# KANSAS GEOLOGICAL SURVEY
# OPEN-FILE REPORT 85-3

A REPORT TO THE SMOKY HILL RIVER TASK FORCE ON WATER CONDITIONS IN THE SMOKY HILL RIVER VALLEY INTENSIVE GROUND-WATER USE CONTROL AREA (IGUCA)

by

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## Introduction

### Purpose

The purpose of this report is to document ground-water and surface-water conditions in the Smoky Hill River Valley Intensive Ground-Water Use Control Area (IGUCA) as they are understood at this time and to compare the present conditions there with historical data. This is an interim document and the conclusions cited at the end of this report should be considered tentative. This report should prove to be useful to the Smoky Hill River Task Force and it is hoped that this report will provide a point of departure for discussion of water resources issues in the area. Much of the data used in this report was collected as a part of a program to study the hydrogeology of the Smoky Hill River valley between Cedar Bluff and Kanopolis reservoirs being conducted by the Kansas Geological Survey.

### The Intensive Ground-Water Use Control Area (IGUCA)

The Smoky Hill River IGUCA was established by David Pope, Chief Engineer, Division of Water Resources, Kansas State Board of Agriculture, to protect the water resources of the Smoky Hill River within the defined area in the public interest. This action resulted because streamflows in the river are diminishing with time and ground water pumped from wells in the valley is used intensively for public water supply and irrigated agriculture. Public hearings were held on February 23 and 24, 1984, by the Chief Engineer at Hays, Kansas, to take testimony on the proposed designation of the IGUCA. The IGUCA was established by the Chief Engineer on May 31, 1984.

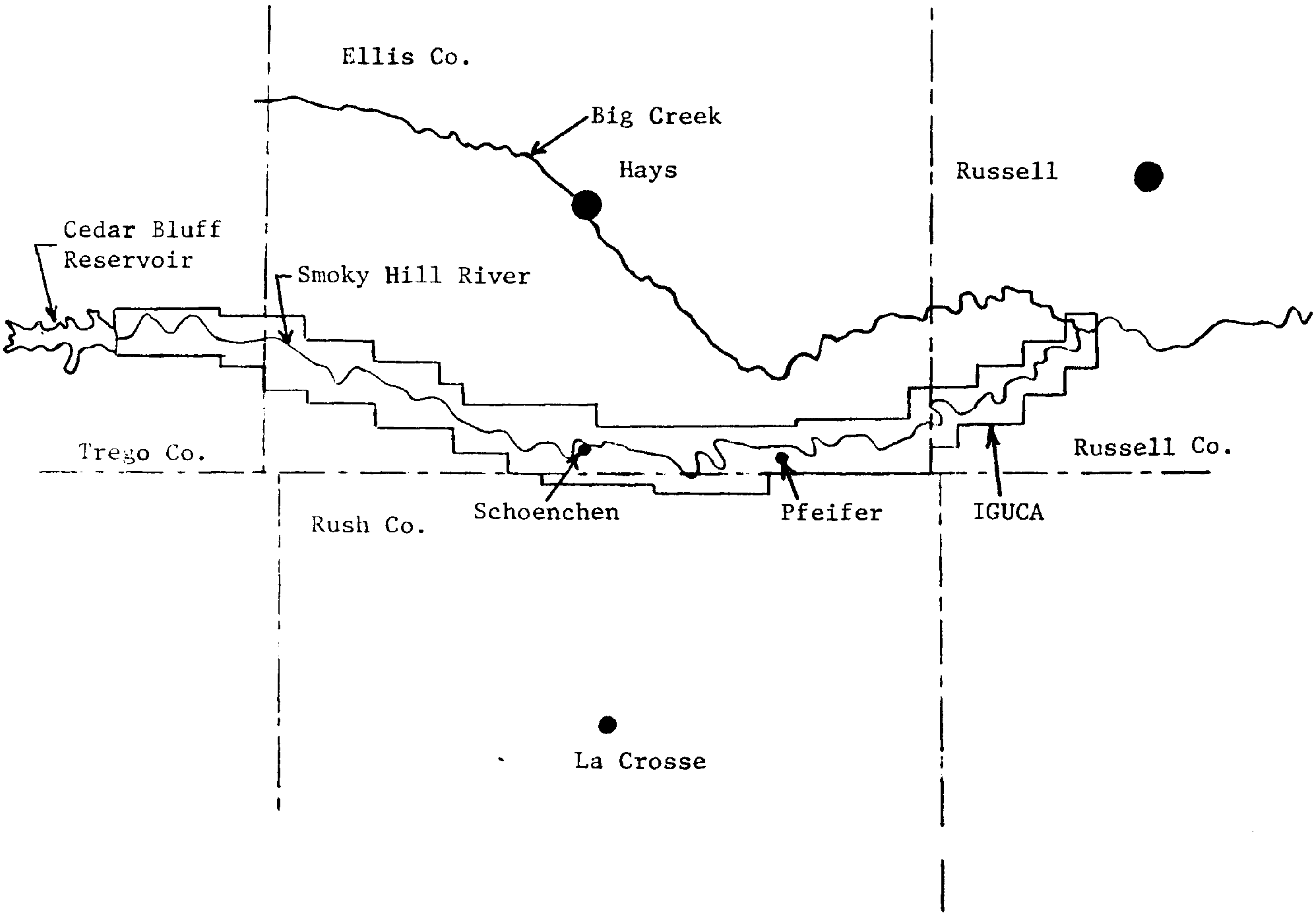
## Water Use Within the IGUCA

Cedar Bluff Dam and Reservoir were completed by the Bureau of Reclamation, Department of the Interior, in 1951 (Fig. 1). The project design was based on regionalized streamflow estimates computed from data collected at the Ellis and Ellsworth, Kansas, gage stations(Bureau of Reclamation, 1984).

The Cedar Bluff Irrigation District No. 6 was organized in southeastern Trego and southwestern Ellis counties downstream of Cedar Bluff Reservoir in 1958. The District began distributing irrigation water to members through unlined canals and laterals in 1963 (Fig. 2). Deliveries of water to the District ceased at the end of the 1978 irrigation season because no water was available. Prior to this time the acres irrigated rose from 2,216 to 6,800. 7,146 acre-feet of water were delivered to the District in 1963 and this amount increased to 19,035 acre-feet during 1978.

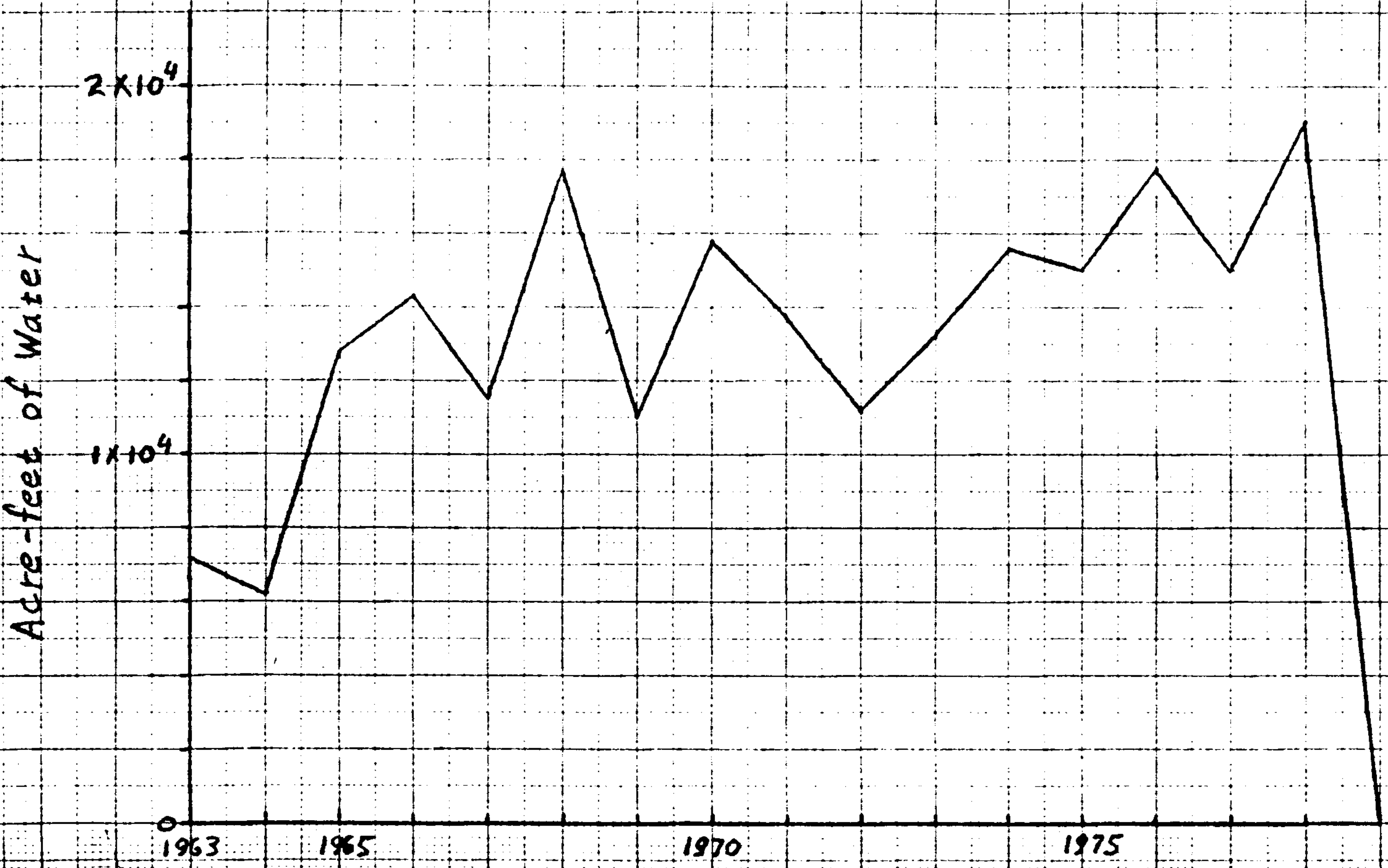
Between 1945 and 1983 the Division of Water Resources authorized approximately 2,300 acre-feet of water per year from the shallow alluvial ground-water aquifer and 1,618 acre-feet from surface water in the Smoky Hill River for irrigated agriculture in the IGUCA. More recently, the actual amount of water used for irrigation has decreased considerably. Total water use for irrigation in the IGUCA declined from 2,139.7 to 918.7 acre-feet between 1979 and 1983 (Watson, 1984).

Figure 1. Location of the Smoky Hill River Intensive Ground-Water Use Control Area (IGUCA) and adjacent areas.



Ellis Co.
Big Creek
Hays
Russell
Cedar Bluff
Reservoir
Smoky Hill River
Trego Co.
Russell Co.
Rush Co.
Schoenchen
Pfeifer
IGUCA
La Crosse

Figure 2. Volume of irrigation water supplied by Cedar Bluff Reservoir to Irrigation District No. 6, 1963-1978.




Irrigation Water Supplied to Cedar Bluff Irrigation District No. 6

Most of the water withdrawn from surface- and ground-water sources in the IGUCA is used by the cities of Hays and Russell for water supply. Figures 3 and 4 show the general pattern of ground-water withdrawal for both cities on a monthly basis. The largest withdrawals occur in the summer months and the smallest in winter. Both cities have well fields located near the river. The Hays well field at Schoenchen consists of a battery of 12 wells and the Russell well field near Pfeifer consists of 10 wells. Between 1981 and 1983 the average daily withdrawal was approximately 4.8 acre-feet for the well field at Schoenchen. The maximum daily withdrawal during 1981-83 was in January 1983 when the city pumped 31 acre-feet of water from the well field. The minimum daily withdrawal was 1.1 acre-feet in April 1982. The average daily summer (June-September) withdrawal rate was 8 acre-feet for 1982 and 10.3 acre-feet for 1983. The average daily withdrawal of water by Russell's well field at Pfeifer was 1.8 acre-feet between April 1982 and August 1984. The minimum withdrawal rate for this period occurred in October 1982 when the city withdrew 0.2 acre-feet from its well field. A maximum withdrawal of 5 acre-feet per day occurred during August 1983. The average daily withdrawal for the summer of 1982 was 1.96 acre-feet, 3.36 acre-feet for the same period of 1983, and 3.06 acre-feet for the same period of 1984.

Ellis County Rural Water Districts also withdraw water from the Smoky Hill River valley near Schoenchen. At the time of this writing, no water-use figures were available from these users, but it is believed that only relatively small amounts of water are withdrawn from the alluvial aquifer.

Figure 3. Monthly water withdrawals from the City of Hays well field at Schoenchen.

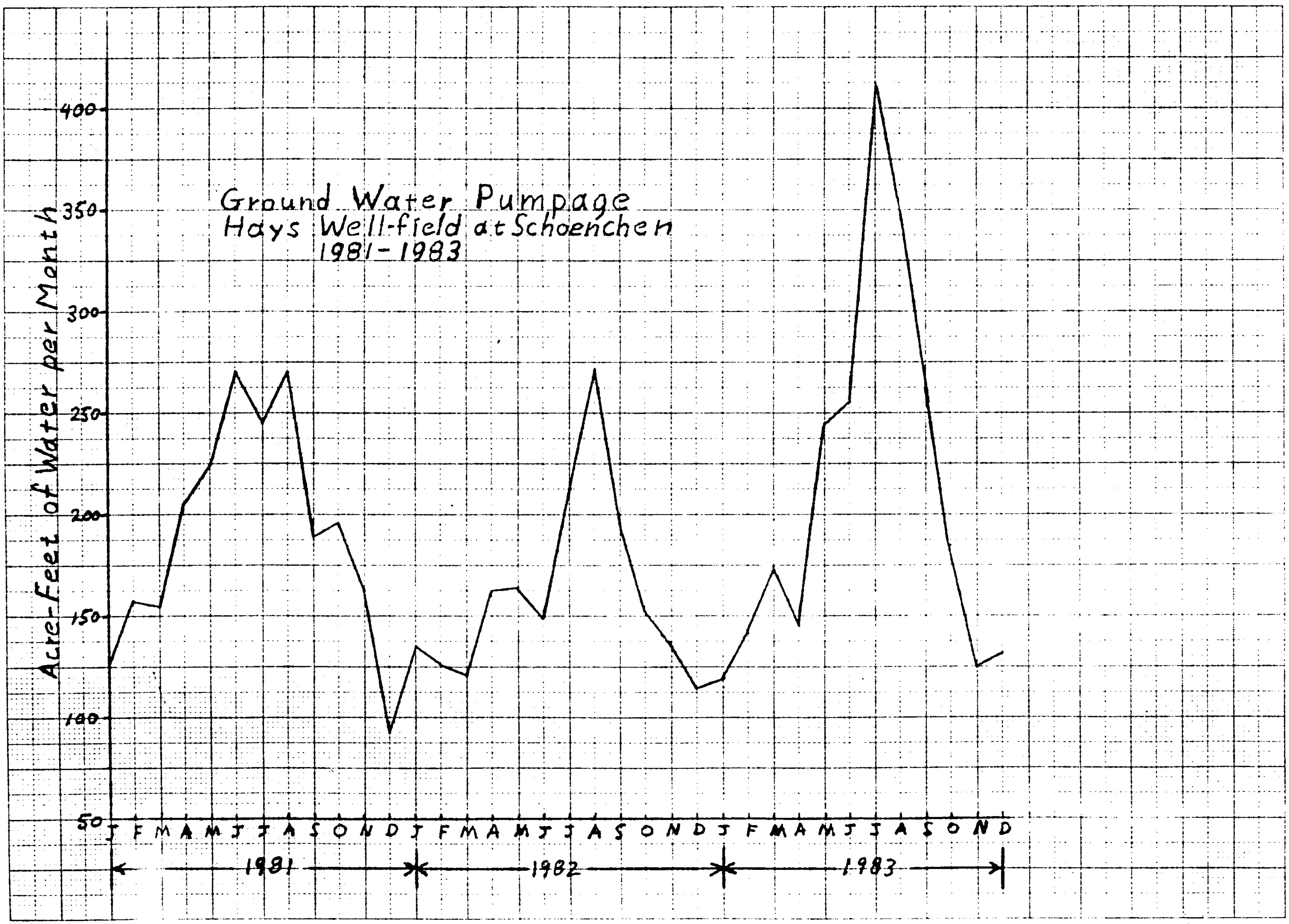
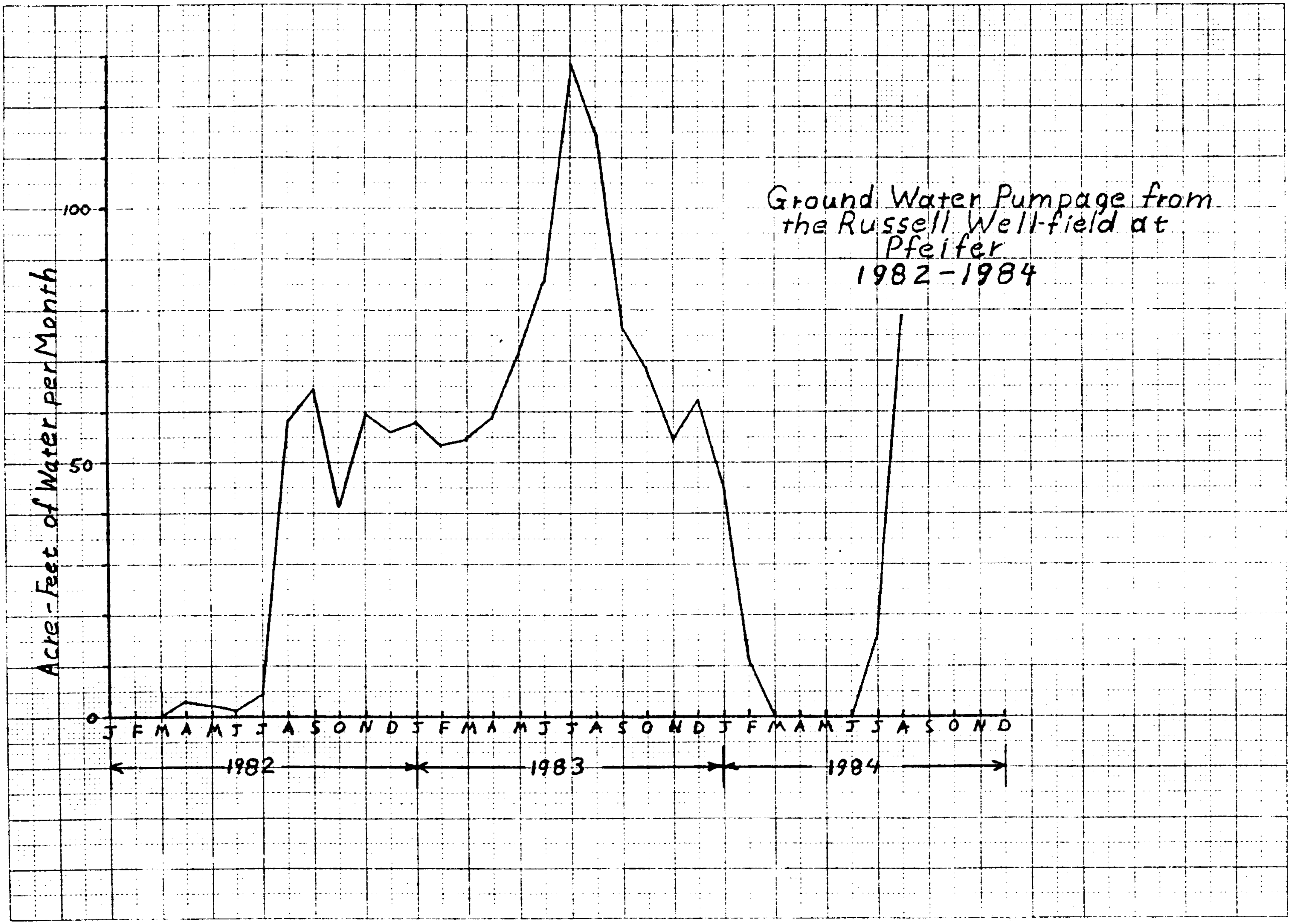

Ground Water Pumpage
Hays Well-field at Schoenchen
1981 - 1983
Acre-Feet of Water per Month
400
350
300
250
200
150
100
50
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1981
1982
1983

Figure 4. Monthly water withdrawals from the City of Russell well field at Pfeifer.

VERNON McMILLAN INC., ELIZABETH N.J. 07208

No. 19-0610 (R-2470 10 C) 10 Millimeters to a Centimeter • Made in U.S.A.

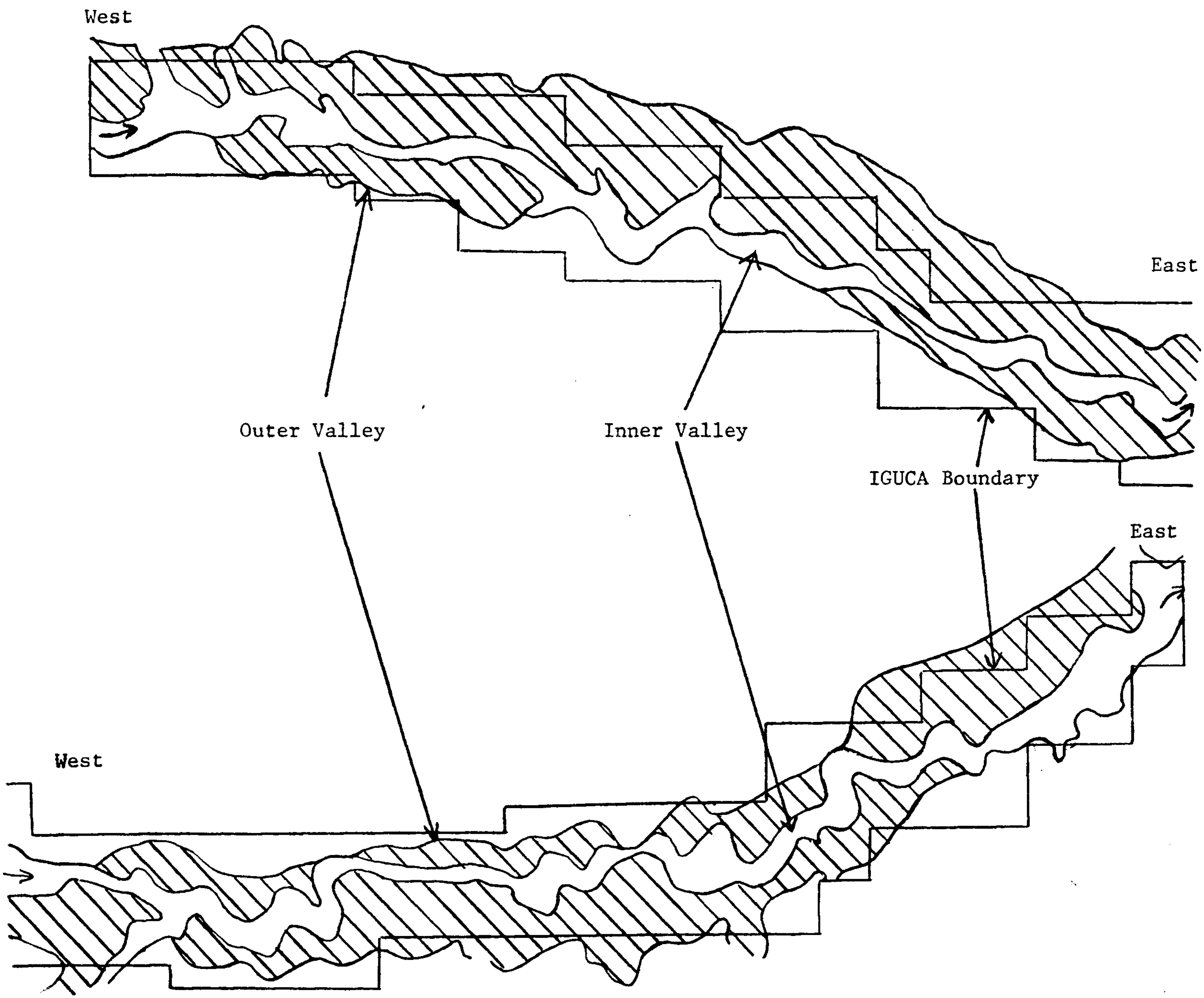


## Previous Investigations

Several investigations related to ground and surface water have been conducted in the IGUCA. Latta (1948) investigated the shallow aquifers in the alluvial and terrace deposits of the Smoky Hill River and Big Creek drainages in the vicinity of Hays and the IGUCA. He noted that supplies of potable water to supplement Russell's water supply could be developed at Pfeifer in the Smoky Hill River alluvium. At the time, Russell was using surface water from the Smoky Hill River for water supply. Later, Leonard and Berry (1961) reported on the surficial geology and ground-water resources of Big Creek east of Hays and of the Smoky Hill River valley between Cedar Bluff Dam and the Ellis-Russell county line. At the time of their study the Cedar Bluff Irrigation District was not yet in operation and the City of Hays already had a well field at Schoenchen. They subdivided the valley into inner and outer portions on the basis of the distribution and age of stream-laid deposits and the location of high terraces and found a buried Kansan-age river channel cut into the Carlile Shale beneath the Illinoisan high terrace (Fig. 5). They also noted that the alluvial aquifer in the inner valley could yield large amounts of water to wells. Saturated thicknesses were found to range from 50 feet in western Ellis and eastern Trego counties to about 35 feet in eastern Ellis County where the alluvial deposits are thinner. Hodson (1965) later reported on the geology and ground waters of Trego County but did not focus on the Smoky Hill River valley east of the Cedar Bluff Dam.

Leonard (1974) conducted a detailed study of the hydrologic system within the Cedar Bluff Irrigation District No. 6. The purpose of his study was to evaluate the effects of surface-water irrigation on the chemical quality of the ground and surface waters in and adjacent to the District. Several findings from his study are worth citing here as they pertain to water

Figure 5. Location of the inner and outer valleys of the Smoky Hill River in the IGUCA.



West
East
Outer Valley
Inner Valley
IGUCA Boundary
East
West

supplies in the IGUCA. Ground-water levels in the observation wells in the terraces where surface-water irrigation was taking place rose rapidly during his study suggesting that recharge to the aquifers in the terrace deposits was occurring as a result of irrigation. At the same time, little or no rise in ground-water levels was seen in observation wells located in the alluvium of the valley (the inner valley of Leonard and Berry [1961]). Tributary streamflow during his study became an increasingly important part of the total net gain in streamflow in the reach between Cedar Bluff Dam and the Schoenchen gage where the Irrigation District is located. The average direct seepage gain for this reach was found to be 2.84 cfs in March-April and 3.11 cfs in October-November for the period between April 1964 and November 1971. Direct seepage as a portion of the total net gain in this reach declined from 91% to 29% during this period. The data for this report are contained in Leonard and Stoltenburg (1972).

Watson (1984) wrote a preliminary report for the Chief Engineer on the available water resources and water demands in the proposed IGUCA. He concluded that ground-water levels in the IGUCA had declined and would continue to decline because the demand for water in the area exceeded the rate of inflow of water.

## Study Methods

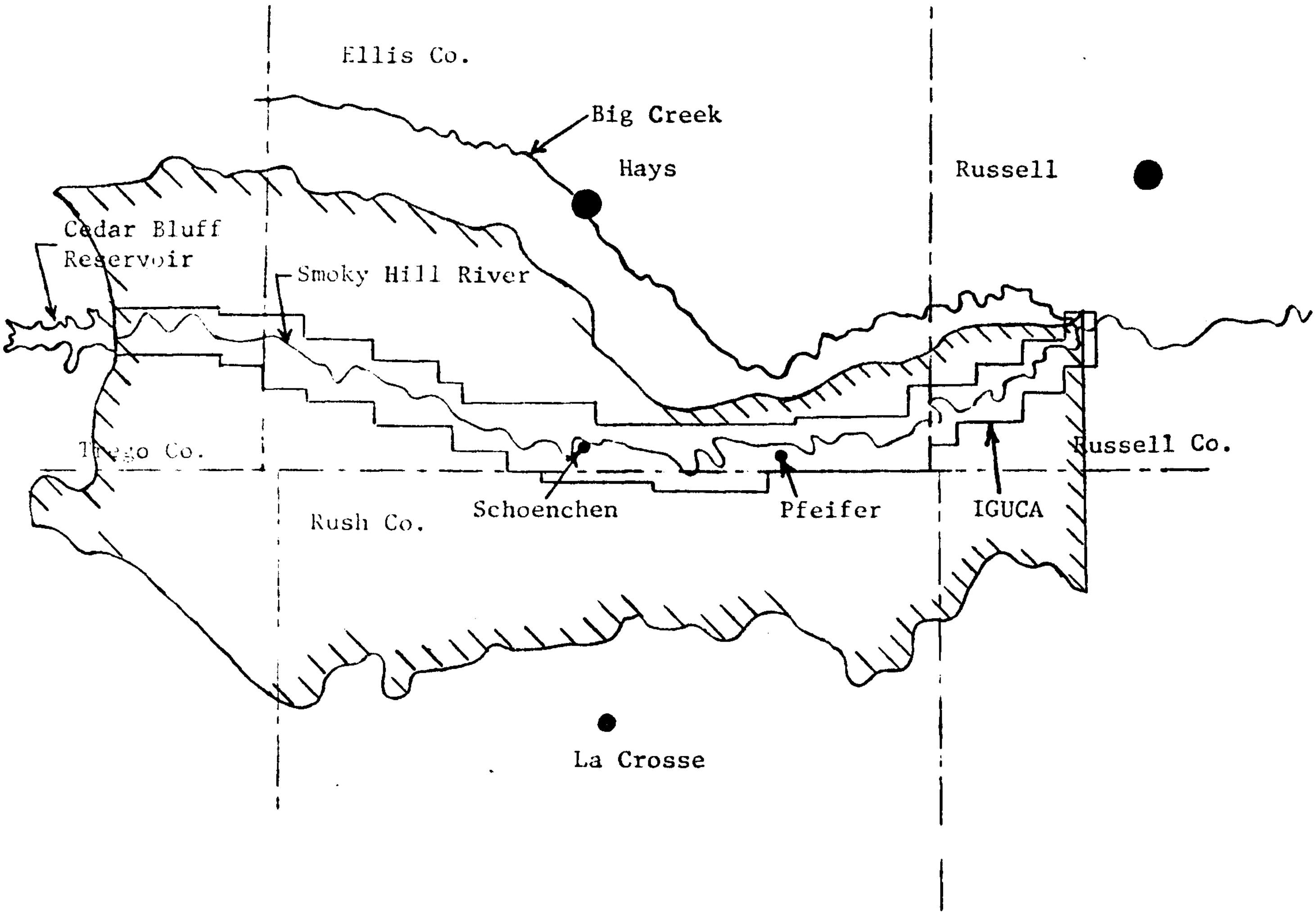
Much of the data for this report came from previous investigations and from U.S. Geological Survey, Kansas Geological Survey, and Division of Water Resources files. Recent 1984 measurements were supplied by the Stockton field office of the Division of Water Resources. In addition, records of wells reported on the WWC-5 well forms sent in to the Kansas Department of Health and Environment constructed in the IGUCA since 1975 were collected and used to develop well inventories. Water-level measurements of wells listed on the inventory were made in the IGUCA by the Kansas Geological Survey in December 1982, and scattered observations were made in the winters of 1980 and 1981. Depth to bedrock, nature of the unconsolidated deposits, and water-level information also were collected from test holes augered by the Kansas Geological Survey to supplement existing data. All of this work was completed by the Kansas Geological Survey to supply information to the hydrogeology of the Smoky Hill River between Cedar Bluff and Kanopolis reservoirs program. Data also were supplied by the cities of Hays and Russell and by the Bureau of Reclamation, Grand Island Office.

## Physical Setting

### Physical Geography

The Smoky Hill River Valley IGUCA is located along the main stem of the Smoky Hill River in southeastern Trego, southern Ellis, northern Rush, and western Russell counties (Fig. 1). The IGUCA is bounded on the west by Cedar Bluff Dam and on the east by the confluence of Big Creek and the Smoky Hill River. The total area covered by the IGUCA is approximately 113 square miles. The total Smoky Hill River drainage-basin size between the east and west ends of the IGUCA is approximately 680 square miles (Fig. 6). Within the IGUCA the valley is subdivided into inner and outer portions (Fig. 5) (Leonard and Berry, 1961). The inner valley consists of the present-day river channel and adjacent low terrace areas. The outer valley consists of a nearly undissected, high, Illinoisan terrace located 25 to 60 feet above the level of the present Smoky Hill River floodplain. In much of the area the high terrace is separated from the present flood plain by bedrock outcrops. The inner

Figure 6. Areal extent of the IGUCA and the Smoky Hill River drainage basin.


Ellis Co.
Big Creek
Hays
Russell
Cedar Bluff
Reservoir
Smoky Hill River
Trego Co.
Russell Co.
Rush Co.
Schoenchen
Pfeifer
IGUCA
La Crosse

valley ranges from less than one-fourth to one mile in width, whereas the outer valley ranges from one to 2.5 miles in width.

## Climate

The area has a semi-arid climate. During the summers, the days are hot, wind velocity is moderate, and the humidity is low. The nights are generally cool. Winters are moderate with occasional, short periods of severe cold. The average year-round temperature at Hays, Kansas, is 53°F. The average annual precipitation is 20.45 inches. Pan evaporation for 1983 at the Hays Experiment Station ranged from 8.83 inches in May to a high of 20.34 inches in July. Average annual precipitation generally increases from west to east across the IGUCA. The annual precipitation at Hays during the period of record has varied from 9.21 inches in 1956 up to 43.34 inches in 1951. Seventy-seven percent of the total precipitation falls during the growing season between April and September. The peak rainfall period is between May and July when the average monthly rainfall exceeds 3.5 inches per month. Nine percent of the total annual precipitation falls between December and February. The average July temperature at Hays is 70.9°F, but the maximum daily summer temperature often approaches 100°F or higher.

## Surficial Geology

A detailed discussion of the surficial geology of the IGUCA and adjacent areas can be found in Leonard and Berry (1961). The following discussion is a summary of their more detailed description. The discussion here covers only what is pertinent to the discussion of hydrology in the IGUCA.

The bedrock units that underlie the surficial unconsolidated materials consist of Lower and Upper Cretaceous limestones, shales, and sandstones (Table 1). In ascending order from oldest to youngest, they are the Dakota

Formation, Graneros Shale, Greenhorn Limestone, Carlile Shale, and Niobrara Chalk. The Dakota Formation is the only bedrock unit that is used as an aquifer in the study area. The Dakota Formation is at the surface in southeastern Ellis and southwestern Russell counties where it outcrops along the axis of the Pfeifer anticline. The bedrock units dip northward at between 25-30 feet per mile in the IGUCA except where local structures alter the dip direction and amount.

Table 1. The bedrock units that outcrop in the IGUCA and their hydrologic significance.

| System | Series | Formation | Thickness | Physical Character |
|---|---|---|---|---|
| | | Niobrara Chalk | 0-10 | Massive soft white limestone interbedded with thin beds of gray shale. Limestone weathers tan. Forms a prominent escarpment. Yields little or no water to wells in the IGUCA. |
| | Upper | Carlile Shale | 300 | Blue-gray shale, noncalcareous containing calcareous septarian concretions in the upper part. Lower 100 feet is calcareous blue-gray to buff shale; contains thin concretionary chalky limestone and thin bentonite seams. Yields little or no water to wells in the IGUCA. |
| Cretaceous | | Greenhorn Limestone | 100 | Blue-gray calcareous shale interbedded with thin chalky limestone and thin bentonite seams. Yields little or no water to wells in the IGUCA. |
| | | Graneros Shale | ±40 | Blue-black to brownish-black noncalcareous shale. Contains selenite crystals, pyrite, and discontinuous thin coquina-like limestone and sandstone lenses. Yields little or no water to wells in the IGUCA. |
| | Lower | Dakota Formation | 150-300 | Varicolored interbedded clay, shale, siltstone, and sandstone. Interbeds are lenticular. The sandstones yield water to wells of highly variable quality and quantity. |

The unconsolidated surficial deposits consist of Pleistocene and Recent aeolian and fluvial deposits forming the terraces and flood plain of the Smoky Hill River. These deposits consist of clay, silt, sand and gravel in variable proportions (Table 2). The deposits are highly variable both laterally and vertically. The inner valley which contains the modern flood plain and adjacent low terraces is underlain by stream-laid deposits of Recent and Late Wisconsinan age. This part of the valley is flanked by a nearly undissected Illinoisan terrace that comprises the outer valley. In many cases the Illinoisan terrace is not contiguous with the inner valley (Fig. 7). This terrace surface is underlain by the Crete and Loveland Formations. The Crete and Loveland Formations consist of arkosic sands and gravels and aeolian sandy silts and silt, respectively. Beneath the Illinoisan terrace in southwestern Ellis and southeastern Trego counties, sediments of the Grand Island and Sappa Formations are confined to an ancestral bedrock channel of the Smoky Hill River located north of the present channel and cut into the Carlile Shale. The Grand Island and Sappa Formations consist of arkosic sands and gravels and silt and sandy clay, respectively. Insufficient drill hole information is available to show that a single channel exists in this area.

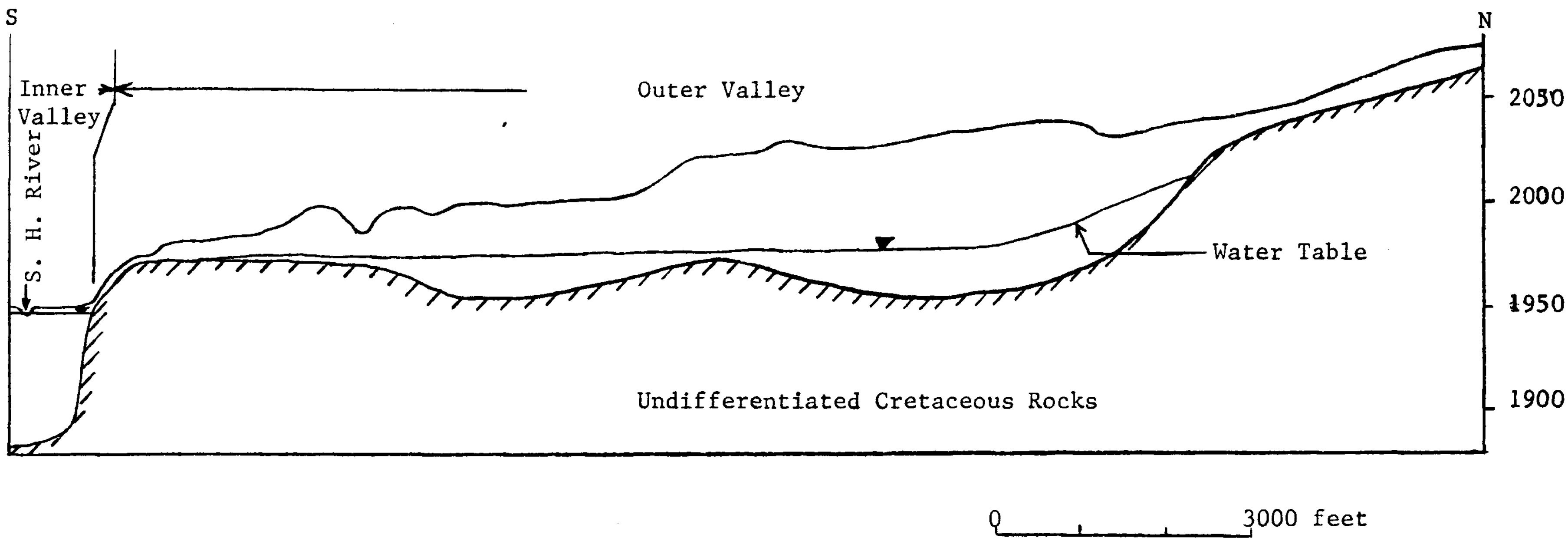
The total thickness of the Pleistocene and Recent sediments in the area ranges up to 70 feet. The maximum sediment thickness is generally greater than 50 feet west of Schoenchen. East of Schoenchen to the confluence of the Smoky Hill River and Big Creek the maximum sediment thickness is generally less than 50 feet.

The soils developed on the modern flood plain and the terraces reflect the nature of the underlying parent materials. Soils on the high terraces are derived from the silts of the underlying Loveland Formation. They are silty

Table 2. Nature, distribution and hydrologic significance of the unconsolidated deposits in the IGUCA

| System | Series | Stage | Formation | Thickness | Physical Character |
|---|---|---|---|---|---|
| | | Recent/Late Wisconsinan | Alluvium/Terrace Deposits | 0-70 | Interbedded silt, sandy silt, sand and gravel. Yields abundant supplies of water along the Smoky Hill River |
| | | Illinoisan | Loveland/Crete Formations | 0-40 | Upper part yellow silt and clay (Loveland). Lower part well sorted stratified sand and gravel (Crete). Underlies the high terrace areas in the outer valley adjacent to the Smoky Hill River. Yields moderate supplies of water to wells. |
| Quaternary | Pleistocene | Kansan | Sappa/Grand Island Formations | 0-55 | Silt, clay, and volcanic ash (Sappa); sand and gravel (Grand Island). Fills a narrow bedrock channel along the Smoky Hill River beneath the high terrace north of the present channel. Yields moderate amounts of water for domestic and stock use. |
| | | Nebraskan(?) | Unnamed | 0-10 | Yellow to buff silt and fine to coarse sand and gravel. Occurs in isolated areas on the bedrock above the Smoky Hill River inner valley. Yields minor amounts of water to wells in the eastern part of the IGUCA. |

Figure 7. Typical cross section across the Smoky Hill River valley in the Cedar Bluff Irrigation District No. 6 (modified from Leonard [1974]).



S
N
Inner
Valley
Outer Valley
S. H. River
Water Table
Undifferentiated Cretaceous Rocks
2050
2000
1950
1900
0
3000 feet

clay loam to silty clay in texture, well drained and have a high water-holding capacity. The soils of the inner valley developed on the Recent and Late Wisconsinan alluvium. Texturally, they are loamy or silty clayey and are well-drained with moderate permeability and a high available water capacity. These soils are well suited for irrigation (Glover et al., 1975).

## Hydrology

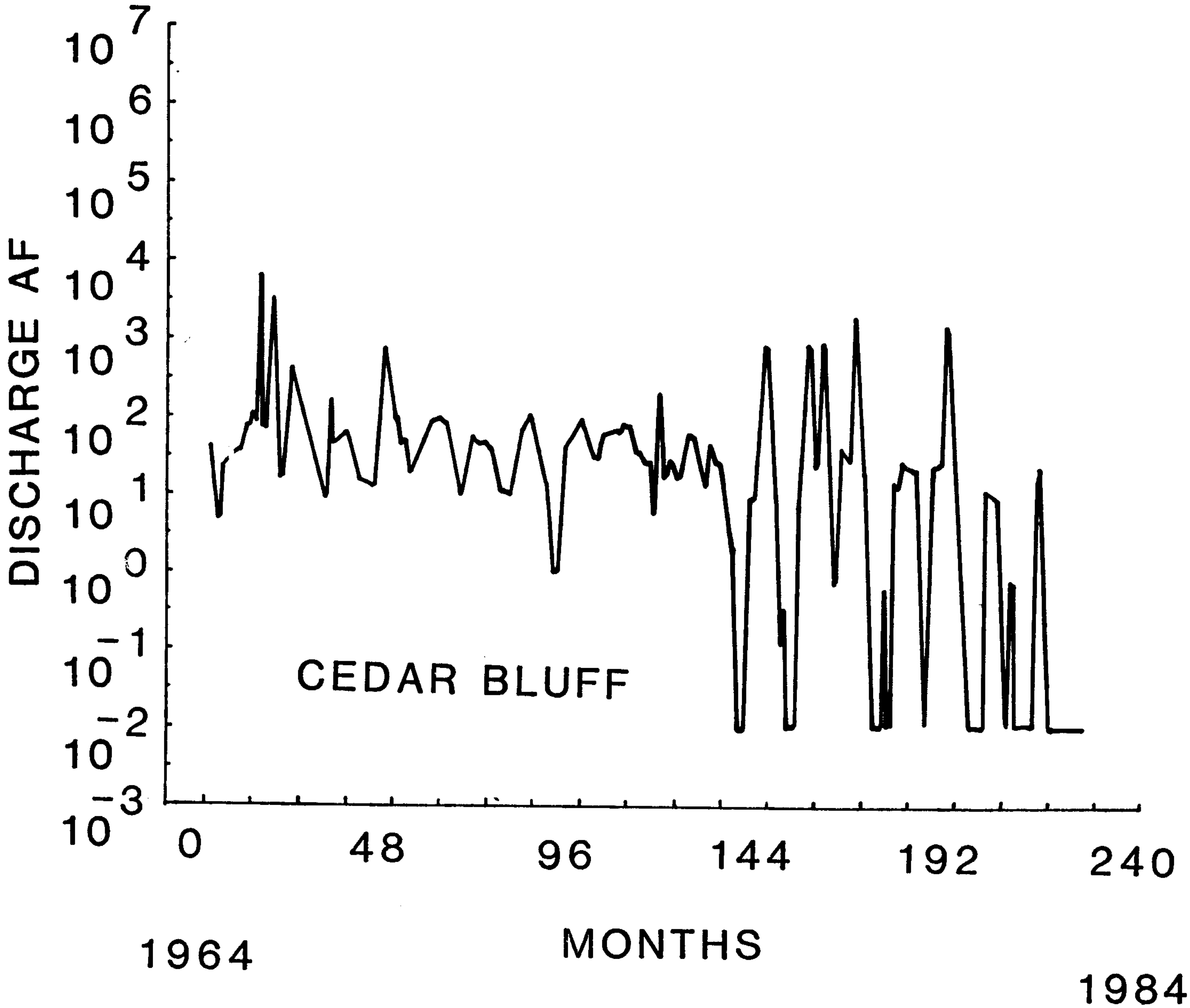
Water Availability - Surface Water

Monthly streamflow discharges for several gaging stations along the Smoky Hill River were plotted beginning with the 1964 water year (October 1, 1963, to September 30, 1964) through the 1983 water year (Fig. 8). These are presented in Figures 9 through 12. Releases from Cedar Bluff Reservoir to the river were generally stable at 32 acre-feet per month from 1964 until 1975 (calendar year). After this time they were infrequent and smaller. At the gage above Schoenchen, stream discharge averaged 1580 acre-feet per month until 1978-1979 (calendar year). The monthly discharge has declined since then until July 1983, when there was no streamflow recorded at the gage for longer than three months. At Bunker Hill stream discharge averages 4,000 acre-feet per month. Water from Big Creek exerts some relatively minor influence on the streamflow measured at this gage. Stream flow has declined only recently beginning in the summer of 1983. The pattern of streamflow decline at the Ellsworth gage is similar to that at Bunker Hill. The average monthly stream flow at the gage is 8,000 acre-feet.

The daily streamflow hydrographs for the stream gage above Schoenchen for water years 1982 and 1983 show that there was little or no flow at this gage during the drier parts of these years. Figure 13 shows the 1982 and 1983 stream hydrographs for the gages above and below Schoenchen.

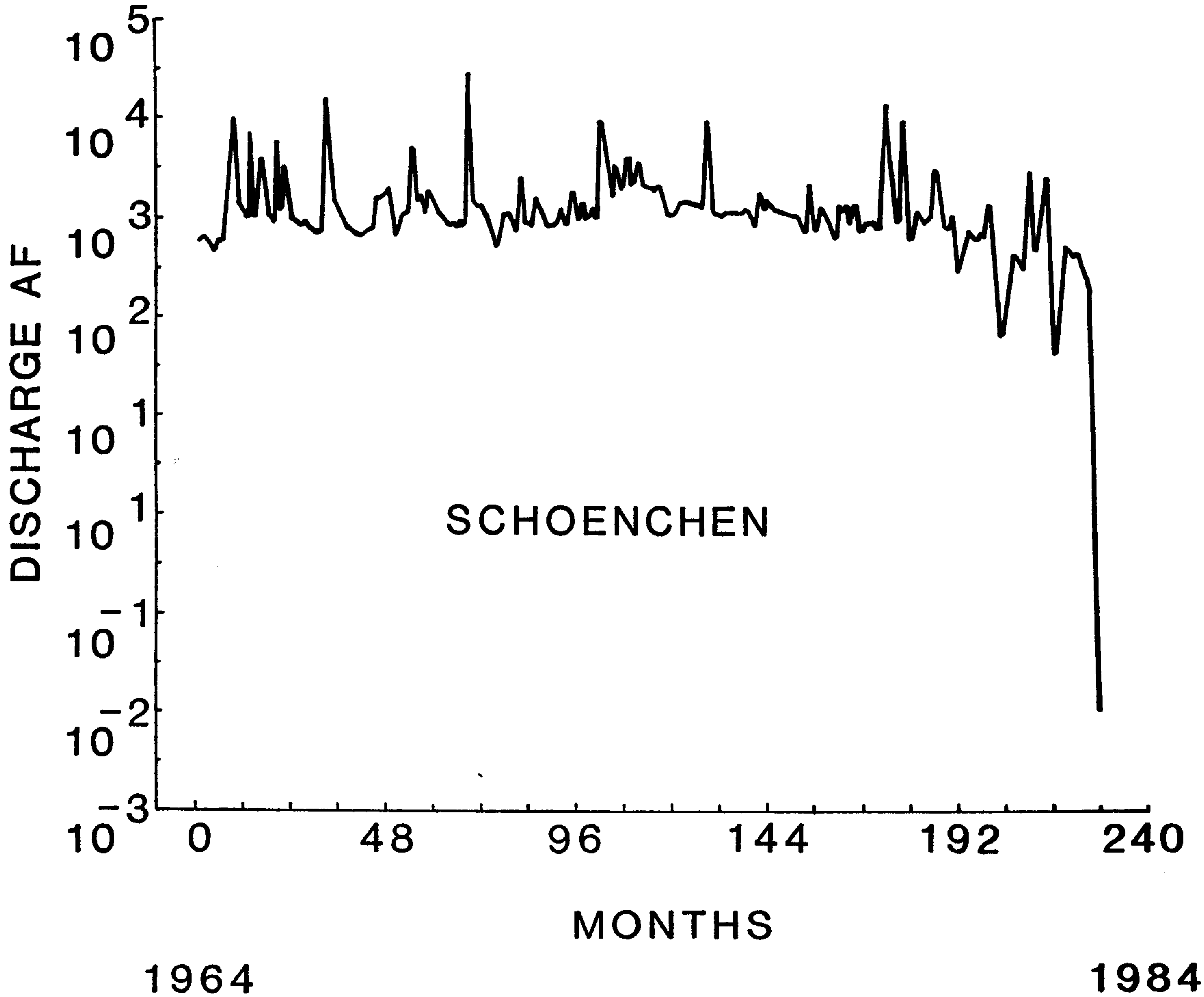
Figure 8. Location of the stream gages along the Smoky Hill River discussed in this report.

Figure 9. Monthly releases from Cedar Bluff Reservoir since 1964.



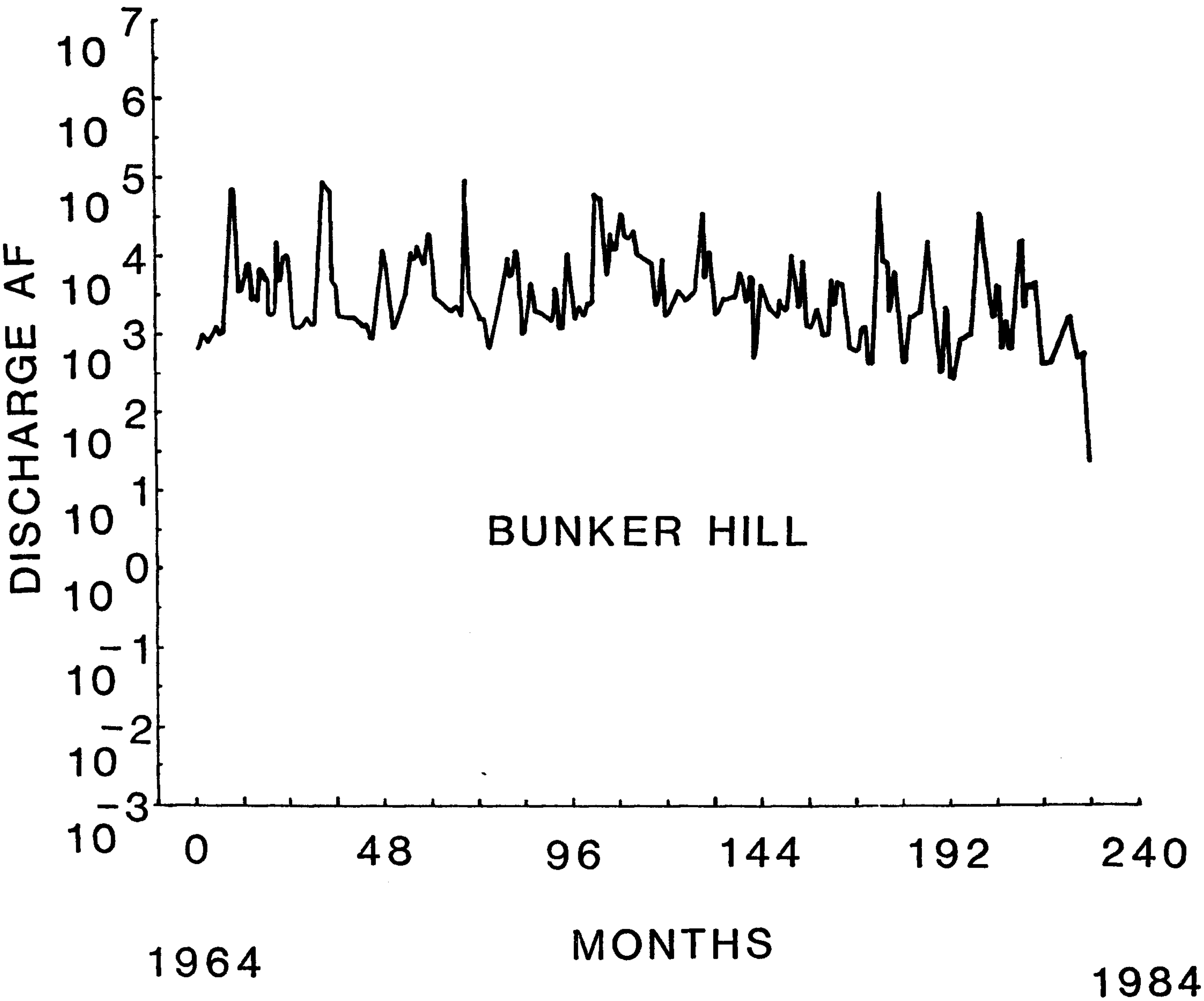
DISCHARGE AF
10 7
10 6
10 5
10 4
10 3
10 2
10 1
10 0
10 −1
10 −2
10 −3
CEDAR BLUFF
0
48
96
144
192
240
MONTHS
1964
1984

Figure 10. Monthly stream discharge from the gage located above Schoenchen, Kansas.



SCHOENCHEN
DISCHARGE AF
$10^5$
$10^4$
$10^3$
$10^2$
$10^1$
$10^1$
$10^{-1}$
$10^{-2}$
$10^{-3}$
0
48
96
144
192
240
MONTHS
1964
1984

Figure 11. Monthly stream discharge from the gage located near Bunker Hill, Kansas.



DISCHARGE AF
$10^{7}$
$10^{6}$
$10^{5}$
$10^{4}$
$10^{3}$
$10^{2}$
$10^{1}$
$10^{0}$
$10^{-1}$
$10^{-2}$
$10^{-3}$
BUNKER HILL
0
48
96
144
192
240
MONTHS
1964
1984

Figure 12. Monthly stream discharge from the gage located at Ellsworth.

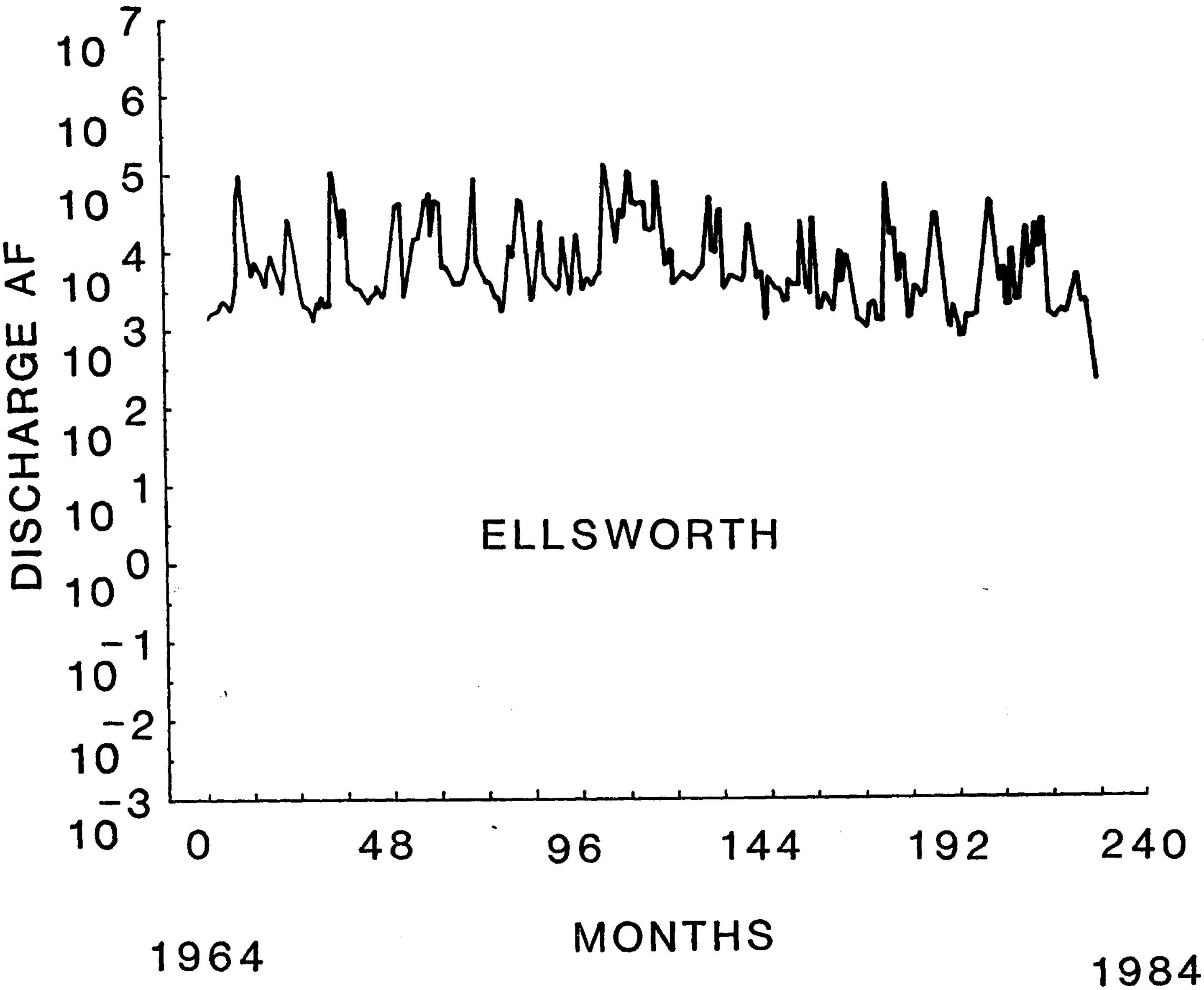

DISCHARGE AF
10^7
10^6
10^5
10^4
10^3
10^2
10^1
10^0
10^-1
10^-2
10^-3
ELLSWORTH
0
48
96
144
192
240
MONTHS
1964
1984

Figure 13. Daily discharge at the stream gages located above (06862700) and below (06862850) Schoenchen, Kansas, for water years 1982 and 1983.

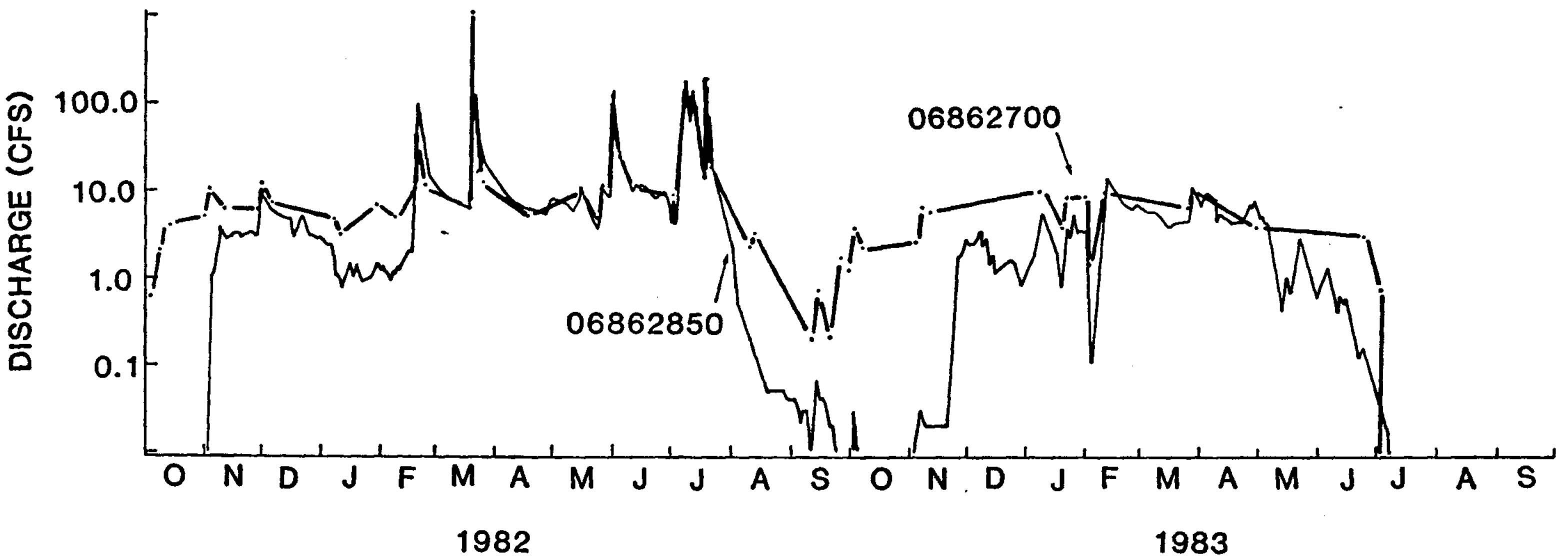
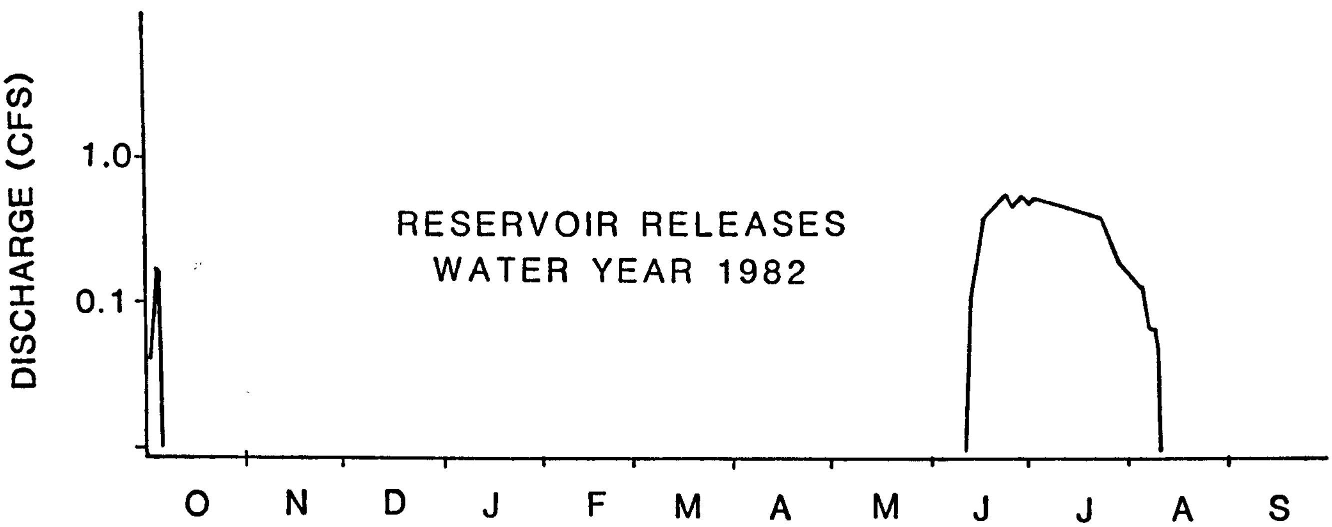

DISCHARGE (CFS)
100.0
10.0
1.0
0.1
06862700
06862850
O
N
D
J
F
M
A
M
J
J
A
S
O
N
D
J
F
M
A
M
J
J
A
S
1982
1983

Figure 14 shows that releases from Cedar Bluff Reservoir were minor during water year 1982. The maximum flow was on the order of 0.5 cfs and lasted for a relatively short time. Figure 15 shows distribution of basin-averaged precipitation during the two years for the section of the Smoky Hill River basin between Cedar Bluff Dam and the stream gage above Schoenchen. The averaged basin precipitation for this period was determined using the Theissen polygon method. The average for water year 1982, a relatively normal year, was 22.39 inches and for water year 1983 the total precipitation was 13.04 inches. Considerably less rainfall fell during May-July of water year 1983 than during 1982. Streamflow declines are much more abrupt in 1983 than in 1982 when the river ceased to flow. In both cases the streamflow declines during the summer are related to a lack of precipitation and possibly the effects of evapotranspiration. The average low flow discharge at the stream gage above Schoenchen during the period between February and May of both water years was 6.5 cfs.

The response of the stream discharge hydrograph at the gage above Schoenchen to major precipitation events shows that the bank storage is quite small. Several major storm events occurred between February and July, 1982. Each is reflected on the discharge hydrograph as a sharp rise in stream discharge signalling the passage of the flood wave in the stream. For each event the recession curve after the flood peak declines quite rapidly suggesting that there is a very rapid exchange of water between the stream and the surrounding alluvial aquifer.

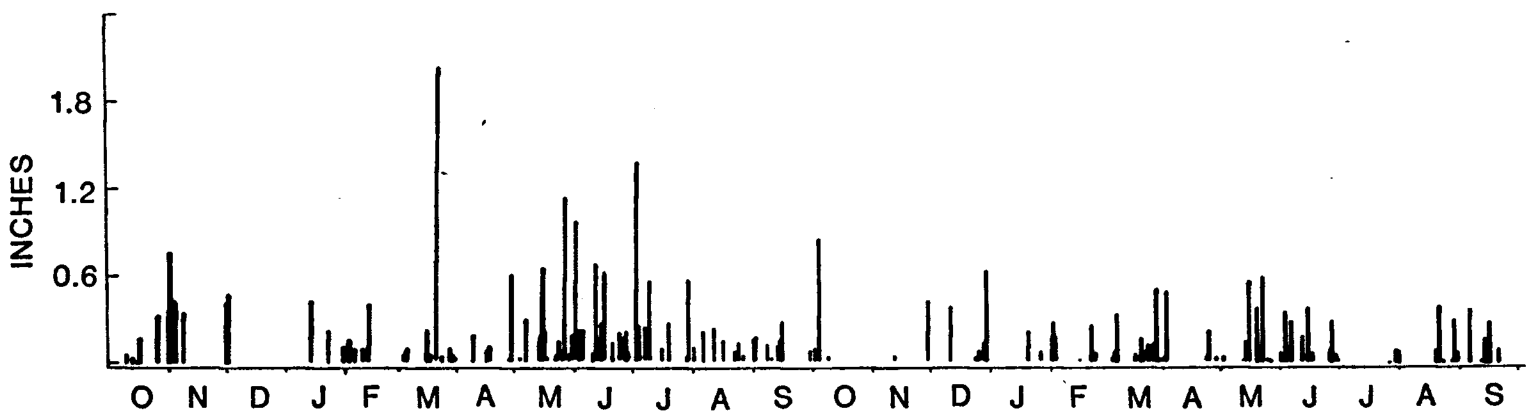
Figure 13 also shows the impact of the Hays well field on streamflow in the Schoenchen area. This effect can be seen by comparing the two discharge hydrographs above and below Schoenchen. The operation of the well field

Figure 14. Releases from Cedar Bluff Reservoir, water year 1982.



DISCHARGE (CFS)
1.0
0.1
RESERVOIR RELEASES
WATER YEAR 1982
O
N
D
J
F
M
A
M
J
J
A
S

Figure 15. Basin-averaged precipitation between Cedar Bluff Reservoir and Schoenchen for water years 1982 and 1983.




PRECIPITATION WATER YEAR 1982-83

clearly diminished streamflow during the summer and fall months of both water years, but the effect is minimized when there is precipitation upstream. However, the decrease in streamflow caused by the Hays well field is not as pronounced as the decrease caused by a lack of precipitation during the hotter parts of the year. These wide fluctuations of streamflow are related to variation in precipitation received by this part of the basin and indicate that there is little water-storage capacity in the basin when precipitation occurs. This seems reasonable since the alluvial aquifer is not very extensive (less than one-fourth to one mile wide) and the soils in the upland part of the basin are thin and clayey. Prior to 1978 the decreases in streamflow associated with seasonal changes do not appear to have been as great because the low flows in the stream have been augmented by surface waters leaving Cedar Bluff Irrigation District No. 6.

Water Availability - Ground Water

The sandstones of the Dakota Formation comprise the only important bedrock aquifers in the IGUCA. Little detailed information is available on aquifers in the Dakota Formation. However, the U.S. Geological Survey is studying the regional hydrogeology of the Lower Cretaceous sandstones in the Central Midwest Regional Aquifer Systems Analysis Program (CM RASA). It is expected that a regional view of the hydrogeology of the Dakota Formation will be developed as a result of this study.

Leonard and Berry (1961) have presented a summary of ground-water conditions in the Dakota Formation in southeastern Trego, southern Ellis, and northern Rush counties. They reported that the Dakota Formation is the principal source of water in the upland areas away from the Smoky Hill River valley in Ellis and Rush counties. The Dakota Formation is at the surface in southwestern Russell and southeastern Ellis counties. Elsewhere in the IGUCA the depth to the top of the Dakota ranges to depths exceeding 500 feet.

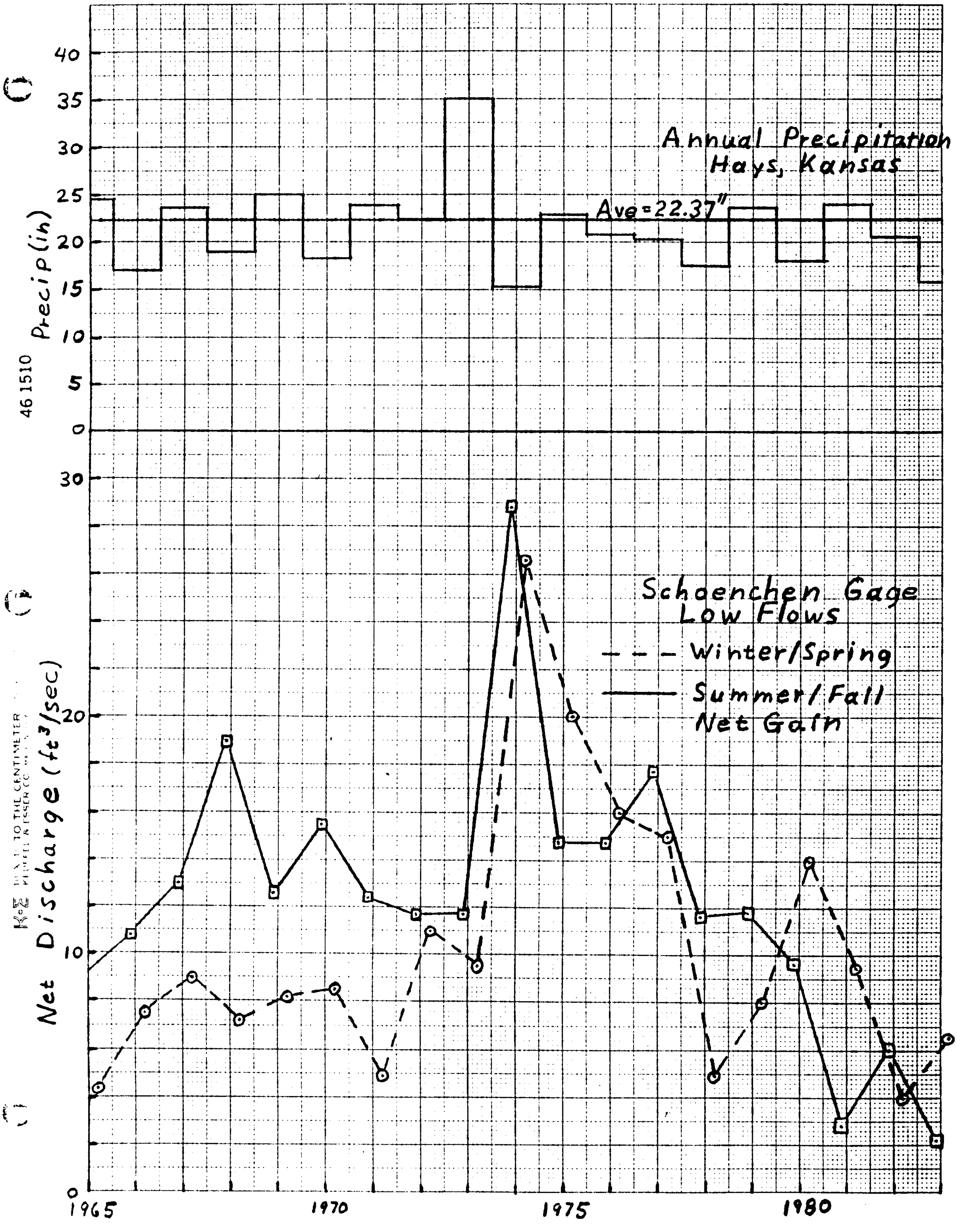
Ground waters in the Dakota Formation are under artesian pressure. Ground water is more readily available from the sandstone lenses than from the surrounding shales that make up the majority of this geologic unit because the sandstones are generally more permeable. The ability of the sandstone lenses to yield water depends on the areal extent, thickness, degree of interconnection of the sandstone lenses, grain size, and degree of cementation of the sandstones (Keene and Bayne, 1977). Although a range of yield for wells tapping the Dakota Formation in the IGUCA is not available, it is probably low to moderate, less than 100 gallons per minute, and highly variable even within a small area.

The chemical quality of ground waters in the Dakota Formation is also quite variable across the IGUCA (Keene and Bayne, 1977). Ground-water types based on the dominant cations and anions in solution vary from calcium-bicarbonate to mixed calcium-sodium-bicarbonate to sodium-chloride type waters. Total dissolved solids of ground waters in the IGUCA range from 500 to more than 3,000 mg/L. In the outcrop area saltwater seeps and springs that emanate from the Dakota Formation discharge water to the Smoky Hill River and increase the chloride concentration of the surface water during low flow conditions (Latta, 1948). In a U.S. Public Health Service (1949) study cited by Hargadine et al (1979), chloride concentration of waters in the Smoky Hill River during low flow was found to be generally less than 200 mg/L west of the Ellis-Russell county line and increased to over 700 mg/L south of Russell.

The principal aquifers in the IGUCA are contained in the Pleistocene and Recent sediments. For the most part, the aquifers are contained in the sands and gravels of these deposits. Ground-water aquifers in the high terrace areas are for the most part not connected with the ground-water aquifers of the inner valley. They may be separated laterally and vertically by bedrock benches or highs that protrude from beneath the unconsolidated sediments (Fig. 7). Leonard and Berry (1961) have pointed out that at many places east of Schoenchen the water table in the inner valley aquifer is continuous with the water table in the high terrace deposits. However, to the west of Schoenchen this is not the case. The unconsolidated cover is either thin or absent near the terrace edge. Well yields are, for the most part, lower for the high terrace aquifers than for the aquifer in the inner valley because the high terrace aquifers have a lower saturated thickness and are not recharged as rapidly as the inner valley aquifer. The saturated thickness of the high terrace aquifers is higher in the vicinity of the ancestral bedrock channel of the Smoky Hill River.

The Smoky Hill River is a gaining stream in the IGUCA with some exceptions. The net streamflow gain by ground-water seepage between Cedar Bluff Reservoir and the stream gage upstream of Schoenchen was approximately 3 cfs between 1964 and 1971 (Leonard, 1974). Figure 16 shows the low flow net gains at two times during the years between 1965 and 1983 for the Cedar Bluff to upstream of the Schoenchen reach of the Smoky Hill River. Winter/spring and summer/fall measurements from discharge hydrographs are shown as a comparison with Leonard's (1974) average seepage gains into the river. Watson's (1984) data show the Smoky Hill River to be a gaining stream in that reach during the summer months up to 1979. After this time, streamflow losses were found at

Figure 16. Low-flow net gains in the reach between Cedar Bluff Reservoir and the stream gage located above Schoenchen, Kansas. Low flows measured for winter/spring and summer/fall. Yearly precipitation data for the Hays weather station are provided for comparison.



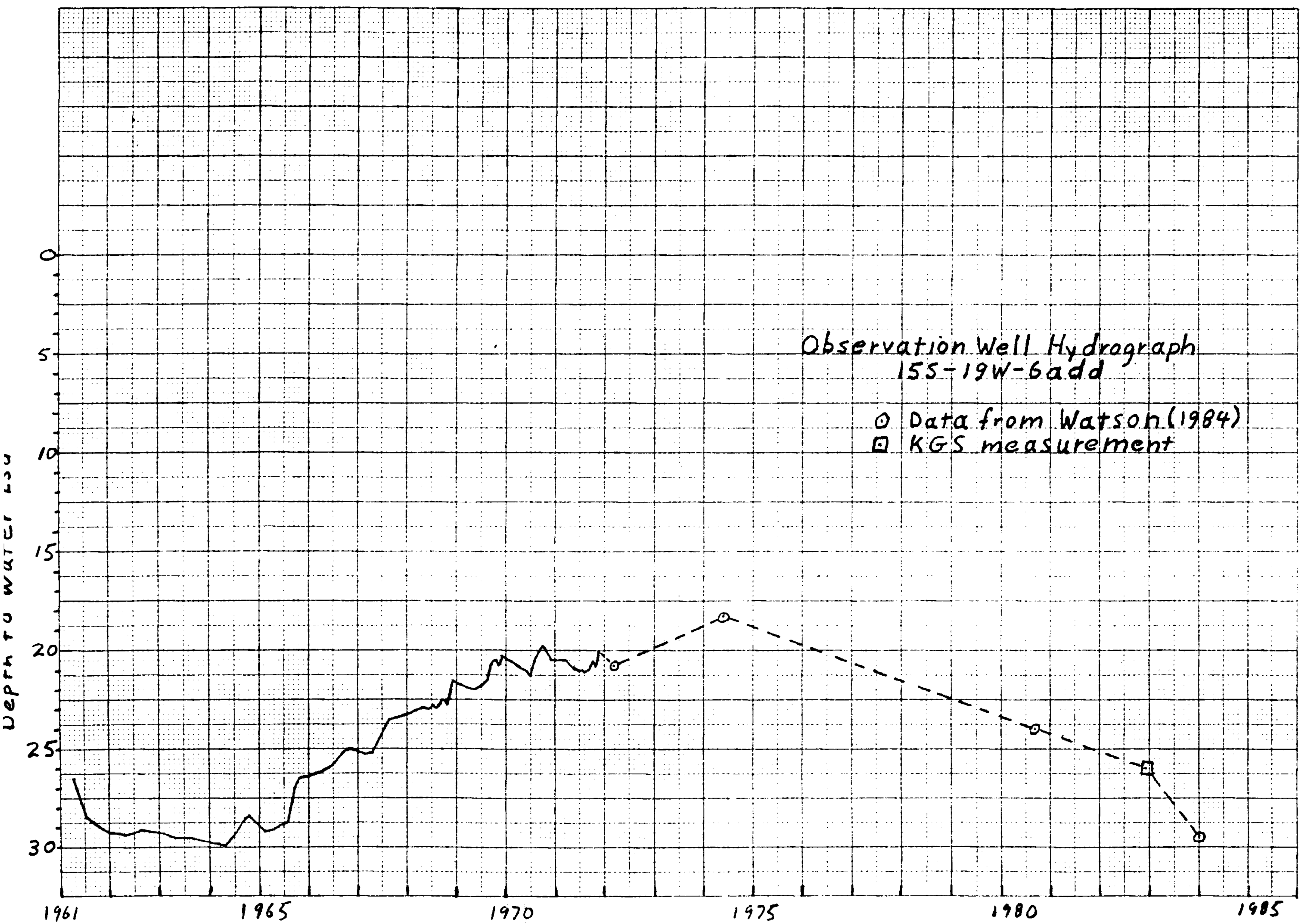
Annual Precipitation
Hays, Kansas
Ave = 22.37"
Precip (in)
40
35
30
25
20
15
10
5
0
Schoenchen Gage
Low Flows
Winter/Spring
Summer/Fall
Net Gain
Net Discharge (ft³/sec)
30
20
10
0
1965
1970
1975
1980
46 1510

least for the period when measurements were made in July and August 1980. An average streamflow loss in the reach of 8 cfs was determined from field measurements in the Cedar Bluff to Schoenchen reach. Another set of stream gage measurements were made in September 1980 and these show a return to increasing stream discharge downstream from Cedar Bluff Reservoir. The streamflow gains measured during the period between 1963 and 1978 in the summer months resulted from increases in tributary inflow to the stream from surface-water irrigation in the Irrigation District. Figure 16 shows that the streamflow gains generally increased in the reach from 1965 to 1975. After this time low flow gains for both seasons have decreased.

The Smoky Hill River is not generally a gaining stream in the vicinity of Schoenchen and Pfiefer where the Hays and Russell well fields are located. Streamflow losses of 3.5 to 5 cfs through the Hays well field during the summer have been noted since 1963 (Watson, 1984). Little data on streamflow losses are available for the Russell well field area. However, the losses at Pfeifer are probably similar to those at Schoenchen, since the wells are in close proximity to the river.

Recharge to the aquifers in the unconsolidated sediments of the inner valley and terrace deposits comes from precipitation in excess of evapotranspiration. Some of this water seeps to the water table. Recharge also comes from interactions with surface water in the river. No estimates of recharge to the alluvial aquifer have been made at this time in the present study being conducted by the Kansas Geological Survey. Leonard and Berry (1961) estimated a long-term recharge rate of 0.3 to 1.0 inch per year based on fluctuations of water levels in some observation wells for the period between 1946 and 1957 and an assumed specific yield of 15%.

Figure 17. A hydrograph of an observation well located on the high terrace in Cedar Bluff Irrigation District No. 6 in 15S-19W-6add.


Observation Well Hydrograph
15S-19W-6add
Data from Watson (1984)
KGS measurement
Depth to Water
0
5
10
15
20
25
30
1961
1965
1970
1975
1980
1985

Several of the observation well hydrographs from Leonard's (1974) study show recharge to aquifers in the terraces in the Irrigation District during the period of surface-water irrigation between 1963 and 1971 (Fig. 17). Leonard's data for the acres irrigated and the computed excess water from the irrigated lands that would be available for recharge were used to compute the appproximate rate of recharge to the terrace deposits. Recharge rates ranged from 13.17 inches in 1966 to 20.85 inches in 1970. The excess water available for recharge is the total water applied to the acreage, including precipitation minus the consumptive use by irrigated crops. This excess is assumed to move downwards to the water table. These figures are only very approximate and may not be very good estimates because of the assumptions used to determine the recharge rate.

Saturated thickness of the alluvial aquifer in the inner valley adjacent to the Smoky Hill River ranges up to 50 feet in the IGUCA. Saturated thicknesses are generally greater than 35-40 feet west of Schoenchen and less than 35 feet east of Schoenchen. Saturated thicknesses as low as 20 feet were found west of Pfeifer in 15S-17W-28. Saturated thicknesses are also lower in the vicinity of the Hays well field at Schoenchen. Ground-water pumpage has produced a cone of depression in the well field area that varies in extent depending on the intensity of pumping and whether or not there is water in the stream. The situation at Pfeifer is similar when the wells there are heavily pumped, but the effects appear to be seasonal up through 1983. More recently, drawdown in the well field has been more severe (Watson, 1984).

Widespread ground-water-level declines between 1949 and 1982 are not apparent in most of the IGUCA. The 1949 data came from Leonard and Berry (1961). Figures 18 and 19 are hydrographs of wells located upstream and downstream of Cedar Bluff Irrigation District No. 6, respectively. Only minor

Figure 18. Hydrograph of an observation well located in the alluvial aquifer of the Smoky Hill River in 14S-21W-33bcc.

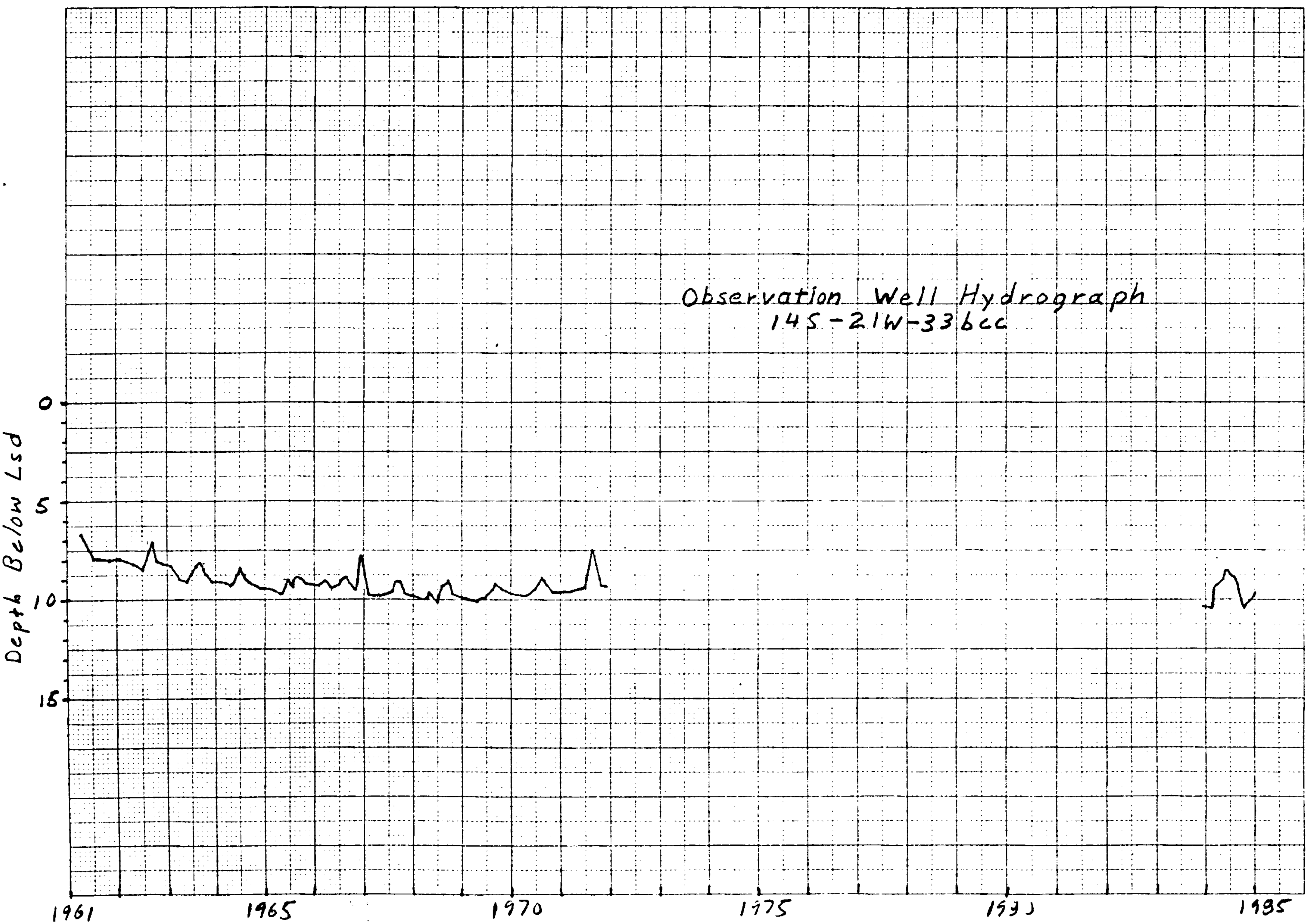
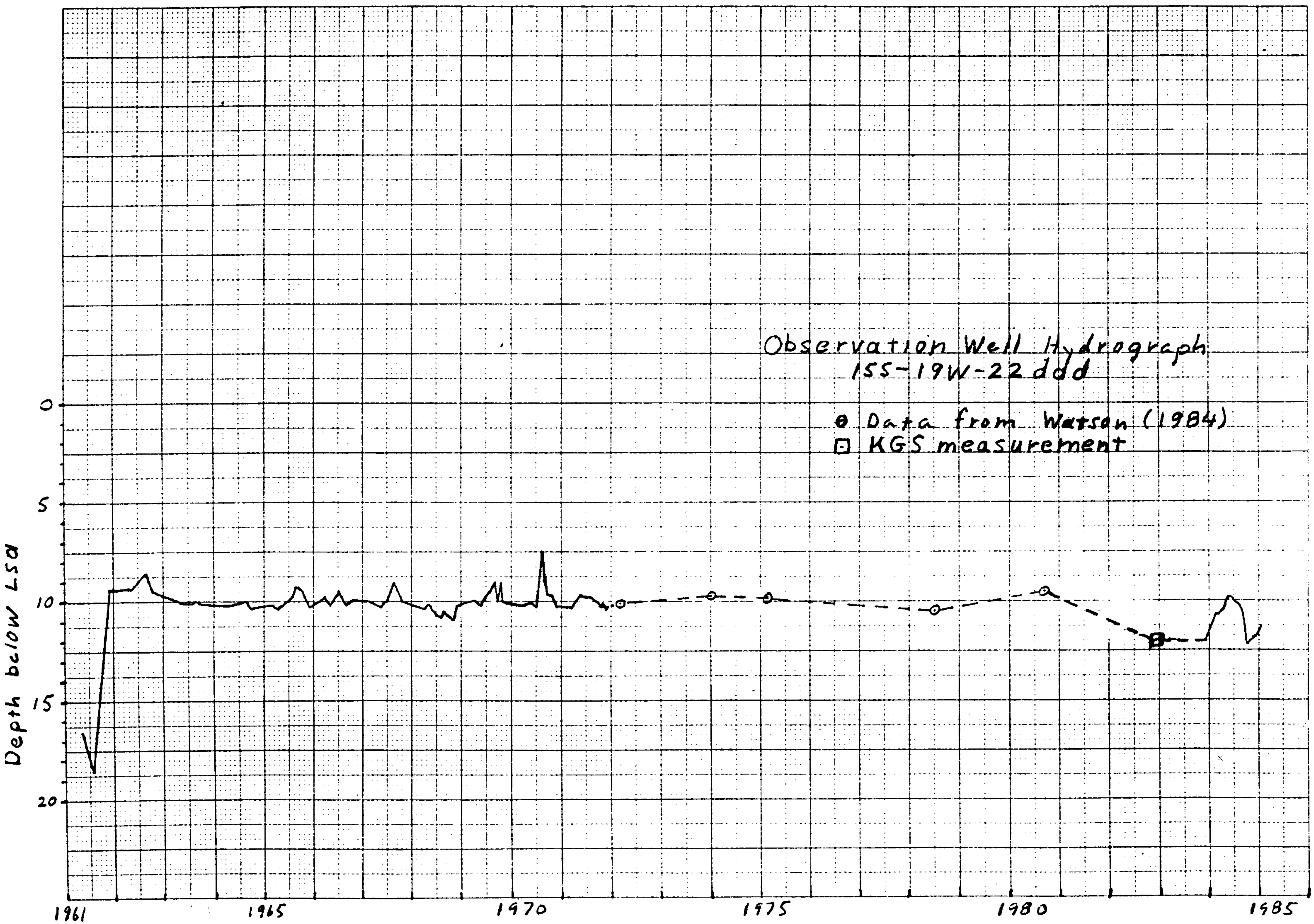

Observation Well Hydrograph
14S-21W-33bcc
Depth Below Lsd
0
5
10
15
1961
1965
1970
1975
1985

Figure 19. Hydrograph of an observation well located in the alluvial aquifer of the Smoky Hill River in 15S-19W-22ddd.



Observation Well Hydrograph
155-19W-22ddd
Data from Watson (1984)
KGS measurement
Depth below LSD
0
5
10
15
20
1961
1965
1970
1975
1980
1985

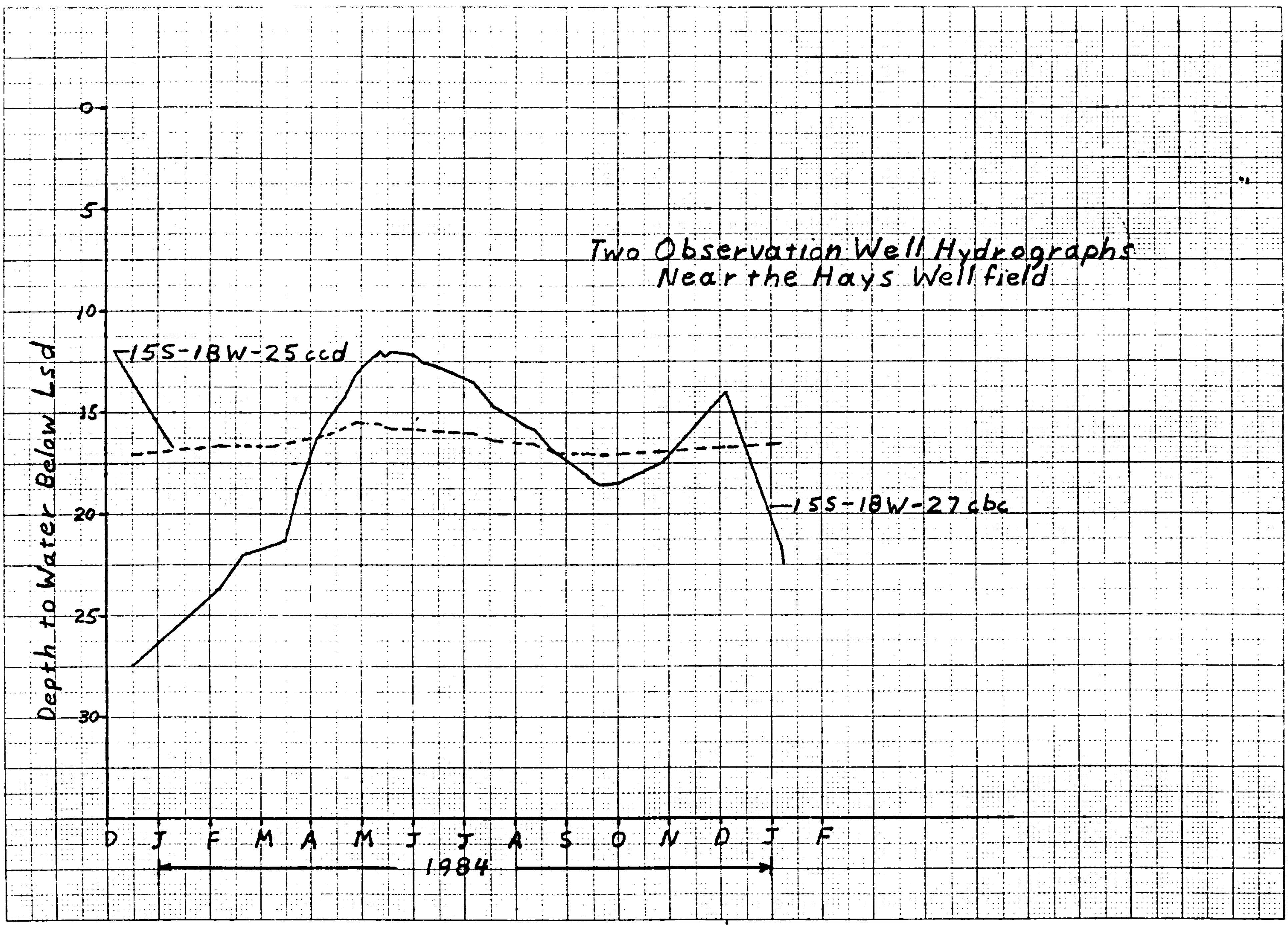
water-level fluctuations over time can be seen in these wells. Significant ground-water level declines are evident in the vicinity of the Hays well field and more recently in the Russell well field. In these areas ground-water levels have declined as much as 17 feet since 1949. Figure 20 shows the ground-water-level hydrographs for two wells in the vicinity of the Hays well field. The well located in 15S-18W-27cbc is in the middle of the well field at Schoenchen. The other well located two miles east is in 15S-18W-25ccd. The observation well in the well field shows wide fluctuations in water level caused by variations in the intensity of pumping and recharge from the river during the west months of the year. The effect of this pumpage is only slightly noticeable at the other observation well.

## The Impact of Water-Resources Development on the Hydrology of the IGUCA

The impact of water-resources development on the hydrology of the IGUCA can be broken down into surface- and ground-water impacts. The net impact of development in the area has been a decline in streamflow. Very little impact on ground-water resources is evident at this time.

Surface-water irrigation in Cedar Bluff Irrigation District No. 6 was active between 1963 and 1978 and augmented surface-water flows in the Smoky Hill River at Schoenchen by: 1) increasing the amount of ground water in storage in aquifers beneath the high terraces and 2) increasing tributary inflow into the Smoky Hill River as a result of the increase in ground-water discharge through springs and seeps located along the tributaries draining the terraces. During this time ground-water seepage into the river from the adjacent alluvial aquifer remained fairly constant. These two effects acted to increase the low-flow gains in the stream with time. Since 1978 when surface-water irrigation in the District ceased, ground-water levels in the

Figure 20. Hydrographs of two observation wells located in the alluvial aquifer of the Smoky Hill River at Schoenchen. Well 15S-18W-27cba is located in the City of Hays well field. Well 15S-18W-25ccd is located two miles east.


Two Observation Well Hydrographs
Near the Hays Well field
Depth to Water Below Lsd
0
5
10
15
20
25
30
15S-18W-25ccd
15S-18W-27cbc
D J F M A M J J A S O N D J F
1984

terraces have been declining, indicating that the terraces are discharging the stored ground water faster than it is being recharged by natural means (Fig. 17). 1984 static water levels in observation wells on the terraces suggest a return to pre-1964 (pre-irrigation) ground-water conditions in the District. Low-flow streamflow gains in this reach are also declining and are approaching the low-flow seepage gains measured by Leonard (1974). The absence of long-term changes of ground-water levels in the alluvium adjacent to the District further indicates that the rate of seepage into the river (which makes up(Fig. 17). 1984 static water levels in observation wells on the terraces suggest a return to pre-irrigation ground-water conditions in the District. Low-flow streamflow gains in this reach are also declining and are approaching the low flow seepage gains measured by Leonard (1974). The absence of long-term changes of ground-water levels in the alluvium adjacent to the District further indicates that the rate of seepage into the river (which makes up the low flows) is not changing. Streamflow losses do occur in the vicinity of the Hays and Russell well fields as a result of pumpage. Further downstream at Bunker Hill and Ellsworth, some recent declines in streamflow are evident but have occurred only recently. As a result, no long-term trends can be estimated.

No regional declines of ground-water levels are evident at this time due to pumpage except in the vicinity of the Hays and Russell well fields. In these areas the declines occur during the dry part of the year when the rate of withdrawal is high and tend to be severe. Some recovery does take place with recharge from precipitation during the wet part of the year. The net effect of ground-water withdrawals on the alluvial aquifer does not appear to be widespread at this time.

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