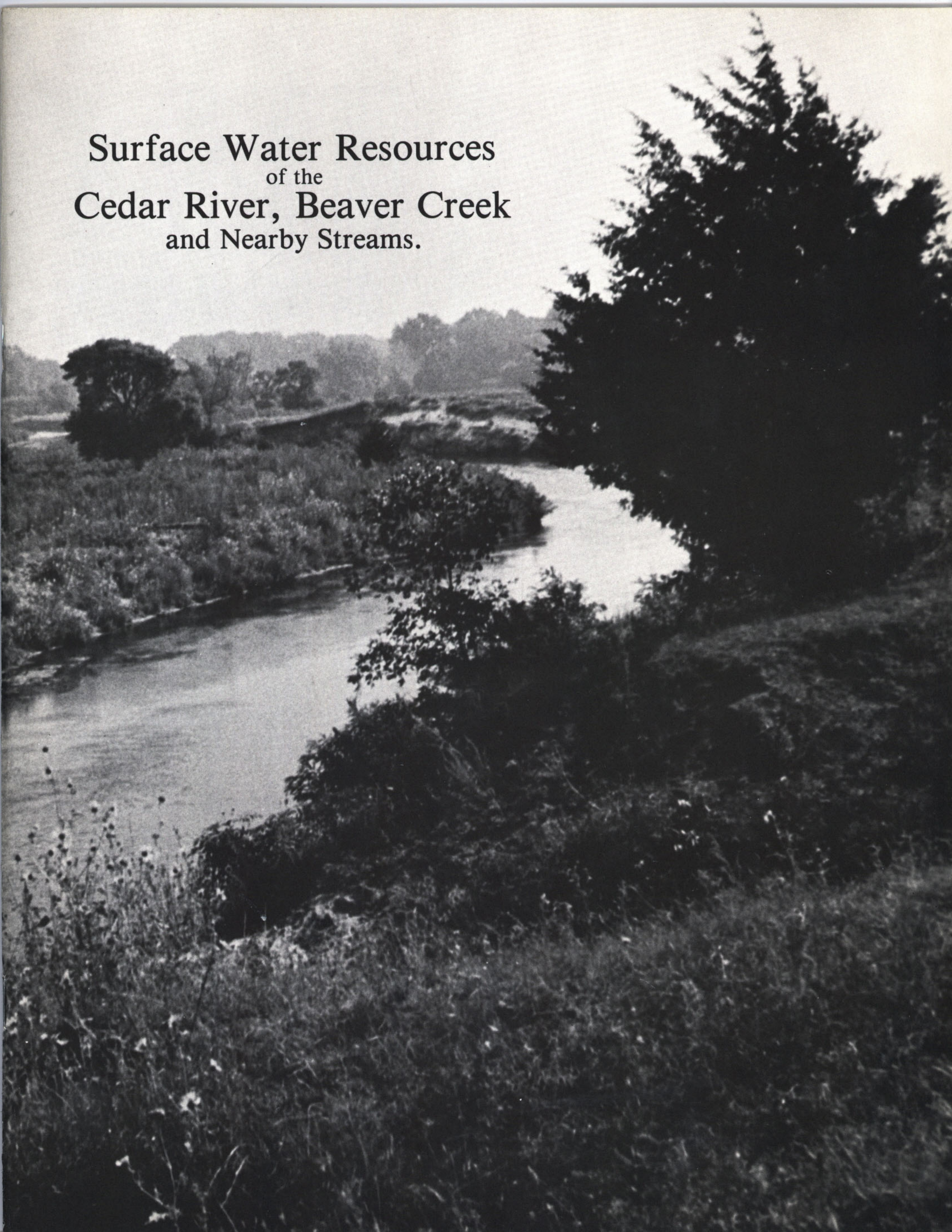
Surface Water Resources
of the
Cedar River, Beaver Creek
and Nearby Streams.



Sandhills in the Upper Cedar River Basin
Courtesy of the Nebraska Game and Parks Commission

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The cover photo is of the Cedar River near Ericson.
Picture courtesy of the Nebraska Game and Parks Commission.

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Introduction

In recent years much attention has been focused on the hydrology of the Sandhills. The region is relatively undeveloped by contrast to other areas in the state, and it possesses an abundant water supply. The vast area of unconsolidated dune sand provides the source for many of the state's streams and rivers. The Cedar River and Beaver Creek drain the eastern portion of the Sandhills. This region lies in the transition zone between the much thicker sand formations to the west and the loess hill region to the south and east. The Cedar River, Beaver Creek and the smaller streams which lie between them are shown in Figure 1.

This report examines the surface water supply provided by the streams in the region. It also summarizes the quantity of surface water used. As streamflow is not constant, both average and extreme flow conditions were examined. A review of extreme events permits a better understanding of the waterway's flood potential and its ability to meet supply needs such as irrigation, sewage dilution or habitat. Average flows, on the other hand, give an indication of the magnitude of the long-term water supply.

The data base for this report consists of the records from continuous recording stream gages and from various point measurements collected since 1894. The collection of continuous streamflow records began with the establishment of gages in 1940 near Fullerton on the Cedar River and at Genoa on Beaver Creek (several months of continuous record were collected on the Cedar River near Fullerton in 1931 and 1932). Gages were added on the Cedar River near Spalding and on Beaver Creek at Loretto in 1944. Additional gages were operated on the Cedar River at Primrose and Belgrade from 1959 to 1965. Although four gages are in operation at present, the gages near Spalding and at Loretto were not operated for extended periods during the last four decades. By necessity the missing discharge values at those sites were estimated using hydrologic simulation techniques.

Another segment of the streamflow data base consists of point or miscellaneous measurements obtained at many locations in the area. A large portion of the miscellaneous measurements were obtained under base flow conditions. For this report base flow is defined as the portion of a stream's discharge which originates from ground water seepage. Measurements of base flow are commonly obtained during periods of no runoff and when significant withdrawals (for irrigation) and water use by nearby plant life are at a minimum. Such conditions typically occur in the fall and early spring.

The remainder of the data base consists of miscellaneous measurements obtained under conditions varying from midsummer drought to severe flooding. Measurements obtained at many sites, when related to continuous gage records, allow estimates of a wide range of flow conditions throughout the study area.

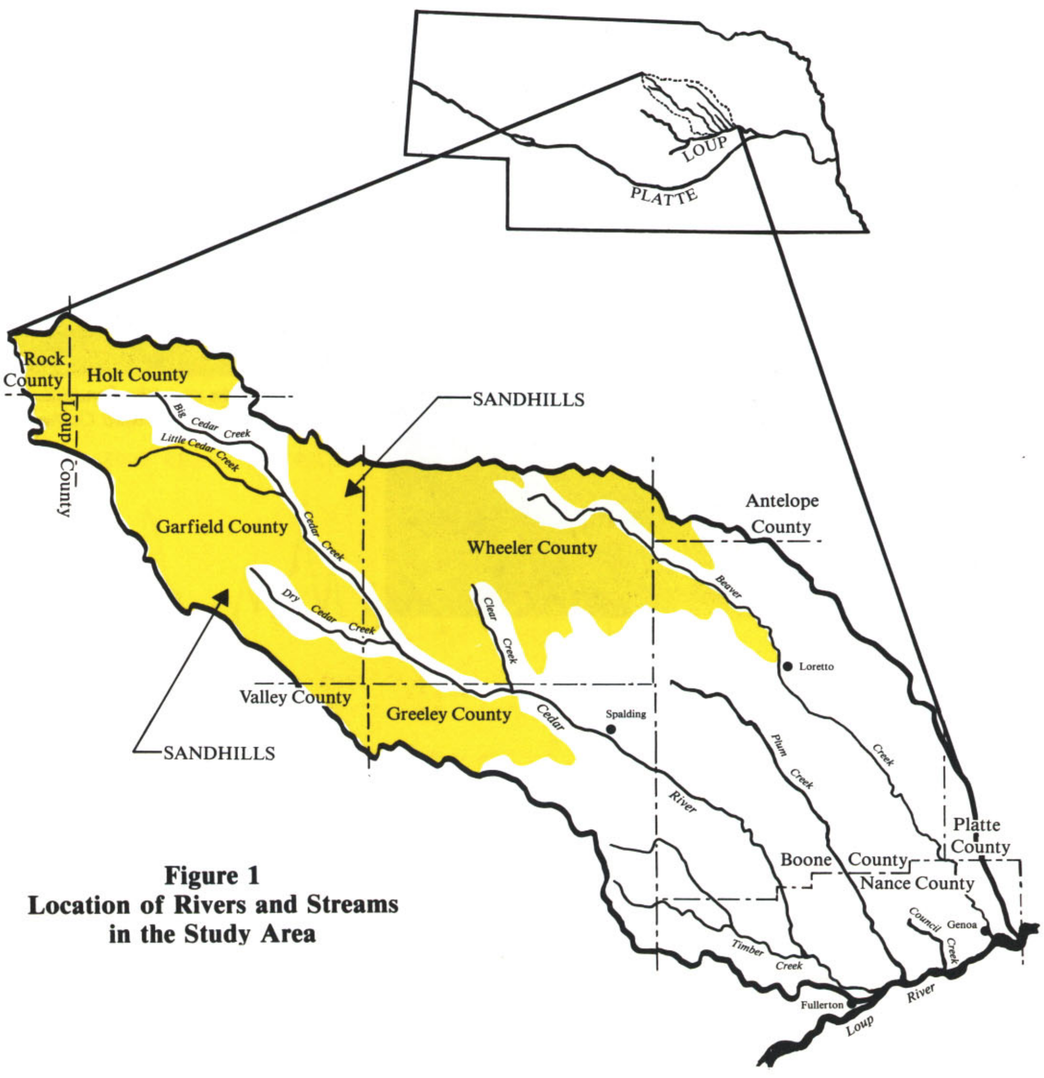


Figure 1
Location of Rivers and Streams in the Study Area

Hydrologic Setting

The headwaters of the Cedar River and Beaver Creek are fed by seeps and springs draining the vast ground water "reservoir" underlying the Sandhills. This reservoir (aquifer) is predominately composed of unconsolidated coarse textured materials. Lenses of finer grained materials, such as silt and clay, also occur beneath the Sandhills. On the surface, sandy textured soils predominate in the upper Beaver and Cedar watersheds.

The ultimate water source in the basins is precipitation. Moisture falling on the loose dune sand is quickly absorbed. Much of it is slowly released to evapotranspiration by plants and as seepage into the region's sparse network of streams and rivers. Local geologic conditions, such as a buried stream channel or clay lense, may cause concentrations of ground water outflow into marshes and springs or directly into stream channels.

Both the Cedar River and Beaver Creek rise in the broad, marshy wet meadows of the eastern Sandhills. The sand formations of the headwater region tend to be low in relief and are set back a considerable distance from the channels. The waterways begin as shallow continuous depressions which meander through cattails and marsh grass.

Streamflow in the Sandhills is characterized by its uniformity. Compared to other streams in the state, day-to-day and year-to-year fluctuations are less significant. The storage capability of the extensive sand formation moderates the effects of climatic extremes. Periods of heavy rainfall or snowmelt are accompanied by only moderate increases in discharge. Many months of drought are necessary to cause a noticeable reduction in streamflow.

Further downstream, finer clay and silt materials characterize the soils and near-surface geology. The less permeable silty soils cause a greater portion of precipitation to flow overland as surface runoff. The greater runoff potential of the finer textured soils relative to the more sandy soils, has resulted in a denser drainage network evidenced by considerably more tributary streams. Additionally, larger variations in flow occur downstream from the Sandhills. Heavy rainstorms have caused quick swelling of small creeks. Floods capable of causing considerable destruction are not uncommon along Beaver Creek and the Cedar River, particularly in the region downstream from the Sandhills.

During times of drought, most of the tributary streams in the lower portions of the watersheds are dry. Streamflow is primarily derived from ground water inflow within the Sandhills. A significant portion of the flow derived from the Sandhills is lost to evapotranspiration, diversion for irrigation and seepage in the downstream portions of the waterways. Under normal climatic conditions, the streams obtain comparatively moderate inflow from ground water seepage downstream from the Sandhills. The ground water inflow gain per channel mile in the lower portion of the basins is much less than the gain per mile realized in the Sandhills.

Clear Creek near Ericson

Thunderstorm over the Sandhills
Courtesy of the Nebraska Game and Parks Commission

Water Supply Characteristics

The annual water supply provided by the Cedar River and Beaver Creek is shown by the hydrographs in Figure 2. The Cedar River carries an average flow which is nearly double the discharge of Beaver Creek (173,740 acre-feet vs. 88,340 acre-feet). Nearly one-fourth of the record for the Cedar River gage near Spalding and more than two-thirds of the Beaver Creek station record at Loretto were synthesized using monthly linear regression equations. Good to excellent correlation coefficients of 0.68 for the Spalding station, and 0.97 for the Loretto gage were realized from the predictive equations. The correlation coefficients, which measure the degree of closeness of the linear relationship between two variables, were calculated by correlating the measured annual discharges against annual discharges synthesized using the monthly regression equations.

Plum and Council Creeks, which are not continuously measured, carry a tiny fraction of the flow transported by their larger neighbors. The water yields of both were approximated by analyzing flows measured near their mouths. Plum Creek is estimated to yield little more than 1,000 acre-feet in an average year. The average annual flow of Council Creek probably amounts to less than ten acre-feet. For both, the majority of flow originates from surface runoff.

No trends are evident in the 40-year measured and synthesized records of annual flows depicted in Figure 2.

Beaver Creek at Boone

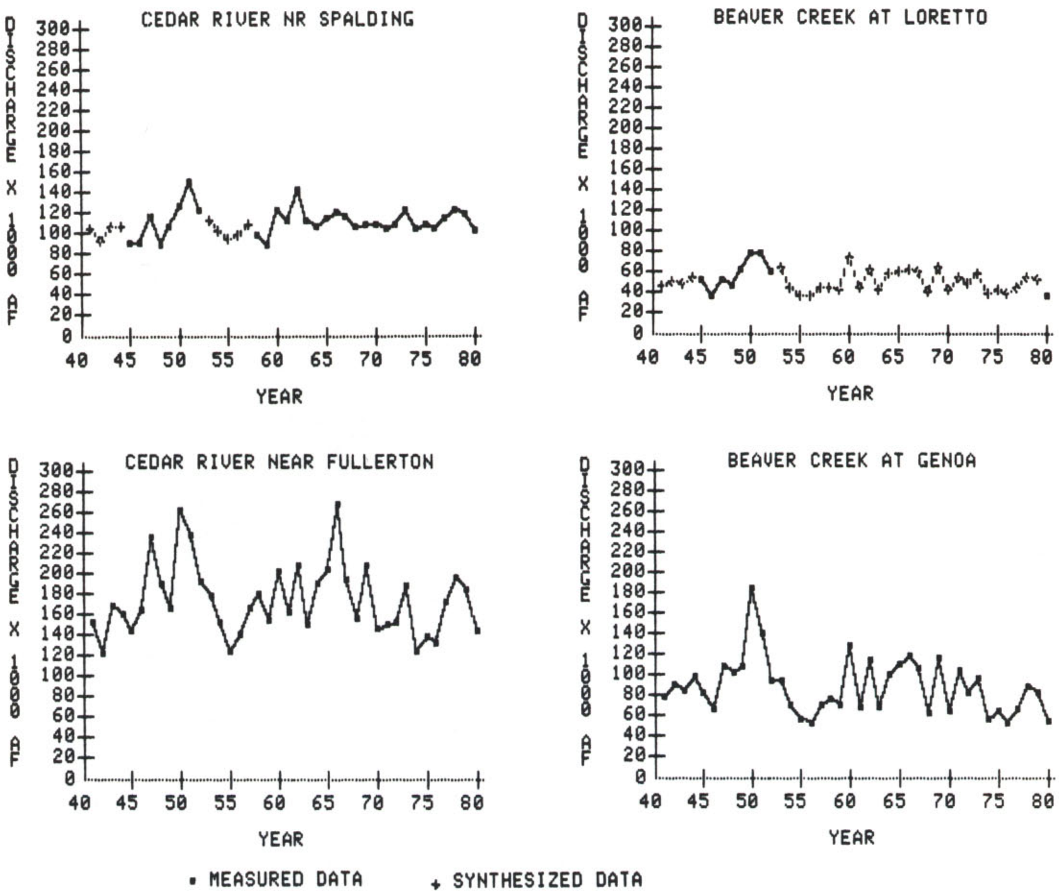


Figure 2
Annual Flow at Gaging Stations

Both wet and dry climatic cycles have occurred in the basins since 1940. Dry periods have included years in the 1940's, the mid 1950's and 1970's and early 1980's. Wetter than normal periods have included the early 1950's and 1960's. From preliminary data, it appears that 1982 was a wetter than normal year as well. It is evident that the fluctuations in the hydrographs reflect short-term climatic variability, rather than significant changes in basin hydrology.

Table 1 lists the computed average flow expected during the wettest and driest months, and a statistical monthly average. From month to month the Cedar River, with its larger inflow from the Sandhills region, exhibits less variation than Beaver Creek.

The smaller variability of the flow at the upstream gages is also evident when comparing the monthly flow of upstream and downstream gaging stations in the two basins. At the Cedar River gage near Spalding, variability about the mean monthly discharge ranges from −14 percent to +19 percent. For the Cedar River gage near Fullerton, the average maximum monthly discharge is nearly 50 percent larger than the mean monthly flow which in turn, exceeds the average minimum monthly flow by 23 percent.

The greater relative stability of flow at the gaging stations nearest to the Sandhills is also evident on Beaver Creek. At Loretto, monthly flows vary from −37 percent to +57 percent about the mean monthly discharge and at Genoa from −38 percent to +91 percent. The impact of more rapid runoff in the lower portions of the basins is apparent.

Despite the different periods of record, it is evident that the recorded range of discharge is far less for the Spalding and Loretto sites, which lie more immediately downstream from the Sandhills. Table 2 lists the maximum and minimum recorded discharges at the four continuous record stations.

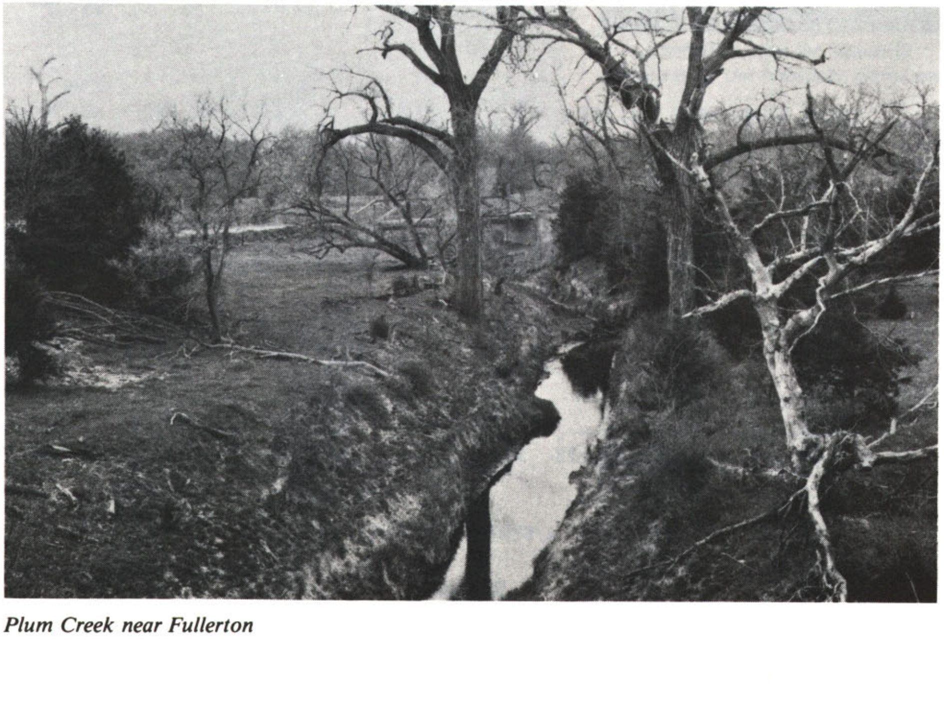
Flood peaks on the Cedar River and Beaver Creek, recorded at the Spalding and Loretto gaging stations, are probably greater than at locations in the Sandhills. Observations made by Department of Water Resources' field personnel measuring large discharges reveal that sharp peaks at Spalding and Loretto were often produced by inflows of small tributaries draining so-called hard ground which lies between the gages and the Sandhills. By contrast, storm hydrographs produced at other stations entirely within the Sandhills are characterized by slow rises and recessions. Storm hydrographs of such streams exhibit rounded peaks which do not rise to the extreme values common to streams draining less permeable land.

The largest flood recorded on the Cedar River near Fullerton (64,700 cfs) occurred on August 13, 1966, in response to extremely heavy rains in the central Cedar River Basin and along Timber Creek. The North Branch of Timber Creek, a nearly dry tributary, attained a discharge of nearly 10,000 cfs on August 12. The devastation of this flood, with a statistical return period of more than 200 years, was extensive. The Fullerton Power Plant was damaged beyond repair.

The largest flood recorded (21,200 cfs) on Beaver Creek was measured at Genoa on July 19, 1950. Statistically, a flood of this magnitude would be expected to occur only once in nearly a century. Many floods of lesser size have occurred on both basins. Appendix A provides additional information on how often floods of a certain magnitude might be expected to occur in the two watersheds.

On both the Cedar River and Beaver Creek, record floods at the gages near Spalding and Loretto did not coincide with those measured at the downstream gages near Fullerton and Genoa. The largest floods in both basins have occurred during the spring or summer in response to intense rainstorms, rather than from snowmelt or ice jams.

Extremes in annual flow are often used in evaluating the limits of basin water yield. Recorded maximum annual flows exceed the minimum yearly flows by only 170 to 354 percent at the four gages. This range is small when compared to other streams in the state where the recorded annual maximum flow has exceeded the annual minimum by substantially more. Table 3 lists the discharge for years of maximum and minimum flow.



Plum Creek near Fullerton

TABLE 1

Computed Average Flow During Months of Greatest and Least Flow and Mean Monthly Discharge in Acre-Feet (1941-1980)

Gaging Station	Maximum (Month)	Minimum (Month)	Mean
Cedar River near Spalding	10,840 (June)	7,840 (Sept.)	9,100
Cedar River near Fullerton	21,570 (June)	11,140 (Sept.)	14,480
Beaver Creek at Loretto	6,770 (March)	2,700 (Sept.)	4,310
Beaver Creek at Genoa	14,030 (June)	4,540 (Sept.)	7,360

TABLE 2

The Maximum and Minimum Discharges at the Cedar River and Beaver Creek Gages in Cubic Feet per Second (cfs)

Gaging Station	Period of Record	Maximum	Minimum
Cedar River near Spalding	1944-1953, 1957-1981	4,000	30
Cedar River near Fullerton	1931-1932, 1941-1981	64,700	30
Beaver Creek at Loretto	1944-1953, 1979-1981	4,570	12
Beaver Creek at Genoa	1941-1981	21,200	0.41

TABLE 3

Maximum and Minimum Annual Flow at the Cedar River and Beaver Creek Gages in Acre-Feet

Gaging Station	Maximum (Year)	Minimum (Year)
Cedar River near Spalding	150,230 (1951)	88,530 (1948)
Cedar River near Fullerton	266,370 (1966)	123,100 (1942)
Beaver Creek at Loretto	78,560 (1951)	36,010 (1980)
Beaver Creek at Genoa	183,730 (1950)	51,930 (1956)

Ground Water Inflow

Spring and tributary to the Cedar River near Ericson

Much can be learned about the relationship between surface and ground water in a watershed by analyzing the ground water inflow (base flow) at a large number of sites. In watersheds which lie in portions of several distinctly different physiographic regions, analysis of base flow measurements can reveal variations in near-surface geology which affect stream flow. The map shown in Figure 3 depicts base flow and low flow measurement sites. They are referenced to Figures 4 through 7. Base flow data shown in Figures 4 and 5 represents an average of seepage measurements made between 1978 and 1982 on the Cedar River and Beaver Creek, respectively.

The Cedar River rises in the broad, marshy wet meadows of northern Garfield County. It begins its flow towards the Loup River as two small streams, Big and Little Cedar Creeks. Ground water slowly oozes into the two streams from the surrounding marshes. Reach gains average less than 0.2 cubic feet per second per mile (cfs/mile) between sites C-1 through C-3.

Further downstream, the small creeks enter more defined channels. It is in this region that the streams experience a considerable increase in base flow. As depicted in Figure 4, gains on Cedar Creek exceed 7 cfs/mile in the reach immediately downstream from the confluence of Big and Little Cedar Creek (sites C-4 through C-6). Large but less dramatic gains of 3 cfs/mile, characterize the remainder of Cedar Creek before it becomes the Cedar River at the mouth of Dry Cedar Creek near Ericson.

The Cedar River continues to receive substantial amounts of ground water inflow from Ericson to Primrose. The Sandhills either bound or flank the river valley along much of this reach. Several tributaries, also supported by base flow, enter the Cedar River above Spalding. Ground water enters the Cedar River at an average rate of more than 2.6 cfs/mile in this portion of the basin.

There is no significant base flow gain between Primrose and the Fullerton gage. A minor base flow loss occurs in the vicinity of Cedar Rapids. The base flow of Timber Creek, 3.8 cfs, contributes a "stair step" gain at site C-20. Base flow enters the Cedar River at a slightly higher rate in the seven mile segment from the Fullerton gage to the mouth. Measured gains amount to almost 2 cfs/mile between sites C-21 and C-22.

Beaver Creek, like the Cedar River, rises in the marshlands of the eastern Sandhills. Ground water begins to enter the shallow channel of Beaver Creek in central Wheeler County. Gains in the headwater region between sites B-1 and B-3 average less than 0.2 cfs/mile.

The area of greatest ground water inflow to the creek occurs in a 19-mile segment. In this reach, which runs from site B-5 to site B-10, the base flow gain amounts to over 2 cfs/mile. Ground water inflow averages over 2.8 cfs/mile in the six-mile long portion of the stream between sites B-8 and B-9.

Downstream, base flow gains drop to about 1 cfs/mile in Beaver Creek, in the reach just above Loretto. There is little increase in base flow between the gaging station at Loretto and the village of Boone. In a portion of that reach near Albion (sites B-14 through B-16), there is a slight base flow loss. Beaver Creek again becomes a gaining stream from Boone to its mouth near Genoa. Ground water inflow amounts to roughly 1.3 cfs/mile in the lower reach of the stream. In addition to the general reach gain in the lower segment, Bogus Creek contributes a "stair-step" gain of 1.3 cfs at site B-20.

Plum Creek receives a small amount of ground water inflow. It appears to gain approximately 0.2 cfs/mile in the lower six to ten miles of the stream. Above that reach Plum Creek is usually dry. Council Creek has no base flow except in wet years when small quantities have been recorded.

Bubbling spring
Courtesy of the Nebraska Game and Parks Commission

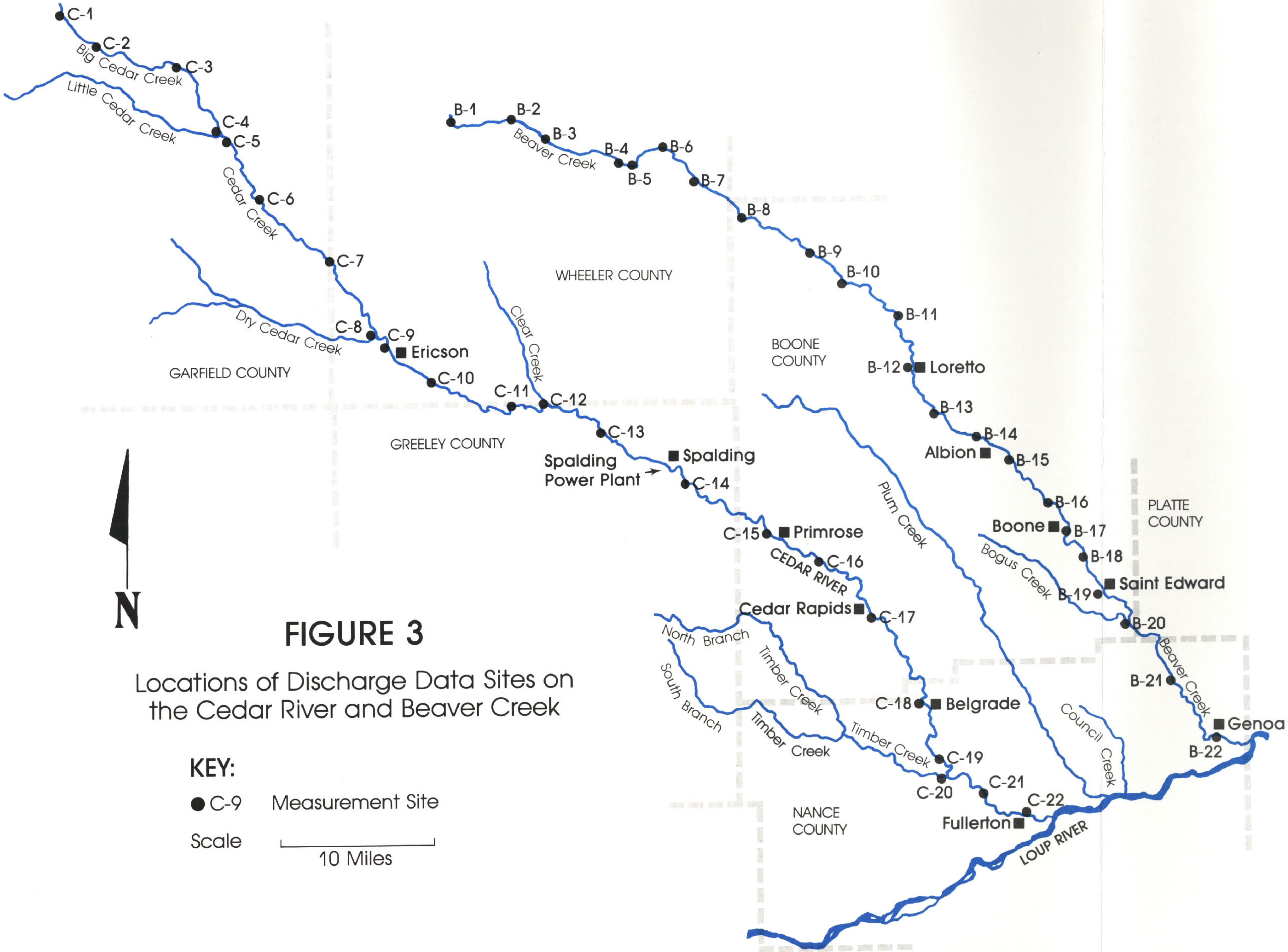


FIGURE 3

Locations of Discharge Data Sites on the Cedar River and Beaver Creek

KEY:

● C-9 Measurement Site

Scale 10 Miles

Analysis of the base flow measurements made on the Cedar River and Beaver Creek, gives further credence to the existence of "hydrologically parallel" reaches in the two waterways. Other researchers concur that the waterways appear to be divided into rather distinct hydrologic segments. Their studies suggest that the segmentation of the Cedar River and Beaver Creek may result from the occurrence of a broad sequence of fine-textured sediments downstream from the region of ground water gain in the Sandhills. This tight soil layer most notably restricts ground water contributions between Loretto and Albion and between Primrose and Cedar Rapids.

The upper portion of Plum Creek, which lies directly between the losing reaches on the Cedar River and Beaver Creek, is dry except during periods of runoff from rainfall or snowmelt. The lower six to ten miles of Plum Creek intercepts some ground water inflow.

The downstream 20 to 25 mile long reaches of the Cedar River and Beaver Creek again experience ground water inflow. Thus, the occurrence of fine-textured subsurface sediments, in effect, interrupts what might otherwise be a continuous streamflow gain from ground water inflow.

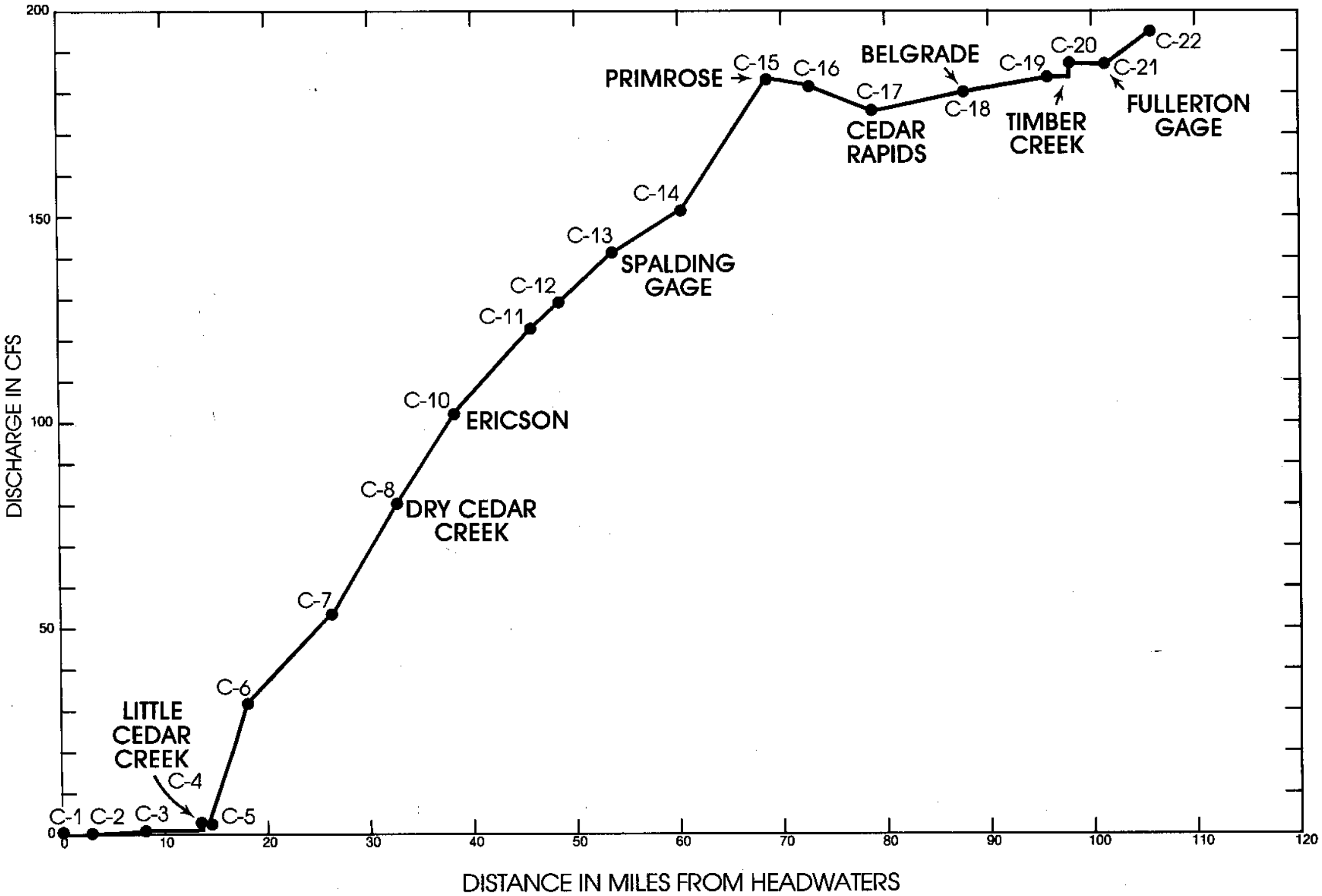


Figure 4
Cedar River Base Flow

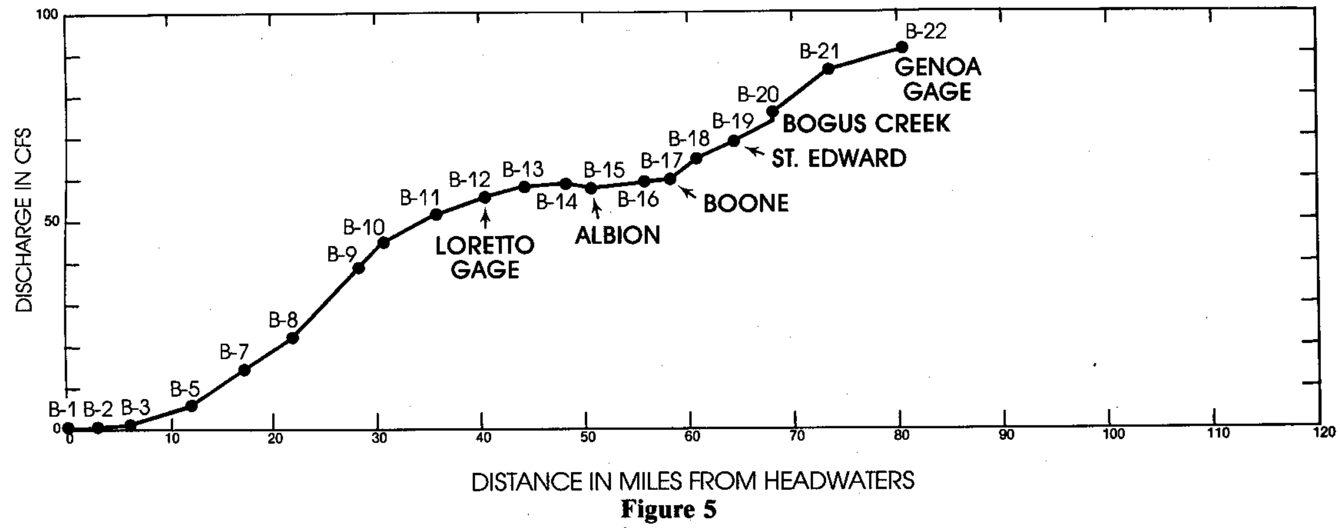


Figure 5
Beaver Creek Base Flow

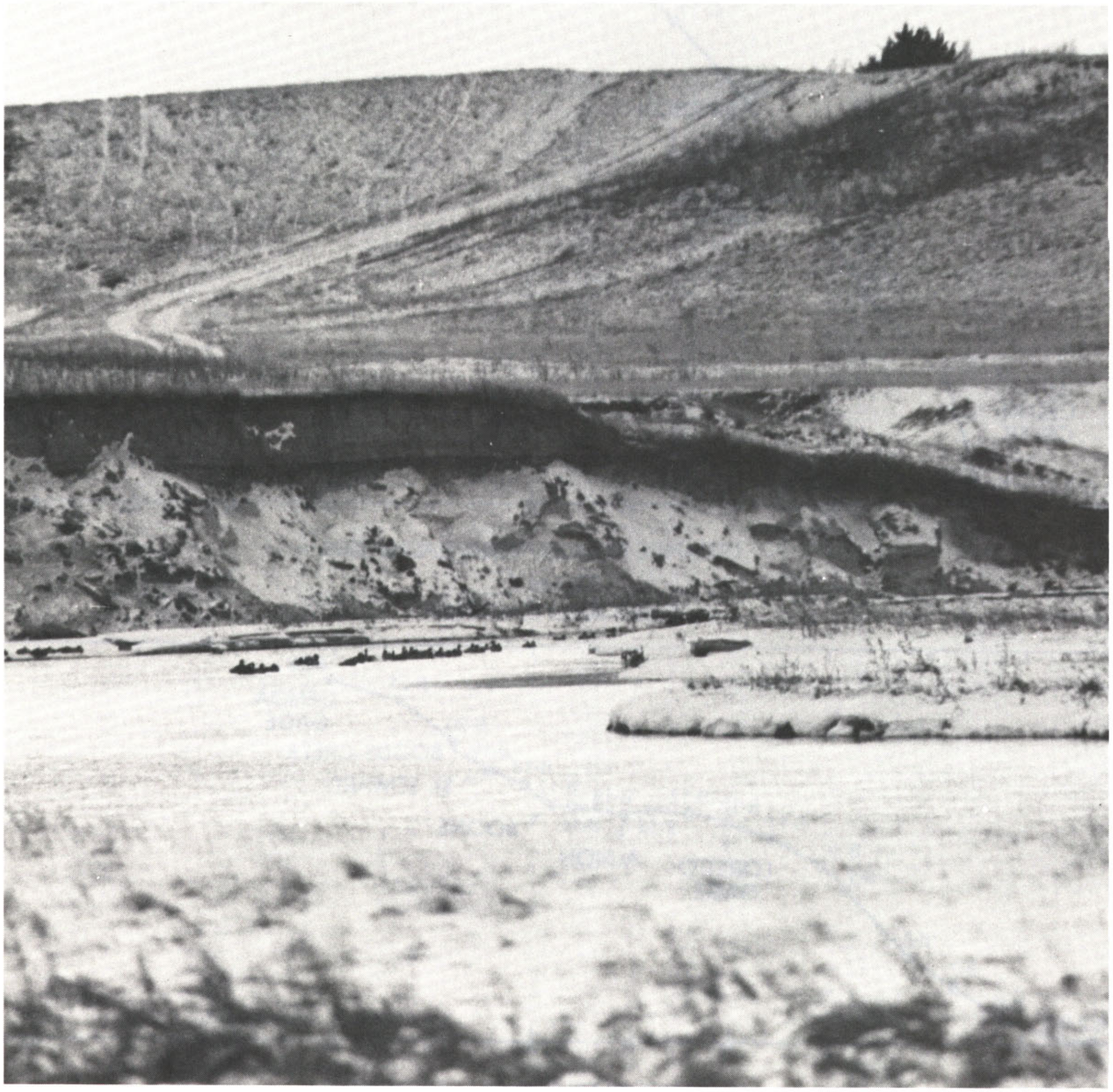
Low Flow

Low flow differs from base flow. Base flow is the portion of the total streamflow maintained entirely by ground water seepage, whereas low flow may include both base flow and some overland runoff. Low flow conditions may result from prolonged drought, from diversion of water from the stream, or from channel freeze-up. Although generally less than base flow, low flow in very wet years may be equal to or even greater than base flow.

An evaluation of the low flow regime of a stream or river provides valuable information about its ability to supply water during times of drought. In providing limits for study and design, such information is of considerable interest to irrigators, fish and game specialists and sewage treatment plant designers.

Low flows are particularly critical to aquatic animal life, as minimum discharges often occur simultaneously with reduced levels of dissolved oxygen. Measurements of discharge, temperature and dissolved oxygen taken on the Cedar River and Beaver Creek show that the quantity of dissolved oxygen drops significantly during low flow periods occurring in the summer. Organisms are forced to compete for the remaining oxygen in the depleted stream flow. Additionally, sewage treatment plant effluent, which would not seriously deplete the dissolved oxygen under more normal flow conditions, poses an additional threat.

The flow at each of the four gages responds in an individual way to drought conditions. At Spalding the Cedar River is very resistant to drought. The lowest recorded discharge at the gage resulted from freezing of the channel during a severe winter. (Since freezeups and ice jams are usually short lived, one-day low flows at the gage are considerably less than three-day average low flows.) Low flows occurring during the summer months are often greater than winter minimum discharges and result primarily from reduced inflow, losses to evapotranspiration and diversions for irrigation. The dependability of the flow of the Cedar River above the Spalding gage is demonstrated by the fact that discharges of less than half the base flow would not be expected to persist for a period of 15 days, more than once in a quarter century.



Cedar River, courtesy of the Nebraska Game and Parks Commission

The flow at the Fullerton gage is somewhat less resilient during times of drought. At this gage a sustained low flow of less than half the base flow for a 15-day period, could be expected to occur as frequently as once every three to four years. Appendix B provides additional information on the magnitude and duration of low flows in the Cedar River and Beaver Creek.

Most of the difference in the drought response of the Cedar River gages is due to the relationship between the river and the ground water reservoir upstream from each gage. During dry years, the reach above the Spalding gage continues to gain quantitites of ground water inflow in excess of evapotranspiration and withdrawals for irrigation. As depicted in Figure 6, the river between the Spalding and Fullerton gages is a net losing reach during periods of drought. Losses to seepage, evapotranspiration and various other water uses exceed the inflow from tributaries and from ground water by approximately 7 cfs during the day of lowest flow expected during a two-year period. The net loss is also 7 cfs for a two-year, one-day low flow, when only those low flows recorded during the warm season were considered.

Based upon a relatively short period of record, the gage at Loretto indicates that the upper reaches of Beaver Creek are relatively resistant to low flows caused by drought. According to an analysis of the low flows at the gage, a sustained low flow of less than half the base flow for 15 days would be expected to occur approximately once every three to four years.

Low flow conditions are slightly better ten miles upstream from Loretto. During a two-year, one-day low flow, the discharge at measurement site B-10 is 3 cfs greater than at Loretto. Analysis using the short period of record at site B-10 and the Loretto gage, indicates that as much as 9 cfs may be lost in the reach during a one-day low flow that would be expected to occur once in ten years.

From Figures 5 and 7, it is evident that the ten-mile reach above the Loretto gage, which gains ground water inflow at a slower rate than reaches further upstream under base flow conditions, actually suffers a loss of flow during

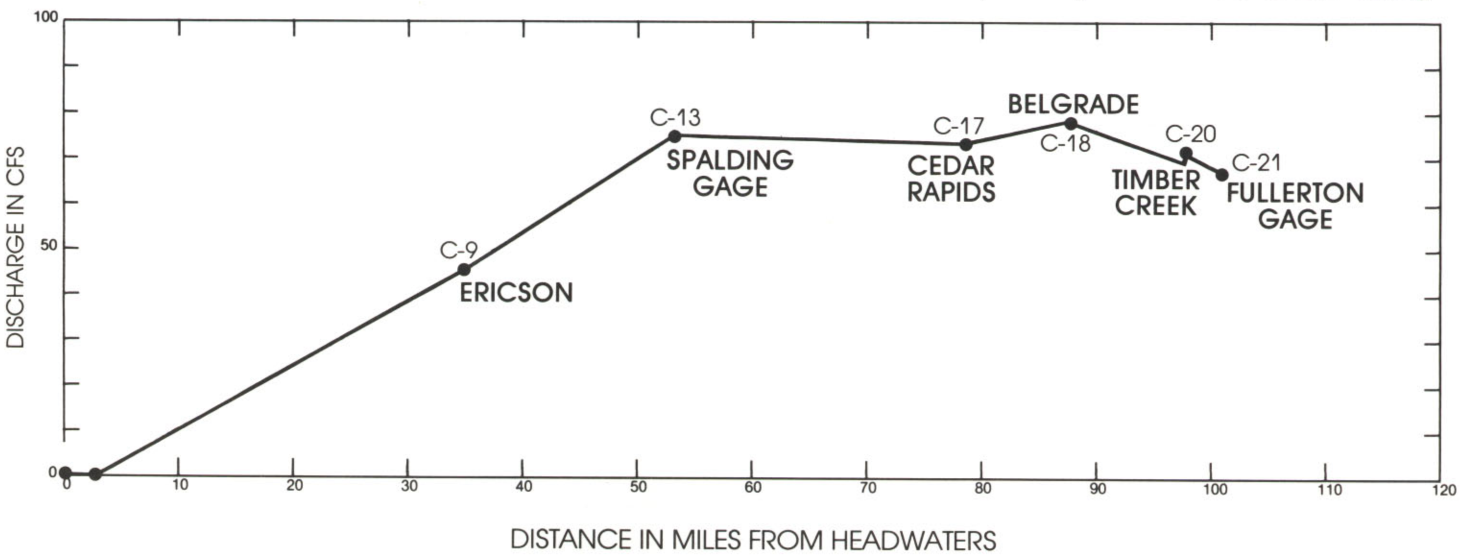


Figure 6
Cedar River Two-Year, One-Day Flow

Upper Beaver Creek in Wheeler County

periods of drought.

The extensive number of low flow measurements on Beaver Creek allows the evaluation of the relationship between base flow and the two-year, one-day low flow to be continued downstream. The reach from the Loretto gage to Boone, which experienced negligible gain under base flow conditions, reflects the greatest loss during dry periods. Given the small inflow to the stream from ground water during base flow conditions in that reach, it is likely that a portion of the flow lost during periods of drought is lost to seepage. This notion is given additional weight in light of the slight loss of discharge to the water table near Albion under base flow conditions.

Of the four gage locations in the Cedar River and Beaver Creek basins, the flow of Beaver Creek at Genoa is the least resistant to drought. At this site, discharges of less than one-half of the base flow occur almost every year for a period of more than 15 days. While the reach from Boone to Genoa gains discharge even during a two-year, one-day low flow, the net inflow permits only a minor recovery from the minimums computed for Boone.

While it is evident that diversions from the lower portions of the Cedar River and Beaver Creek reduce the flow during dry summers, the low flow periods are followed by a recovery to historic flow levels during the fall. Additionally in terms of quantities, the reduction is small when compared to annual volumes. As a result, the minor summer depletion is not evident in the annual records of the four gages.

Low flow in Cedar Creek upstream from Ericson
Courtesy of the Nebraska Game and Parks Commission

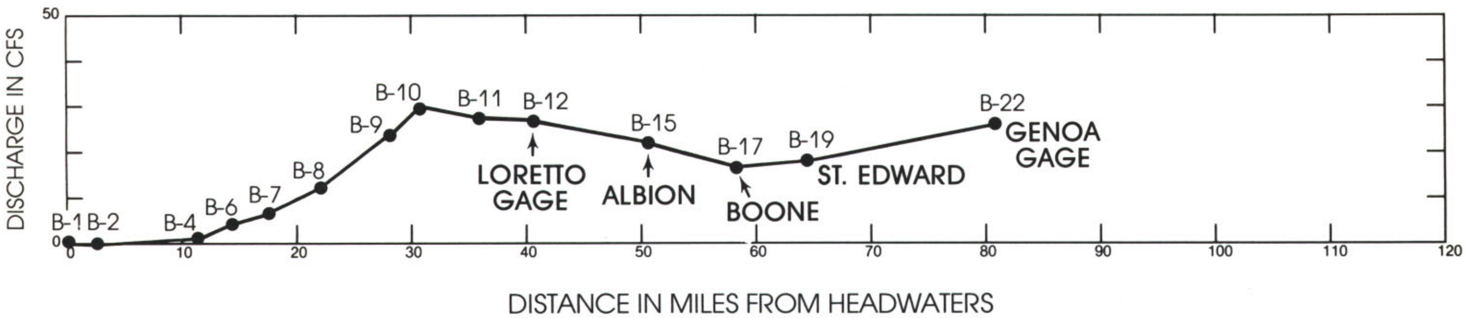


Figure 7
Beaver Creek Two-Year, One-Day Flow

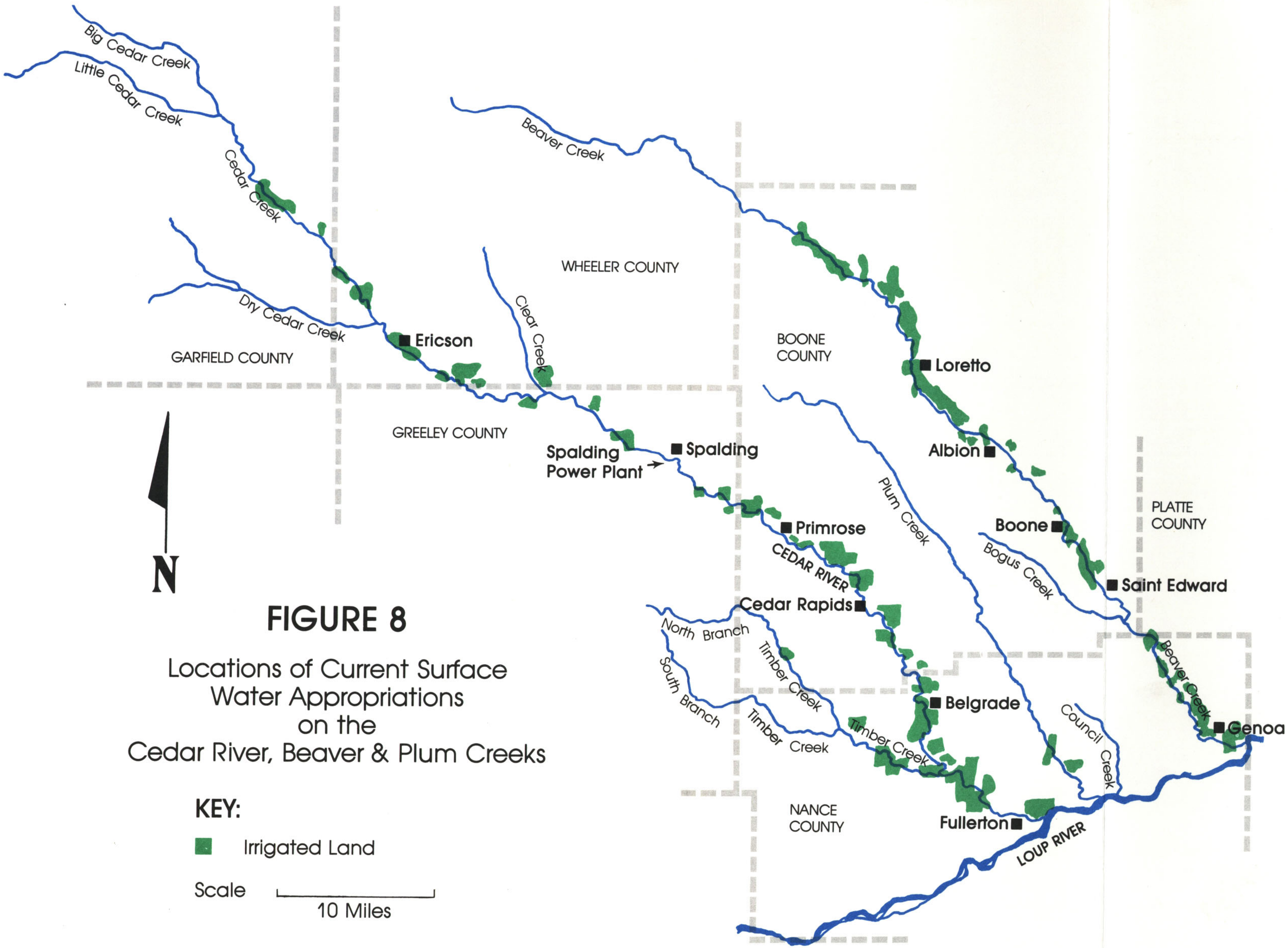


FIGURE 8

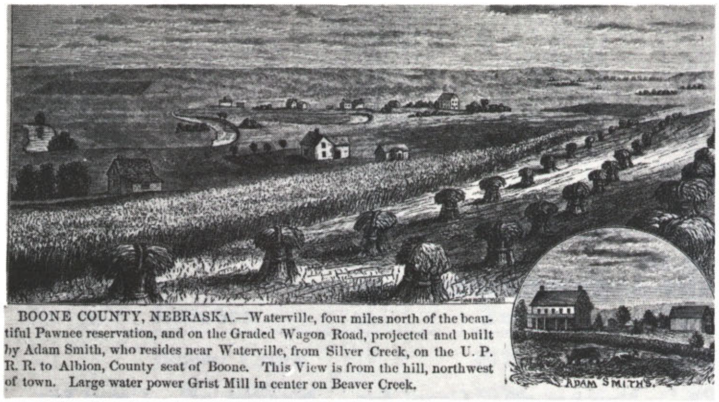
Locations of Current Surface Water Appropriations on the Cedar River, Beaver & Plum Creeks

KEY:

Irrigated Land

Scale 10 Miles

Water Use



Waterville (St. Edward) in the 1800's
Courtesy of the Nebraska Historical Society

Ericson Power Plant on the Cedar River
Courtesy of the Nebraska Public Power District

The history of surface water use from the Cedar River and Beaver Creek began in the late 1800's. Early developments utilized the streams primarily as a source of power. An early drawing of the town of Waterville, later renamed St. Edward, shows a large water-powered grist mill on Beaver Creek. On the same stream, the St. Edward Power and Light Company operated a hydropower turbine from 1911 to 1944.

One of the first hydropower generation plants on the Cedar River was the Van Ackeren Power Plant in Cedar Rapids. This plant operated from 1881 until 1944. Cedar Valley Roller Mills at Spalding started using the Cedar River for milling grain in 1890. It continued until 1911. The mill was then converted to hydropower and continues to operate. The facilities are now owned and operated by the City of Spalding.

At least two other power plants operated on the Cedar River. A flour mill at Fullerton operated from 1902 until 1910 when the facility was converted to electric generation for milling and utility service in Fullerton. Flood damage in 1919 put the plant out of commission until 1922. After reconstruction, it operated until the 1966 flood fatally damaged the plant. It was dismantled shortly thereafter. The Ericson power plant operated from 1919 until 1975. Now inoperative, the dam and reservoir remain.

The first appropriation for irrigation from Beaver Creek was made in the mid 1890's. The Pioneer Canal was located near Albion. It operated for about 15 years before being abandoned. Another appropriation made during the same time period was a small project near Genoa. Several tracts of land within this project are still being served.

Only one appropriation for irrigation was granted on the Cedar River in the 1800's. The Cedar River Canal near Ericson operated approximately one year. With a few exceptions, using water for irrigation was not a common practice on either Beaver Creek or the Cedar River until the 1930's. During the "dust bowl" years, numerous water appropriations for irrigation were obtained all along these streams.

Most of the current demand for surface water diversion is for irrigation. Approximately 18,800 acres of land are authorized for irrigation from the Cedar River, Beaver Creek, Plum Creek and their tributaries. In addition, there are 12 small storage reservoirs that have a combined capacity of approximately 1,100 acre-feet. One appropriation for hydroelectric power generation on the Cedar River remains. The locations of current surface water appropriations are shown in Figure 8.

Table 4 summarizes current appropriations on the Cedar River by stream reach. As reported by irrigators, Table 5 tabulates the amount of water used from 1977 to 1982. Although there are approximately 12,200 acres under appropriations from the Cedar River, annual reported diversions averaged only 0.24 acre-feet per acre per year during 1977 to 1982.

Monthly summer-time flows recorded at both Cedar River stations are also summarized in Table 5. Comparing the flow values with the respective irrigation diversions reveals that the summer-month supply far exceeded irrigation demands. Supply exceeding demand is further evidenced by realizing that senior water right holders have never called upon the Department of Water Resources to regulate or curtail operations of junior appropriators.

From Beaver Creek and its tributaries, approximately 6,300 acre-feet are approved for irrigation. Together the appropriations total 71.45 cfs. Table 7 summarizes the permits.

From time to time, concern for water shortages on Beaver Creek has been expressed. The concern is apparent when considering irrigation season flows during several recent years (see Table 6). For example, the minimum daily discharge for the 1977-82 irrigation seasons was 0.5 cfs at Genoa. Had all appropriators wanted to divert at their allowed maximum rates, the supply would likely have been insufficient. At the request of irrigation appropriators in 1976 and in 1980, the Department of Water Resources investigated reports of insufficient flow. Those efforts, however, did not result in formal action to regulate junior priority appropriations. Instead, the field investigations at that time showed that slightly more than 50 percent of the land entitled to be served was in fact being irrigated.

TABLE 4

Summary of Surface Water Appropriations Cedar River and Tributaries As of February 28, 1983

Location	Number of Permits for Irrigation	Grant for Irrigation CFS	Acres Approved for Irrigation	Number of Permits for Storage	Grant for Storage Acre-Feet	Number of Permits for Power	Grant for Power CFS
Above Spalding	17	22.20	1,934.40	1	572.0	–	–
Between Spalding and Fullerton	77	86.94	8,264.95	4	273.1	1	290.0
Below Fullerton	12	26.86	1,972.81	–	–	–	–
TOTAL	106	136.00	12,172.16	5	845.1	1	290.0

TABLE 5

Comparison of Water Supply and Water Use on the Cedar River in Acre-Feet (1977-1982)

Location	Year	Supply June	Supply July	Supply August	Supply Total	Use Total
Above Spalding	1977	10,460	9,400	9,330	29,190	70.3
	1978	9,510	8,380	9,030	26,920	224.0
	1979	9,080	8,580	8,930	26,590	152.6
	1980	7,410	5,790	6,420	19,620	341.4
	1981	6,950	8,900	11,550	27,400	131.4
	1982	17,900	7,770	8,670	34,340	40.6
Below Spalding	1977	18,220	13,160	15,040	46,420	2,769.5
	1978	14,950	10,320	14,150	39,420	3,144.7
	1979	13,510	12,580	10,000	36,090	2,857.0
	1980	10,760	3,680	8,900	23,340	3,986.3
	1981	8,520	9,450	26,850	44,820	2,652.7
	1982	24,840	17,950	11,750	54,540	922.1

TABLE 6

Water Supply 1977-1982 at Gages on Beaver Creek in Acre-Feet

Location	Year	June	July	August	Total
Beaver Creek at Loretto[1]	1977	2,240	2,730	3,040	8,010
	1978	2,850	2,870	3,010	8,730
	1979	2,590	2,850	1,570	7,010
	1980	2,410	1,250	1,440	5,100
	1981	2,360	2,530	3,220	8,110
	1982[2]	8,960	4,570	3,810	17,340
Beaver Creek at Genoa	1977	5,550	2,760	6,400	14,710
	1978	6,580	4,720	6,360	17,660
	1979	5,960	4,370	2,690	13,020
	1980	3,810	790	3,730	8,330
	1981	6,220	3,420	9,050	18,690
	1982[2]	16,700	49,900	9,670	76,270

[1]Monthly discharges for Beaver Creek at Loretto for 1977-1979 were synthesized using hydrologic simulation techniques.

[2]Provisional data; subject to change.

TABLE 7

Summary of Surface Water Appropriations Beaver Creek and Tributaries As of February 28, 1983

Location	Number of Permits for Irrigation	Grant for Irrigation CFS	Acres Approved for Irrigation	Number of Permits for Storage	Grant for Storage Acre-Feet
Above Loretto	23	28.39	2,332.09	1	33.50
Loretto to Genoa	54	41.47	3,781.88	5	217.20
Below Genoa	2	1.59	150.50	–	–
TOTAL	79	71.45	6,264.47	6	250.70

Conclusion

The Cedar River and Beaver Creek basins have been the focus of considerable interest in recent years. In light of considerable ground water irrigation development, concern has been expressed regarding the continuation of dependable flows. Both streams drain the eastern Sandhills, a vast region of unconsolidated dune sand which provides the water source for many of the state's important streams and rivers. In addition, these two waterways and nearby tributary streams drain a region mantled by silt and clay which is capable of delivering large volumes of surface runoff to the channels in times of flooding. During periods of drought, the rivers and streams experience a loss of discharge while flowing through portions of the same region.

The flow of the Cedar River is nearly double that of Beaver Creek. Plum and Council Creeks provide only a tiny fraction of the flow produced by their larger neighbors. Monthly flows of the Cedar River are subject to less variability than those of Beaver Creek. Likewise, the flow in the upstream portions of both waterways which drain the Sandhills are subject to much less variability than the flow in the downstream reaches.

Both waterways begin as poorly defined channels in the wet meadows of the Sandhills. They gain large amounts of ground water seepage as they flow through the eastern Sandhills. Downstream from the Sandhills, the waterways obtain negligible seepage from the surrounding water table under base flow conditions and lose flow during droughts. Near their confluence with the Loup River, the Cedar River, Beaver and Plum Creeks once again receive considerable ground water inflow.

The analysis of discharges made during periods of base flow and drought has provided an understanding of the relationship between streamflow and interconnected ground water aquifers. The Cedar River and Beaver Creek exhibit similar patterns of flow in parallel channel reaches, indicating regional relationships between ground and surface water.

Surface water use from the Cedar River and Beaver Creek began in the late 1800's. Since then, uses have included irrigation, livestock watering, recreation, hydropower and milling. Irrigation has been by far the largest user of surface water. It has continued to grow in recent years.

A comparison of the water supply and demand in the two basins indicates that water shortages have been infrequent and short-lived. Shortfalls in water supply have never lasted for longer than a period of a few days during dry summers. Even during those times, there was no need to ration or administer water for irrigators. Calculated in terms of the discharge during the irrigation season, the maximum demand is only a fraction of the available supply.

The Cedar River is particularly capable of handling the demands placed upon it. During the dry summer of 1980, irrigation demand above the Spalding gage was the highest for the period 1977-1982. Despite the larger than normal demand and lower than normal stream flow, the surface water use above that gage amounted to less than two percent of the available supply.

During the last six years, the greatest surface water withdrawal between the Spalding and Fullerton gages also occurred in the summer of 1980. In that summer, roughly 3,000 acre-feet were diverted from the Cedar River and its tributaries between the two gaging stations. The June through August flow recorded at the Fullerton gage amounted to 23,340 acre-feet and was the lowest irrigation season discharge of the 1977-1982 period. Despite the lower than normal flows that summer, the quantity of water diverted amounted to only 13 percent of the flow passing the Fullerton gage.

Due to the lack of water use records on Beaver Creek, it is not possible to accurately compare the quantity of flow used and the discharges recorded at the gaging stations. Based upon the amount of flow authorized for diversion from Beaver Creek, periodic shortages can be expected. Although the available surface water supply was severely taxed by demand for irrigation during the summers of 1976 and 1980 in the lower portion of Beaver Creek, the shortage was not of sufficient magnitude and duration to require water rationing.

While the total appropriated demand of 3.54 cfs exceeds the average base flow of 2.00 cfs measured near the mouth, no water shortages have been reported on Plum Creek. Apparently, all possible demands for water for irrigation from Plum Creek have not occurred simultaneously. Council Creek has no appropriations and is not considered to be a source of water supply for irrigation.

In general, the Beaver and Cedar basins have provided more than an ample supply of water for present irrigation demand. Additional water for other uses, such as fish habitat and the dilution of processed effluent from sewage treatment plants, has usually been sufficient. During periods of severe drought, the flow in the lower portions of Beaver and Plum Creeks may not be sufficient to satisfy all possible demands which could occur. Fortunately, periods of extreme low flow have rarely lasted more than a few days, even on the lower portion of Beaver Creek. Periods of summer low flow have always been followed by a return to historic flows the following fall, due to the dependable supply of ground water.

Despite large increases in demand for surface water for irrigation during the past three decades, annual stream flow records indicate that no lasting depletion of flow has occurred. Short term trends toward lower annual flows during droughts have been erased by a return to wetter conditions. While man's activities have a noticeable impact upon stream flow during dry summers, they are minor in comparison to the effects caused by fluctuations in climatic conditions.

Harvest along the Cedar River
Courtesy of the Nebraska Game and Parks Commission

Appendix A

Flood Flow Frequency Analysis

The discharges for selected return periods for flood events on the Cedar River and Beaver Creek were calculated using the log-Pearson Type III distribution as outlined in Bulletin 17B of the U.S. Water Resources Council. Discharges for various return periods for the Cedar River gage near Fullerton and the Beaver Creek gage at Genoa are listed below.

TABLE A-1

Predicted Instantaneous Peak Discharges in cfs
Cedar River near Fullerton

Probability of Occuring in any Given Year	Return Period	Discharge to be Exceeded
.5	2	2,880
.1	10	10,000
.05	20	15,040
.04	25	17,020
.02	50	24,560
.01	100	34,690
.005	200	48,210

TABLE A-2

Predicted Instantaneous Peak Discharges in cfs
Beaver Creek at Genoa

Probability of Occuring in any Given Year	Return Period	Discharge to be Exceeded
.5	2	2,140
.1	10	7,090
.05	20	10,440
.04	25	11,730
.02	50	16,540
.01	100	22,830
.005	200	30,980

Appendix B

Low Flow Duration — Frequency Analysis

Statistical frequency analysis was used to estimate how often low flows of a certain magnitude may occur and how long they would persist. The log-Pearson Type III distribution was used to calculate the low flow discharges that would be expected to occur for selected return periods and durations. Table B-1 provides annual low flow frequency-duration information for all four gages. Durations of 1, 3, 7, 15 and 30 days are listed horizontally, and expected return frequencies are listed vertically. The discharges listed in the block of each table are the maximums that would be expected for a given duration and frequency.

TABLE B-1

Annual Low Flow Duration — Frequency Analysis
Results for the Four Gages in cfs

Cedar River near Spalding

Years	Duration (Days) 1	3	7	15	30
2	75	87	97	105	111
5	58	71	84	92	98
10	48	63	75	84	91
20	41	56	68	77	85
25	39	54	66	75	83

Beaver Creek at Loretto

Years	Duration (Days) 1	3	7	15	30
2	27	28	29	31	33
5	18	20	21	23	26
10	14	16	17	20	23
20	12	13	14	18	20
25	11	12	13	17	19

	Cedar River near Fullerton				
Years	Duration (Days)				
	1	3	7	15	30
2	68	78	93	112	130
5	49	57	68	84	99
10	41	47	56	69	82
20	35	40	46	58	68
25	34	38	44	55	64

	Beaver Creek at Genoa				
Years	Duration (Days)				
	1	3	7	15	30
2	26	28	33	39	46
5	8	10	13	19	26
10	3	4	7	11	17
20	1	2	3	6	11
25	1	1	2	5	9

For instance, in Table B-1, an average discharge of less than 75 cfs would be expected to occur for a seven-day period, once every ten years in the Cedar River at the Spalding gage. Table B-2 lists the results of duration frequency analysis for low flows occurring between April 1 and September 30 (warm season). The tabulation of predicted warm season low flows for the four gages may be used to estimate the discharges which would be expected at the stations during droughts occuring in the irrigation season.

TABLE B-2

Warm Season Low Flow Duration — Frequency Analysis Results for the Four Gages in cfs

	Cedar River near Spalding	
Years	Duration (Days)	
	1	3
2	89	99
5	74	86
10	65	78
20	58	72
25	55	70

	Beaver Creek at Loretto	
Years	Duration (Days)	
	1	3
2	29	30
5	19	20
10	15	16
20	12	13
25	11	12

	Cedar River near Fullerton	
Years	Duration (Days)	
	1	3
2	82	90
5	56	62
10	44	49
20	36	40
25	34	38

	Beaver Creek at Genoa	
Years	Duration (Days)	
	1	3
2	26	28
5	8	10
10	3	4
20	1	2
25	1	1

Low flow data should be used with caution when making predictions about the magnitude and recurrence of drought flows. Two factors, seasonality and trends in discharge with time, must be considered in any prediction using a series of annual low flow data. Predictions of low flow for a specific use, such as irrigation water supply, must make use of streamflow data for the appropriate season. The use of data dominated by low flows caused by ice conditions may result in predictions of discharges less than what would actually occur during the summer. Trends in low flow also affect predictions. If an upward trend is evident in low flow, it can be assumed that low flows will actually be greater than forecast.

In both the Cedar River and Beaver Creek, the lowest flow of the year is occasionally caused by channel freeze-up. This condition has occurred more often in the Cedar River. Channel freezing and ice jams have restricted flows for periods of hours or days at a time. This seasonal factor has caused the annual one-day low flow in the Cedar River at both the Spalding and Fullerton gages often to be recorded during January and February. For the purpose of this report, warm season low flows are defined as minimum discharges recorded during the period April 1 through September.

No trends are evident in either the annual low flow or warm season low flow records for the Cedar River near Spalding. No significant trend is evident in the annual low flow data at the Cedar River near Fullerton, but a mild downward trend is apparent in warm season low flows. Since no downward trend is apparent in total annual flow (Figure 2), the slight downward tendency noted in low flow during more recent dry summers has evidently been followed by quick recovery. More significantly, it has been masked by a much larger flow volume occurring during the remainder of the year.

The record for the Beaver Creek gage at Loretto is too short for low flow trend analysis. While the low flow discharges drought years 1980 and 1981 were the lowest recorded at the station, preliminary data for 1982 indicates that low flows have returned to the historic levels recorded from 1944 to 1953.

Low flows recorded at the Beaver Creek gage at Genoa indicate a definite downward trend with time. The reduction in flow for a few days each year has not been large enough in magnitude, nor long enough in duration to produce a definable trend in annual flow, however. Beyond the examination of the hydrograph shown in Figure 2, mass (cumulative) curve and running average analysis failed to show a definable trend in annual discharge.

Glossary

Acre-foot — The quantity of water which will cover one acre of land to a depth of one foot. This equals 43,560 cubic feet or 325,851 gallons.

Administration — The regulation and enforcement of statutes regarding surface water irrigation.

Aquifer — A formation of rock or loose material that contains extractable water.

Base Flow — The portion of total streamflow which is maintained entirely by ground water seepage.

Basin — An area of land which contributes runoff to a stream or river. Same as a watershed.

Continuous Gage — A stream measuring station that houses instruments which provide a record of the discharge on a round-the-clock basis.

Drainage Network — The system of drainageways, ditches and stream channels which carry surface runoff from the land.

Duration-Frequency Analysis — The statistical computations required to determine how often a particular flow might be expected to occur.

Hydrograph — A graphic plot of discharge (y axis) versus time (x axis).

Hydrologically Parallel — A situation where two basins or rivers respond in a similar fashion to streamflow, ground water-surface water interrelationships, or other hydrologic conditions.

Hydrologic Simulation — The use of statistical models to determine a hydrologic property such as streamflow.

Hydrology — The study of the occurrence of water in the atmosphere, land, soil and underlying rock formations.

Loess — A brown colored soil composed of clay and some silt-sized material which was deposited by wind.

Low Flow — Discharges which are lower than normal. Low flow may result from drought, diversion or channel freezeup.

Mass (Cumulative) Curve — A plot of cumulative discharge (y axis) versus time (x axis).

Miscellaneous (Point) Measurement — A discharge measurement of a stream, river or canal at one point in time and at a single location.

Physiographic Region — An area of land which has topographic, geologic and hydrologic characteristics which set it apart from nearby areas of land.

Running Average — A series of averages computed on sets of numbers taken from a string of numbers. Each time a new average is computed, the next consecutive quantity in front of the set is included in the set of numbers being averaged and the quantity at the end of the set is removed, such that the size of the set remains constant.

Seepage — The outflow of ground water to streams and marshes.

Stream Gaging — The measurement of the quantity of water flowing in rivers, streams and canals.

Stream Reach (segment) — A particular length of stream channel.

Surface Water — Water which occurs on the surface of the land and is typically contained in rivers, steams, lakes and canals.

Synthesized — A term used to describe water data derived by hydrologic simulation.

Trend Analysis — The evaluation of a series of numbers in order to determine whether or not values in the series are increasing or decreasing with time.

Water Appropriation — A state permit to use surface water that has been perfected in accordance with terms stipulated by the department.

Watershed — An area of land which contributes runoff to a stream or river. Same as a basin.

Water Yield — The net outflow of water from a basin or stream reach.

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Cedar River near Fullerton
Courtesy of the U.S. Geological Survey