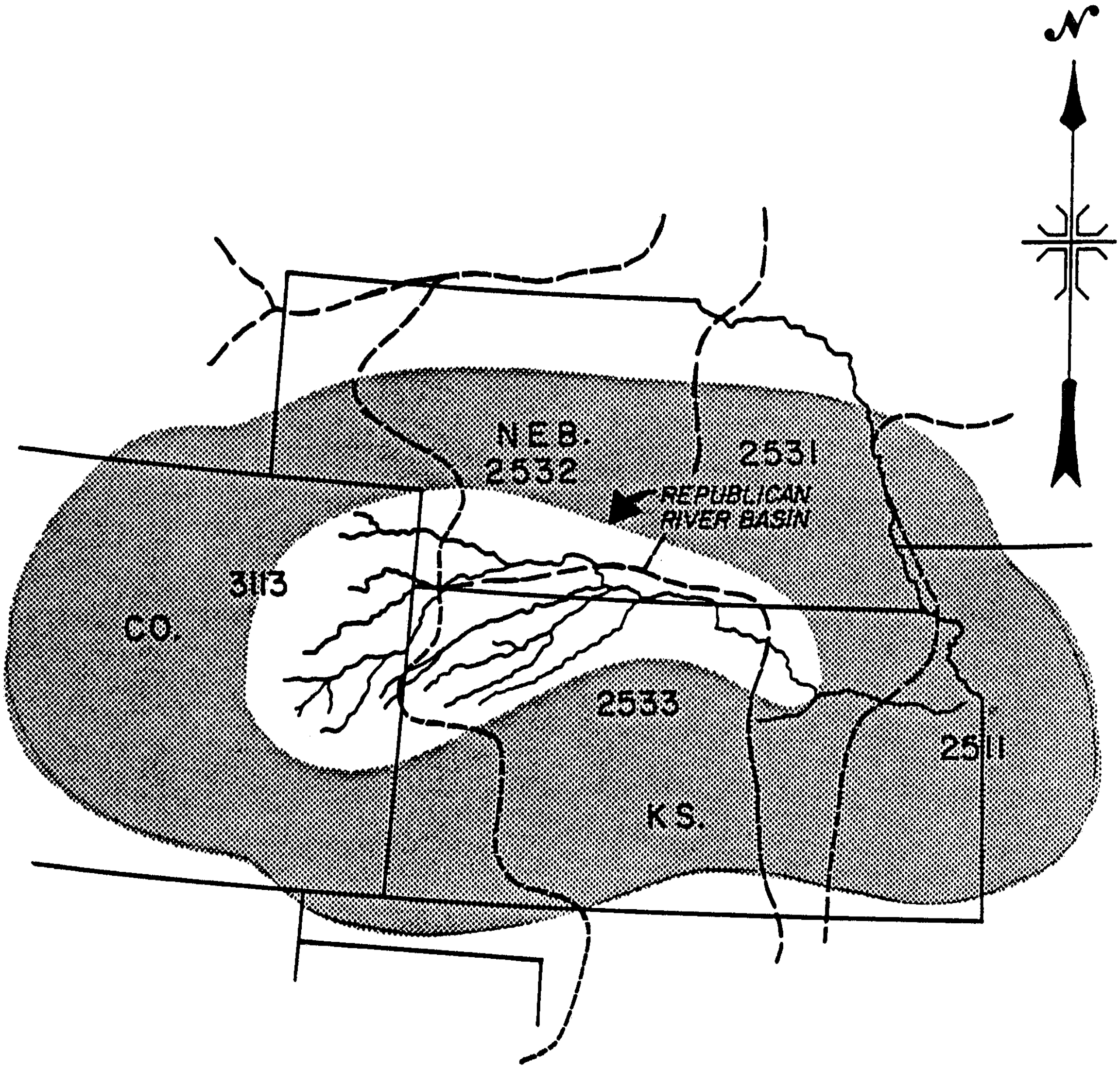

Figure 4.--Republican River Basin showing Bailey's Ecoregions

bufflehead, American goldeneye, ruddy duck, and white-fronted geese. Migratory mourning doves are also heavily hunted. Big game species pursued by archers and firearm hunters include mule deer, white-tailed deer, antelope, and turkey.

Public lands, managed for fish and wildlife resources, comprise only 0.8 percent of the 24,900 mi^2 (square miles) of the basin. There are 45 public areas which include over 82,500 acres of upland habitat, over 4,700 acres of wetlands, over 40,000 surface acres of reservoirs and lakes, and 2.75 miles of river. Nine public areas (16,300 acres) are located in Colorado, 30 areas (65,500 acres) in Nebraska, and 6 areas (46,500 acres) are located in Kansas.

HISTORY

Settlers began arriving in the region after 1873. Completion of the railroad in 1882, connecting the Republican Valley with Omaha and Denver, stimulated homesteading. Few "choice" tracts of land remained after 1886. The droughts of the 1890's and 1930's and the 1935 flood brought widespread disappointment. The recurrent cycles of wet and dry years caused a corresponding fluctuation from farm settlement to abandonment. Many enterprising farmers built distribution systems using horse-drawn slips and hand labor to irrigate with stream water.

Today, dryland farming is still common with wheat as the primary crop. The introduction of irrigation from both surface and ground-water sources has diversified crops and increased livestock production. Irrigation development also has stabilized the population by reducing the effect of droughts and floods. Corn, grain sorghum, and alfalfa are the main irrigated crops grown today. Grazing lands are utilized for beef cattle. Hog production also plays an important role in the economy. Agriculture continues to be the dominant economic sector in the basin.

Historical Floods

Flooding of the tributaries and main stem of the Republican River has occurred periodically, beginning with the legendary flood of 1876. Other major floods occurred in 1915, 1923, 1935, 1947, and 1957.

The flood of May-June 1935 is the largest of record. This flood was the result of a cloudburst in the upper portion of the watershed, mainly on the Arikaree and South Fork Republican Rivers. Local residents measured as much as 20 inches of rainfall during the night of May 30. Flood stage was exceeded for 8 days in Franklin, Nebraska. Some of the peak discharges measured were: 280,000 ft^3/s (cubic feet per second) at Cambridge, Nebraska, 200,000 ft^3/s at the gage near Stratton, Nebraska, and 168,000 ft^3/s near Junction City, Kansas. These flows were as large as any recorded since 1876. Losses included 150 lives, bridges, highways, and $1 million in property and crops.

The second largest flood in the basin occurred in June 1947. A storm over the entire Republican Basin dropped 5 inches of rain over a 3-day period.

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The Medicine Creek area received intense rainfall during the onset of the storm and was the largest tributary watershed affected. The largest residential area affected was Cambridge, Nebraska. Thirteen people were killed and approximately $16 million damage to agricultural lands, roads, bridges, and municipal property occurred. Peak flows for this flood were: 30,000 ft^3/s at Red Willow Dam, 140,000 ft^3/s at Harlan County Dam, and 116,400 ft^3/s at Medicine Creek Dam. These compare to 45,000 ft^3/s at Red Willow Dam and 260,000 ft^3/s at Harlan County Dam during the 1935 flood.

Flood Potential

The Kansas City District, Corps of Engineers, has completed a study that examined the potential for increased benefits or degree of flood protection resulting from modification of flood control operations at Reclamation projects in the Republican River Basin. Areas between Harlan County Lake, Nebraska, and Wray, Colorado, were examined. The reach between Wray, Colorado, and Benkelman, Nebraska, was inspected and did not appear to warrant further study. The analysis for the remaining portions of the Republican River included developing water surface profiles for 100-and 500-year events as well as some preliminary economic analyses of the associated floods.

The study concluded there would be no apparent increase in the benefits or degree of flood protection by changing the flood control operations of the reservoirs. The dams in existence function adequately to control flooding on the rivers and tributaries they serve. However, a potential exists for flooding on the uncontrolled portions of the rivers and tributaries in the study area.

SOCIOECONOMIC

The socioeconomic characteristics of the basin were derived using data from 4 counties in Colorado, 14 counties in Nebraska, and 10 counties in Kansas. Data derived from these counties, including the cities and towns, were representative of the basin.

Agriculture has been a major influence on both past trends and present conditions in almost every area of socioeconomic concern because the basin is located in one of the most agriculturally productive regions of the United States.

Population

Agricultural areas are often characterized by low population density and a relatively high proportion of persons living in rural areas. Although the Republican River Basin accounted for 10.1 percent of the total land area in the Tri-State Area in 1980, the 169,025 people represented only 2.5 percent of the total population in all three states. The Republican Basin had 6.4 persons per square mile in 1980 compared to 26 persons per square mile in the Tri-State Area, and 64 persons per square mile in the Nation.

A much larger proportion of the people live in rural areas in the basin as compared to the Tri-State Area as a whole with 69.4 and 28.3 percent,

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respectively. This proportion has been decreasing and corresponds to national trends. For example, between 1950 and 1980, the percentage of the basin's population living in rural areas decreased from 80.8 to 69.4 percent. The rural population of the Tri-State Area as a whole decreased by an even greater amount, from 46.3 percent to 28.3 percent. Between 1970-1980, the basin rural population has decreased only 1.6 percent.

Another pattern of change has been a slow but steady decline in the actual size of the population. Between 1930 and 1980, the population of the basin decreased from 266,457 to 169,025. Between 1970-1980, nine counties in the basin experienced growth; however, only Phelps County in Nebraska and Sherman and Thomas Counties in Kansas had 1980 populations larger than their 1930 populations. These population changes are typical of many rural/agricultural areas in the Nation. As agriculture becomes more mechanized, fewer jobs exist and rural residents either leave or migrate to urban areas in search of employment and higher education. Table 4 shows population changes from 1930 to 1980.

Median age in the basin is higher than either the Tri-State Area or the Nation. The median age in the Republican Basin in 1980 was 35.5 as compared to 29.4 in the Tri-State Area and 30 in the United States. Since 1970, the median age decreased in the basin and increased in both the Tri-State Area and the Nation.

Ethnic and racial minorities made up less than 2 percent of the basin's population in 1980. The largest minority group was of Spanish origin.

Employment, Income, and Earnings

Between 1970 and 1978, per capita income in the Republican Basin increased 192 percent from $2,483 to $7,253. This was greater than the 165 percent increase in the Tri-State Area.

Employment and earnings are concentrated in the agricultural and related industries in the basin. In 1978, 28.9 percent of employment and 30.8 percent of earnings were generated by the agricultural industry in the basin compared to 7.2 percent of employment and 5.6 percent of earnings for the Tri-State Area. Other sectors accounting for high proportional amounts included retail and wholesale trade, Government, and services. Mining was the smallest sector.

ECONOMIC BASE

Basic sectors answer demands that are external to the area's economy, and are usually export sectors. Nonbasic (service) sectors answer demands from within the area and usually serve the local population. These distinctions are built around the concept of comparative advantage - a region produces goods and services for which it is most efficient and then exchanges them for goods and services of other regions. A single industrial sector may include both basic and nonbasic activities, but one type of activity is usually dominant.

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Table 4.--Population - 1930, 1950, 1970, 1980
Republican River Basin

State/county	1930	1950	1970	1980	Growth rate 1970-1980 (percent)
Nebraska					
Chase	5,484	5,176	4,129	4,758	15.2
Dundy	5,610	4,354	2,926	2,861	- 2.2
Franklin	9,094	7,096	4,566	4,377	- 4.1
Frontier	8,114	5,282	3,982	3,647	- 8.4
Furnas	12,140	9,385	6,897	6,486	- 6.0
Gosper	4,287	2,734	2,178	2,140	- 1.7
Harlan	8,957	7,189	4,357	4,292	- 1.5
Hayes	3,603	2,404	1,530	1,356	-11.4
Hitchcock	7,269	5,867	4,051	4,079	0.7
Nuckolls	12,629	9,609	7,404	6,726	- 9.2
Perkins	5,834	4,809	3,423	3,637	6.3
Phelps	9,261	9,048	9,553	9,769	2.3
Red Willow	13,859	12,977	12,191	12,615	3.5
Webster	10,210	7,395	6,477	4,858	-10.0
Kansas					
Cheyenne	6,948	5,668	4,256	3,678	-13.6
Clay	14,556	11,697	9,890	9,802	- 0.9
Cloud	18,006	16,104	13,466	12,494	- 7.2
Decatur	8,866	6,185	4,988	4,509	- 9.6
Jewell	14,462	9,698	6,099	5,241	-14.1
Norton	11,701	8,808	7,279	6,689	- 8.1
Rawlins	7,362	5,728	4,393	4,105	- 6.6
Republic	14,745	11,478	8,498	7,569	-10.9
Sherman	7,400	7,373	7,792	7,759	- 0.4
Thomas	7,334	7,572	7,501	8,451	12.7
Colorado					
Kit Carson	9,725	8,600	7,530	7,599	0.9
Phillips	5,797	4,924	4,131	4,542	9.9
Washington	9,591	7,520	5,550	5,304	- 4.4
Yuma	13,613	10,827	8,544	9,682	13.3
Total	266,457	215,507	173,581	169,025	- 2.6

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The 1978 basic sectors in the Republican River Basin were agriculture, construction, transportation, and retail and wholesale trade. Nonbasic sectors included mining, services, manufacturing, Government, finance, insurance and real estate, and communications and public utilities.

Agriculture

The basin's agricultural output has both regional and national significance. Table 5 shows a selected crop comparison and table 6 presents crop value.

The Tri-State Area is among the Nation's top 10 producers of winter wheat, sorghum grain and silage, dry beans, corn, and sugar beets. The Republican River Basin accounted for significant amounts of many of these crops grown in the Tri-State Area as shown in the preceding tables.

Of the total crop value, corn accounted for 47.1 percent, wheat for 31.4 percent, and hay for 6.4 percent. The remaining 15.1 percent came from soybeans, barley, dry beans, sugar beets, and other crops. Phelps and Franklin Counties in Nebraska and Yuma County in Colorado led in corn production. Leading producers of wheat included Thomas and Cloud Counties in Kansas and Washington County in Colorado. Yuma and Washington Counties in Colorado led in the production of hay. Processing of these crops also makes a significant contribution to the economic base of the basin.

Livestock production makes a major contribution to the economy. Much of the livestock produced in the basin, as well as the by-products, are shipped to points all over the Nation for futher feeding and/or processing. Table 7 presents the 1978 livestock inventory.

Retail and Wholesale Trade

In 1978, retail and wholesale trade was the second largest employment and earning sector in the basin accounting for 16.8 percent of the labor force and 18.3 percent of total earnings.

The retail and wholesale trade sector is unique in that it has both strong basic and nonbasic qualities. The export of raw and finished agricultural products, as well as the sale of farm machinery and fertilizer, give it strong basic qualities. The import and purchase of commodities needed to support the local population makes this sector strongly nonbasic. Major nonbasic activities include automobile, service station, grocery, and restaurant sales.

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Table 5.--Selected crop production 1978 1/
(units = 1,000)

Area	Wheat (bu)	Corn (bu)	Sugar beets (tons)	Sorghum for grain (bu)	Hay (tons)
United States	1,799,000	7,082,000	25,800	748,000	142,000
Tri-State Area	447,452	967,400	3,348	354,970	14,201
Percent of Nation	24.9	13.7	13.0	47.5	10.0
Republican River Basin	84,732	159,140	758	34,818	1,198
Percent of Tri-State Area	18.9	16.4	22.6	9.8	8.4
Percent of Nation	4.7	2.2	2.9	4.7	0.8

Table 6.--Value of crop production, 1978 1/
($1,000)

Crop	Republican River Basin	Tri-State Area
Wheat	$245,686	$1,264,851
Corn	367,927	2,227,046
Soybeans	4,396	448,510
Barley	1,793	41,711
Hay	50,360	623,600
Dry beans	10,218	59,888
Sugar beets	14,136	80,479
Other	86,814	1,505,194
Total	$781,330	$5,659,634

Table 7.--Selected livestock inventory, 1978 1/

Livestock	Republican River Basin	Tri-State Area
Cattle and calves	1,623,000	15,680,000
Hogs and pigs	603,800	5,980,000
Sheep and lambs	53,200	892,000

1/ Agricultural Statistics - 1979; Colorado, Nebraska, Kansas. Published by the Department of Agriculture in each respective state.

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For the past decade, the retail and wholesale trade sector has been growing in its importance to the economy of the basin. Retail sales in the basin increased from over $310 million in 1967 to $491 million in 1977, and wholesale sales increased from $369 million to $990 million. Between 1967 and 1977, the number of retail establishments decreased 18 percent, and the number of wholesale establishments increased almost 14 percent.

Primary trade centers include Akron, Burlington, Holyoke, and Wray in Colorado; Goodland, Colby, Norton, Clay Center, Belleville, and Concordia in Kansas; and McCook, Holdredge, Superior, Franklin, and Red Cloud in Nebraska. Rural residents rely heavily on these centers as well as smaller local establishments to provide essential consumer goods and services. Travel to major cities such as Grand Island or Lincoln, Nebraska; Denver, Colorado; and even Kansas City for a better selection, more competitive prices, or major purchase of durable goods is not unusual.

Government

In 1978, Government was the third largest sector accounting for approximately 16.8 percent of total employment and 14.4 percent of total earnings. The majority of Government activities are of a local/service-type making this sector primarily nonbasic. Such activities include local education, law enforcement, and city and county administration. The basic state or Federal acitivities that exist are service-type such as post offices, state employment services, and several small state institutions of higher education.

Services

The services industry was the fifth largest employer and fourth largest earnings sector in the basin in 1978. This is one of the fastest growing sectors in the area's economy. Employment in the services sector increased 46 percent between 1968-1978. This growth accompanied both the migration of residents from rural to urban areas and the expansion of economic activity in the area as a whole. This created an increased demand for local personal and professional services such as automotive repair shops, dry cleaners, hair stylists, doctors, and dentists. The continued emphasis on providing local services makes this sector primarily nonbasic and this emphasis is likely to continue in the future as the area's economy grows. Basic services include hotels, motels, and restaurants that cater more to visitors.

Manufacturing

Manufacturing in 1978 was the sixth largest employment sector and fifth in earnings, accounting for 5.4 percent of total employment and 7.3 percent of total earnings. Manufacturing in the Republican River Basin is primarily nonbasic in nature.

Manufacturing establishments in 1977 totaled 199, an increase of almost 20 percent from 1972. Manufacturing employment is increasing, as is value added by manufacture. Census data for all counties are not available due

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to nondisclosure of operations by individual companies. Of those counties where information was available, value added by manufacture was $67.4 million in 1977, an increase of 174 percent from 1972.

Communities with the largest number of manufacturing establishments are: McCook and Holdrege in Nebraska; Colby, Clay Center, Concordia, Belleville, and Goodland in Kansas; and Burlington, Wray, and Holyoke in Colorado. Manufactured items are primarily agriculturally oriented.

Contract Construction

In 1978, contract construction employed 2.8 percent of the labor force and generated about 5.1 percent of total earnings. Contract construction is a nonbasic employment and earnings sector, because little or nothing is exported, and activity centers around local demand for commercial and residential structures. Contract construction supports the basic industry of agriculture as well as the manufacturing sector. Because of the support the construction sector makes toward end products that are exported from the area, it is also a basic sector.

Finance, Insurance, and Real Estate

Commercial banks, savings and loans, investment, and real estate companies are all typical establishments in this sector. This sector is primarily nonbasic. Almost every town has at least one local bank and several insurance and real estate companies that deal primarily with the day-to-day needs of the local residents. This sector has been growing and with this growth it has taken on more basic qualities as it facilitates the entry of new businesses and manufacturing in the area. This trend is expected to keep pace with continuing efforts to obtain greater diversification in the area's economic base.

Transportation, Communications, and Public Utilities

Communications, public utilities, and particularly transportation are extremely important to the area in terms of the support given other economic sectors. Economic prosperity in the basin is heavily dependent on the agricultural sector; transportation connections between rural points of farm production and urban points of processing and consumption throughout the Nation are vital to the uninterrupted flow of agricultural goods. Because of this support, as well as that given to other industries, this sector is primarily basic in nature.

Railroads and trucks are the primary modes for transporting commodities. Major railroads serving the area include the Burlington Northern and Union Pacific lines which, in combinations with other lines outside of the area, provide commodity transportation to the west coast in approximately 4 days, and to the east coast in 4 to 5 days. Trucks also play an important role. Lines using the major interstate highways such as I-70 (east-west) through the southern portion of the basin can transport goods to the west coast in 3 days, and the east coast in 4 days. Interstate I-80, just north of the basin, is also used.

KS003656

There is no well-developed public transit system and rural residents usually travel by car. Several inter- and intrastate bus lines provide service to cities along the major highways. AMTRAK provides rail service through part of the basin.

Commercial air service is available only in Goodland, Kansas, and McCook, Nebraska. Several towns outside of the area (Hays, Kansas and Grand Island, Nebraska) also have commercial facilities. There are smaller airfields offering varying levels of services to charter and private flights.

The major source of local information is the weekly newspaper, although daily publications from larger cities are available. Several radio and television stations also serve the area. Mountain Bell serves a small part of the basin with telecommunications services and several small independent companies serve the majority of the rural areas.

Public utilities such as water, sewer, sanitation, and electrical power are provided through individual communities or larger utilities serving the area. Because communications and public utilities are a service and are not involved in exporting products, they are primarily nonbasic.

Mining

In 1978, the mining sector was the smallest employment sector in the basin and is primarily nonbasic. Most activity centers around the production of sand and gravel and stone for use in local construction and highway maintenance. All counties in the basin produce some sand and gravel for local use. Mineral value and production statistics for the basin are not available due to nondisclosure of individual firm information. Basic activity exists because a small amount of the petroleum produced in the area is exported. According the 1976 Minerals Yearbook; Volume II (Bureau of Mines), Washington County was the fourth largest petroleum producing county in the State of Colorado. Also, Great Western Sugar's lime plant in Sherman County, Kansas, was the state's leading producer of lime. The mining industry plays a relatively small role in the industrial resource base of the basin's economy.

KS003657

CHAPTER III--EXISTING CONDITIONS

WATER SUPPLY AND USES

The surface water supply for the Republican River Basin originates as rainfall, accumulates as surface water runoff, and runs downstream to the confluence of the tributaries. Base flow from the alluvial aquifers and return flows from surface irrigation are other surface water sources.

Since the mid-to-late 1960's, significant decreases in instream flow have occurred. This has reduced the water supply for irrigation or other demands.

Historical Streamflows

Figure 5 shows locations of gaging stations and reservoirs, as well as the assumed locations of the section gains from base flow accretions. Also shown are the 1949-1978 average annual reservoir inflows, section gains, and gaging station flows.

The historical streamflows for the Republican River Basin were examined in a point flow study and the results are shown in figure 6. The locations of the tributary inflows and gages in the basin are shown schematically. Included are the mean annual flows, based on average monthly flows, for the 1946-1978 and 1968-1978 periods of record. Also included are the average flows for the 1978 calendar year. The dashed lines on figure 6 indicate there may be other gaging stations in these reaches. However, due to incomplete data they were not included in the point flow study.

Diversions

Table 8 shows each division and its respective conveyance system, acres supplied, average annual net supply, and minimum and maximum diversions for the 1969-1978 study period.

Farm Water Requirments

The basin was divided into three study areas using mean annual precipitation as a basis for the divisions. Figure 7 shows the farm water management study areas. Average precipitation in Area I ranges between 16-20 inches per year, while Areas II and III receive between 20-24 and 24-28 inches per year, respectively.

Consumptive Use

The consumptive use for the 1920-1978 study period has been calculated using the modified Blaney-Criddle method. The Blaney-Criddle method is explained in the Soil Conservation Service's Technical Release No. 25, entitled "Irrigation Water Requirements." Data required for estimating the consumptive use include temperature, precipitation, crop planting and

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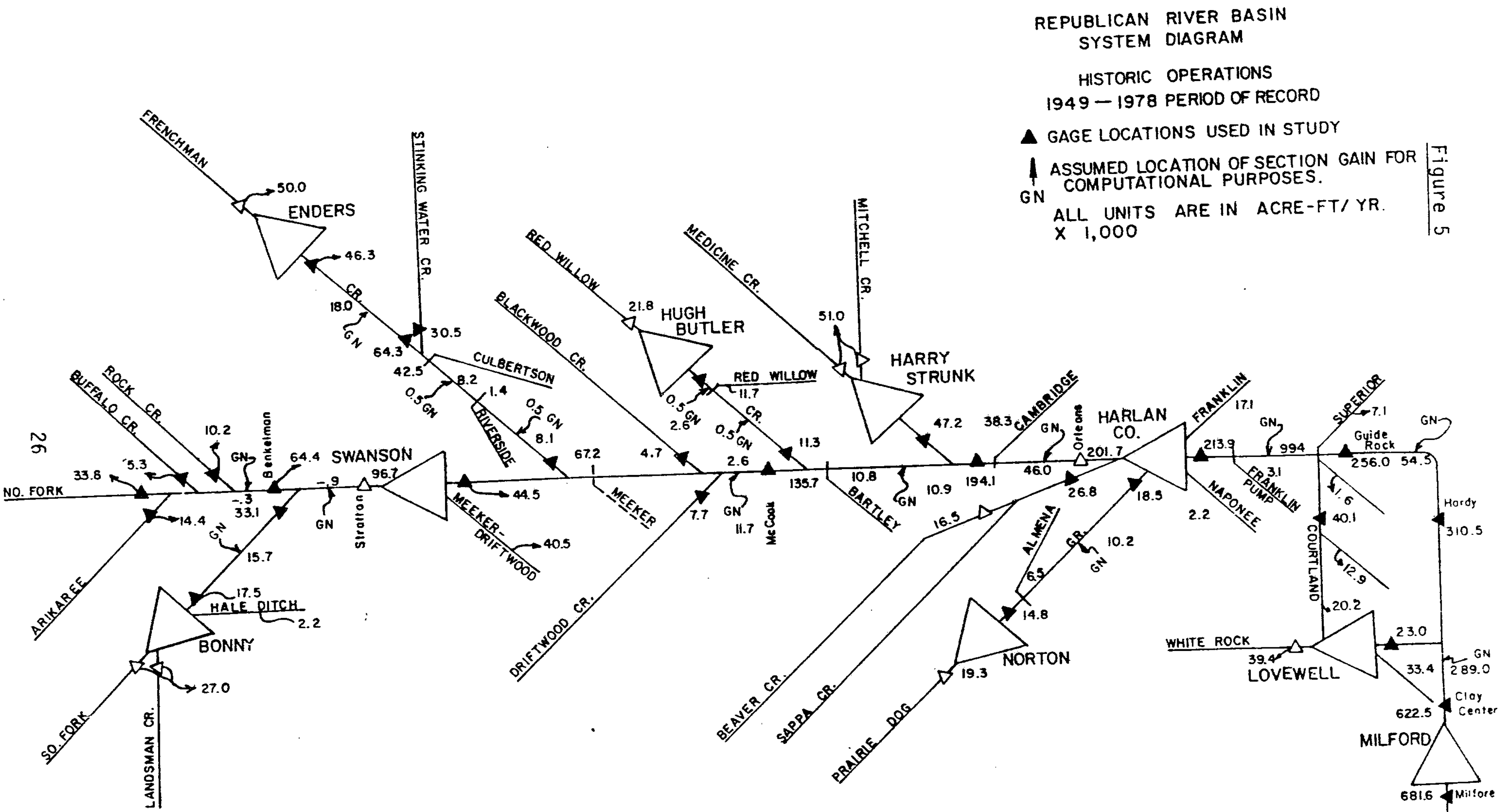

Figure 5

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Figure 6

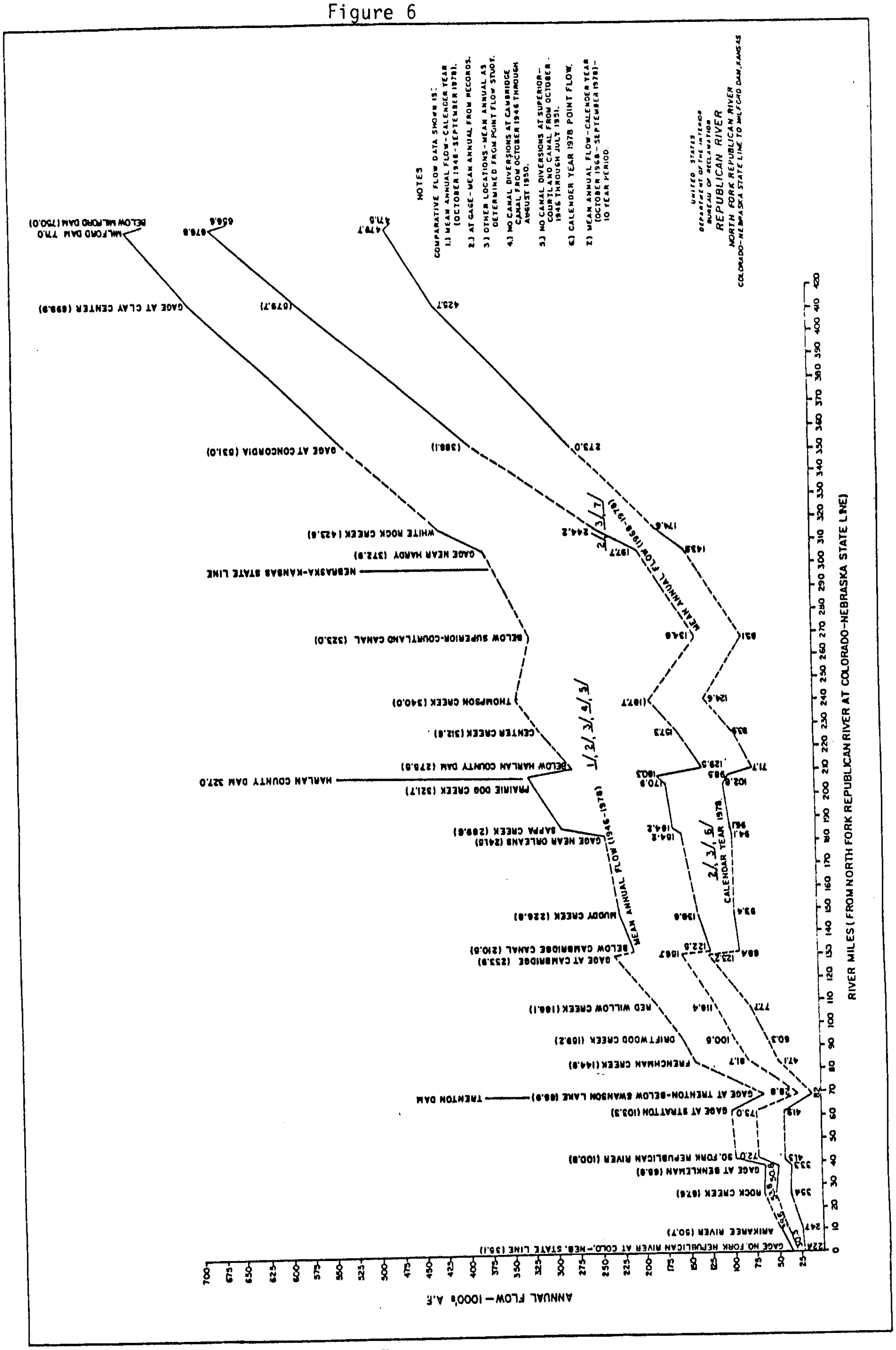
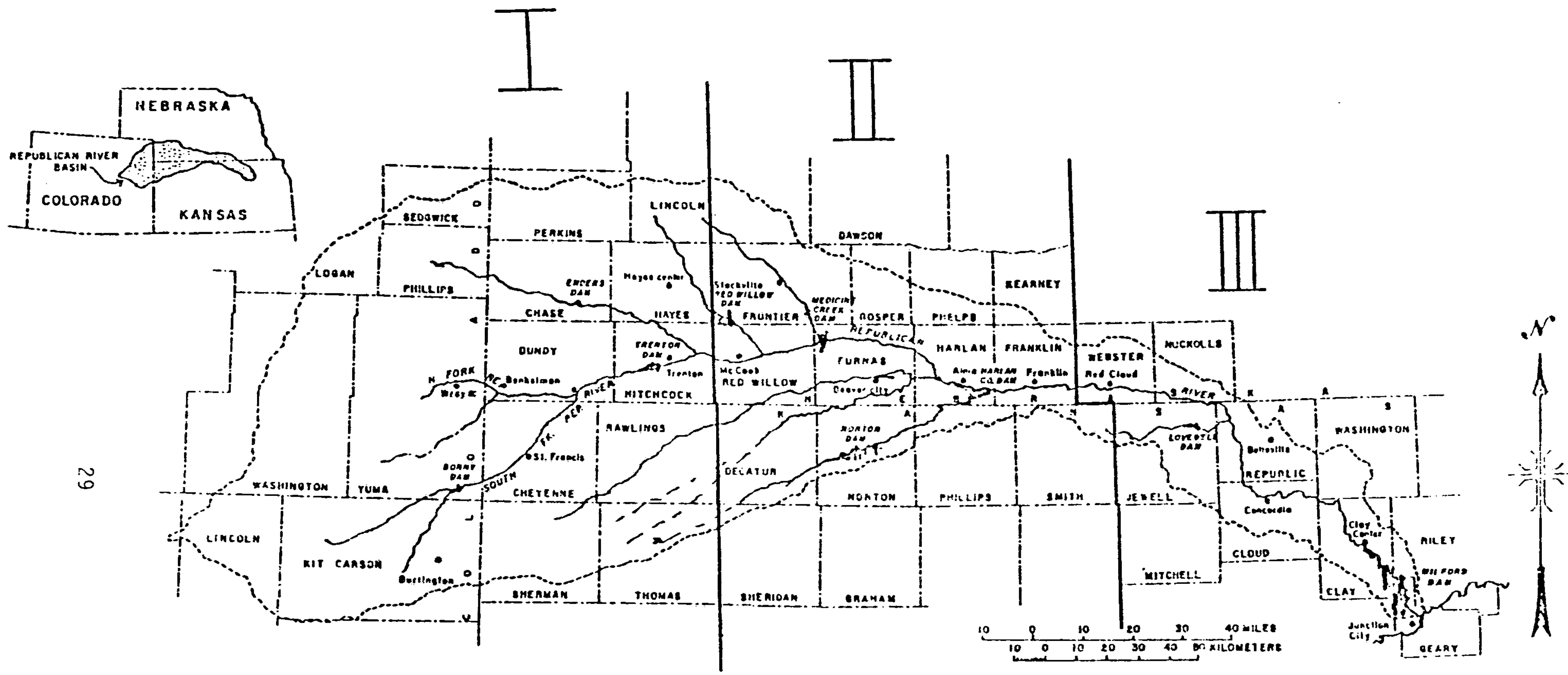

ANNUAL FLOW—1000's A.F
RIVER MILES (FROM NORTH FORK REPUBLICAN RIVER AT COLORADO-NEBRASKA STATE LINE)
GAGE NO. FORK REPUBLICAN RIVER AT COLO.-NEB. STATE LINE (35.1)
ARIKAREE RIVER (50.7)
ROCK CREEK (67.6)
GAGE AT BENKLEMAN (68.8)
SO. FORK REPUBLICAN RIVER (100.8)
GAGE AT STRATTON (103.3)
GAGE AT TRENTON-BELOW SWANSON LAKE (66.9)
TRENTON DAM
FRENCHMAN CREEK (144.9)
DRIFTWOOD CREEK (159.2)
RED WILLOW CREEK (186.1)
GAGE AT CAMBRIDGE (233.9)
BELOW CAMBRIDGE CANAL (210.8)
MUDDY CREEK (226.8)
GAGE NEAR ORLEANS (241.0)
SAPPA CREEK (289.6)
PRAIRIE DOG CREEK (321.7)
HARLAN COUNTY DAM 327.0
BELOW HARLAN COUNTY DAM (278.8)
CENTER CREEK (312.8)
THOMPSON CREEK (340.0)
BELOW SUPERIOR-COURTLAND CANAL (323.0)
NEBRASKA-KANSAS STATE LINE
GAGE NEAR HARDY (372.8)
WHITE ROCK CREEK (423.8)
GAGE AT CONCORDIA (531.0)
GAGE AT CLAY CENTER (698.9)
MILFORD DAM 771.0
BELOW MILFORD DAM (750.0)
MEAN ANNUAL FLOW (1946-1978)
1/, 2/, 3/, 4/, 5/
MEAN ANNUAL FLOW (1968-1978)
2/, 3/, 7/
CALENDAR YEAR 1978
2/, 3/, 6/
NOTES
COMPARATIVE FLOW DATA SHOWN IS:
1.) MEAN ANNUAL FLOW-CALENDER YEAR (OCTOBER 1946-SEPTEMBER 1978).
2.) AT GAGE-MEAN ANNUAL FROM RECORDS.
3.) OTHER LOCATIONS-MEAN ANNUAL AS DETERMINED FROM POINT FLOW STUDY.
4.) NO CANAL DIVERSIONS AT CAMBRIDGE CANAL FROM OCTOBER 1946 THROUGH AUGUST 1950.
5.) NO CANAL DIVERSIONS AT SUPERIOR-COURTLAND CANAL FROM OCTOBER 1946 THROUGH JULY 1951.
6.) CALENDER YEAR 1978 POINT FLOW.
7.) MEAN ANNUAL FLOW-CALENDER YEAR (OCTOBER 1968-SEPTEMBER 1978)-10 YEAR PERIOD.
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
REPUBLICAN RIVER
NORTH FORK REPUBLICAN RIVER
COLORADO-NEBRASKA STATE LINE TO MILFORD DAM, KANSAS

Table 8.--Conveyance systems and diversions

Conveyance system	Point of diversion	Acres supplied	1969-1978 Average annual net supply (acre-ft)	Diversion Minimum (acre-ft)	Year	Maximum (acre-ft)	Year
Upper Republican Division							
Hale Ditch	Bonny Dam	743	2,543	1,600	1978	3,950	1969
Frenchman-Cambridge Division							
Meeker-Driftwood	Trenton Dam	15,112	38,036	28,425	1977	42,960	1970
Red Willow	Red Willow Creek Diversion Dam	4,439	9,759	7,539	1977	12,037	1976
Bartley Canal	Bartley Diversion Dam	5,925	12,395	9,828	1969	14,935	1976
Cambridge	Cambridge Diversion Dam	15,958	34,787	15,088	1971	32,089	1976
Culbertson	Culbertson Diversion Dam	8,249	19,330	15,687	1978	22,333	1971
Culbertson Extension	Culbertson Diversion Dam	10,846	21,441	15,953	1978	26,980	1969
Total		60,529	135,748				
Kanaska Division							
Almena	Almena Diversion Dam	5,118	5,758	2,576	1972	10,091	1970
Bostwick Division							
Franklin	Harlan County Dam	9,806	29,229	21,554	1969	34,665	1976
Naponee	Harlan County Dam	1,472	3,530	2,222	1969	4,661	1976
Franklin South Side Pump	Franklin South Side Pumping Plant	1,978	3,408	1,806	1969	4,312	1971
Superior	Superior-Courtland Diversion Dam	5,125	14,589	10,262	1969	20,199	1976
Courtland-Nebraska	Superior-Courtland Diversion Dam	1,575	10,008	1,015	1969	3,261	1976
Courtland-Kansas	Superior-Courtland Diversion Dam	10,049	67,405	18,343	1972	38,614	1976
Courtland below Lovewell	Lovewell Dam	19,439	45,803	30,206	1973	71,792	1976
Total		49,444	173,972				



REPUBLICAN RIVER BASIN

Figure 7- Farm water management study areas

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harvest dates, percent of daylight hours per day, and crop distribution patterns. Corn is the predominant irrigated crop in the basin; however, silage, winter wheat, alfalfa, grass pasture, and small grain are also irrigated. Table 9 shows the average consumptive use for the crop distribution in the basin.

Table 9.--Republican River Basin
Consumptive use, Blaney-Criddle method, 1920-1978

(inches)

Month	Area I	Area II	Area III
January	0.02	0	0
February	0.03	0	0
March	0.06	0	0.01
April	0.40	0.28	0.43
May	2.25	2.29	2.63
June	4.75	5.30	5.91
July	8.10	8.89	9.22
August	7.09	7.55	7.75
September	3.29	2.88	2.27
October	0.37	0.17	0.09
November	0.05	0.01	0.01
December	0.02	0	0
Total	26.43	27.37	28.32

Crop Irrigation Requirement

The water supply to meet the consumptive use demand does not come from irrigation only. Both precipitation and nongrowing season soil moisture carryover can be effective toward meeting crop growth demands. Effective precipitation is the amount of rainfall that is effective in meeting the consumptive use. The soil moisture carryover is the water stored within the root zone during the winter, when the crop is dormant or before planting. The crop irrigation requirement is the amount of irrigation water required for crop production. Crop irrigation requirements were determined by subtracting the monthly effective precipitation and the carryover soil moisture from the monthly consumptive use.

The crop irrigation requirements for the 1920-1978 study period are:

Area I	13.73 inches
Area II	13.84 inches
Area III	12.98 inches

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Farm Delivery Requirement

The onfarm irrigation practice determines farm delivery requirement. Losses can occur from the farm turnout on the main canal system to the irrigated field. The greatest loss is seepage from the ditches. Seepage can be reduced by lining the canals or placing these ditches in buried pipe. Conveyance losses are spillage, phreatophyte use, and leaky farm gates. Other factors determining onfarm efficiencies are field characteristics and irrigation methods. Land surface contour, slope, soil type and intake rates, method of irrigation, and timing of water deliveries are important in determining the onfarm efficiency.

Table 10 shows the farm delivery requirement by area while table 8 presents the total acres irrigated from each of the canal and lateral systems.

Existing Water Conveyance System

Three irrigation districts in the Republican River Basin were analyzed. They include the Frenchman-Cambridge Irrigation District, the Bostwick Irrigation District in Nebraska, and the Kansas-Bostwick Irrigation District. The canal seepage rates were computed using the 1971-1980 average monthly volumetric losses, which were reported by the districts, and the calculated wetted perimeter from dimensions in the construction specifications. Table 11 shows the calculated average seepage rate of canals. Canal seepage losses as reported by the districts, is the difference between diverted and recorded deliveries less recorded waste. Analyses were not made for overdelivery and/or unrecorded delivery, which could significantly change the estimated canal seepage losses by as much as 50 percent. The four canals calculated to have the highest seepage rates are in the Bostwick Irrigation District in Nebraska and the Kansas-Bostwick Irrigation District. They are the Naponee, Franklin, Franklin South Side Pump, and the Courtland below Lovewell.

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Table 10.--Farm delivery requirement by area

Area I
(units-inches)

	Existing (55% efficiency)	Attainable (65% efficiency)
Consumptive use	26.43	26.43
Effective precipitation	10.71	10.71
Carryover soil moisture	2.0	2.0
Crop irrigation requirement	13.73	13.72
Onfarm losses	11.22	7.38
Farm delivery requirement	24.94 or 2.07 ft	21.10 or 1.75 ft

Area II
(units-inches)

	Existing (58% efficiency)	Attainable (65% efficiency)
Consumptive use	27.36	27.36
Effective precipitation	11.31	11.31
Carryover soil moisture	2.2	2.2
Crop irrigation requirement	13.84	13.85
Onfarm losses	9.95	7.45
Farm delivery requirement	23.80 or 1.98 ft	21.30 or 1.76 ft

Area III
(units-inches)

	Existing (61% efficiency)	Attainable (65% efficiency)
Consumptive use	28.32	28.32
Effective precipitation	12.53	12.53
Carryover soil moisture	2.80	2.80
Crop irrigation requirement	12.98	12.99
Onfarm losses	8.31	6.99
Farm delivery requirement	21.30 or 1.76 ft	19.98 or 1.66 ft

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Table 11.--Canal seepage rates

Irrigation district and canal	Average annual seepage 1971-1980 (acre-ft/yr)	Average July seepage 1971-1980 (acre-ft/mo)	Average seepage rate 1/ ($ft^3/ft^2/day$)
Kansas-Bostwick			
Courtland above Lovewell in Kansas	6,110	1,030	0.27
Courtland below Lovewell	6,130	2,720	1.20
Bostwick in Nebraska			
Courtland to state line	8,060	2,290	0.70
Franklin	11,040	4,530	1.05
Franklin South Side Pump	660	360	1.47
Naponee	880	450	1.61
Superior	4,940	1,940	0.78
Frenchman Cambridge			
Bartley	2,910	1,030	0.41
Cambridge	9,990	3,150	0.78
Meeker-Driftwood	8,850	3,220	0.93
Red Willow	2,460	780	0.58

1/ Calculated using average July seepage for 1971-1980, less high and low months.

Open ditch laterals were the standard design when the irrigation systems were constructed. The open ditch systems have high seepage losses, high annual maintenance costs, and associated drainage costs.

Harlan County Lake is the principal storage reservoir of the Kansas-Bostwick Irrigation District. Water is released from Harlan County Lake into the Republican River for diversion at the Superior-Courtland Diversion Dam. Water is then delivered through the Courtland Canal for secondary storage in Lovewell Reservoir. River fluctuations have occurred in the 44 miles between Harlan County Dam and the diversion dam due to precipitation. There is no opportunity to store the resulting peak flows and much of this water is unable to be diverted into the Courtland Canal at the diversion dam (bypassed).

Except for the five canal gates at the diversion dam, none of the control gates in the canal structures are motorized. Normal regulation of flows in the canal occurs during daylight hours, with only emergency situations dictating afterhours operation. In order to maintain near constant turnout flows for laterals and farm deliveries, along with accurate measurement and accounting of these flows, the water surface elevation in the canal must be maintained relatively constant. Consequently, present manual operations preclude the conservation of the erratic fluctuating bypass flows.

Surface Water Irrigation

Surface water supply for irrigation is affected by the amounts of water available for diversion to the canals and laterals that comprise the irrigation districts in the Republican River Basin. Significant changes have occurred in the watershed runoff characteristics during the past 3 decades. Several factors that are affecting surface water supply in the basin are: development and addition of soil and water conservation practices, changes in base flow due to increased ground-water pumping for irrigation, and cyclical variations in the precipitation regime.

Recharge from surface water irrigation practices has contributed a significant amount of water to the ground-water system in several areas of the basin. Deep percolation from applied surface water and seepage from canals and reservoirs in the Platte River Basin have caused water level rises up to 50 feet along the northern edge of the study area in Nebraska. In Kansas, water level rises due to surface water irrigation have occurred in the Grand Island Formation east of Lovewell Reservoir and in Pleistocene and Cretaceous deposits to the southwest. Small areas of rising water tables have also occurred near several reservoirs in the basin as a result of seepage.

Return flows from surface water have also increased the base flows in several of the major streams. Streams showing large increases in base flow include Driftwood and Blackwood Creeks, and the Republican River reach from Hardy, Nebraska, to Concordia, Kansas.

The estimated average annual recharge from surface water irrigation in the Republican River Basin (including seepage from the Platte River Basin) for the historic period is 211,300 acre-ft.

Ground-Water Pumping

Well development in the study area since the mid-1950's to 1960 has increased at a significant rate. Figures 8 and 9 graphically show the increase in well development by subbasin for the historic period. The number of irrigation, municipal, and industrial wells registered with the three states and acres irrigated with ground water as of May 1, 1978, are:

Figure 8.--Annual number of registered wells as of May 1, 1978, in each subbasin of the Upper Republican River Basin

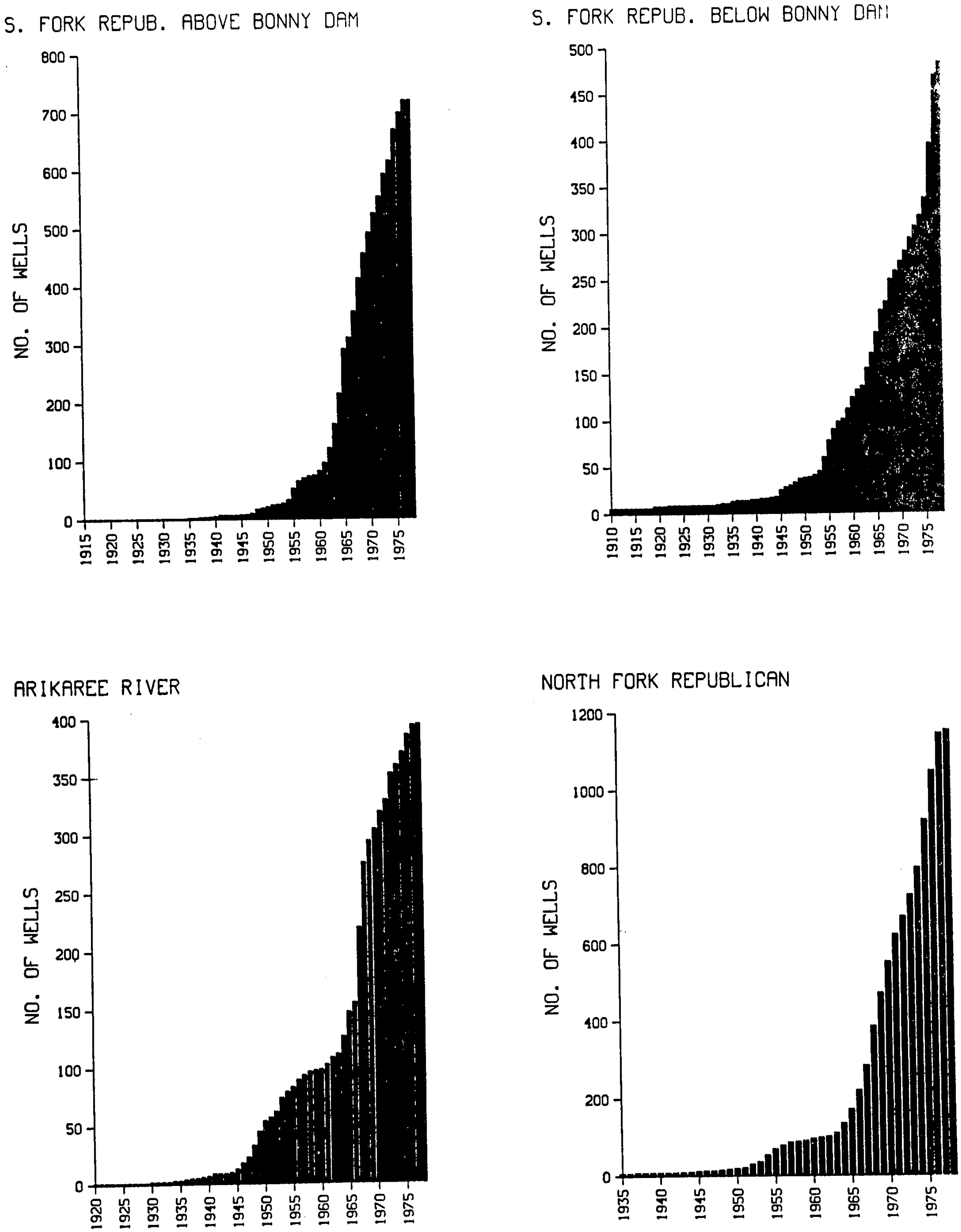

Figure 8 (con.).--Annual number of registered wells as of May 1, 1978, in each subbasin of the Upper Republican River Basin

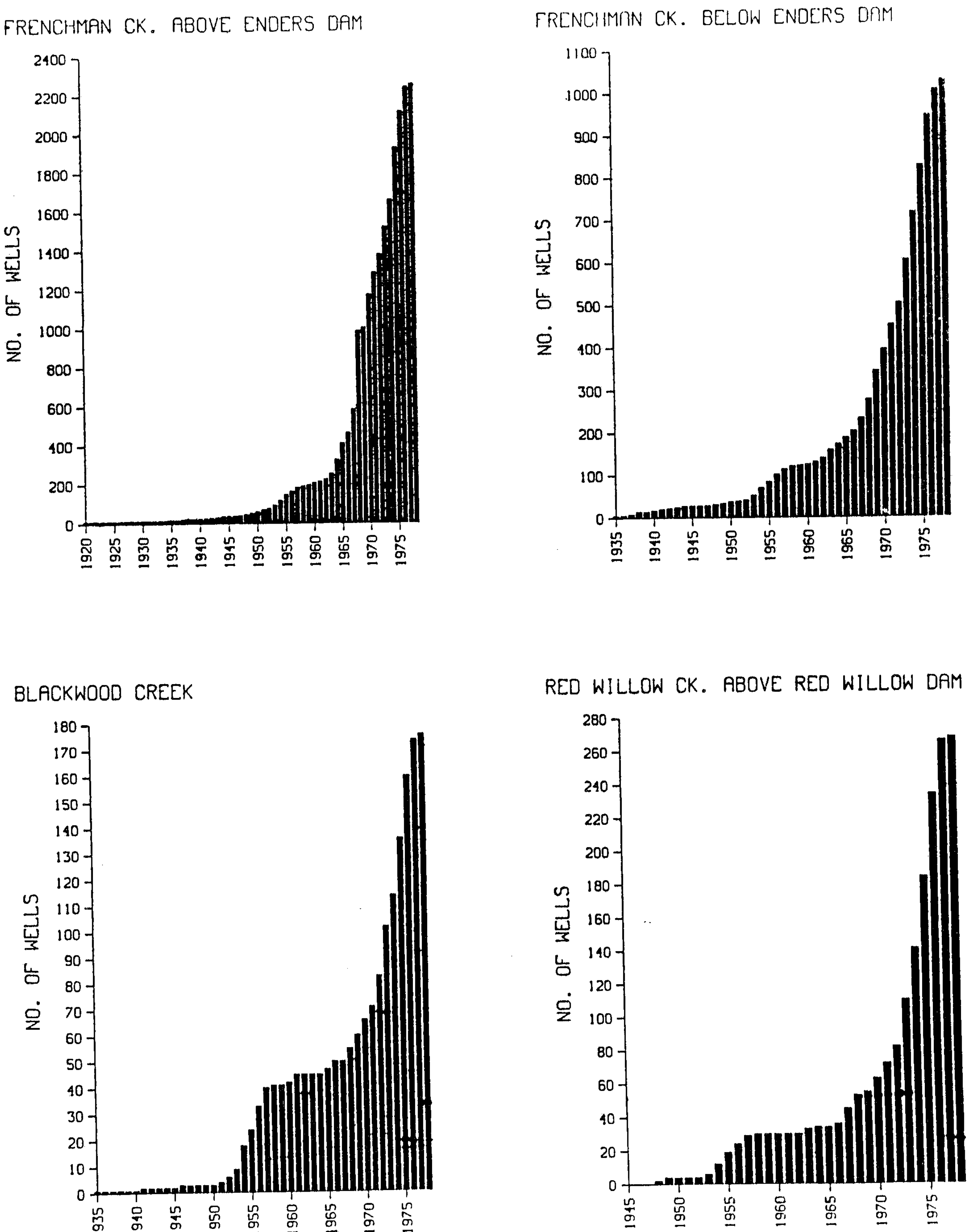

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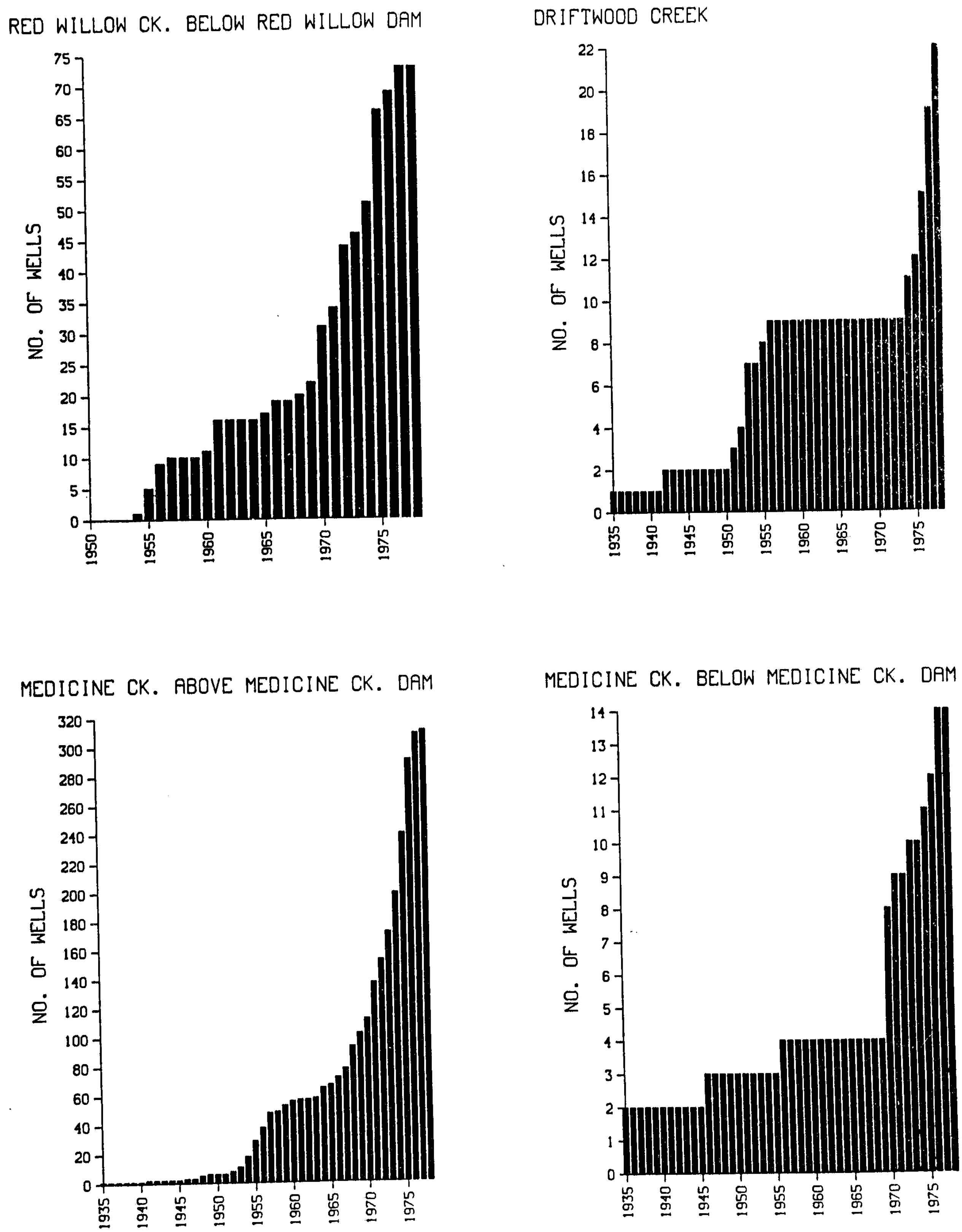
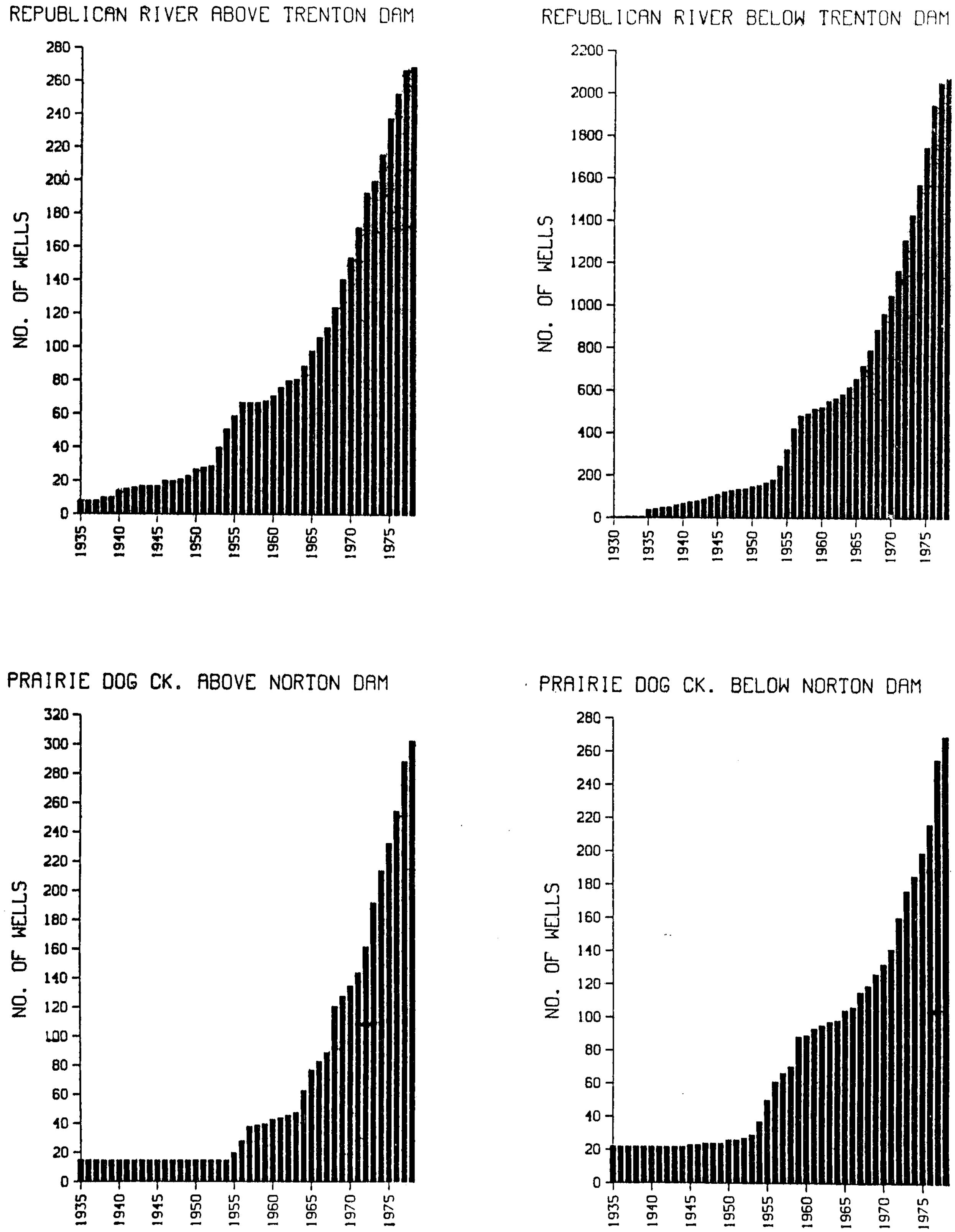
Figure 8 (con.).--Annual number of registered wells as of May 1, 1978, in each subbasin of the Upper Republican River Basin



KS003670

Figure 8 (con.).--Annual number of registered wells as of May 1, 1978, in each subbasin of the Upper Republican River Basin



KS003671

Figure 8 (con.).--Annual number of registered wells as of May 1, 1978, in each subbasin of the Upper Republican River Basin.

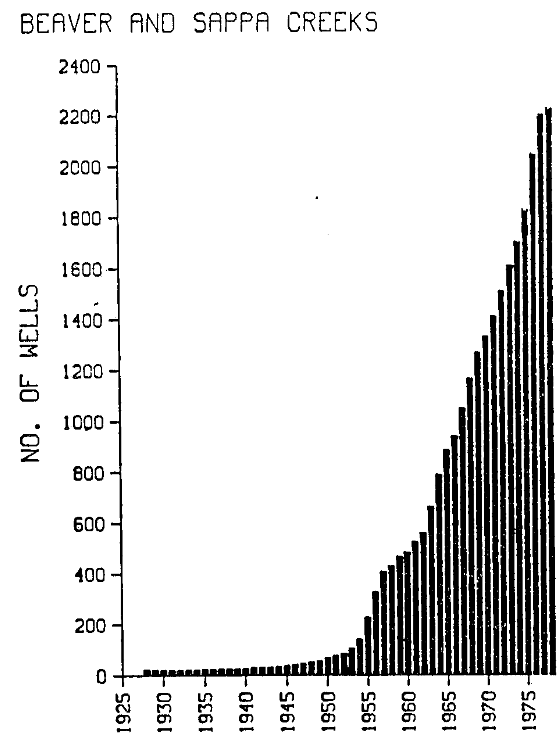


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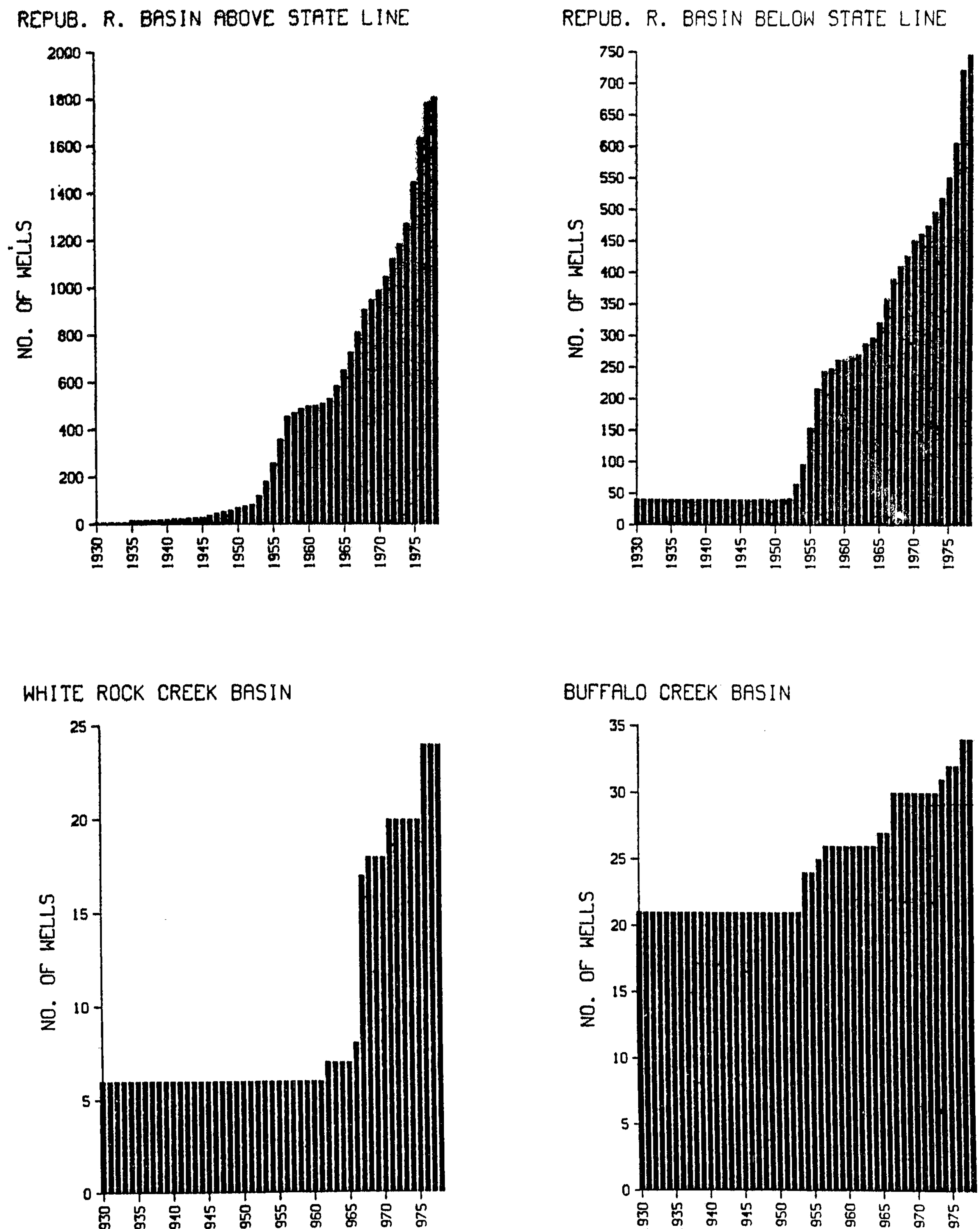
Figure 9 -- Annual number of registered wells as of May 1, 1978 in each subbasin of the Lower Republican River Basin



	Number of wells	Acres irrigated
South Fork Republican	1,202	112,300
Arikaree	395	42,900
North Fork Republican	1,152	145,600
Frenchman	3,287	441,600
Blackwood	176	19,600
Red Willow	341	40,400
Medicine	325	53,200
Driftwood	22	2,300
Beaver and Sappa	2,228	225,300
Prairie Dog	572	31,200
Mainstem Republican above Harlan County Dam	2,339	159,000
Republican from Harlan County Dam to Nebraska-Kansas State line	1,807	187,000
State line to Milford Dam	803	72,700
Total	14,649	1,533,100

In 1978, these wells were estimated to have pumped 2,131,400 acre-feet. This pumping caused an extensive amount of water level declines. The areas showing the greatest amount of water level declines are generally those portions of the basin adjacent to the Colorado State line. Declines of up to 40 feet have occurred in the areas along the southern half of the Colorado State line, mainly in the upper reaches of the Beaver and Sappa Creeks subbasin. Along the northern half of the state line declines have not been as great, ranging up to 20 feet. This is probably due to the sandier soils found in the upper half of the study area which allows for an increased recharge rate.

Although there has been a significant decline of water levels in certain areas, the overall reduction in volume of ground water in storage has not been as significant. This is mainly due to a saturated thickness that is generally quite large. The greatest saturated thickness, over 500 feet, occurs in the Ogallala Formation in the upper reach of the Medicine Creek subbasin in Nebraska. Saturated thickness in the northern half of the study area averages about 200 feet and decreases in a southerly direction. Average saturated thickness in the southern half of the basin is about 100 feet. The total predevelopment (pre-1950's) volume of ground water in storage for the Republican River Basin above Harlan County Dam and the section of the basin from Harlan County Dam down to the Nebraska-Kansas State line was determined to be 347,893,300 acre-feet. The 1977-1978 storage volume for the same area was 341,396,000 acre-feet. This represents a historic decline in storage of 6,497,300 acre-feet, which is 2 percent of the predevelopment storage volume. Table 12 shows storage changes that have occurred from predevelopment to 1977-1978 by subbasin. The 1977 storage volume of the lower Republican River Basin in Kansas for alluvium and terrace deposits was calculated to be 1,173,700 acre-feet.

Ground-water pumping has also had a significant effect on base flow contributions to streams in the basin. When a pumping well operates near a

Table 12.--Predevelopment and 1977-1978 volumes of ground water in storage and change in storage

Subbasin	Predevelopment volume in storage (acre-ft)	1977-1978 volume in storage (acre-ft)	Change in storage (acre-ft)	Percent change
South Fork Republican	21,201,900	19,357,700	-1,844,200	-9
Arikaree	10,528,700	9,776,200	- 752,500	-7
North Fork Republican	30,341,500	29,170,100	-1,171,400	-4
Frenchman	105,830,700	103,986,000	-1,844,700	-2
Blackwood	13,887,500	13,892,900	5,400	0
Red Willow	27,182,400	28,001,900	819,500	3
Medicine	35,522,000	36,592,200	1,070,200	3
Driftwood	1,270,300	1,271,000	700	0
Beaver and Sappa	42,166,800	38,351,300	-3,815,500	-9
Prairie Dog	7,211,500	6,946,700	- 264,800	-4
Republican above Harlan County Dam	38,002,600	38,903,000	900,400	2
Republican from Harlan County Dam to Nebraska-Kansas State line	14,747,400	15,147,000	399,600	3

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stream it can either reverse the water table gradient between the well and the stream, which induces streamflow to seep to the aquifer, or it can decrease the former gradient towards the stream which in turn decreases the aquifer to stream discharge. These effects do not instantaneously affect the stream, but rather lag behind the operation of the well depending upon aquifer properties and distance from the well to the stream.

The base flow used in this report is actually the mean wintertime streamflow for the months of November to February for the upper Republican Basin and November to January for the lower Republican Basin. This mean streamflow was assumed to represent the annual average base flow and was calculated for every year of available record. These annual values were then plotted into a single-mass diagram to determine if there were any significant changes in the long-term base flow regime. Note that in several instances the estimated base flow is greater than the average annual flow (Buffalo Creek), figure 5 and table 13). This occurs because diversions in the spring and summer months reduce the average annual flows to values lower than the base flows calculated by averaging streamflows over the winter months.

Several streams in the upper Republican River Basin have been experiencing significant declines in base flow and are listed in table 13. Beaver Creek at Cedar Bluffs, Kansas, has experienced the greatest decline with 98 percent reduction in base flow since 1968. Probable maximum streamflow depletions caused by pumping wells were calculated by the Glover method. The results of those calculations, listed in table 14 by subbasin, show that wells are significantly stressing the streamflow in the basin.

It should be noted that the above derived streamflow depletions were not verifiable and based on the assumptions needed to use the Glover method, they are probably higher than the actual depletions. Since the calculated depletions were used to project the future water supply in the basin, the results will probably show a smaller future water supply than will actually exist.

Soil and Water Conservation Practices

Soil and water conservation practices (residue management, terracing, and farm ponds) contribute the largest depletions to the basin water supply.

During the past 3 decades, soil and water conservation practices have increased dramatically. The purpose of the practices is to reduce soil erosion and increase the available soil moisture for plant growth by holding more moisture in the soil profile. Changes in runoff have reduced the inflows to the reservoirs in the Republican River Basin. Table 15 shows how the farm water pond distribution has developed over the study period. Figure 10 graphically shows the development of the land terrace and contouring, crop residue management, and farm ponds based on percentages of the 1979 levels. Table 16 presents the total acres terraced and total acres of crop residue management in use as of 1979. There are two curves for lands treated with crop residue management practices. These imply that lands with higher percentages of row crops historically have had lower levels of crop residue management.

KS003676

Table 13.--Streams with significant changes in base flow

Stream	Approximate year of change	Average base flow before change (acre-ft/yr)	Average base flow after change (acre-ft/yr)	Change in base flow (acre-ft)	Percent change
Streams with decreasing base flow					
Landsman Creek near Hale	1962	1,200	700	- 500	- 42
Arikaree River at Haigler	1953	11,700	5,800	- 5,900	- 50
Buffalo Creek near Haigler	1959	7,400	6,300	- 1,100	- 15
Frenchman Creek near Imperial	1968	56,900	40,700	-16,200	- 28
Frenchman Creek from Palisade to Culbertson	1969	13,600	9,700	- 3,900	- 29
Beaver Creek at Cedar Bluffs	1968	4,500	100	- 4,400	- 98
Sappa Creek near Beaver City	1955	5,700	3,200	- 2,500	- 44
Prairie Dog Creek above Keith Sebelius Lake	1970	2,900	1,000	- 1,900	- 66
Sappa Creek near Stamford	1968	14,300	2,100	-12,200	- 85
Streams with increasing base flow					
Blackwood Creek near Culbertson	1961	600	1,600	1,000	+167
Driftwood Creek near McCook	1959	300	2,800	2,500	+833

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Table 14.--Historic streamflow depletions due to pumping wells in the Lower Republican River Basin (continued)

YEAR	REPUB. R. SUBBASIN ABOVE NEB.-KS. STATE LINE (ACRE-FT)	REPUB. R. SUBBASIN BELOW NEB.-KS. STATE LINE (ACRE-FT)	WHITE ROCK CREEK SUBBASIN (ACRE-FT)	BUFFALO CREEK SUBBASIN (ACRE-FT)
1930	0	1300	100	100
1931	0	1600	200	100
1932	0	1700	200	100
1933	0	1800	200	100
1934	0	1800	200	100
1935	400	1800	200	100
1936	500	1800	200	100
1937	600	1800	200	100
1938	700	1800	200	100
1939	800	1800	200	100
1940	900	1800	200	100
1941	1000	1800	200	100
1942	1100	1900	200	100
1943	1100	1900	200	100
1944	1200	1900	200	100
1945	1400	1900	200	100
1946	1500	1900	200	100
1947	1700	1900	200	100
1948	2200	1900	200	100
1949	2600	1900	200	100
1950	3100	1900	200	100
1951	3300	2000	200	100
1952	3600	2000	200	100
1953	4200	3600	200	100
1954	5400	5600	200	300
1955	6500	10000	200	400
1956	7600	14500	200	400
1957	8400	17500	200	500
1958	9100	18900	200	500
1959	9600	20100	200	500
1960	10000	20700	200	500
1961	10400	21300	200	500
1962	10800	21700	200	500
1963	11100	22500	200	500
1964	11700	23400	200	500
1965	12400	24600	200	600
1966	13100	26600	300	600
1967	14100	28600	600	800
1968	15200	30500	800	800
1969	16100	32000	800	800
1970	17200	33300	800	800
1971	18600	34400	800	800
1972	20000	35600	800	800
1973	21600	36900	800	800
1974	23200	38400	800	800
1975	24700	40500	800	900
1976	26900	43300	800	900
1977	29300	48300	900	1000
1978	31100	51600	900	1000

KS003678

Table 14.--Historic streamflow depletions due to pumping wells in the Upper Republican River Basin

	S. FORK REPUB. ABOVE BONNY DAM (ACRE-FT)	S. FORK REPUB. BELOW BONNY DAM (ACRE-FT)	ARIKAREE (ACRE-FT)	N. FORK REPUB. (ACRE-FT)	FRENCHMAN ABOVE ENDERS (ACRE-FT)	FRENCHMAN BELOW ENDERS (ACRE-FT)	BLACK-WOOD (ACRE-FT)	RED WILLOW ABOVE R.W. DAM (ACRE-FT)
1940	300.	200.	0.	0.	900.	1400.	0.	0.
1941	300.	200.	0.	0.	1000.	1700.	0.	0.
1942	300.	200.	0.	100.	1100.	1900.	0.	0.
1943	300.	200.	0.	200.	1200.	2100.	0.	0.
1944	300.	200.	0.	300.	1400.	2400.	0.	0.
1945	300.	400.	0.	500.	1500.	2500.	0.	0.
1946	300.	700.	0.	600.	1600.	2600.	0.	0.
1947	300.	800.	0.	600.	1600.	2600.	100.	0.
1948	400.	900.	0.	600.	1700.	2700.	100.	0.
1949	400.	1100.	0.	700.	1800.	2700.	100.	0.
1950	400.	1200.	0.	1000.	2000.	2900.	100.	0.
1951	600.	1300.	100.	1200.	2200.	3000.	100.	0.
1952	700.	1400.	100.	1700.	2500.	3100.	100.	0.
1953	800.	1500.	100.	1900.	3000.	3400.	300.	0.
1954	800.	2000.	300.	2400.	3800.	4200.	900.	400.
1955	800.	2300.	300.	2900.	4700.	5000.	1400.	700.
1956	1000.	2500.	600.	3500.	6000.	6000.	1900.	1000.
1957	1200.	2900.	700.	4100.	6800.	6600.	2200.	1200.
1958	1300.	3000.	800.	4200.	7300.	7200.	2400.	1400.
1959	1400.	3500.	800.	4400.	7800.	7500.	2500.	1500.
1960	1600.	4200.	800.	4700.	8400.	7700.	2600.	1600.
1961	1800.	4500.	900.	5000.	8900.	8300.	2800.	1600.
1962	2300.	4700.	1000.	5100.	9300.	8800.	3000.	1700.
1963	2500.	4900.	1200.	5400.	9500.	10000.	3000.	1800.
1964	2600.	5200.	1300.	5600.	10900.	[illegible]	3100.	2000.
1965	3100.	5600.	1400.	5800.	11600.	11500.	3100.	2100.
1966	3300.	6300.	1500.	6200.	13200.	12000.	3200.	2200.
1967	3400.	6600.	1800.	6500.	15200.	12600.	3300.	2300.
1968	3600.	7000.	2100.	7500.	18100.	13800.	3400.	2500.
1969	3800.	7500.	2300.	8700.	21700.	15800.	3400.	2600.
1970	4000.	7900.	2500.	9800.	25200.	18000.	3500.	2900.
1971	4400.	8300.	2700.	11100.	28900.	19400.	3700.	3100.
1972	4700.	8800.	2900.	12400.	32900.	21000.	4100.	3300.
1973	4900.	9200.	3100.	13400.	37400.	22600.	4400.	3500.
1974	5100.	9600.	3300.	14400.	41900.	24300.	5000.	3800.
1975	5400.	10000.	3600.	15900.	46600.	25900.	5300.	4600.
1976	5800.	10800.	4000.	17500.	51300.	27900.	5600.	5500.
1977	6200.	12600.	4400.	18900.	56300.	30400.	6100.	6500.
1978	6700.	13900.	4700.	20200.	60400.	32300.	6400.	7400.

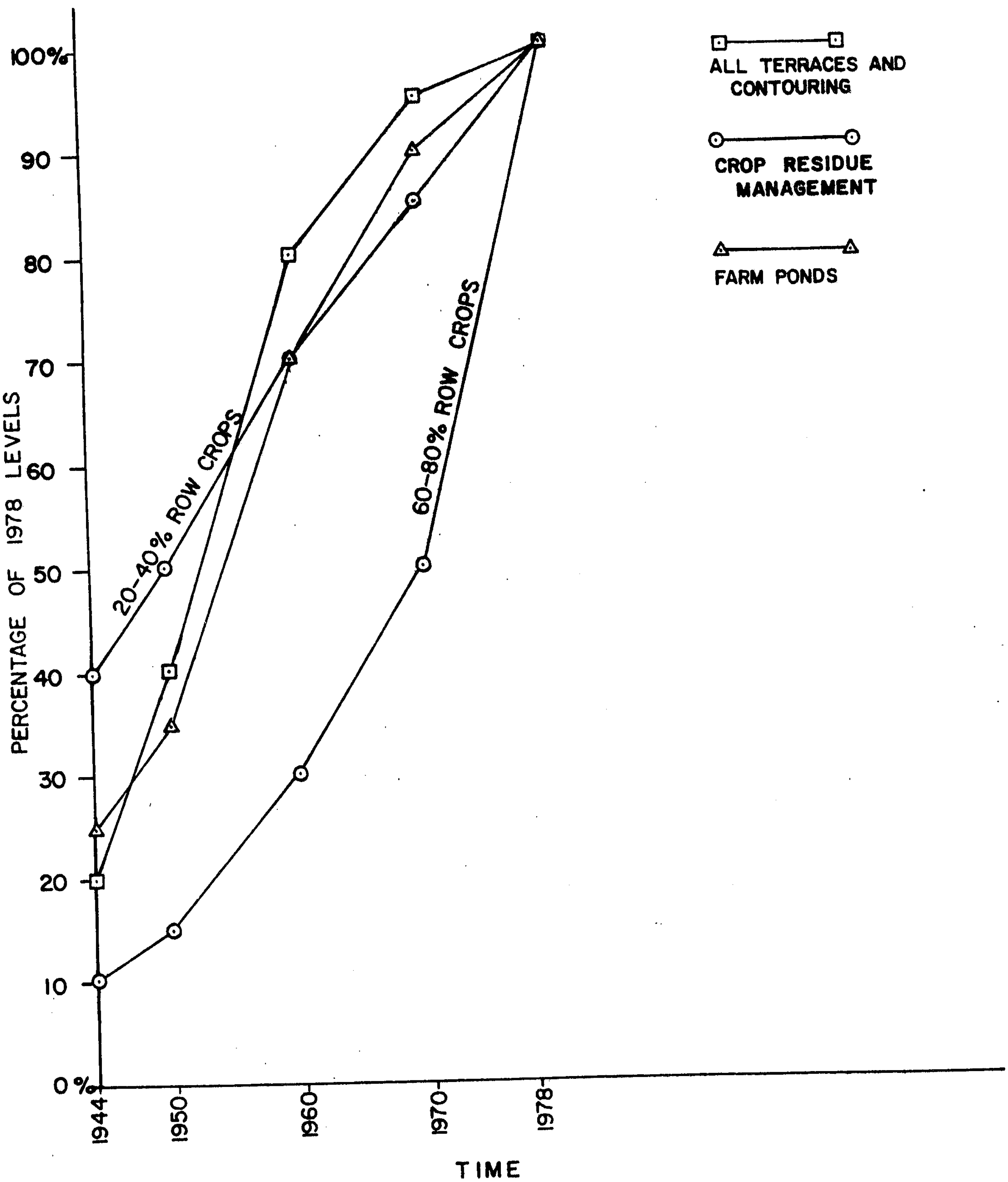
	RED WILLOW BELOW R.W. DAM (ACRE-FT)	MEDICINE CREEK ABOVE MED. DAM (ACRE-FT)	MEDICINE CREEK BELOW MED. DAM (ACRE-FT)	DRIFT-WOOD (ACRE-FT)	BEAVER AND SAPPA (ACRE-FT)	P. DOG ABOVE NORTON DAM (ACRE-FT)	P. DOG BELOW NORTON DAM (ACRE-FT)	REPUB. ABOVE TRENTON DAM (ACRE-FT)	REPUB. BELOW TRENTON DAM (ACRE-FT)
1940	0.	0.	200.	100.	900.	0.	700.	800.	3000.
1941	0.	0.	200.	100.	1200.	0.	700.	1000.	3300.
1942	0.	0.	200.	100.	1300.	0.	700.	1000.	3600.
1943	0.	0.	200.	100.	1400.	0.	700.	1100.	4000.
1944	0.	0.	200.	200.	1600.	0.	700.	1100.	4400.
1945	0.	0.	200.	200.	1800.	0.	700.	1200.	4800.
1946	0.	100.	200.	200.	2100.	0.	700.	1400.	5300.
1947	0.	100.	300.	200.	2300.	0.	700.	1400.	5700.
1948	0.	100.	300.	200.	2700.	0.	700.	1600.	6200.
1949	0.	300.	300.	200.	3000.	0.	700.	1800.	6400.
1950	0.	300.	300.	200.	3300.	0.	800.	2000.	6800.
1951	0.	400.	300.	200.	3700.	0.	800.	2200.	7100.
1952	0.	400.	300.	300.	4500.	0.	800.	2300.	7500.
1953	0.	700.	300.	500.	5100.	0.	800.	2800.	[illegible]
1954	0.	1000.	300.	600.	6400.	0.	900.	3400.	9400.
1955	200.	1400.	300.	700.	9400.	0.	1200.	3800.	11000.
1956	400.	2200.	400.	800.	13200.	100.	1500.	4000.	[illegible]
1957	500.	2600.	400.	800.	16900.	300.	1800.	4100.	14400.
1958	600.	3000.	400.	800.	18600.	300.	2000.	4200.	15400.
1959	600.	3500.	400.	900.	20600.	300.	2500.	4400.	16200.
1960	700.	4000.	400.	900.	21800.	300.	2800.	4600.	16300.
1961	1100.	4300.	400.	900.	23300.	300.	2900.	4900.	17800.
1962	1200.	4500.	400.	900.	24200.	300.	3100.	5100.	18600.
1963	1200.	4700.	400.	900.	25400.	300.	3200.	5300.	19300.
1964	1200.	5300.	400.	900.	26800.	400.	3300.	5700.	19900.
1965	1300.	5700.	400.	900.	28000.	400.	3500.	5900.	20700.
1966	1500.	6200.	500.	900.	29500.	500.	3600.	6100.	21500.
1967	1500.	6700.	500.	900.	31100.	500.	3800.	6400.	22400.
1968	1600.	7100.	500.	900.	32700.	500.	4000.	6600.	23400.
1969	1700.	7600.	500.	900.	34800.	600.	4100.	7000.	24400.
1970	1900.	8100.	700.	900.	36500.	700.	4400.	7300.	25600.
1971	2100.	8700.	900.	900.	38500.	800.	4500.	7600.	27400.
1972	2400.	9600.	1000.	900.	41000.	1000.	5000.	8200.	29000.
1973	2600.	10500.	1000.	900.	43500.	1100.	5500.	8600.	31100.
1974	2800.	11400.	1100.	1000.	45900.	1200.	5900.	8700.	33200.
1975	3200.	12400.	1100.	1100.	49400.	1300.	6100.	9200.	35400.
1976	3500.	13700.	1300.	1400.	54500.	1500.	6400.	9500.	38400.
1977	3800.	15100.	1500.	1700.	59400.	1800.	7100.	9800.	41200.
1978	4000.	16600.	1600.	2000.	63200.	1900.	7800.	10000.	43400.

Table 15.--Number of farm water ponds, Republican River Basin

Subbasin		1949	1954	1959	1964	1969	1974	1979
Above Harlan County Dam								
Frenchman Creek	(CO)	237	354	472	539	607	640	674
	(NE)	388	581	775	886	996	1,052	1,107
North Fork Republican	(CO)	54	81	109	124	140	147	155
	(NE)	37	56	75	85	96	101	107
	(KS)	6	10	13	15	17	18	18
Arikaree Rvr	(CO)	102	153	204	233	262	277	291
	(NE)	1	2	2	2	3	3	3
	(KS)	8	12	16	18	20	22	23
South Fork Republican	(CO)	111	166	222	253	285	301	317
	(NE)	1	2	2	3	3	3	3
	(KS)	117	175	233	267	300	317	333
Blackwood Crk	(NE)	50	75	100	114	129	136	143
Red Willow Crk	(NE)	145	217	289	331	372	393	414
Driftwood Crk	(NE)	80	120	160	183	206	217	229
	(KS)	28	42	57	65	73	77	81
Sappa Crk	(CO)	39	59	78	90	101	106	111
	(NE)	550	825	1,100	1,257	1,414	1,492	1,571
	(KS)	466	699	932	1,066	1,199	1,266	1,332
Prairie Dog Crk	(NE)	56	84	113	129	145	153	161
	(KS)	232	347	463	529	596	629	662
Medicine Crk	(NE)	260	391	521	595	670	707	744
Main Stem Republican Rvr	(NE)	1,264	1,896	2,528	2,889	3,250	3,431	3,611
	(KS)	36	54	72	82	92	98	103
Below Harlan County Dam								
Main Stem Republican Rvr	(NE)	1,335	2,002	2,669	3,050	3,432	3,622	3,813
	(KS)	1,636	2,453	3,271	3,739	4,206	4,440	4,673
White Rock Crk	(KS)	415	620	827	945	1,063	1,123	1,182
Buffalo Crk	(KS)	362	543	724	827	930	982	1,033

KS003680

FIGURE 10— TIME DISTRIBUTION OF CONSERVATION PRACTICES



KS003681

Table 16.--Conservation Practices - 1979 - Republican River Basin

Subbasin		Terraced (total acres)	Crop residue mgmt (total acres)
Above Harlan County Dam			
Frenchman Creek	(CO)	185,555	1,454,373
	(NE)	213,925	926,953
North Fork Republican River	(CO)	8,776	791,325
	(NE)	60,110	301,000
	(KS)	27,312	123,647
South Fork Republican River	(CO)	174,706	1,350,768
	(NE)	27,312	123,647
	(KS)	128,504	696,000
Blackwood Creek	(NE)	170,904	730,210
Red Willow Creek	(NE)	469,757	858,614
Driftwood Creek	(NE)	287,635	435,014
	(KS)	234,211	575,592
Sappa Creek	(CO)	83,685	530,000
	(NE)	447,747	459,474
	(KS)	790,246	1,387,012
Prairie Dog Creek	(NE)	256,299	259,474
	(KS)	975,091	1,520,268
Arikaree River	(CO)	174,706	1,350,768
	(NE)	27,312	123,647
	(KS)	60,110	301,000
Medicine Creek	(NE)	587,348	1,004,614
Main Stem Republican River	(NE)	833,240	1,277,554
	(KS)	377,497	770,592
Below Harlan County Dam			
Main Stem Republican River	(NE)	209,878	242,088
	(KS)	631,764	1,371,300
White Rock Creek	(KS)	310,769	768,485
Buffalo Creek	(KS)	276,898	789,159

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The impacts of the various soil and water conservation practices have been estimated using an adapted version of the SCS (Soil Conservation Service) method described in the SCS National Engineering Handbook, section 4 (1972).

To assess these impacts, two computer models have been developed. The first model simulates the surface hydrology of the basin by segregating the conservation practice water uses into each factor contributing to runoff (land uses). This program also models the water budget of a typical farm pond. The second model uses the precipitation excess as calculated by the first program to determine runoff depletions in the watershed. Depletions are segregated into those attributed to terraces, crop residue management, and farm/stock ponds.

The subbasins of the upper Republican River Basin have an average annual historic conservation practice depletion of 197,300 acre-feet/year while the subbasins below Harlan County Lake are depleted by 129,500 acre-feet/year.

If conservation practice development remains at a level consistent with those of 1978, 238,200 acre-feet/year of depleted inflow may be expected above Harlan County Dam. Depletions in the lower basin may be expected to occur at a rate of 97,300 acre-feet/year.

Table 17 shows the depletions on an average annual basis for each of the subbasins in the Republican River Basin. Table 18 presents the historic and present level of development depletions for the entire basin.

In several of the subbasins in the lower basin, depletions are lower than expected when compared to historic rates. This is because levels of development are less as a result of decreased acreages harvested in 1978 than they have been historically. For example, in 1978 there were 1.6 million acres harvested in the Kansas portion of the lower Republican River Basin versus 1.75 million acres in 1974.

Based on future rates of development, it is estimated that depletions will be 15 percent larger than what currently exists. This implies that depletions of 273,900 and 111,900 acre-feet would occur annually in the upper and lower basins, respectively.

Conservation is an important factor. If the future water supply of the basin is to be assured, conservation practices need to be recognized as a major source of depletion to the flows in the Republican River Basin and managed accordingly.

The conservation practice depletions are not easily verifiable. The methodology used is empirically derived and is data intensive. In all fairness, the depletions are probably high and should be used with caution. Any estimates of future water supply are probably not as low as the results indicate.

Table 17.--Average annual conservation practice depletions 1949-1978

Basin and subbasin	Level of development Historic (acre-ft)	Present 1978 (acre-ft)
Upper Republican		
Frenchman Creek	26,500	33,900
North Fork Republican	4,200	5,900
Arikaree	3,600	5,300
South Fork Republican	9,400	11,800
Blackwood Creek	2,300	3,000
Red Willow Creek	6,000	7,400
Driftwood Creek	6,100	7,000
Beaver and Sappa Creeks	66,500	76,400
Prairie Dog Creek	19,000	20,400
Medicine Creek	9,600	12,200
Main Stem Republican River	44,100	54,900
Lower Republican		
Buffalo Creek	13,800	18,400
Lower Republican River - NE	36,500	22,300
Lower Republican River - KS	65,300	38,100
White Rock Creek	13,900	18,500
Total depletion	326,800	335,500

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Table 18.--Total Republican River Basin conservation practice depletions

Year	Level of development: Historic (1,000 acre-ft)	Level of development: Present (1978) (1,000 acre-ft)
1949	203.52	414.97
1950	157.08	298.72
1951	318.09	639.16
1952	60.58	115.21
1953	112.26	240.63
1954	67.59	82.88
1955	90.57	122.68
1956	45.43	60.26
1957	342.54	472.13
1958	226.59	304.32
1959	237.82	233.63
1960	302.92	289.63
1961	374.91	360.59
1962	476.59	551.11
1963	248.59	274.00
1964	252.29	219.57
1965	851.00	834.15
1966	167.28	175.21
1967	457.46	425.74
1968	310.55	277.25
1969	453.40	407.03
1970	270.89	197.74
1971	583.17	484.68
1972	480.51	385.02
1973	791.49	639.62
1974	205.40	186.91
1975	549.01	459.35
1976	177.73	146.16
1977	704.01	566.01
1978	282.33	195.29
Total depletion	9,799	10,062

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Precipitation Changes

In an arid to semiarid basin, such as the Republican, agriculture is extremely sensitive to any changes in the precipitation regime. These changes must be analyzed as a possible source of declining water supply in the Republican River Basin.

Precipitation patterns in the Republican River Basin are quite variable and spotty, especially the highly localized thunderstorms that are so frequent. Because of the storms, the conclusions presented below are based on trends and changes which occurred over a period of 5 or more years.

In the upper portion of the basin above Harlan County Lake, Thiessen-weighted annual precipitation has averaged 0.50 and 2.60 inches for 1966-1973 and 1974-1978, respectively, below a 59-year (1920-1978) average of 18.64 inches. The 1957-1978 precipitation is 18.54 inches.

For the lower portion below Harlan County Lake, Thiessen-weighted precipitation averaged 2.86 inches (1966-1973) above and 1.25 inches (1974-1978) below a 59-year average of 26.74 inches. The 1957-1978 precipitation is 2.54 inches greater than the 59-year average.

In the upper basin, from Thiessen-weighted precipitation averages, it is apparent that predevelopment precipitation was not significantly greater than what has occurred historically since 1957. However, since 1974, Thiessen-weighted precipitation has been reduced for both the upper and lower basins.

The amounts of surface water runoff in a basin are not as much a function of the total annual precipitation as the frequency, duration, and intensity at which this precipitation occurs. The number of storms with amounts greater than 1 inch and with durations of 24 hours or less have been declining since the 1957-1965 period. Compared to the 1957-1965 period, 1966-1973 and 1974-1978 had only 77 and 70 percent as many storms per year, respectively.

Such a marked decrease in these events coincides with decreases in precipitation. Since these events are the ones that likely cause much of the surface runoff in the basin, it would follow that inflows to reservoirs would be decreasing with time as well.

In substantial parts of the basin, soils have high infiltration rates leaving insignificant amounts of surface runoff. Where surface runoff is an important component of inflow and with soil and water conservation practices in recent times, little runoff is expected unless daily precipitation exceeds 1.25 inches.

Over the period of record precipitation exhibits cyclic variations. This is substantiated by the droughts of the 1930's, 1950's, and mid-to-late 1970's. Whether or not the precipitation trends of the late 1970's are permanent or merely part of a cycle remains to be seen. More recent records of precipitation would indicate that a return to the cyclic fluctuations more common in the past 60 years would be a probable future condition. With the addition of soil and water conservation practices, the relative amount of precipitation and the magnitude, frequency, intensity, and duration required to produce runoff may have increased.

Riparian Vegetation

Consumption of ground water by riparian vegetation is significant. The consumption by riparian vegetation is estimated to be 18 percent of the total outflow of ground water from the aquifer system over the historic period in the Upper Republican River Basin. It is not known if the amount of riparian vegetation has changed over the historic period. The installation and filling of reservoirs has eliminated some streamside vegetation, but this could have been partially offset by an increase in vegetative growth along reservoir shorelines. There has probably been some decline in vegetation in areas where the water table has declined. Increases in vegetative growth could have occurred in areas where the water table has risen and along streams where the streamflow has increased or stabilized to a more consistent annual flow such as below reservoirs. It also is not known how much vegetation has been removed to make space for agricultural land development.

Riparian vegetation has provided protection to numerous species of wildlife and enabled increases in their numbers. Many of these species provide numerous hours of recreational activity as well as economic benefits to the area. The amount of riparian vegetation in the Upper Republican River Basin in 1978 was determined to be 53,200 acres from Landsat photos. Fader (1968) determined (from aerial photos) that the Lower Republican River Valley between Hardy, Nebraska, and the Clay County line in Kansas contained 3,800 acres of cottonwoods and willows. The remainder of the Lower Republican River Valley below Harlan County Dam was estimated (from 1:250,000 USGS topographic maps) to have 11,700 acres of riparian vegetation. Table 19 shows the riparian acreage by subbasin for the Republican River Basin. Assuming that the riparian vegetation consists essentially of cottonwoods and willows, the estimated average annual depth of consumptive use of the vegetation determined by the Blaney and Criddle (1949) method is 4.1 feet, or a total basin average consumption of 281,500 acre-feet/year of ground water.

Republican River Compact

The Republican River Compact of 1942 is an agreement between the States of Colorado, Nebraska, and Kansas governing the waters of the Republican River and its tributaries and provides for their most efficient use and equitable division. Specific allocations in acre-feet are made to each state derived from the computed average annual virgin water supply originating in each of the designated drainage subbasins of the Republican River Basin.

If the computed annual virgin water supply of any source varies more than 10 percent from the original compact virgin water supply, the allocations made from the water sources in the following years are increased or decreased in relative proportions so that the yearly computed virgin water

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Table 19.--Acres of riparian vegetation per subbasin in the Republican River Basin

Subbasin	Acres
South Fork Republican	3,625
Arikaree	941
North Fork Republican	2,528
Frenchman	2,313
Blackwood	365
Red Willow	1,186
Medicine	2,458
Driftwood	254
Beaver and Sappa	9,261
Prairie Dog	3,300
Republican above Harlan County Dam	26,949
Republican from Harlan County Dam to Nebraska-Kansas State line	9,920
Republican from Nebraska-Kansas State line to Milford Dam	5,568

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supply is proportional to the original compact computed virgin water supply.

Within Colorado, Nebraska, and Kansas, a total of 54,100 acre-feet, 234,500 acre-feet, and 190,300 acre-feet, respectively, of water is allocated for beneficial consumptive use annually. The water is to be derived from the sources in the amounts specified, subject to such quantities being physically available from the sources.

Water Rights Law

Each state containing the Republican River Basin has specific water rights laws which govern the use of both surface and ground water. The following summarizes the laws by which each state appropriates its surface water and ground water supply.

Colorado

Surface Water.--Colorado is an appropriation doctrine state. Since Colorado was the first state to adopt a pure appropriation system and having never followed the riparian rights theory, the doctrine early became known as the Colorado doctrine. The state engineer is charged with the administration and distribution of the State's waters. As chief of the Division of Water Resources, Department of Natural Resources, he has control over measurement, record keeping, and distribution of the public water of the State.

The State constitution declares that the unappropriated water of every natural stream is the property of the public, subject to appropriation, and that the right to divert unappropriated waters of any natural stream to beneficial uses shall never be denied. The state engineer and division engineers administer and distribute water to water rights holders in accordance with court adjudicated decrees for certain amounts of water and priorities for each right. Administration, distribution, and regulation of the use of water, both surface and ground water, is accomplished through the declaration of rules and regulations, and through the issuance of orders to individual owners and users of water rights.

Ground Water.--Ground water in the State of Colorado is, like surface water, subject to the law of appropriation. This water is characterized as either tributary or not tributary to a major stream.

Tributary ground water includes seepage, underflow, or percolating water, if that water would eventually become a part of a natural stream. A natural stream's waters include water in the unconsolidated alluvial aquifer of sand, gravel, and other sedimentary materials, and other waters hydraulically connected which can influence the rate or direction of movement of the water in that stream. Water rights for tributary water wells must be adjudicated in order to be given priority as to their actual dates of initiation. Ground water is classified as tributary if its withdrawal will significantly deplete any adjacent streams within 100 years at its adjudicated rate of withdrawal as specified on the well permit application.

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Nontributary ground water includes all subsurface waters which are not hydraulically connected to any adjacent surface streams and whose withdrawal will not affect the rate or direction of movement of the water in those surface streams. Nontributary ground-water appropriation is based on the area of an applicant's property to which the water is to be put to beneficial use, the estimated quantity of water stored in the aquifer(s) underlying the applicant's property, the estimated annual rate of recharge, the estimated use of ground water in the area, and the number of users drawing water at the time of determination. If there are no unappropriated waters in the designated source, or if the appropriation would unreasonably impair existing water rights, then the application is denied. If the proposed appropriation will not unreasonably impair existing rights, then the permit is granted, subject to any specified conditions or limitations.

Kansas

Surface Water.--As part of the initial settlement and development of the State, Kansas adopted the riparian system of water rights. It was not until 1945 that legislation was enacted which implemented the appropriation system as the exclusive method of acquiring water rights in the State. Under the water code, unallocated water is subject to appropriation while all prior rights, whether appropriation or riparian, are preserved and protected.

The general administrative control of Kansas water resources is vested in the Division of Water Resources, State Board of Agriculture. This division is administered by the chief engineer, who is responsible for administering the statutes governing the appropriation and distribution of the water. All water within the State is dedicated to the use of the people of the State. No person may acquire an appropriation right for the use of water of the State for other than domestic purposes without making an application to the chief engineer for a permit to make such appropriation.

Ground Water.--Kansas ground water, since the adoption of the water code of 1945, is now subject to State administration and control. Prior to this enactment, ground water belonged to the owner of the land overlying it for use as he wished. However, ground water hydraulically connected to a surface stream never belonged to the overlying landowner, but has always been governed by appropriation. The 1945 act dedicated all of the unallocated water to the use of the people of the State and provided that rights, except for domestic use, could only be acquired by filing an application for a permit with the State Chief Engineer. All prior water rights were protected if the ground water was previously put to beneficial use or put to beneficial use within a reasonable time after the act was passed. The owner of an existing right did not acquire a vested right to the existing water level. In considering the effect of new applications on existing ground-water rights, the act specified that impairment is limited to the unreasonable raising or lowering of the static water level. The approval of each application is subject to the express condition that the water right must allow for a reasonable raising or lowering of the static water level.

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Special provisions relate to artesian rights. Water obtained by an artesian well and put to beneficial use is considered to be appropriated. In addition, regulation of the drilling, construction, and use of artesian water is specified.

Nebraska

Surface Water.--Early decisions in the 1890's recognized the riparian system in Nebraska. In 1895, a more comprehensive irrigation law was enacted. Under it, the water of every natural stream not already appropriated was declared to be the property of the public and subject to appropriation for a beneficial use. Between users for the same purpose, priority in time of appropriation was recognized as conferring a prior right. However, a preference was accorded to domestic uses which were considered to be the highest value. The Department of Water Resources has supervisory power over all waters of the state, and acts upon all applications to appropriate or store water.

Riparian rights are confined to pre-1895 grants. Between riparians, the common-law doctrine of reasonable use governs their relative rights to the water. Between a riparian and an appropriator, early Nebraska court decisions found the appropriator superior. In 1966, the courts ruled differently. They now consider and decide water right disputes between riparians and appropriators on the basis of equality, having now recognized that both sides possess equally protected interests. Since the preference system applies only to appropriators, riparians may seek the protection of equitable remedy regardless of the contesting use.

Ground Water.--Before 1963, the Nebraska Court followed the "reasonable use" rule as a guide to a landowner's right to appropriate ground water. There was no requirement that a permit be obtained by an appropriator of ground water. A ground-water code adopted in 1963 defines this water as water which occurs, seeps, filters, or percolates through the ground under the surface. Due to the fact that pumping water for irrigation near streams may affect those streams, the legislature required that appropriators secure a permit in such a situation from the Nebraska Department of Water Resources before initiating such use. The department may take into consideration the effect of the pumping on the amount of water in the stream, and the ability of the stream to meet the requirements of appropriators from the stream. Municipalities receive a special preference for domestic use.

Nonproject Water Rights for the Republican River Basin

Applications for permit to appropriate surface water for beneficial use in the Republican River drainage have been summarized from records of the Kansas State Board of Agriculture, Division of Water Resources; Colorado State Engineer's Office; and the Nebraska State Department of Water Resources. Table 20 summarizes the applications for the use of surface water in the Republican River Basin by non-Federal entities. The water right summaries have been grouped according to their location within either

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Table 20.--Summary of Nonproject surface water rights
Republican River Basin

Basin, state, and subbasin	Flow water rights		Storage water rights	
	number	total ft^3/s	number	total acre-feet
Lower Republican				
Kansas				
Main Stem	85	218.64	3	2,065.0
White Rock Creek	31	73.5	0	---
Buffalo Creek	10	21.1	3	4,336.0
Nebraska				
Main Stem	42	28.94	3	364.7
Upper Republican				
Colorado				
Frenchman Creek	4	2.20	2	141.9
North Fork	22	175.01	3	143.5
Arikaree River	18	84.50	1	459.0
South Fork	34	202.02	5	182.0
Beaver and Sappa Creeks	0	---	1	42.3
Kansas				
South Fork	6	10.64	0	---
Beaver and Sappa Creeks	25	40.08	1	322.0
Prairie Dog Creek	64	240.24	0	---
Nebraska				
Frenchman Creek	122	627.55	16	5,989.1
North Fork	26	66.79	11	324.7
South Fork	1	0.79	0	---
Blackwood Creek	4	6.42	0	---
Red Willow Creek	55	144.03	2	45.2
Beaver and Sappa Creeks	120	140.63	17	940.3
Prairie Dog Creek	13	8.82	1	101.0
Medicine Creek	75	49.79	13	782.2
Main Stem	179	590.00	29	1,756.5

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the upper or lower Republican River Basin (above or below Harlan County Dam, Nebraska), their location by state, and by the subbasin they are located in. The water rights are also divided between flow and storage. Flow water rights are measured in units of ft^3/s while storage water rights are measured in units of acre-feet.

Reclamation Irrigation Divisions Water Right Filings

Within the Republican River Basin are the Upper Republican, Frenchman-Cambridge, Kanaska, and Bostwick Divisions. Applications for permit to appropriate water within these four divisions provide for both the storage of water within the nine storage facilities utilized to supply the irrigation divisions and for the application of water on the division lands.

Upper Republican Division

The Upper Republican Division contains the Armel Unit, which consists of Bonny Reservoir and Hale Ditch. This unit is located in eastern Colorado on the South Fork of the Republican River. A water right to store 351,460 acre-feet in Bonny Reservoir was filed in November 1950. It most likely will be reduced when Bonny Reservoir's water right filing becomes adjudicated, because it exceeds the conservation storage capacity of the reservoir.

Originally, irrigation was to have been one of the benefits derived from Bonny Reservoir. Later investigations disclosed that an economically feasible plan for Federal development could not be formulated for the 24,000 acres of irrigable land. As a result, Bonny Reservoir's conservation space was sold to the State of Colorado for fish, wildlife, and recreation use.

Frenchman-Cambridge Division

The Frenchman-Cambridge Division is located in southwestern Nebraska and extends from Palisade southeastward along the Frenchman River and from Swanson Lake eastward along the Republican River to Harlan County Lake.

Storage facilities for this division consist of Enders Reservoir and Swanson, Hugh Butler, and Harry Strunk Lakes. Storage water right filings for these reservoirs and their priority dates are:

Enders Reservoir - 44,079 acre-feet, May 1946
Swanson Lake - 122,800 acre-feet, July 1951
Hugh Butler Lake - 38,400 acre-feet, July 1951 and August 1960
(two filings)
Harry Strunk Lake - 40,000 acre-feet, May 1946

Four units are located within the Frenchman-Cambridge Division. These are the Meeker-Driftwood, Frenchman, Red Willow, and Cambridge Units.

The Meeker-Driftwood Unit is located along the south side of the Republican River immediately below Swanson Lake in Hitchcock and Red Willow Counties.

The unit receives its water supply directly from Swanson Lake, located on the Republican River near Trenton, Nebraska. Water right filings have been made for this unit providing for the irrigation of 34,783 acres.

The Frenchman Unit utilizes water stored in Enders Reservoir, which is located on the Frenchman River near Enders, Nebraska. This unit is situated along the north side of the Frenchman River between the Culbertson Diversion Dam and Culbertson, Nebraska, and on the north side of the Republican River from near Culbertson to just east of McCook, Nebraska. Water right filings for this unit provide for the irrigation of 43,022 acres.

The Red Willow Unit receives water from Hugh Butler Lake, located on Red Willow Creek north of McCook, Nebraska.

The unit is located along the north side of the Republican River from the confluence of Red Willow Creek and the Republican River to Cambridge, Nebraska, and on the south side of the Republican River between the Bartley Diversion Dam and Holbrook, Nebraska. Water right filings for the Red Willow Unit provide for the irrigation of 25,029 acres.

The Cambridge Unit is located along the north side of the Republican River between the towns of Cambridge and Alma, Nebraska. Water for this unit is supplied by Harry Strunk Lake, located on Medicine Creek, and by natural flow of the Republican River. Water rights filed for the Cambridge Unit provide for the irrigation of 34,994 acres.

Kanaska Division

The Kanaska Division, located along Prairie Dog Creek in north-central Kansas, contains the Almena Unit, which consists of Keith Sebelius Lake and the Almena Irrigation District. Keith Sebelius Lake is located about 2.5 miles west of Norton, Kansas. The Almena Irrigation District lands are located about 11 miles below Keith Sebelius Lake on both the north and south sides of Prairie Dog Creek, immediately downstream of the Almena Diversion Dam. A water right to store 36,700 acre-feet within Keith Sebelius Lake was filed in February 1957. The corresponding Almena Irrigation District has water right filings which provide for irrigation of 5,350 acres. Norton, Kansas receives a full municipal water supply from Keith Sebelius Lake. A 1963 water right grants the city storage of 1,600 acre-feet in the lake and maximum releases from storage of 1,600 acre-feet/year.

Bostwick Division

The Bostwick Division is located in south-central Nebraska and north-central Kansas. It extends from Harlan County Lake, located on the Republican River in Nebraska, to Concordia, Kansas, and includes lands on both sides of the Republican River.

Water for the Bostwick Division is stored in Harlan County Lake in Nebraska and Lovewell Reservoir located on White Rock Creek in Kansas. A water right to store 350,000 acre-feet in Harlan County Lake was filed in January 1948. Lovewell Reservoir has a water right which was filed in October 1955 and provides for the storage of 41,690 acre-feet. Of this storage within Lovewell Reservoir, 19,700 acre-feet annually can be supplied from White Rock Creek with the remaining to come from the Republican River through canal diversion.

Three units are located within the Bostwick Division. These are the Franklin, Superior-Courtland, and Courtland Units in Kansas.

The Franklin Unit diverts water directly from Harlan County Lake and from the Republican River through a pumping station 17 miles downstream from the reservoir. This unit extends from Harlan County Lake along the north side of the Republican River to a point 47.9 miles east. In addition, it extends approximately 10 miles along the south side of the Republican River from Harlan County Lake, and 5 miles along the south side from the pumping station. Associated water rights filings provide for the irrigation of 30,607 acres.

The Superior-Courtland Unit originates at the Superior-Courtland Diversion Dam, located on the Republican River in Nebraska. It extends 30 miles eastward along the north side of the Republican River to near the Nebraska-Kansas State line. South of the Republican River, the Superior-Courtland Unit extends just past the Nebraska-Kansas State line to Lovewell Reservoir in Kansas. Water right filings for this unit provide for the irrigation of 31,341 acres.

The Courtland Unit is located in Republic and Jewell Counties, Kansas. Water is diverted from Lovewell Reservoir and conveyed southeast to the vicinity of Courtland, Kansas. Water right filings for this unit provide for the irrigation of 27,329 acres.

Water Quality

Surface waters of the Republican River Basin are turbid, containing a moderate concentration of dissolved minerals. Streams display good oxygen concentrations to support warm-water aquatic life. They carry a fairly high level of nutrient materials as evidenced by the high concentrations of nitrates and phosphates.

Water quality trends in the Republican River Basin are altered by the nine major lakes and reservoirs located in the basin. Within these storage facilities, there are reductions in suspended solids, BOD (biochemical oxygen demands), COD (chemical oxygen demands), turbidity levels, and dissolved solids. Biological and chemical reactions cause the reduction in BOD, COD, and dissolved solids as well as small increases in pH. Water retention reduces velocity and allows particulate matter to settle out. This causes reduced turbidity and suspended solid concentrations in these lakes and reservoirs. Keith Sebelius Lake and Lovewell Reservoir are both very eutrophic; Milford Lake is slightly eutrophic. Pesticides have been detected in both Milford Lake and Lovewell Reservoir water. Diminished streamflow is lowering water quality since low flows are of higher quality than high flows. With high quality low flows being depleted, reservoirs will become more dependent upon high flows of lower quality, which will cause their quality to further deteriorate.

Within the upper areas of the Republican River Basin, water quality parameter values are altered by the addition of water of lesser quality from the Frenchman River and Red Willow and Medicine Creeks. Agricultural practices and agricultural runoff contribute to the increase in fecal coliform, turbidity, suspended solids, and nitrates throughout the basin. Additionally, sewage treatment plant and industrial discharges and animal feedlot runoff contribute to increases of suspended solids, fecal coliform, and BOD. These nonpoint and point source contributions are the major factors influencing the water quality parameters.

The major factor in determining surface water quality conditions is the amount of flow. BOD, nutrients, bacterial numbers, and turbidity are at their lowest level during low flow periods. During periods of high flow, most surface waters display their poorest quality with significant increases in these parameters. In terms of total yearly load, land runoff is by far the largest contributor of BOD and nutrient materials to streams.

The Ogallala Formation, which is the largest supply of ground water in the basin, contains water that is of good to excellent quality. Water from the Ogallala tends to be a calcium-magnesium-bicarbonate type when the formation overlies the Pierre Shale and a calcium-bicarbonate type when it overlies the Niobrara Chalk.

Alluvium and terrace deposits show a decline in quality of the water. Samples from these deposits show a high percentage exceeding the maximum contaminant levels for total dissolved solids, sulfate, chloride, and nitrate-nitrogen. When compared to Ogallala water, water from alluvial deposits shifts to a sodium-bicarbonate-sulfate type.

There are several reasons for the increase in dissolved solids in the alluvial deposits. These deposits act as collection zones for dissolved salts moving in from the adjacent aquifer system to the major streams. Water tables are also generally more shallow in these deposits, resulting in higher evaporation rates and an increase in salt concentrations. Agricultural practices can also be contributing to the decrease in water quality in these deposits. Fader (1968) reports that in Clay and Cloud Counties, Kansas, wells pumping in alluvium of the Republican River are causing a local influx into the alluvial aquifer of more brackish water from underlying formations.

FISH AND WILDLIFE

Fishery Resources

Reservoirs

Data relative to fishing activity in the Republican River Basin was collected by the FWS (Fish and Wildlife Service) from the CDW (Colorado Division of Wildlife), NGP (Nebraska Game and Parks) and KFG (Kansas Fish and Game) Commissions, and the 1980 National Hunting and Fishing Survey ("Republican River Reservoir Analysis," FWS, June 1982 and "Evaluation of Existing Use of Fish and Wildlife Resources in the Republican River Basin," FWS, August 1983). The 1982 analysis determined the effects of sustained declines in surface areas and water level fluctuations on reservoir fisheries.

Water records indicate that Hugh Butler Lake, Bonny and Lovewell Reservoirs and Milford Lake remained at relatively the same sustained water surface area between 1961 and 1980 (table 21). Bonny Reservoir and Milford Lake are not subject to irrigation drawdown. Harlan County and Harry Strunk Lakes exhibited a moderate decline and Swanson Lake and Enders Reservoir experienced severe declines in water levels. Keith Sebelius Lake sustained severe declines in water storage and surface area. During the years 1982 and 1983, with the exception of Keith Sebelius Lake and Enders Reservoir, most water levels in the basin reservoirs returned to the top of their regular conservation pool as a result of above average precipitation. These conditions will not affect the results of the FWS studies unless they continue over a long-term cycle (5 to 10 years).

The States of Kansas and Nebraska are currently studying various aspects of reservoir fishery management. The studies include estimates of carrying capacity and yield predictions while future studies will include habitat suitability index calculations. State personnel note that the timing, duration, frequency, and rate of reservoir discharge can be an important factor to fish populations and crucial to the success or failure of a single year class. This success or failure can affect the fishery for extended periods of time. Of particular interest relative to instream fisheries are flows during the spawning, hatching, and fry life stages which can also drastically affect fish populations.

The CDW estimated annual fisherman hours (based on random surveys) covering 4 weekdays and 4 weekend days per month. The surveys covered April through August and consisted of instantaneous fisherman counts in the morning and afternoon. The counts were multiplied times the number of weekdays and weekend days in the year and added together to get the total estimated hours. A creel census on 10 percent of the fishermen provided the basis for estimates of the species and number of fish being caught.

Information based on a statewide postal census of approximately 5 percent of their resident anglers was provided by NGP. The number of trips was estimated based on the observation that 3 hours was the average length of the fisherman trip. The KFG used randomly designed creel censuses for

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Table 21.--Estimates of annual angler days and percent decreases in angler use at various stages of reservoir drawdowns for reservoirs in the Republican River Basin

Reservoir	Water years for reservoir level	Sustained surface water area (acres)	Annual angler days for levels	Level comparisons	Percent decrease of angler days
Bonny, CO	1961-1980*	1,924	34,354	---	0
Swanson, NE	1961-1970 (I)	4,602	67,765	I vs II	2.7
	1971-1975 (II)	4,301	65,913	II vs III	15.5
	1976-1980 (III)*	3,262	55,699	I vs III	17.8
Enders, NE	1961-1970 (I)	1,413	27,172	I vs II	8.0
	1971-1975 (II)	1,222	24,990	II vs III	3.6
	1976-1980 (III)*	1,116	24,100	I vs III	11.3
Hugh Butler, NE	1963-1980*	1,420	31,418	---	0
Harry Strunk, NE	1961-1970 (I)	1,753	29,626	I vs II	12.1
	1971-1980 (II)*	1,506	26,054		
Harlan County, NE	1961-1970 (I)	13,213	132,989	I vs II	4.0
	1971-1980 (II)*	11,524	127,628		
Keith Sebelius, KS	1966-1970 (I)	1,645	38,843	I vs II	48.5
	1971-1980 (II)*	661	19,995		
Lovewell, KS	1961-1980*	2,772	48,302	---	0
Milford, KS	1968-1980*	16,453	190,567	---	0

* Existing reservoir conditions in 1980.

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selection of 8-hour or 2-hour census periods. Anglers were censused during selected periods and estimates of angler hours were also computed from boat counts on the reservoirs. Total annual angling hours were calculated by multiplying the number of fishing hours by the number of time periods in the year.

Multiple regression formulas were used in estimating Reclamation's reservoir standing crops, sport fish harvest, and angler effort as well as predicting total angler days in the Republican River Basin. The reliability and applicability of these formulas were verified by the FWS and Colorado, Kansas, and Nebraska fishery biologists.

The CDW estimated that during the period 1966 through 1980, Bonny Reservoir averaged 47,500 4-hour fishing days annually. The fisherman days per surface acre on Bonny for the period ranged from a high of 106.8 in 1978 to a low of 20.8 in 1980. In some instances car counts rather than creel censuses were used which left some question regarding the final data. Bonny has maintained an excellent standing crop of sport fish and receives very heavy fishing pressure. Bonny fulfills a large portion of the reservoir fishing demand in eastern Colorado.

The estimates of reservoir fisherman days for Nebraska were taken from a 1975 NGP study. Estimates revealed that over 50 percent of the total fisherman days on Reclamation-operated reservoirs were in Harlan County. Using days per surface acre for comparison of fisherman pressure, Hugh Butler Lake led with 25.6 followed by Harry Strunk Lake (21), Enders Reservoir (14.5), Harlan County Lake (11.4), and Swanson (3.5) (table 22). The mean fisherman days per surface area for Nebraska reservoirs and lakes in the basin in 1975 were 11.8 days per surface acre.

Estimates for at least 3 years were used to arrive at fisherman days on Kansas reservoirs in the basin. Fisherman days ranged from 51.2 days (1974) to 7.7 days (1979) on Keith Sebelius Lake, from 2.4 days (1974) to 4.3 days (1976) on Lovewell Reservoir, and from 7.9 days (1976) to 2.4 days (1979) on Milford Lake. The overall mean fisherman days on Kansas reservoirs was 4.21 days per surface acre (table 23). Fisherman-day use declined from 51.2 days per surface acre in 1974 to only 7.7 days per surface acre in 1979 on Keith Sebelius Lake. Relatively light fishing pressure on Lovewell Reservoir probably reflects the negative effects of large annual fluctuations of surface area and the associated impacts on the fishery.

Streams

Biologists with the CDW made no projections or estimates of stream fishing days on the Republican River or its tributaries in Colorado. Colorado does maintain a fish stocking program on the North Fork of the Republican and Chief Creek, a spring-fed tributary, which sustains a good trout fishery and receives relatively heavy local fishing pressure.

Estimates of total stream miles and fishable miles for Nebraska were taken from a 1973 basin inventory report conducted by NGP. The KFG estimated

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Table 22.--Number of fishing days and fisherman days per surface acre in Nebraska, 1975 1/

Reservoirs or lakes	Fishing days 2/	Surface acres	Fisherman days per surface acre
Swanson	14,900	4,301 3/	3.46
Enders	17,666	1,222 3/	14.45
Hugh Butler	36,428	1,420 4/	25.65
Harry Strunk	31,590	1,506 5/	20.97
Harlan County	131,723	11,524 5/	11.43
Rock Creek	407	50	8.14
Wellfleet	3,556	50	71.12
Hayes Center	1,008	40	25.20
Nebraska totals	237,278	20,113	11.79

1/ Estimated by the Nebraska Game and Parks Commission for the Republican River Basin reservoirs and lakes in Nebraska.
2/ Nebraska trip estimates were standarized to a 4-hour fishing day.
3/ 1971-1975
4/ 1963-1980
5/ 1971-1980

Table 23.--Annual number of fishing days and fisherman days per surface acre1/

Year	Keith Sebelius Lake			Lovewell Reservoir			Milford Lake		
	Fishing2/ days	Surface acres	Fisherman days per surface acre	Fishing2/ days	Surface acres	Fisherman days per surface acre	Fishing2/ days	Surface acres	Fisherman days per surface acre
1974	33,856	661 3/	51.21	6,598	2,772 4/	2.38	89,402	16,453 5/	5.43
1975	24,410	661	36.92	10,838	2,772	3.90	---	---	---
1976	26,814	661	40.56	12,057	2,772	4.34	130,301	16,453	7.91
1978	9,644	661	14.59	---	---	---	---	---	---
1979	5,079	661	7.68	---	---	---	38,752 6/	16,453	2.35
1981	---	---	---	---	---	---	66,728 7/	16,453	4.05
Totals8/									
Fishing days8/			83,864						
Surface acres			19,886						
Fisherman days per surface acre			4.21						

1/ Estimated by the Kansas Fish and Game Commission for the Republican River Basin reservoirs in Kansas.
2/ State estimates were standarized to a 4-hour fishing day.
3/ Mean annual surface acres for 1971-1980.
4/ Mean annual surface acres for 1961-1980.
5/ Mean annual surface acres for 1968-1980.
6/ Extremely low use year, not used as the 1980 value.
7/ Used for 1980 base year comparison.
8/ Based on 1979 for Keith Sebelius, 1976 for Lovewell, and 1981 for Milford.

KS003701

fisherman days, total stream miles, and anglable miles per stream for the upper basin in 1972 to 1977 and the lower basin 1977 to 1979. The estimated fishermen per week were expanded into a yearly estimate (table 24).

Of the 1,136 stream miles in the Republican River and its tributaries in Nebraska, only 767 miles are fishable. In Kansas, 548 miles of the total 1,410 stream miles are fishable. All but a few miles of the fishable rivers and streams in the basin are in private ownership. The fishing days per fishable stream miles averaged 70.5 in Nebraska and 55.3 in Kansas. No pounds per acre estimates were made because of the streamflow variations.

Even though the Republican River is still considered to have a good fishery below the Superior-Courtland Diversion, the existing population is not comparable to those of prior years (Hilgert, 1982). Reduced streamflows and increased water use demands have greatly contributed to the decline of the Republican River stream fisheries. Additional adverse stream conditions of channelization, dewatering, and turbidity are also contributing factors. A 1951 creel census by FWS showed that, prior to the construction of Harlan County Dam, channel catfish were the mainstay of the fishery (Hilgert, 1982). When operation of the dam began in 1952, water turbidity in the Republican River below the dam decreased and game fish that require clearer water, including walleye and white bass, became established. Fishing success during the spring or high water period is excellent but declines below the Superior-Courtland Diversion Dam in the summer as irrigation demand increases.

During normal operations, approximately 20 ft^3/s riverflow passes over the Superior-Courtland Diversion Dam. Zero flows occasionally occur as a result of water fluctuations caused by increased river depletions. Zero flow conditions do not occur each year. During May 1964, a fish kill occurred in the stretch of river below the diversion dam. After the die off, FWS, USGS and NGP personnel conducted a study to determine what flows were needed to prevent future fish kills. With the cooperation of Reclamation, various flows from 20-50 ft^3/s were evaluated, and it was concluded that a flow of 50 ft^3/s "would go far towards restoration and perpetuation of the river's fish population..." (FWS, 1966).

Hilgert (1982) studied the Republican reach between Superior-Courtland Diversion Dam and the Nebraska-Kansas state line using the Water Surface Profile (WSP)/Habitat Incremental Method. He found a positive, nearly linear relationship between adult and juvenile channel catfish weighted usable area of habitat (WUA) and discharge. Fry WUA peaked at flows between 60-175 ft^3/s. Spawning habitat appeared to be limited in the reach studied but this may be because the WSP hydraulic simulation model cannot adequately model the natural cavities channel catfish utilize for spawning.

During the 1984 legislative session, the State of Nebraska passed L.B. 1106, which recognizes instream flows for fish and wildlife as a beneficial use of water. Any application for an instream flow right for fish and wildlife must be submitted and approved by the Department of Water Resources. Use of instream flows for fish and wildlife purposes is fairly

Table 24.--Stream fishing data, Republican River and tributaries, Nebraska and Kansas

Quantity	Stream: Nebraska: Republican River	Nebraska: Tributaries	Nebraska: Stream Totals	Kansas: Republican River	Kansas: Tributaries	Kansas: Stream totals
Stream length (miles)	285.2	850.4	1,135.6	176.2	1,234.2	1,410.4
Fishable miles per stream	285.2	481.4	766.6	176.2	371.7	547.9
Fishing days	40,236.0 1/	13,817.0 1/	54,053.0 1/	22,710.0	7,603.0	30,313.0
Fishing days per stream mile	141.1	28.7	70.5	128.9	20.5	55.3

1/ Nebraska trip estimates were standardized to a 4-hour fishing day.

KS003703

low on the priority use list and ranks behind uses such as domestic and irrigation. These water rights also follow the seniority rule. Water for instream flow purposes would need to be acquired by the state and protected from other downstream appropriators by the state engineer.

Even though the Republican River continues to provide a fishery as well as other recreational benefits in the region downstream from Harlan County Dam, stream fishing has become a minor portion of the total fisherman-days throughout the basin.

Wildlife Resources

Habitat

There are over 128,000 acres of public use area in the Republican River Basin, which provides the bulk of the land and water surface used for hunting and fishing. Of the almost 41,000 acres of the total water surface area in the public use areas, over 99 percent is in reservoirs and over 75 percent of the upland acres are around the reservoirs built by the Corps of Engineers or Reclamation. The nine Colorado public use areas (over 16,000 acres) contain over 14,000 acres of upland habitat and about 2,000 acres of water surface. Nebraska has 30 areas in the basin containing about 65,500 acres of public use area which consists of over 43,000 acres of upland habitat, 3,500 acres of wetland habitat, and nearly 19,000 acres of water surface. Kansas has six areas in the basin containing 46,500 acres, consisting of over 25,000 acres of upland habitat, 1,250 acres of wetland habitat, and nearly 20,000 acres of water surface.

The difficulty in gaining access to the rivers and streams in private ownership, for fishing or the adjacent riparian habitat for both small and big game hunting, has magnified the importance of the public areas in the basin. Native grasses, riparian habitat, food plots, and agricultural leases all managed by state agencies adjacent to the water surface areas have been very beneficial in providing habitat essential to increased numbers of various wildlife species.

Wildlife

The public use areas provide most of the land and water surface for hunting, fishing, and other nonconsumptive use activities in the basin. Habitat associated with public use areas provides food and protection for numerous species of fish and wildlife. Ring-necked pheasant, mourning doves, bobwhite quail, cottontail rabbits, and fox squirrels are the major species pursued by small game hunters throughout the basin. Numerous species of migratory waterfowl also provide hunting opportunities. Big game species represented by wild turkeys, antelope, and white-tailed and mule deer provide public hunting by various means during open seasons (wild turkeys are considered small game in Kansas).

KS003704

Participation level estimates for hunting activities were gathered from CDW, KGF, FWS Reservoir Analysis, annual records maintained by Reclamation and the Corps of Engineers, and the 1980 National Hunting and Fishing Survey. The three states used the card mail survey method to collect hunting and harvest estimates for small game, waterfowl, and mourning doves. These cards were mailed after the seasons ended to a percentage of resident and nonresident hunters randomly selected by license type. The questionnaires were tabulated and the information expanded to provide estimates of hunter numbers, bags, and hunter days statewide. These estimates were the basis for annual small game hunter and harvest reports by each of the states in the basin.

The basin contains good populations of ring-necked pheasant and bobwhite quail. They were considered the small game in the basin. Harvest of these species is a good indicator of population levels. Table 25 indicates the greatest number of hunters per square mile in Kansas followed by Nebraska and Colorado. Environmental factors, such as weather and yearly habitat conditions, influence increases and decreases of small game populations and their corresponding hunting uses.

Reclamation and Corps of Engineers reservoirs provide the majority of waterfowl hunting opportunities. Some waterfowl are hunted on the river and marshes on state and Federal wetland areas. Canada geese and mallards are the two species most sought after in the basin. Nebraska and Colorado had relatively the same number of waterfowl hunters with Kansas having fewer participants (table 26). Waterfowl information was available for Kansas from 1971 through 1977 and for Nebraska from 1974. Waterfowl hunter days tended to remain fairly high, particularly in Colorado, even when harvest figures declined. During the period 1971-1975, there was a 73 percent decrease in waterfowl use of reservoirs in the Nebraska portion. This reduction partially resulted from reduced surface areas of the Nebraska reservoirs and waterfowl being attracted to other Kansas river basins and marsh areas (FWS, August 1983).

Mourning doves are migratory birds which rank as one of the top game birds in the Republican River Basin. Dove hunting appeals to many hunters because of their numbers and relative ease with which they can be located. Doves are hunted during the fall and offer a challenge because of their size and speed. Dove hunting occurred in Colorado and Kansas for several years prior to the introduction of a season in Nebraska in 1975. Kansas hunters annually average a larger dove harvest than Nebraska followed by Colorado. Trends relating to hunter numbers and success ratio vary according to the annual dove reproduction and the weather patterns affecting their migration (FWS, August 1983).

Turkeys have been hunted in the Nebraska portion of the basin for several years and the number of turkey hunters, hunter days, and harvest generally reflect the population levels. Annual harvests have increased from 5 in 1972 to 43 in 1981. The State of Kansas opened two areas along the Republican River to turkey hunting in 1983 reflecting the thriving turkey population in the lower river basin.

KS003705

Table 25.--Annual estimates of hunters, hunter days and harvest of small game (pheasant and quail) in the Republican River Basin - Colorado, Nebraska, and Kansas

Year	Colorado			Nebraska			Kansas		
	Hunters	Days	Harvest	Hunters	Days	Harvest	Hunters	Days	Harvest
1969	-	-	-	23,749	143,053	143,328	-	-	-
1970	-	-	-	22,419	148,015	174,142	-	-	-
1971	-	-	-	23,160	169,281	151,852	30,786	125,517	171,713
1972	-	-	-	26,852	200,946	205,264	28,181	135,826	202,403
1973	-	-	-	22,861	232,740	201,579	27,007	146,969	202,364
1974	15,441	45,026	32,167	22,867	225,764	157,802	26,644	133,763	159,717
1975	9,237	26,954	20,676	18,918	124,052	116,514	27,937	147,562	163,683
1976	7,577	19,562	11,980	19,628	133,842	90,601	25,327	137,692	146,092
1977	8,795	21,817	14,231	19,012	161,406	157,329	29,712	155,743	240,447
1978	11,702	33,281	25,364	30,188	206,743	278,007	28,949	190,069	255,190
1979	11,376	38,355	31,374	30,211	208,628	207,215	34,808	200,693	294,362
1980	16,224	53,111	47,379	32,715	244,932	273,068	30,470	159,147	202,652
1981	-	-	-	30,917	257,432	246,045	31,637	187,159	268,780

KS003706

Table 26.--Annual estimates of hunters, hunter days and harvest of waterfowl in the Republican River Basin - Colorado, Nebraska, and Kansas

Year	Colorado			Nebraska			Kansas		
	Hunters	Days	Harvest	Hunters	Days	Harvest	Hunters	Days	Harvest
1971	2,503	17,919	15,046	-	-	-	204	1,076	1,288
1972	1,918	14,013	15,303	-	-	-	160	909	1,187
1973	2,294	20,340	20,217	-	-	-	124	755	750
1974	1,998	14,162	7,627	3,767	22,297	24,479	115	737	624
1975	1,965	15,056	14,761	2,073	10,579	19,970	91	562	453
1976	2,495	14,457	10,806	3,670	26,712	40,043	105	669	599
1977	2,481	15,560	12,917	2,788	24,513	28,930	135	738	819
1978	3,158	18,968	18,518	4,092	25,056	44,285	-	-	-
1979	3,056	18,143	14,685	2,908	19,934	23,906	-	-	-
1980	3,709	22,290	13,373	2,420	15,293	19,850	-	-	-
1981	-	-	-	2,562	18,843	33,520	-	-	-

KS003707

Antelope are hunted in Colorado and Nebraska with very little antelope hunting in Kansas. Larger populations of antelope are present in Colorado than in Nebraska where hunting occurs only in Dundy and Chase Counties. The number of hunters and the harvest generally reflect the relative populations in the respective states. Colorado hunters harvested 162 antelope in 1972 and 491 in 1981. Nebraska started their antelope season and harvested 9 in 1974; 10 were harvested in 1980.

Deer are hunted by archers in all basin states; however, few records were maintained by Nebraska and Colorado prior to 1972. A general trend of increases of hunters and harvest indicates an increase in deer populations in the river basin in the past 10 years. Probably the major reason the deer harvest has increased in greater proportions in Kansas than in Colorado, is the mixture of croplands and riparian timber which supports higher deer populations and the higher populations of white-tailed deer whose habits make them more susceptable to harvest by archers than the mule deer in the grassland areas in Colorado.

Firearm deer hunting is the most popular big game hunting activity in the basin. Records indicate Nebraska had the largest number of firearm hunters, hunter days, and harvest followed by Kansas and Colorado in decreasing order (FWS, August 1983). A decrease in permits issued in 1971 through 1973 resulted in a decline in hunter days and harvest, but the remainder of the years indicated a general increase. The general increase in numbers of permits issued indicates an increase in deer population levels. In Kansas, the trend has been a moderate annual increase in the number of hunters, hunter days, and harvest. Colorado records reflect a more erratic increase/decrease when comparing the deer hunter days and the harvest. The general trend of hunter numbers, hunter days, and harvest was upward.

Deer populations in the basin are good to excellent and are increasing. Populations are being managed through issuance of either sex permits to insure against overpopulation. The basin deer population can be expected to increase and provide good hunting in future years.

The numerous nongame species found throughout the Republican River Basin provide recreational activities for an increasing number of people. Photography, feeding, and general viewing of waterfowl and other species has become increasingly popular.

Threatened and Endangered Species

No threatened or endangered plant species are listed or proposed for listing by the Department of the Interior in the Republican River Basin. Colorado lists the Plains orangethroat darter (Etheostoma spectabile pulchellum), found in the eastern segments of the Arikaree River and the North and South Forks of the Republican, as a threatened fish. A shiner listed on the Kansas threatened species list, the Topeka shiner (Notropis Topeka), was collected from Cherry Creek in the upper Republican River Basin in 1947.

KS003708

Wildlife species, which have historically occurred in the basin, currently on the endangered species list include the peregrine falcon, whooping crane, Eskimo curlew, bald eagle, and the black-footed ferret. Peregrine falcons are known to infrequently migrate through the basin and are normally found in association with shorebird and waterfowl concentrations. Whooping cranes have been sighted on their migration through the area. Bald eagles occur as transient and winter residents of the area where they feed on fish in the streams and reservoirs. Seven Reclamation aerial surveys conducted in 1978 through 1980 revealed an average count of 28 bald eagles on Swanson Lake during the winter of 1979-1980. Bald eagles were observed on all Reclamation reservoirs in the basin.

Kansas lists the prairie falcon and the least tern as threatened. The prairie falcon was formerly more common in Kansas and the least tern is represented by only a small summer population which nest on sandbars and exposed salt flats along western Kansas rivers. The Eskimo curlew is possibly extinct; however, there have been several reported sightings between 1932 and 1976 on the Texas and Atlantic Coasts (National Audubon Society, September 1981). The last black-footed ferret documented sighting in Kansas was in 1957 and at present there are none known to be in the basin.

CHAPTER IV--FUTURE CONDITIONS AND OPPORTUNITIES

FUTURE WATER CONDITIONS

Ground-Water Supply

The future ground-water supply was projected for the period 1979 to year 2020 under two conditions of well development; no additional well development in the basin after 1978 and continued well development in Nebraska only.

Under the condition of no additional well development, well pumpage was held to the May 1, 1978 level. Streamflow depletions by these wells were calculated to the year 2020 using the Glover method. Annual ground-water budgets were constructed to show the projected volume of ground water in storage. A summary of those budgets by subbasin is shown in table 27. The budget projections show that sufficient ground water in storage is available (assuming 75 percent of the predevelopment storage volume is usable) for well pumpage at the 1978 level to the year 2020. Base flows in the Arikaree, Blackwood, and Beaver and Sappa Creek subbasins are estimated to decline to zero in the years 2006, 1999, and 1979, respectively. Geological Survey water supply papers for 1979, 1980, and 1981 indicate that at the gage on Sappa Creek near Stamford, Nebraska, winter base flow in the Beaver and Sappa Creek subbasin is essentially zero.

The condition of additional well development was simulated by increasing well development in Nebraska and holding well development at the 1978 levels for Colorado and Kansas. A report entitled the Six-State High Plains Ogallala Aquifer Regional Resources Study (Camp Dresser and McKee Inc., et al., 1982, page 5-4) predicted that from 1977 to year 2020, water usage in Colorado and Kansas will decline 43 and 75 percent, respectively, while usage in Nebraska will increase 89 percent. However, a draft report from the Kansas Water Office entitled Kansas Water Supply and Demand Estimates, Background Paper No. 15 (August 1984) states that for Kansas, a more reasonable scenario would be that projected demands will remain constant at the 1980 level. This situation is also more probable for Colorado rather than a significant decline in water usage. Water usage in Nebraska, however, will probably continue to increase since they have much more available ground water in storage than either Colorado or Kansas.

The increase in water use for Nebraska was simulated using estimates of ground water irrigated acreage for the year 2020 calculated for each county by the Nebraska Natural Resources Commission (1982, pages 23-26). Table 28 shows the annual increase of ground-water development per subbasin used to project the future ground-water supply under the condition of additional well development. Streamflow depletions for the additional wells were calculated by the Glover method and budgets were constructed to show annual ground-water storage volumes to year 2020. A summary of the results of those budgets is shown in table 29. Again, none of the subbasins exceeded the usable volume of ground water in storage although only the South and North Fork Republican and the Republican from Harlan County Dam to the Nebraska-Kansas State line subbasins are projected to have any base flow remaining in them by the year 2020.

KS003710

Table 27.--Summary of projected ground-water budget based on condition of no additional well development after 1978

Subbasin	1978 storage volume (acre-ft)	2020 storage volume (acre-ft)	Change in storage (acre-ft)	Percent change in storage	2020 streamflow depletion (acre-ft/yr)	1969-1978 average base flow (acre-ft/yr)	2020 base flow (acre-ft/yr)
South Fork Republican	19,357,700	14,059,100	- 5,298,600	-27	39,000	24,000	5,700
Arikaree	9,776,200	7,968,700	- 1,807,500	-18	9,300	4,600	(0 in 2006)
North Fork Republican	29,170,100	23,573,300	- 5,596,800	-19	52,400	62,100	29,900
Frenchman	103,986,000	90,003,000	-13,983,000	-13	183,000	100,100	9,900
Blackwood	13,892,000	13,324,700	- 567,300	- 4	8,200	1,900	(0 in 1999)
Red Willow	28,001,900	27,843,300	- 158,600	- 1	23,000	23,100	11,600
Medicine Creek above Medicine Creek Dam	36,592,200	37,066,500	+ 474,300	+ 1	34,000	40,500	23,100
Driftwood	1,271,000	1,210,200	- 60,800	- 5	2,300	4,000	4,000
Beaver and Sappa	38,351,300	26,761,500	-11,589,800	-30	66,100	2,300	(0 in 1979)
Prairie Dog	6,946,700	5,817,600	- 1,129,100	-16	12,500	4,700	2,000
Main Stem Republican above Harlan County Dam	38,903,000	40,795,100	+ 1,892,100	+ 5	83,400	46,000	16,000
Republican from Harlan County Dam to Nebraska-Kansas State line	15,147,000	14,802,700	- 344,300	- 2	66,100	102,600	67,600

KS003711

Table 28.--Projected annual increase of ground-water development per subbasin

Subbasin	Net pumpage (acre-ft)	Irrigated acres
South Fork Republican	86	75
Arikaree	86	75
North Fork Republican	2,920	2,561
Frenchman	14,028	12,306
Blackwood	1,798	1,578
Red Willow	3,771	3,306
Medicine Creek above Medicine Creek Dam	4,054	3,526
Driftwood	562	493
Beaver and Sappa	2,064	1,795
Prairie Dog	290	252
Main Stem Republican above Harlan County Dam	12,589	10,947
Republican below Harlan County Dam to Nebraska-Kansas State Line	6,119	5,665

KS003712

Table 29.--Summary of projected ground-water budget based on condition of additional well development after 1978

Subbasin	1978 storage volume (acre-ft)	2020 storage volume (acre-ft)	Change in storage (acre-ft)	Percent change in storage	2020 streamflow depletion (acre-ft/yr)	1969-1978 average base flow (acre-ft/yr)	2020 base flow (acre-ft/yr)
South Fork Republican	19,357,700	14,032,500	- 5,325,200	-28	41,200	24,000	3,500
Arikaree	9,776,200	7,916,800	- 1,859,400	-19	9,400	4,600	(0 in 1997)
North Fork Republican	29,170,100	21,500,200	- 7,669,900	-26	69,900	62,100	12,300
Frenchman	103,986,000	79,895,800	- 24,090,200	-23	196,400	100,100	(0 in 1999)
Blackwood	13,892,000	11,940,700	- 1,951,300	-14	8,200	1,900	(0 in 1988)
Red Willow	28,001,900	25,307,000	- 2,694,900	-10	35,400	23,100	(0 in 1998)
Medicine Creek above Medicine Creek Dam	36,592,200	34,652,700	- 1,939,500	- 5	60,100	40,500	(0 in 2002)
Driftwood	1,271,000	886,200	- 384,800	-30	6,200	4,000	(0 in 1998)
Beaver and Sappa	38,351,300	25,157,000	- 13,194,300	-34	66,700	2,300	(0 in 1979)
Prairie Dog	6,946,700	5,649,400	- 1,297,300	-19	14,400	4,700	(0 in 2006)
Main Stem Republican above Harlan County Dam	38,903,000	31,851,400	- 7,051,600	-18	102,500	46,000	(0 in 1996)
Republican from Harlan County Dam to Nebraska-Kansas State line	15,147,000	11,100,400	- 4,046,600	-27	110,700	102,600	23,000

KS003713

Surface Water Supply

The future water supply available for irrigation was estimated through the use of a surface water operations study. Reclamation has developed a sizing criteria for irrigation districts by relating irrigation shortages to safe reservoir yield. The criteria states that the irrigation shortage cannot be larger than 50 percent of the irrigation demand in any 1 year; the accumulated shortage cannot exceed 75 percent in any 2 consecutive years, or 100 percent in any 10 consecutive years. Table 30 shows the acreages that can be irrigated under five levels of development. These levels of development vary by the amount of soil and water conservation practices and ground-water pumping assumed in the basin. The five levels are:

1. Historic
2. Present (1978)
3. Future 1: includes additional soil and water conservation practices but no additional ground-water pumping
4. Future 2: includes additional soil and water conservation practices and ground-water pumping
5. Environmental

The historic level of development uses the levels of conservation practices and ground-water pumping which are consistent with how they occurred throughout the 1949-1978 study period. The present condition assumes 1978 levels of conservation practices and ground-water pumping throughout the study period. Both of the future options are based on estimates of increased soil and water conservation practices. Based on future rates of development, it is estimated that conservation practice depletions will be 15 percent larger in year 2008 than what currently exists. This implies that 273,900 and 111,900 acre-feet of depletions would occur annually in the upper and lower basins, respectively. Table 31 shows the depletions on an average annual basis for each of the subbasins in the Republican River Basin for the 2008 level of development superimposed over the 1949-1978 period of record. Table 32 presents the depletions as they would have occurred if soil and water conservation practices existed at the 2008 level.

For the future 1 condition, ground-water pumping is held at the 1978 level; however, the depletions continue to increase beyond present conditions due to lag effects. For the future 2 condition, ground-water pumping was increased to year 2008 levels in Nebraska and held constant in Kansas and Colorado.

The environmental option attempts to maintain the average annual reservoir surface as an ideal situation. Bonny Reservoir, Keith Sebelius Lake, and Lovewell Reservoir should not fluctuate more than 30 percent of their average annual surface areas and Enders Reservoir and Swanson, Hugh Butler, and Harry Strunk Lakes should not fluctuate more than 55 percent of their surface areas. Figure 11 shows historic streamflows at the historic, present, and future levels of development.

KS003714

Table 30.--Estimated irrigated acreage under five levels of development using Bureau of Reclamation sizing criteria

Canal	Maximum service area	Average service area (1969-1978)	Historic	Present	Future 1 without development	Future 2 with development	Environmental
Hale	750	743	750	750	750	750	750
Meeker-Driftwood	16,476	15,112	14,500	7,000	0	0	5,000
Culbertson Extension	21,090	19,095	16,700	800	0	0	325
Riverside	562	562	500	400	0	0	200
Red Willow	4,932	4,439	4,400	3,000	270	0	2,800
Bartley	6,539	5,925	4,500	1,400	700	0	1,100
Cambridge	17,053	15,958	15,000	9,500	4,900	0	8,600
Almena	5,763	5,118	2,350	2,600	1,635	1,625	0
Franklin	11,116	9,806	5,600	0	0	0	0
Naponee	1,737	1,472	800	0	0	0	0
Franklin Pump	2,091	1,978	1,100	0	0	0	0
Superior	5,863	5,125	2,700	0	0	0	0
Courtland-Nebraska	1,980	1,575	800	0	0	0	0
Courtland-Kansas	12,771	10,049	5,000	0	0	0	0
Courtland below Lovewell	27,329	19,439	12,000	11,000	8,200	7,200	10,100

KS003715

Table 31.--Average annual conservation practice depletions 1949-1978 period of record

Basin and subbasin	Future level of development year 2008 (acre-ft)
Upper Republican	
Frenchman Creek	39,000
North Fork Republican	6,700
Arikaree	6,100
South Fork Republican	13,500
Blackwood Creek	3,500
Red Willow Creek	8,500
Driftwood Creek	8,100
Beaver and Sappa Creeks	87,900
Prairie Dog Creek	23,500
Medicine Creek	14,000
Main Stem Republican River	63,100
Lower Republican	
Buffalo Creek	21,200
Lower Republican River - Nebraska	25,600
Lower Republican River - Kansas	43,800
White Rock Creek	21,300
Total depletion	385,800

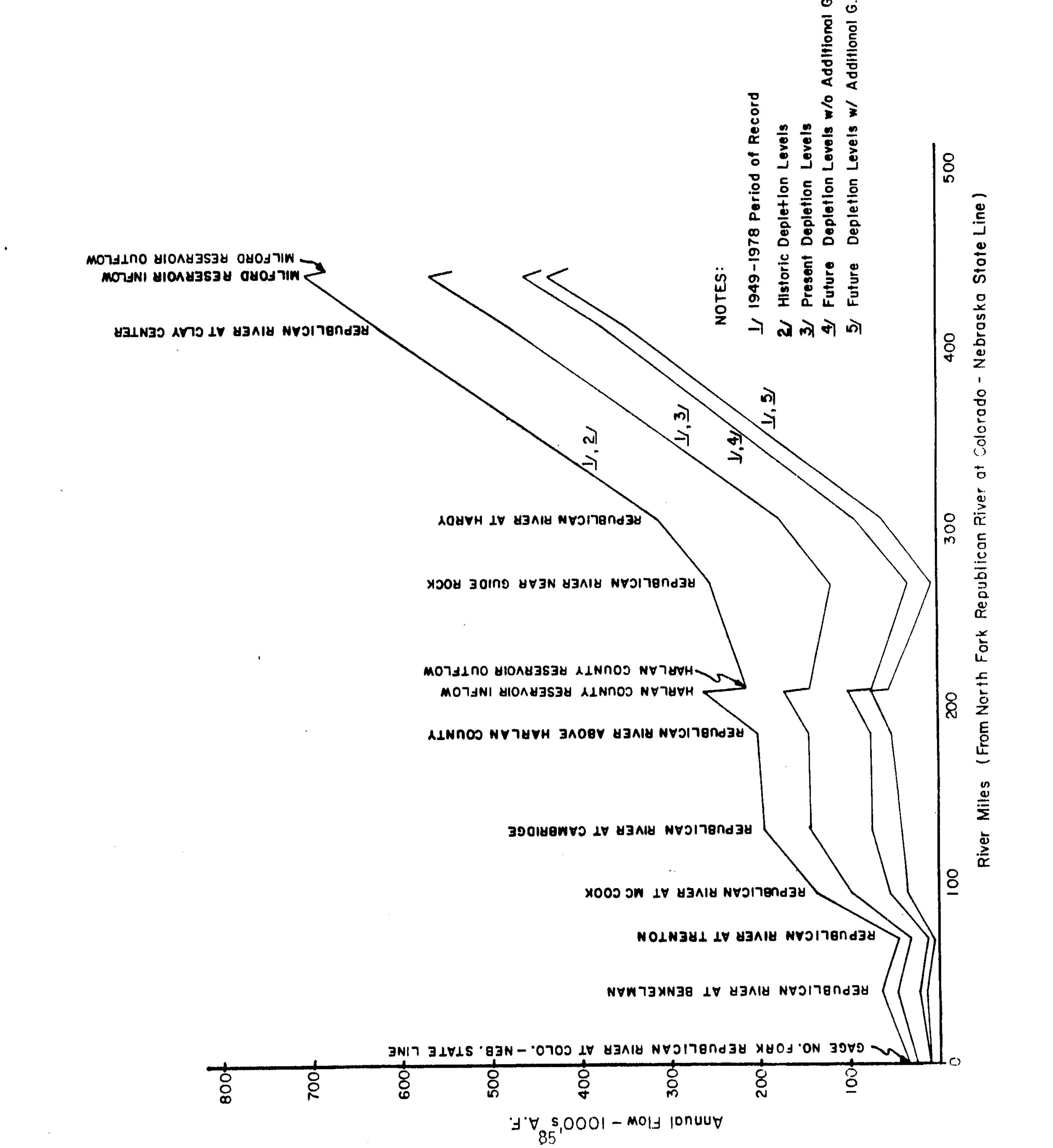
KS003716

Table 32.--Total Republican River Basin conservation practice depletions by year

Year	Future level of development year 2008 (1,000 acre-ft)
1949	477
1950	344
1951	735
1952	133
1953	277
1954	95
1955	141
1956	69
1957	543
1958	350
1959	269
1960	333
1961	415
1962	634
1963	315
1964	253
1965	959
1966	202
1967	490
1968	319
1969	468
1970	227
1971	557
1972	443
1973	736
1974	215
1975	528
1976	168
1977	651
1978	225
Total depletion	11,571

KS003717

Figure 11 - Estimated Historic, Present, and Future Streamflows



SENSITIVITY ANALYSIS

Reducing Depletions

In order to evaluate the impacts of the depletionary effects associated with ground-water pumping and soil and water conservation practices on the sizing of the irrigation districts, a sensitivity analysis has been performed. Arbitrarily the total of the ground water and conservation practice depletions have been reduced by 50 percent throughout the historic, present, future, and environmental levels of development. The resized irrigation acreages presented in table 33 show minor differences when looking at the basin as a whole. However, several of the irrigation districts, particularly in the upper basin, show significant increases in capability with the reduced depletions.

Realistically, it should be noted that over an entire study period reducing the depletions will generate larger quantities of water throughout the basin. However, the critical water use period for sizing the irrigation districts occurs during the 1950's drought. This is when depletions to the water supply are less critical, because precipitation and runoff are already low.

Irrigation District Capability

The irrigation acreages previously presented are based on Reclamation design standards that indicate the potential service area that can be assured a full water supply within the shortage criteria. With an existing reservoir and irrigation district such as the districts in the Republican River Basin, the sized irrigation acreages may be overly conservative.

Consequently, for each level of development, the number of nonshortage years have been determined for acreages between the sized acreage and the 1969-1978 average service acreage. This information shows how much additional acreage each of the irrigation ditches can service without developing shortages outside of the drought periods. Tables 34 through 38 show for each level of development how many years a full water supply may be expected at the average service area, one-third and two-thirds the acreage between the historic average and the sized acreages.

At the historic level of development (table 34), all of the ditches in the Republican River Basin, with the exception of the Almena Canal, can support nearly as much irrigation at the historic acreage as at the sized acreages.

At the present level of development (table 35), canals in the upper basin have a fairly dependable water supply until shortages for the 1969-1978 average acreages are examined. At this level, shortages appear nearly half of the time (15 out of 30 years). In the lower basin, the sizing criteria cannot be met at any sized acreage. However, at one-third and two-thirds of the average service area, full water supply is available 80 to 90 percent of the time. At the historic average acreage, shortages appear nearly half of the time as is the case in the upper basin.

Table 33.-- Estimated irrigated acreage under five levels of development (50 percent total of ground-water and soil and water conservation practice depletions)

Canal	Maximum service area	Average service area (1969-1978)	Historic	Present	Future 1 without development	Future 2 with development	Environmental
Hale	700	743	750	750	750	750	750
Meeker-Driftwood	16,476	15,112	14,500	11,000	6,000	2,400	11,650
Culbertson Extension	21,090	19,095	16,700	7,750	800	0	7,550
Riverside	562	562	500	550	100	0	400
Red Willow	4,932	4,439	4,400	4,500	3,000	1,000	4,450
Bartley	6,539	5,925	4,500	3,000	2,500	2,000	850
Cambridge	17,053	15,958	15,000	14,000	10,000	7,500	12,900
Almena	5,763	5,118	2,350	2,600	2,100	2,100	2,600
Franklin	11,116	9,806	5,600	0	0	0	0
Naponee	1,737	1,472	800	0	0	0	0
Franklin Pump	2,091	1,978	1,100	0	0	0	0
Superior	5,863	5,125	2,700	0	0	0	0
Courtland-Nebraska	1,980	1,575	800	0	0	0	0
Courtland-Kansas	12,771	10,049	5,000	0	0	0	0
Courtland below Lovewell	27,329	19,439	12,000	15,500	12,200	10,800	16,600

KS003720

Table 34.--Historic level of development
(acres/number of years without shortage in the 30-year study period)

Hale	Meeker-Driftwood	Culbertson & Extension	Riverside	Red Willow	Bartley	Cambridge	Almena
750/30	15,112/23	19,095/18	562/26	4,439/29	5,925/25	15,958/24	5,118/15
750/30	14,900/23	18,300/18	540/27	4,426/29	5,450/25	15,640/24	4,195/20
750/30	14,700/23	17,500/19	520/27	4,413/29	4,975/25	15,320/25	3,272/22
750/30	14,500/24	16,700/20	500/27	4,400/29	4,500/25	15,000/25	2,350/26

Franklin	Naponee	Franklin Pump	Superior	Nebraska-Courtland	Kansas-Courtland	Lower Courtland
9,806/26	1,472/26	1,978/26	5,125/26	1,575/26	10,049/26	19,439/25
8,404/27	1,248/27	1,684/27	4,316/27	1,316/27	8,366/27	16,959/26
7,002/28	1,024/28	1,392/28	3,508/28	1,058/28	6,683/28	14,479/27
5,600/29	800/29	1,100/29	2,700/29	800/29	5,000/29	12,000/28

KS003721

Table 35.--Present level of development
(acres/number of years without shortage in the 30-year study period)

Hale	Meeker-Driftwood	Culbertson & Extension	Riverside	Red Willow	Bartley	Cambridge	Almena
743/30	15,112/17	19,095/0	562/16	4,439/17	5,925/20	15,958/17	5,118/16
750/30	12,408/23	12,997/1	508/18	3,959/20	4,417/25	13,805/24	4,279/17
750/30	9,704/26	6,898/11	454/21	3,480/24	2,908/26	11,653/26	3,439/21
750/30	7,000/27	800/27	400/27	3,000/24	1,400/27	9,500/27	2,600/28

Franklin	Naponee	Franklin Pump	Superior	Nebraska-Courtland	Kansas-Courtland	Lower Courtland
9,806/15	1,472/15	1,978/15	5,125/15	1,575/15	10,049/15	19,439/15
6,537/24	981/24	1,319/24	3,417/24	1,050/24	6,699/24	16,626/23
3,269/26	491/26	659/26	1,708/26	525/26	3,350/26	13,813/25
0/N/A	0/N/A	0/N/A	0/N/A	0/N/A	0/N/A	11,000/27

KS003722

Table 36.--Future 1 - no additional ground-water development
(acres/number of years without shortage in the 30-year study period)

Hale	Meeker-Driftwood	Culbertson & Extension	Riverside	Red Willow	Bartley	Cambridge	Almena
743/30	15,112/3	19,095/0	562/7	4,439/1	5,925/3	15,958/2	5,118/12
750/30	10,075/7	12,730/0	375/13	3,049/5	4,183/8	12,272/8	3,957/16
750/30	5,037/14	6,365/0	187/18	1,660/13	2,442/16	8,586/17	2,796/20
743/30	0/N/A	0/N/A	0/N/A	270/29	700/28	4,900/28	1,635/28

Franklin	Naponee	Franklin Pump	Superior	Nebraska-Courtland	Kansas-Courtland	Lower Courtland
9,806/6	1,472/6	1,978/6	5,125/5	10,049/4	10,049/4	19,439/6
6,537/11	981/11	1,319/11	3,417/10	6,699/10	6,699/10	15,692/12
3,269/17	491/17	659/17	1,708/16	3,350/16	3,350/16	11,946/21
0/N/A	0/N/A	0/N/A	0/N/A	0/N/A	0/N/A	8,000/26

Table 37.--Future 2 - additional ground-water development
(acres/number of years without shortage in the 30-year study period)

Hale	Meeker-Driftwood	Culbertson & Extension	Riverside	Red Willow	Bartley	Cambridge	Almena
743/30	15,112/3	19,095/0	562/5	4,439/0	5,925/2	15,958/2	5,118/12
750/30	10,075/3	12,730/0	375/8	2,959/2	3,950/3	10,639/2	3,954/16
750/30	5,037/8	6,365/0	187/13	1,480/3	1,975/10	5,319/8	2,789/20
750/30	0/N/A	0/N/A	0/N/A	0/N/A	0/N/A	0/N/A	1,625/28

Franklin	Naponee	Franklin Pump	Superior	Nebraska-Courtland	Kansas-Courtland	Lower Courtland
9,806/4	1,472/4	1,978/4	5,125/3	1,575/3	10,049/3	19,439/4
6,537/5	981/5	1,319/5	3,417/3	1,050/3	6,699/3	15,359/6
3,269/9	491/9	659/9	1,708/7	525/7	3,350/7	11,280/13
0/N/A	0/N/A	0/N/A	0/N/A	0/N/A	0/N/A	7,200/28

KS003724

Table 38.--Environmental alternative
(acres/number of years without shortage in the 30-year study period)

Hale	Meeker-Driftwood	Culbertson & Extension	Riverside	Red Willow	Bartley	Cambridge	Almena
743/30	15,112/14	19,095/0	562/16	4,439/16	5,925/16	15,958/13	5,118/1
750/30	11,741/20	12,838/1	441/18	3,893/19	4,317/22	13,505/19	3,412/1
750/30	8,371/26	6,582/12	321/21	3,346/24	2,708/26	11,053/26	1,706/1
750/30	5,000/27	325/28	200/30	2,800/30	1,100/30	8,600/30	0/N/A

Franklin	Naponee	Franklin Pump	Superior	Nebraska-Courtland	Kansas-Courtland	Lower Courtland
9,806/16	1,472/16	1,978/16	5,125/16	1,575/16	10,049/16	19,439/16
6,537/25	981/25	1,319/25	3,417/25	1,050/25	6,699/25	16,326/23
3,269/26	491/26	659/26	1,708/26	525/26	3,350/26	13,213/25
0/N/A	0/N/A	0/N/A	0/N/A	0/N/A	0/N/A	10,100/27

KS003725

ALTERNATIVE MANAGEMENT ACTIONS

Structural

The structural measures presented would conserve or use existing and future water supplies more efficiently. Changes in Nebraska's water laws now allow interbasin transfers and provide the potential to transfer out-of-basin water to the upper Republican River Basin. It has been determined not to make a financial analysis based on potential water savings and ability to pay. Feasibility of any structural measures would be contingent upon additional analyses.

Canal Lining

Two alternatives were analyzed to reduce seepage rates: (1) full prism membrane lining and (2) bottom membrane lining. Only canals with capacities above 30 ft^3/s were analyzed for these alternatives. A reduction in the seepage rate to 100 percent was used for full prism membrane lining and 50 percent for bottom membrane lining. The cost estimates are based on subappraisal level investigations using January 1983 price indexes. The total construction cost includes 25 percent contingencies and 35 percent indirects. Tables 39 through 41 summarize canal data.

Pipe Laterals

PVC (polyvinyl chloride) pipe was the only material analyzed to replace open ditch laterals. Since available head was a primary consideration in determining which reaches of laterals could be replaced, concrete pipe was not analyzed due to its higher friction loss coefficient. The existing lateral alinements were used in all analyses. Lateral capacity for the Bostwick Irrigation District in Nebraska system was calculated using an application rate of R=0.30. The "R" factor is the irrigation application during the maximum 10-day period and is measured in feet per 10-day period. The R=0.30 design curve was developed by the Lower Missouri Region for gravity irrigated acreages. Lateral capacity for the Kansas-Bostwick Irrigation District system was based on existing ditch capacity and is somewhat higher than required. A reduction in the seepage rate of 100 percent for PVC pipe was used.

Cost estimates are based on subappraisal investigations using January 1983 price indexes with 25 percent contingencies and 15 percent indirects. The lateral system in the Frenchman-Cambridge Irrigation District was not studied since approximately 85 percent is presently being converted to PVC pipe under a rehabilitation and betterment program.

Canal Automation

The automation of the first 33.5 miles of the Courtland Canal from the Superior-Courtland Diversion Dam to Lovewell Reservoir would permit a portion of the bypass flows at the diversion dam to be diverted into the canal and stored in Lovewell Reservoir for subsequent release and use by

KS003726

Table 39.--Summary of alternatives
Kansas-Bostwick Irrigation District

Name of canal and lateral	Type of lining	Canal Length (miles)	Canal Capacity (ft^3/s)	Canal Total cost ($1,000)	Canal Water savings (acre-ft/yr)	Lateral Length (miles)	Lateral Total cost ($1,000)	Lateral Water savings (acre-ft/yr)
Courtland (from state-line to Lovewell Reservoir)	FPM	18.7	685	$11,900	5,670	--	$ --	--
	BM	18.7	685	3,500	2,830	--	--	--
	P	--	--	--	--	14.2	1,850	950
	NC	--	--	--	--	8.0	--	--
Pump #1	FPM	--	--	--	--	--	--	--
	BM	--	--	--	--	--	--	--
	P	2.0	18-9	260	130	4.5	590	300
	NC	3.4	36-18	--	--	0.2	--	--
Pump #1 South	FPM	--	--	--	--	--	--	--
	BM	--	--	--	--	--	--	--
	P	--	--	--	--	--	--	--
	NC	1.5	15-9	--	--	--	--	--
North	FPM	2.3	50-42	470	160	--	--	--
	BM	2.3	50-42	120	80	--	--	--
	P	1.4	15-9	180	90	2.9	380	200
	NC	0.9	30-15	--	--	1.4	--	--
Ridge	FPM	3.8	90-36	850	320	--	--	--
	BM	3.8	90-36	220	160	--	--	--
	P	2.0	30-9	260	130	5.9	770	400
	NC	--	--	--	--	3.2	--	--
Courtland (from Lovewell Reservoir to end)	FPM	20.9	635-50	9,000	5,700	--	--	--
	BM	20.9	635-50	2,650	2,850	--	--	--
	P	1.1	15-9	145	60	19.1	2,500	970
	NC	0.3	15	--	--	12.9	--	--
Courtland West	FPM	9.9	200-45	4,650	1,660	--	--	--
	BM	9.9	200-45	810	830	--	--	--
	P	--	--	--	--	17.4	2,300	890
	NC	--	--	--	--	16.2	--	--
Miller	FPM	8.2	190-30	1,900	850	--	--	--
	BM	8.2	190-30	500	420	--	--	--
	P	--	--	--	--	6.0	790	300
	NC	--	--	--	--	8.0	--	--
White Rock	FPM	9.7	100-36	2,150	1,000	--	--	--
	BM	9.7	100-36	550	500	--	--	--
	P	2.1	18-9	275	100	4.4	570	220
	NC	1.0	24	--	--	4.2	--	--
Total for Irrigation District	FPM	73.5		30,920	15,360	--	--	--
	BM	73.5		8,350	7,670	--	--	--
	P	8.6		1,120	510	74.4	9,750	4,230
	NC	7.1		--	--	54.1	--	--

FPM - Full prism membrane lining
BM - Bottom membrane lining
P - PVC pipe
NC - No change

KS003727

Table 40.--Summary of alternatives
Bostwick-Irrigation District in Nebraska

		Canal				Lateral		
Name of canal and lateral	Type of lining	Length (miles)	Capacity (ft^3/s)	Total cost ($1,000)	Water savings (acre-ft/yr)	Length (miles)	Total cost ($1,000)	Water savings (acre-ft/yr)
Franklin	FPM	39.2	230-42	$13,500	9,930	--	$ --	--
	BM	39.2	230-42	3,600	4,970	--	--	--
	P	4.2	24-9	550	190	39.1	5,120	1,730
	NC	1.7	30	--	--	7.8	--	--
Naponee	FPM	--	--	--	--	--	--	--
	BM	--	--	--	--	--	--	--
	P	--	--	--	--	1.1	150	50
	NC	7.8	42-9	--	--	0.8	--	--
Franklin South Side	FPM	2.0	42-36	390	270	--	--	--
	BM	2.0	42-36	90	140	--	--	--
	P	--	--	--	--	2.4	310	120
	NC	3.0	30-18	--	--	1.9	--	--
Superior	FPM	28.0	140-46	7,500	4,470	--	--	--
	BM	28.0	140-46	2,100	2,240	--	--	--
	P	1.2	24	160	30	14.7	1,950	330
	NC	1.4	24	--	--	6.7	--	--
Courtland (from diversion dam to State line)	FPM	15.9	754-685	10,500	7,950	--	--	--
	BM	15.9	754-685	3,100	3,980	--	--	--
	P	--	--	--	--	5.4	710	80
	NC	--	--	--	--	1.9	--	--
Total for irrigation district	FPM	85.1		31,890	22,620	--	--	--
	BM	85.1		8,890	11,330	--	--	--
	P	5.4		710	220	62.7	8,240	2,310
	NC	13.9		--	--	19.1	--	--

FPM - Full prism membrane lining
BM - Bottom membrane lining
P - PVC pipe
NC - No change

Table 41.--Summary of alternatives
Frenchman-Cambridge Irrigation District

Name of canal and lateral	Canal				
	Type of lining	Length (miles)	Capacity (ft^3/s)	Total cost ($1,000)	Water savings (acre-ft/yr)
Red Willow	FPM	13.4	90-42	$ 3,200	2,560
	BM	13.4	90-42	840	1,280
	NC	6.2	30-6	--	--
Cambridge	FPM	38.1	325-60	13,400	8,960
	BM	38.1	325-60	3,800	4,480
	NC	4.7	30-6	--	--
Meeker-Driftwood	FPM	32.5	284-36	11,500	9,070
	BM	32.5	284-36	3,200	4,540
	NC	2.0	30-6	--	--
Bartley	FPM	16.4	130-42	4,500	2,210
	BM	16.4	130-42	1,250	1,100
	NC	--	--	--	--
Total for irrigation district	FPM	100.4		32,600	22,800
	BM	100.4		9,090	11,400
	NC	12.8		--	--

FPM - Full prism membrane lining
BM - Bottom membrane lining
NC - No change

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project irrigators. This would provide an estimated 6,200 acre-feet of additional water for district use of which approximately 4,800 acre-feet would be available at Harlan County Lake and 1,400 acre-feet at Lovewell Reservoir. A reduction in the amount of personnel needed to operate the 33.5-mile reach of the canal would be offset by the additional training and number of personnel needed to maintain the new automated system.

The estimated total cost of automation for the first 33.5 miles of the Courtland Canal is $3,350,000 based on January 1983 price indexes.

Canal automation would not modify the historic low flows in the river and it does not appear that this modification would produce any adverse environmental impacts on the downstream segment of the Republican River.

Transbasin Diversions

Due to extensive ground-water development above Enders Reservoir, the total water supply available to irrigators in the Frenchman Unit has been continually declining since the late 1960's and early 1970's. The Geological Survey has projected that even without further ground-water development, perennial flows in Frenchman Creek above Enders Reservoir are expected to be reduced to zero by 1991. Studies have been conducted and water right applications have been made to divert water from the Platte River Basin to the Republican River Basin.

The transfer of water from one hydrologic basin to another is a fairly common practice throughout the United States. Water supplies for municipal and industrial or irrigation uses are often obtained from remote watersheds. Out-of-basin transfers were, from the first days of settlement of the West, recognized as a proper use of water under the western appropriation system. In recent years as state and Federal Governments have planned and built larger projects, they have, for the most part, accepted this principle and have not hesitated to plan for the transfer of water from one watershed to another.

Nebraska's basin of origin protection statutes were passed as early as 1889. These statutes had once prohibited all out-of-basin water transfers, then later allowed some transfer from certain size streams and still later permitted certain transfers if the return flows were within the greater basin of the Missouri River (which includes all of Nebraska as well as much of the surrounding states). In 1980, a Nebraska Supreme Court decision reversed an earlier (1936) decision which held that interbasin water transfers were illegal.

In April 1980, the Bureau of Reclamation was requested to provide an assessment regarding the potential to divert water from the South Platte River to Frenchman Creek in the Republican River Basin. The Corps of Engineers studied a plan to divert water from the Missouri River at Fort Randall, South Dakota to Bonny Reservoir in the Republican River Basin of Colorado. Transbasin projects provide opportunities for additional water supplies within the basin; but, not without additional cost and potential effects in the basin of origin.

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Analysis of Structural Alternatives

The structural measures described, if constructed, would provide more efficient use of water supplies to project beneficiaries; however, the features are generally not economically justified. There also may be major institutional and political problems connected with their implementation.

There may be certain specific measures which are relatively low cost and would yield substantial benefits that local and regional sponsors could pursue, if desired.

Nonstructural

Moratorium on Well Development

Due to the advent of efficient center-pivot sprinklers, well development in the basin dramatically increased in the 1960's. Land in the river valleys, which was previously economically infeasible to level and surface irrigate, has been brought into production with a well irrigation system.

Each state is responsible for administration of water rights and controlling the rate of ground-water development through either ground-water management or control of future well development. Individual state water law dictates the system for establishing and prioritizing water rights for surface and ground water in each of the basin states. A user must apply for a water right to divert and use water within the state.

Controlling future well development in the basin could provide relief from the worst condition (future with continued conservation practices and ground-water development) being realized.

The State of Kansas and Groundwater Management District No. 4 established a moratorium on well development in alluvial deposits for Beaver and Prairie Dog Creeks, as of June 27, 1984.

Weather Modification

A major field program to develop and evaluate the use of seeding techniques for the enhancement of precipitation in the High Plains area of Kansas, Colorado, and Nebraska was conducted by the Bureau of Reclamation from 1976 to 1980. The summary of results of this study is included in the final report of the Hiplex Program in Colby-Goodland, Kansas: 1976-1980. The results of the program indicate that by using weather modification techniques an increase of less than 4 percent in rainfall could be realized. The cloud seeding program was primarily conducted from June through September on convective-type storms. It can be concluded from this study that seeding methods could not significantly enhance precipitation in the Republican River Basin.

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Management of Riparian Vegetation

Water, which is being consumptively used by existing riparian vegetation in the basin, could be available for other uses and would contribute to the economic and/or environmental development of the basin.

Existing woody riparian vegetation could be cleared and the water conserved could be used for alternatives which would improve the economic and environmental condition of the basin. Estimates of water savings for the various types of riparian vegetation would be needed to make estimates of potential water savings in the basin. These studies have not been made. Examples would include maintaining instream flows, wetlands, ground-water recharge, stabilize reservoir levels, and irrigation.

Riprarian vegetation is recognized as an important habitat for many wildlife species. Therefore, any management plan for riparian vegetation should be thoroughly analyzed for potential environmental impacts.

Since the land on which the riparian vegetation exists is owned privately, riparian management plans which would contribute to the landowners economic well-being would be best received.

Other groups which would use conserved water could purchase riparian lands and/or easements or negotiate zoning to restrict riparian land use.

There are a variety of methods using combinations of mechanical and/or chemical means to clear and control the woody vegetation and prevent future encroachment.

Onfarm Alternatives

Water Management and Conservation Program

The WMC (Water Management and Conservation) Program seeks to provide better management and more efficient use of water, energy, and other resources on operating irrigation projects. The WMC Program was developed by Reclamation as a means to promote improvements in project and onfarm water systems and management practices.

The principal activities of the WMC Program include:

1. Determination of irrigation requirements.

2. Field and farm irrigation scheduling demonstrations.

3. District management

    a. Water delivery policies and standards
    b. Ditchrider rules and regulations
    c. Improved water management technology

4. Distribution system operation

   a. Water measurement capabilities
   b. Operating practices and procedures
   c. System scheduling procedures
   d. Technical reviews
   e. Planning for system improvements and/or optimization of operations
   f. Upgrading of data processing capabilities
   g. Technical assistance to identify and reduce system losses

An analysis was conducted to determine the potential for establishing a WMC Program for the Bostwick, Frenchman-Cambridge, and Kanaska Divisions in the states of Kansas and Nebraska. Two programs were analyzed to manage a total of 122,809 acres (based on 1980 irrigated acreage). A 3-year WMC Program provided for an intensive and concerted effort to realize the anticipated benefits of such a program as rapidly as possible. A lower cost alternative would be a continuous program which would require fewer personnel. Benefits of this program, however, would be realized at a slower rate.

The estimated annual cost of implementing the 3-year program based on January 1983 price indexes would total $170,000 or $1.38/acre. The annual cost of the continuous program would be $49,000 or $0.40/acre. It is anticipated that increased productivity from the program will generate revenues sufficient to pay for the program.

The anticipated benefits of a WMC Program instituted in the Republican River Basin include the following:

1. Effective and efficient utilization of the available water resources.

2. Continued productivity of irrigated croplands.

3. Minimized requirements for structural improvements and capital investments.

4. Improved public cooperation and support.

Altered Cropping Patterns

The water requirements for crops grown in the Republican River Basin are an integral part of the hydrologic modeling of historic, present, and future conditions. The farm delivery requirements for the area range from 1.76 to 2.07 acre-feet per acre, with irrigation efficiency ranging from 55 to 61 percent. The average crop irrigation requirement is based on the cropping pattern for each of the three areas in the basin. The distribution of crops for each area shown below represents a 15-year average (1962-1976). The Frenchman Valley Irrigation District is included in area I. Area II includes Frenchman-Cambridge, H&RW, and Almena Irrigation Districts. Area III encompasses the Bostwick Division, which consists of the Bostwick Irrigation District in Nebraska and the Kansas-Bostwick Irrigation District.

Crop	Area I (percent)	Area II (percent)	Area III (percent)
Corn, grain	78	80	88
Corn, silage	3	5	6
Grain sorghum	2	9	3
Alfalfa	12	6	3
Winter wheat	3	0	0
Pasture	2	0	0
Total	100	100	100

Crop distribution

The altered cropping pattern for this alternative was considered in order to reduce water use to 75 percent of the current or average district farm delivery requirement per acre as depicted in the following tabulation.

Area	Farm delivery requirement (acre-feet per acre)	
	Historic crop pattern	Altered crop pattern
I	2.07	1.55
II	1.98	1.49
III	1.76	1.32

Adopting a cropping pattern that would satisfy this goal would result in a greater number of acres being served in each district for a given reservoir yield over current cropping practices. The goal would increase acreage served by 33 percent over the last several years.

The alternative cropping pattern selection to lower water use per acre considered the following crop choices.

Crop	Farm delivery requirement (acre-feet per acre)
Corn	2.00
Grain sorghum	1.67
Soybeans	1.50
Grain sorghum-limited irrigation	1.00
Winter wheat	1.00

The crops that can be produced in the area do not present any significant adoption of new crops or changes in equipment. Soybeans have been grown in the districts recently.

The following crop distributions meet the water use goal previously established.

Cropping patterns

Crop	Area I and Area II (percent)	Area III (percent)
Corn	34	25
Soybeans	33	20
Grain sorghum-limited irrigation	33	55
Winter wheat	--	--
Total	100	100

These crop distributions were developed to reduce the irrigation requirement per acre. Two other considerations are: (1) corn is an established crop and may be difficult to displace, and (2) more crops grown provide diversification for the individual farmer, but may not maximize returns. Winter wheat may be substituted on an equal basis with limited irrigated grain sorghum without altering the farm delivery requirement.

Analysis of Nonstructural and Onfarm Alternatives

The paradox of these measures is that the successful operation of one development may adversely impact a downstream user. It is impossible to analyze each measure independent of all the other basin conditions. In the most cursory evaluation, water conserved and used at the site would be the most cost effective.

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CHAPTER V--ECONOMIC AND SOCIAL STATUS

The manmade and natural changes in the Republican River Basin over the past few decades have been dramatic. This report has presented the complex cause and effect relationship of many social, economic, and natural conditions. This chapter arrays the historic and present baseline conditions with different factors to highlight the resulting impacts and effects.

The acreage irrigated, value of crop production, and net income for historic and present conditions of the irrigation districts in the basin are presented in table 42. Net income provides an indication of the economic viability of the district lands and allows comparisons to be made between various management scenarios. However, this analysis is not an indepth estimation of either National Economic Development benefits or payment capacity valuation. Total irrigable acres available for service are presented to show the impact of conservation practices and ground-water development on areas originally planned for service.

Historically, the productivity of irrigated district lands in the Republican River Basin have contributed to the economic and social well-being of the area. Communities throughout the basin depend on the agricultural sector for their economic base and stability. The productivity of the district lands contribute to individual operator's standard of living as well as supporting employment opportunities on and off the farm.

During the last 2 decades declining streamflow conditions and subsequent reservoir yields have resulted in fewer acres irrigated in the districts by surface water. Present (1978) conditions show 60 percent of the irrigable service area irrigated in the basin.

The area of most economic concern in the basin is Almena, Frenchman Valley, and H&RW Irrigation Districts. In the Almena Irrigation District, 40 percent of the serviceable area is presently being irrigated. The Frenchman Valley and H&RW Irrigation Districts were combined in this analysis. Only 25 percent of their original service area is irrigated at this time. These decreases in acreage diminish the income producing ability of the districts and the resulting contribution to the basin's socioeconomic stability. Areas outside of the district boundaries, through ground-water and conservation development, have taken up the economic slack and most communities have not experienced the districts' decreased economic activity.

The Frenchman-Cambridge Irrigation District appears to be better off than other districts under 1978 conditions, as 75 percent of its service area is irrigated. The Bostwick Division in the lower portion of the basin irrigates between 55 and 65 percent of its serviceable area under 1978 assumptions.

Many farm operators are feeling the financial effects of water shortages and are already taking steps to alleviate the situation through

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Table 42.--Economic status of historic and present conditions by irrigation district

Irrigation district	Historic	Present 1978 conditions
Almena	(5,763 acres)1/	
Irrigated acres2/	3,600	3,500
Nonirrigated acres	2,163	2,263
Crop value	$ 1,365,000	$ 1,341,000
Net income3/	$ 613,000	$ 604,000
Frenchman Valley - H&RW	(19,095 acres)1/	
Irrigated acres2/	16,800	5,100
Nonirrigated acres	2,295	13,995
Crop value	$ 5,704,000	$ 2,848,000
Net income3/	$ 2,448,000	$ 1,081,000
Frenchman-Cambridge	(45,000 acres)1/	
Irrigated acres2/	39,100	33,700
Nonirrigated acres	5,900	11,300
Crop value	$13,394,000	$12,109,000
Net income3/	$ 5,850,000	$ 5,305,000
Bostwick in Nebraska	(22,787 acres)1/	
Irrigated acres2/	18,300	14,700
Nonirrigated acres	4,487	8,087
Crop value	$ 8,186,000	$ 7,145,000
Net income3/	$ 3,556,000	$ 3,150,000
Kansas-Bostwick	(40,100 acres)1/	
Irrigated acres2/	27,200	22,700
Nonirrigated acres	12,900	17,400
Crop value	$10,329,000	$ 9,258,000
Net income3/	$ 4,576,000	$ 4,169,000
Total	(132,745 acres)1/	
Irrigated acres2/	105,000	79,700
Nonirrigated acres	27,745	53,045
Crop value	$38,978,000	$32,701,000
Net income3/	$17,043,000	$14,309,000

1/ Total irrigable area for service.
2/ Irrigated acres represent a 30-year average annual acreage served. There could be years of zero acreage served included in these averages. These acreages do not necessarily meet Bureau of Reclamation design shortage criteria.
3/ Net income computed from crop enterprise budgets as returns less variable expenses for district cropping patterns. These values indicate the economic productivity of the district lands, but are not benefit estimates or payment capacity values.

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installation of pipe laterals, improving onfarm efficiency, and adopting cropping patterns.

FUTURE

Economic and Social Impacts

The future alternatives range from an optimistic condition where conservation practices and ground-water development remain steady at 1978 conditions to the worst condition (Future 2), which represents continued development of both soil and water conservation practices and ground-water pumping. The optimistic condition seems to be the most probable future. Current factors affecting development could change in the future. The economic and social impacts of alternatives are displayed in tables 43 and 44, respectively.

Continuation of Present Conditions

During the last few years a marked slowdown in development has occurred in the basin indicating development may be steadying. Under this future, the major socioeconomic impacts are the same as present conditions.

The best economic condition in the basin would occur if development does not continue to increase (present conditions) past 1978 levels if some cropping pattern adjustments are made. Almost 80 percent of the service area could then be irrigated as indicated in table 43 (present with cropping pattern). The value of crop production and net income would be lower than in the past (historic conditions), but this represents a considerably better situation than other alternative outlooks.

Future 1

This alternative assumes no further ground-water development but continued soil and water conservation practice development. Approximately 46 percent fewer acres in the districts would be irrigated with a full water supply compared to present conditions and net income would be reduced 25 percent. The tax base would be reduced, which would have ripple effects on significant social institutions such as schools. Economic stability in the basin would decline. Local communities would feel the effects through employment declines and general business activity. Individual farm operators would be financially burdened and land values would decline.

Future 2

This alternative assumes a continuation of both ground-water and conservation development. This is the worst condition.

Economic hardship to the irrigation districts could occur if the worst condition is realized. Only 21 percent of the serviceable acreage would be irrigated in this alternative. This alternative would have almost 65 percent fewer acres irrigated and a 35 percent reduction in net income from a future with continued present conditions. Effects on the tax base,

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Table 43.--Economic impacts of future alternatives by irrigation district, Republican River Basin

Irrigation district	Present 1/	Present with cropping pattern 2/	Present with environmental consideration 3/	Future 1 4/	Future 2 5/
Almena	(5,763 acres) 6/				
Irrigated acres 7/	3,500	4,650	1,100	2,900	2,900
Nonirrigated acres	2,263	1,113	4,663	2,863	2,863
Crop value	$ 1,341,000	$ 1,371,000	$ 753,000	$ 1,194,000	$ 1,194,000
Net income 8/	$ 604,000	$ 676,000	$ 375,000	$ 547,000	$ 547,000
Frenchman Valley - H&RW	(19,095 acres) 6/				
Irrigated acres 7/	5,100	6,780	5,000	0	0
Nonirrigated acres	13,295	12,315	14,095	19,995	19,995
Crop value	$ 2,848,000	$ 2,897,000	$ 2,823,000	$ 1,603,000	$ 1,603,000
Net income 8/	$ 1,081,000	$ 1,223,000	$ 1,069,000	$ 484,000	$ 484,000
Frenchman-Cambridge	(45,000 acres) 6/				
Irrigated acres 7/	33,700	44,820	31,900	17,900	10,200
Nonirrigated acres	11,300	180	13,100	27,100	34,800
Crop value	$12,109,000	$12,328,000	$11,681,000	$ 8,350,000	$ 6,519,000
Net income 8/	$ 5,350,000	$ 6,023,000	$ 5,183,000	$ 3,886,000	$ 3,172,000
Bostwick in Nebraska	(22,787 acres) 6/				
Irrigated acres 7/	14,700	19,550	14,600	8,000	4,900
Nonirrigated acres	8,087	3,257	8,187	14,787	17,887
Crop value	$ 7,145,000	$ 5,382,000	$ 7,117,000	$ 5,210,000	$ 4,314,000
Net income 8/	$ 3,150,000	$ 2,556,000	$ 3,139,000	$ 2,395,000	$ 2,045,000
Kansas-Bostwick	(40,100 acres) 6/				
Irrigated acres 7/	22,700	30,190	22,100	14,300	10,000
Nonirrigated acres	17,400	9,190	18,000	25,800	30,100
Crop value	$ 9,258,000	$ 8,628,000	$ 9,114,000	$ 7,257,000	$ 6,233,000
Net income 8/	$ 4,169,000	$ 4,143,000	$ 4,115,000	$ 3,410,000	$ 3,021,000
Total	(132,745 acres) 6/				
Irrigated acres 7/	79,700	105,990	74,700	43,100	28,000
Nonirrigated acres	53,045	26,755	58,045	89,645	104,745
Crop value	$32,701,000	$30,606,000	$31,488,000	$23,614,000	$19,863,000
Net income 8/	$14,309,000	$14,621,000	$13,881,000	$10,722,000	$ 9,269,000

1/ Assumes 1978 conditions for development of both conservation practices and ground-water pumping. With current expectations of development steadying, depicts a most probable and optimistic future.
2/ Represents a 25 percent reduction in the farm delivery requirement per acre via different cropping patterns in the district.
3/ Represents an effort to maintain water surface elevations in the reservoirs to meet environmental recommendations.
4/ Assumes development of ground water does not continue, conservation development continues in future and ground-water pumping lag effects are realized. Depicts a mid-range future.
5/ Assumes both conservation practices and ground-water development continue into the future. Depicts a worst condition future.
6/ Total irrigable area for service in district.
7/ Irrigated acres represent a 30-year annual average acreage served meeting full crop consumptive requirements. There could be years of no water supply and zero acreage served included in these averages. These averages do not necessarily meet Bureau of Reclamation design shortage criteria.
8/ Net income computed from crop enterprise budgets as returns less variable expenses for district cropping patterns. These values indicate the economic productivity of the district lands, but are not benefit estimates or payment capacity values.

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Table 44.--Social account - Republican River Basin

Impact factors	Historic conditions	Present 1978 conditions[1]	Present 1978 conditions with environmental	Present 1978 conditions with cropping pattern changes	Future 1[2]	Future 2[3]
Individual Effects						
Attitudes - district farmers	---	---	Majority of district farmers opposed to this alternative.	Water shortages will require cropping changes to keep farm viability Changes in farm operations will be required which may be opposed by the less progressive operators.	Opposed to continued development. Development controls are needed.	Opposed to continued development. Development controls are needed.
Area Effects						
Irrigated acres	105,000	79,700	74,900	105,990	43,100	28,000
Nonirrigated acres	27,745	53,045	58,045	26,755	89,645	104,745
Crop value	$38,978,000	$32,701,000	$31,488,000	$30,606,000	$23,614,000	$19,863,000
Net income	$17,043,000	$14,309,000	$13,881,000	$14,621,000	$10,722,000	$ 9,269,000
Community Effects						
Economic base (districts)	---	Net crop income of $14,309,000	Decreased net crop income of 3 percent from 1978 conditions.	Increased net crop income of 2.2 percent from 1978 conditions.	Decreased net crop income of 25.1 percent from 1978 conditions.	Decreased net crop income of 35.2 percent from 1978 conditions.
Tax base (districts)	---	---	Decreased tax base.	Probable decreased tax base with county classification. Change due to water shortages.	Large decrease in tax base.	Large decrease in tax base.
Employment opportunities (on-farm-basin)	---	---	Small decrease from 1978 conditions.	Small increase from 1978 conditions.	Large decrease from 1978 conditions.	Large decrease from 1978 conditions.
(Nonfarm related business)	---	---	Small decrease from 1978 conditions.	Same as 1978 conditions.	Decrease from 1978 conditions.	Decrease from 1978 conditions.
Other						
Food production (shifts in major types)	Corn	Corn	Corn	Grain sorghum, soybeans, wheat, corn	Corn	Corn
Aggregate Social Effects						
Quality of Life — Standard of living (farmers)	---	---	Decrease from 1978 conditions.	Approximately the same as 1978 conditions.	Sharp decrease from 1978 conditions.	Sharp decrease from 1978 conditions.
Relative Social Position	---	---	Benefits of irrigating in districts continue to decline.	Benefits of irrigating in districts are approximately the same as 1978 conditions.	Benefits of irrigating in districts decrease sharply.	Benefits of irrigating in districts decrease sharply.
Social Well-Being	---	---	Decrease in economic stability in basin from 1978 conditions.	Economic stability is approximately the same as 1978 conditions.	Sharp decrease in stability in districts. Ripple effects will affect many communities in basin.	Sharp decrease in economic stability in districts. Ripple effects will affect all communities in basin.

1/ Assumes 1978 conditions for development of both conservation practices and ground-water pumping. With current expectations of development steadying, depicts a most probable and optimistic future.

2/ Assumes ground-water development does not continue, conservation development continues in future and ground-water pumping lags are realized. Depicts a mid-range future.

3/ Assumes both conservation practices and ground-water development continue in the future. Depicts a worst condition future.

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social institutions, farm employment, and economic activity and stability of communities would be more drastic than future 1.

This future might be prevented if an immediate moratorium on ground-water development affecting the reservoir yields is undertaken by the states, especially in Nebraska. Cropping pattern changes would be necessary with this alternative.

Water savings in the districts could be attained through lining of distribution and conveyance systems and through improvements in farm irrigation efficiency. Water savings through canal and lateral lining offer the means to increase acreages served in some districts. The cost required to achieve these solutions appears high for current economic and financial conditions.

Environmental

In addition to the two future considerations, another alternative was analyzed using results from the computerized reservoir operation models to determine the effects on water distribution of water level recommendations made by the FWS. The FWS recommendations were:

1. Maintenance of reservoir levels at the average annual surface area of the conservation pools.

2. Fluctuation of no more than 30 percent of the surface area of Bonny Reservoir, Keith Sebelius Lake, and Lovewell Reservoir.

3. Fluctuation of no more than 45 percent of the surface area of Swanson Lake, Enders Reservoir, and Hugh Butler and Harry Strunk Lakes.

4. Maintenance of existing surface area at Keith Sebelius Lake through elimination of irrigation releases.

Based on the above recommendations the acreages that could receive water are shown in table 43.

A recommendation received from the State of Nebraska Game and Parks Commission is for annual information/coordination meetings between state, FWS, and Reclamation personnel to discuss basin water management. Nebraska personnel feel that appropriate state agency personnel should be involved in proposals to initiate new or modify existing agreements that may affect fish and wildlife resources. In 1984, the Nebraska Legislature passed legislation regarding minimum instream flows.

Various management plans were proposed and displayed, and the environmental impacts are listed in table 45. An additional plan containing alternate cropping patterns was not arrayed in the table. Present conditions with an environmental enhancement alternative improve the recreational and fish and wildlife opportunities, but reduces irrigation possibilities in the basin. Cropping pattern changes would not necessarily affect the habitat available or wildlife. The quantity and quality of food available to wildlife could be impacted.

Table 45.--Environmental account
Republican River Basin

Impact factor	Present	Present with environmental consideration	Future 1*	Future 2**
Aquatic species				
Reservoirs	Extreme fluctuations result in declines in fisheries and declines in desirable aquatic habitat	Probable return to a higher quality fishery and improved aquatic habitat	Continued decline in water levels and desirable aquatic habitat	Severe water depletion and loss of desirable aquatic habitat as a result of reduced inflows
Streams	Reduced streamflows decreased fishery habitat and reproduction	Probable reduction in streamflow and loss of fishery	Continued low streamflows and further degradation of fishery habitat	Reduction of streamflows with probable intermittent flows and loss of stream fishery
Terrestrial species	Habitat supports numerous wildlife species	Continued support of numerous species in reservoir areas	Continuation of desirable habitat for wildlife	Decreased water levels will result in declines of suitable habitat
Riparian habitat	Decline in trees and associated shrubs adjacent to streams in the upper basin	Probable loss of riparian habitat along streams	Continued loss of riparian habitat in the upper basin	Extreme losses of desirable instream and streamside habitat
Migratory waterfowl	Extreme reservoir fluctuation and low water levels reduce vegetation beneficial to waterfowl	Probable stabilization in reservoir use	Continued decline in suitable habitat	Severe loss of desirable habitat and probable change in migratory habits
Threatened and Endangered Species	Reduced streamflows and loss of streamside vegetation in the upper basin have resulted in a decrease in habitat favorable to state threatened fish species and the bald eagle	Probable increase in aquatic habitat and conditions conducive to bald eagles	Continued decline in aquatic habitat and loss of streamside vegetation in in the upper basin resulting in a decline in desirable bald eagle and state threatened fish species habitat	Reduction in streamflow and reservoir water levels will result in further degradation of aquatic habitat and loss of related species

* Assumes development of ground water does not continue and farm conservation practices continue.
** Assumes both farm conservation practices and ground-water development continue.

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CHAPTER VI--STUDY REVIEW AND FUTURE ACTIVITIES

Upon completion of the investigations, an internal critique of the process and methodologies was undertaken. In a study as large and data intensive as the Republican River Basin Water Management Study, it was necessary to make certain assumptions in order to hydrologically model the basin. These assumptions, when applied to the entire Republican River Basin, are not always as sensitive to the area needs as they would be in a smaller study.

Another significant finding was the difficulty encountered in transferring methodologies from one basin to another, such as from the Solomon River Basin to the Republican River Basin. The difficulties encountered in a large basinwide analysis, the derivation of solutions, the sensitivity of assumptions, and the gaps in the existing data base may prove to be the most valuable findings of this study.

CONSERVATION PRACTICE MODELING ASSUMPTIONS

In order to implement the conservation practices model, several assumptions were made to simplify the data base and the computer modeling. The assumptions were: (1) the Republican River Basin can be divided into subbasins with flows and depletions that follow the laws of superposition, (2) one weather station adequately represents the climatological parameters over an entire subbasin, (3) the conservation practices are distributed evenly over each subbasin and county area, (4) a typical pond designed for each subbasin is representative of all ponds in the subbasin, (5) all ponds in each subbasin have the same infiltration rates, (6) the soils in each subbasin can be characterized by one soil type that most accurately describes all of the soils, (7) the runoff curve numbers selected as input to the models most adequately describe the runoff characteristics in the basin, (8) estimates of conservation practice quantities over time can be expressed as linear relationships, and (9) short periods of missing weather data can be replaced with data from nearby stations.

GROUND-WATER ASSUMPTIONS

The number of irrigation wells located in the study area was determined from well registration lists obtained from the three states of Colorado, Nebraska, and Kansas. The irrigation wells were plotted on a map to the nearest section and were assumed to be irrigating land only in their subbasin. Since the well registration lists did not accurately list the acreage irrigated by each well, the following method was used to derive each well's irrigated acreage. The irrigated acreage per subbasin was assumed to equal the irrigated acreage derived from 1978 Landsat photos minus the 1978 irrigated acreage by project water. The irrigated acreage per well was then assumed to equal the subbasin irrigated acreage divided by the number of irrigation wells in the subbasin. Net pumpage per well was then assumed to equal the well's irrigated acreage multiplied by the average 1920-1978 crop irrigation requirement. Each well was assumed to begin pumping based on its priority date or the date the well was drilled if no priority date was provided.

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Recharge to the aquifer system was the sum of several components in the water budget. Deep percolation of water applied to land by irrigation wells was assumed to be 20 percent of the total pumpage by each well. Thirty percent of applied surface water was also assumed to percolate to the aquifer system. Ninety percent of canal and lateral losses were assumed to return to the aquifers. Recharge to the aquifers by precipitation was assumed to equal a historical average annual value which was estimated for each subbasin using a water budget method. No attempt was made to determine what changes may have occurred to the precipitation recharge rate with the development of agricultural lands; however, when budgets were constructed to project future ground-water storage, the average annual recharge by precipitation was increased by 10 percent of the average annual precipitation which occurred on the increased ground-water irrigated acreage.

When using the Glover methodology to estimate depletions on base flow due to ground-water pumping, several assumptions are required to make the mathematics of the modeling valid. Several of these assumptions are: (1) the stream is hydraulically connected with the aquifer, (2) the stream channel and well fully penetrated the aquifer, (3) the aquifer is isotropic, homogeneous, and infinite in areal extent, (4) there is no resistance to flow or sealing due to sedimentation in the stream, (5) the stream is straight and of infinite extent, (6) the aquifer is of constant thickness, (7) Darcy's Law and Dupuit-Forchheimer assumptions apply, (8) the transmissivity and storage coefficients are constant with time, (9) the well has an infinitesimal diameter, (10) the aquifer is bounded by a horizontal, impermeable base, (11) there is an instantaneous accretion or release of water in storage due to a change in piezometric levels, (12) the source of the pumped water is aquifer storage and water from the stream (reduced base flow is induced seepage), and (13) the well pumps at a constant rate.

FUTURE ACTIVITIES

If the conservation practice depletions are further examined, a longer period of study would be useful to extend the data base. This would allow a more accurate calibration of the models so that depletions could be examined before development of any of the conservation practices. Model assumptions should be refined to more accurately represent the conditions in the basin.

When computing the evapotranspiration using the modified Blaney-Criddle method, it is assumed that the temperature and precipitation data when averaged over a large area are representative of the irrigation districts. Dividing the basin into smaller segments would give more accurate values. Also, better estimates of effective precipitation and nongrowing season carryover moisture in the soil profile would give better estimates of the crop irrigation requirements.

In future studies involving ground-water aquifer modeling and streamflow depletions due to pumping wells, a digital finite element or difference modeling effort would be invaluable. To refine the modeling effort an

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extension of the data base should include more accurate values of transmissivity, storativity, well discharge, evapotranspiration, precipitation recharge, and deep-percolation from applied irrigation water.

An even more effective method of examining the ground-water and conservation practice depletions would be through the use of a conjunctive surface water/ground-water model. This would more effectively portray the complex interactions in the hydrologic system. In this way things such as recharge to the aquifer system due to conservation practices can be more accurately represented. Return flows to surface water and ground-water systems from irrigation and conservation practices would also be better represented.

The subreconnaissance level analysis of potential modifications to existing delivery systems provides an indication of structural alternatives which could increase water system efficiency. Additional analyses, if requested, should utilize site specific data and provide results of a higher degree of reliability and accuracy.

Hydrologic, socioeconomic, and environmental conditions resulting from conservation practices, ground-water pumping, and structural modifications need to be considered in greater detail in future studies. The inclusion of these data will be essential to those making long-term decisions and will provide a basis to formulate action relating to future use of the basin's water resources.

Reclamation will continue to provide technical expertise to irrigation districts under its technical assistance programs. This could assist water users in the analysis of their current and future water problems.

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CHAPTER VII--FINDINGS AND CONCLUSIONS

FINDINGS

1. Surface water supply in the basin has been shown to be declining in recent years (1966-1978). Factors that are affecting the supply are: changes in base flow due to increased ground-water pumping for surface irrigation, development and addition of conservation practices, and cyclical variations in the precipitation regime.

2. Significant declines in ground-water levels have occurred in the upper Republican River basin, generally along the Colorado State line due to extensive well development in the area. This has led to significant declines in base flow of several major streams in the upper basin.

3. The total basin change in ground-water storage is small when compared to the total volume of ground water in storage; a 2 percent decline from a predevelopment storage volume of 347,893,000 acre-feet. However, in individual areas where the saturated thickness is relatively thin, the percent change in storage can be higher, up to 9 percent.

4. Soil and water conservation practices are the largest source of depletion to the surface water supply in the basin.

5. Consumption of ground water by riparian vegetation is estimated to be 18 percent of the total outflow from the aquifer system over the historic period.

6. Projections to year 2020 show there is sufficient ground water in storage for continued well development. However, surface water supply will be limited severely by the same development.

7. The reduction in base flow in streams in the upper basin is due to wells which are either intercepting ground water that formerly discharged into streams or reversing the gradients to the streams, thereby inducing streamflow to the aquifer.

8. Seepage from surface water irrigation practices and systems has caused significant ground-water level rises along the northern border of the Republican River Basin and around the Courtland Unit in the lower portion of the basin. During the historic period, seepage has also contributed to increased base flow in Blackwood and Driftwood Creeks in the upper basin, and in the Republican River reach from Harlan County Dam to Hardy, Kansas in the lower basin.

9. Surface water runoff is a function of the frequency, duration, and intensity of precipitation rather than the total annual precipitation. Runoff producing storms delivering 1 inch or more of precipitation in 24 hours or less have been less frequent since the 1957-1965 period.

10. Farm delivery requirements for the area range from 1.76 to 2.07 acre-feet per acre, with an irrigation efficiency of 55 to 61 percent.

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11. The areas most concerned with declining water supplies in the basin are the Almena, Frenchman Valley, and H&RW Irrigation Districts.

12. Significant water savings could be achieved by the irrigation districts by lining their canals and laterals.

13. Automation of the canals and laterals in the Superior-Courtland irrigation facilities would result in better utilization of peak flows in the river.

14. Changing the operation of the reservoirs would not increase flood protection in the basin. Dams on the rivers and tributaries adequately control flooding on the reaches they serve, but the potential for flooding exists on uncontrolled reaches.

15. Reservoirs are important sources of fishing, hunting, and related recreational activities in the basin.

16. Decreased base flow has resulted in reduced riparian habitat and related wildlife in the basin.

17. Reduced inflows to reservoirs have resulted in a loss of fish habitat and recreational opportunity.

18. Between 1950 and 1980, the population in the basin has declined from 215,507 to 169,025 and population of rural areas decreased by 11.4 percent. This is typical of most rural areas in the Nation.

19. In 1978, 28.9 percent of employment and 30.8 percent of earnings in the basin were generated by agriculture. Other major sectors of the economy are construction, transportation, and retail and wholesale trade.

20. Winter wheat, sorghum grain and silage, dry beans, corn, sugar beets, and livestock are the major contributors to the agriculture economy of the basin.

CONCLUSIONS

1. Continued development of ground water and conservation practices could cause decreases in acreage irrigated in the irrigation districts diminishing their income producing ability and their contribution to the basin's socioeconomic stability.

2. An immediate moratorium on ground-water development that is reducing reservoir yields might prevent the worst condition future from occurring.

3. With no additional well development after 1978, base flow in the Arikaree River and Blackwood, Beaver and Sappa Creek subbasins will decline to zero by 2020.

4. Under the condition of continued well development after 1978, only the streams in North and South Fork Republican subbasins and in the lower Republican Basin are predicted to have any base flow by the year 2020.

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5. Severe limitations may be imposed on the reliability of the water supply for irrigation districts at future levels of ground-water pumping and conservation practices.

6. Assuming 1978 conditions would continue into the future for ground-water development and conservation practices, one-third more acres could be irrigated by changing the cropping pattern which would result in stabilizing net farm incomes at somewhat higher levels for most districts.

7. The cost of lining canals and laterals is not economical under current conditions.

8. Soil and water conservation practices must be managed effectively.

9. Recreational fish and wildlife opportunities could be improved with the environmental enhancement alternative, but irrigation would be reduced.

10. Reservoir levels could be stabilized and/or minimum streamflows could be maintained for selected reaches reducing undesirable conditions for fish and wildlife.

11. While management actions could be effective, none would restore a full water supply to the irrigation districts.

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