GEOLOGICAL SURVEY CIRCULAR 781

The Case of the Shrinking Channels—the North Platte and Platte Rivers in Nebraska

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CONTENTS

ILLUSTRATIONS

TABLES

METRIC-ENGLISH EQUIVALENTS

Metric Unit	English equivalent
millimeter (mm)	= 0.0394 inch
millimeter (mm)	= .00328 foot
meter (m)	= 3.28 feet
kilometer (km)	= .62 mile
cubic meter per second (m3/s)	= 35.3 cubic feet per second

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ABSTRACT

This reconnaissance investigation was undertaken to determine whether the channels of the North Platte and Platte Rivers in western and central Nebraska have been changing in character since the latter part of the 19th century and, if so, the general nature and extent of such changes. The 480-kilometer study reach extended from Minatare on the North Platte River to Grand Island on the Platte River.

The channels have indeed changed considerably. Changes in the 365-km reach from Minatare to Overton differ in magnitude and sometimes in character from the downstream stretch from Overton to Grand Island (115 km). Within the former reach, the channel by 1969 was only about one- to two-tenths as wide as in 1865. The 1969 channel for this reach was less braided and slightly more sinuous than the 1938 channel. (No data are available for braiding and sinuosity prior to 1938.) From Overton to Grand Island, the 1969 channel was about six- to seven-tenths as wide as in 1865, and various changes in braiding and sinuosity took place between 1938 and 1969.

The decreases in channel width are related to decreases in water discharge. Such flow reductions have resulted primarily from the regulating effects of major upstream dams and the greater use of river water by man. Much of the former river channel is now overgrown with vegetation.

INTRODUCTION

The North Platte and Platte Rivers in Nebraska (fig. 1) are among the most important rivers of the Great Plains. Much of the vast westward migration of the 19th century followed their routes, and travelers cursed and praised the rivers simultaneously for their benefits and disadvantages. Settlers depended on these rivers for water and built a very complex system of diversions and controls. Wildlife, too, plays a large role. Sandhill cranes, for example, use the North Platte and Platte channels as a major migration stopover. In mid-March each year, an estimated 70-80 percent of the world's lesser sandhill cranes move into a 260-km stretch of the river between Sutherland and Grand Island (fig. 1) (Frith, 1974; Farrar, 1975).

Is man's extensive manipulation of the water flow changing the riverine habitat? This reconnaissance investigation examines the character of the Platte's channel to determine whether any significant changes have taken place since the latter part of the 19th century.

Local historians Emil Roeser, Paul Henderson, and Ted Genoways took me on interesting excursions to old bridge sites, most of which today are unrecognizable as the important crossings they once were. Many people generously provided information and assistance during the study. Among these are Frank Dragoun of the Central Nebraska Public Power and Irrigation District, Glenn Tabor of the Union Pacific Railroad, Jim Potter and Paul Riley of the Nebraska State Historical Society, Jim Holmes of the Nebraska Department of Roads, Harold Nagel and Steele Becker of Kearney State College, Robert Petersen of the Nebraska Public Power District, Emery Coonrod and Ernie Peterson of the Burlington Northern Railroad, Warren Corbet and Fred Otradovsky of the U.S. Bureau of Reclamation, and Ray Bentall of the University of Nebraska-Lincoln. Ray Bentall, Richard Hadley, and Stanley Schumm improved the manuscript considerably with their many constructive comments.

GEOGRAPHIC SETTING

The North Platte River originates in the Rocky Mountains of Colorado, flows northward into central Wyoming, then generally southeastward into Nebraska. In west-central Nebraska it joins the South

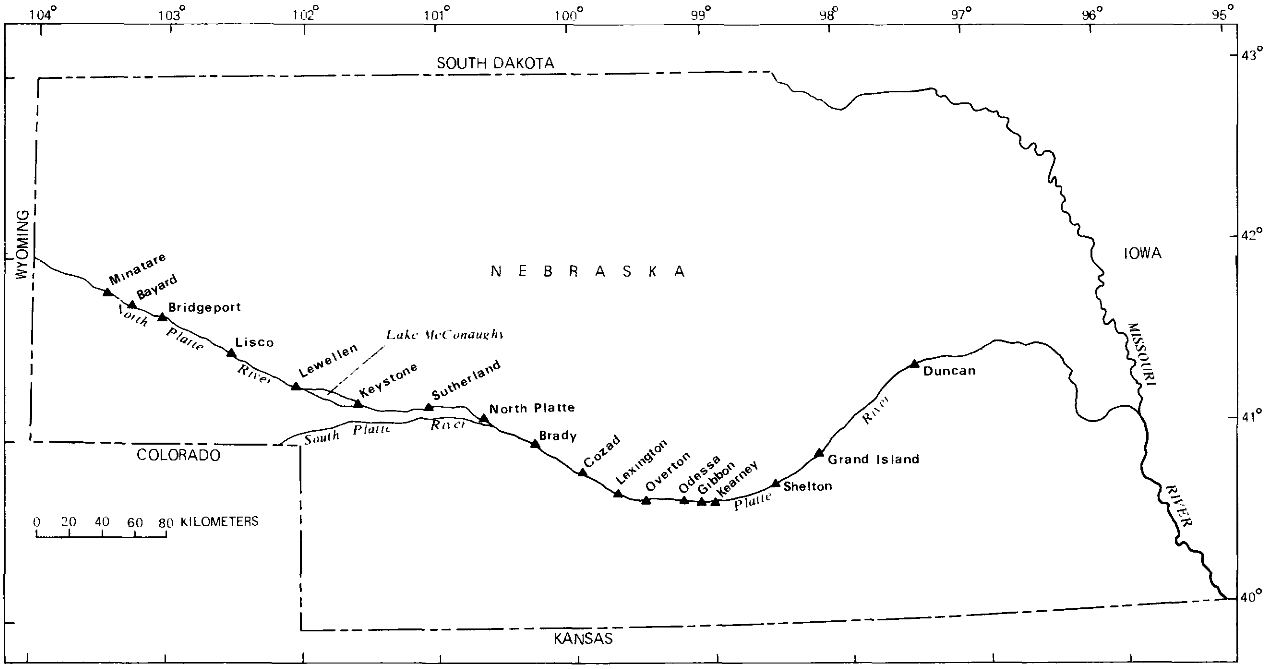

FIGURE 1.—Platte River study area.

Platte River to form the Platte River (fig. 1). The Platte flows eastward to join the Missouri River at the eastern edge of Nebraska.

The reach studied in this report extends from Minatare on the North Platte River, about 50 km east of the Wyoming-Nebraska boundary, to Grand Island on the Platte River in central Nebraska, a river distance of about 480 km (fig. 1). Throughout most of this stretch, the river is several hundred meters wide and only 0-2 m deep. The drop in elevation is from 1,162 m above mean sea level at Minatare to 558 m above mean sea level at Grand Island or about 604 m—an average slope of about 0.00126 m/m.

Many islands of various sizes, some bare sand and others completely vegetated, dot the channels. This gives the rivers a braided pattern. Few tributaries of any size enter the study reach from the south, but several enter from the north. Alluvial sand, gravel, and loam make up most of the Platte valley. The adjacent plains consist mainly of loess.

The climate ranges from semiarid in the west to subhumid in the east. Mean annual rainfall near Lake McConaughy is about 460 mm and this gradually increases eastward to about 625 mm at Grand Island. About 80 percent of the annual precipitation falls during April-September. A few violent thunderstorms usually occur in late spring and early summer.

HYDROLOGY

GENERAL

Analysis of U.S. Weather Bureau precipitative data for North Platte, Kearney, and Grand Island reveals that there have been no significant long-term trends or changes in total annual precipitation for these cities during the period 1900-74. Therefore, any observed long-term changes in streamflow probably are not attributable to changes in climate.

Flow in the North Platte and Platte Rivers depends not only on climatic and geologic conditions but also on many influences of man. Transmountain diversions occur in the headwaters of the North Platte. Several dams on the North Platte (table 1) detain and store the flow and regulate the downstream discharge. Within the study reach, many structures—especially Keystone Dam (and Sutherland Canal) since 1937 and the Tri-County Diversion Dam (and Tri-County Canal) since 1941—divert significant amounts of river water via canals to offstream reservoirs, irrigated croplands, or powerplants (fig. 2). A considerable quantity of ground water is pumped from wells for irrigation of lands bordering the Platte River. Excess irrigation water and hydropower releases reenter the Platte at various locations. Increasing population over the years has demanded more and more water from the river.

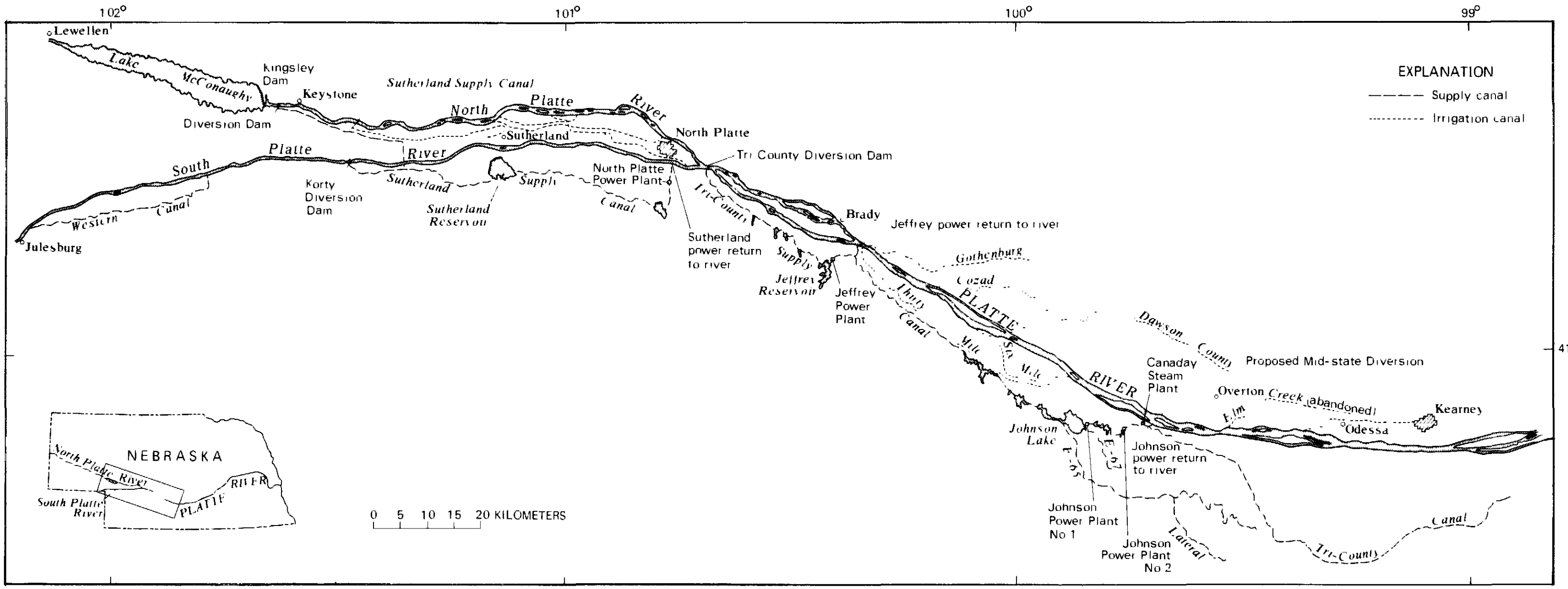

FIGURE 2.—Main water-use features of the Nebraska Public Power District and the Central Nebraska Public Power and Irrigation District (modified from Bentall, 1975, p. 30).

TABLE 1. — *Major storage reservoirs on the North Platte River, in downstream order*

[From Dragoun, F. J., unpublished data, 1976]

Name of reservoir	Date storage began	Maximum storage capacity (m^3)	Nearest town
Seminoe	April 1, 1939	$1.25x10^9$	Leo, Wyo.
Pathfinder	April 1909	$1.26x10^9$	Alcova, Wyo.
Alcova	Feb. 8, 1938	$2.35x10^8$	Alcova, Wyo.
Glendo	Oct. 17, 1957	$9.84x10^8$	Glendo, Wyo.
Guernsey	July 1927	$5.52x10^7$	Guernsey, Wyo.
McConaughy	Feb. 9, 1941	$2.40x10^9$	Ogallala, Nebr.

Furthermore, the greater amount of vegetation (described later in this report) now growing along the present channel probably consumes much more water through evaportranspiration than formerly (Dragoun, unpublished report, 1976).

Irrigation along the Platte began about 1870 (McKinley, 1938, p. 101). The benefits of irrigation were viewed somewhat skeptically for the following 20 years or so, in spite of several impressive examples of its usefulness. General acceptance of irrigation came in the 1890's, at which time the total mileage of irrigation ditches and canals expanded rapidly. (See Bentall, 1975, p. 24-34, for a summary of the history of irrigation.)

What have been the effects of all these influences of man on the river's flow characteristics? It is impossible to isolate and identify the influence of any one factor (storage reservoir, irrigation diversion, and so forth), because (1) several such factors have operated in varying degrees simultaneously, and (2) measurements of water discharge are scarce for most gaging stations prior to the 1930's. Nevertheless, it might be possible to determine roughly the effects of certain major influences, such as big dams.

Table 5, at the end of this report, gives the entire record available of annual peak flows, mean annual discharges, and number of days per year of no flow for each of the 12 gaging stations in the study reach. The stations are listed in downstream order. All data were taken from U.S. Geological Survey publications, especially water-supply papers. For the present study, the data were converted into metric units.

PEAK DISCHARGES

Dams store water for irrigation and hydroelectric power production. They also provide some measure of downstream flood protection by detaining or impeding the big flows. The more dams that are built, the greater the likelihood that the natural high flows will be retarded. The peak-flow data in table 5 should reveal whether this has been accomplished on the North Platte and Platte Rivers, if we can assume that the effects of canals and other diversions on peak flows are small compared to the effects of the major dams. Discharges measured prior to 1909, when Pathfinder was built, most closely represent natural flows. The magnitudes of all post-1909 peaks are to varying degrees the result of an increasing amount of control by man as more and more dams and diversion structures have been built.

Table 2, based on the data in table 5, shows the average yearly peak flows for the approximate time periods indicated by the dam constructions in table 1. The brief period from 1971 to the present is omitted in this analysis because in 1971, 1973, and 1974, the various reservoirs had to bypass abnormally large inflows from spring snowmelt, thus producing unusually high peaks for stations in the study reach (Bentall, 1975, p. 7-9).

The first four stations (Minatare to Lewellen) are not influenced by Lake McConaughy (1941 and later) and are less affected by major diversions. These stations therefore are more apt to reveal the approximate effects of the upstream dams on peak discharges. Table 2 shows that, for each of these stations, average peak discharge has decreased consistently and progressively after closure of each major dam.

Discharges at some or all of the stations downstream from Lewellen have been influenced since the mid-1930's or shortly thereafter by Lake McConaughy, the Sutherland Canal, the Tri-County Canal, Johnson Power Plant releases (fig. 2), and other features. Average peak flows for all periods of record prior to 1957 decreased consistently. The average peak discharges for the period 1957-70 have increased slightly (table 2).

At the three stations having records in the pre-dam era (before 1909), the average yearly peak flow for the most recent period (1957-70) was only about 0.1-0.2 of the average peak flow for the pre-1909 period. This is a considerable reduction. At the seven stations having records for both the 1909-27 and 1957-70 periods, the average peak flow for the latter period was only about 0.1-0.3 of the average yearly peak for the earlier period.

MEAN ANNUAL DISCHARGES

By withholding or diverting water which otherwise would flow downstream, dams also lower the mean annual discharges at downstream stations, unless other factors influence the flow. The right-hand part of table 2 shows average values of mean annual discharge for the same time periods discussed earlier. As with peak flows, the pre-1909 flows were least affected by man, whereas flows in recent decades were almost entirely regulated and used.

As with peak discharges, the average values of mean annual discharge at most gaging stations have generally decreased with successive time periods. This trend is most pronounced at the upstream stations, as expected. For the two stations which have records prior to 1909, namely Bridgeport and North Platte, the average of the mean annual discharges for the 1957-70 period was roughly 0.2-0.3 that of the pre-1909 period. Four stations (table 2) have enough data to permit a comparison of the 1909-27 and 1957-70 periods.

TABLE 2.—*Average water discharges (geometric means) for selected historical periods*

[Each period begins with closure of an upstream dam. Numbers in parentheses are numbers of years of record available within applicable period]

Station	Average of yearly peak flows, in cubic meters per second, for period indicated					Average of mean annual discharges, in cubic meters per second, for period indicated				
	Before April 1909	April 1909-June 1927	July 1927-March 1939	April 1939-Oct. 16, 1957	Oct. 17, 1957-1970	Before April 1909	April 1909-June 1927	July 1927-March 1939	April 1939-Oct. 16, 1957	Oct. 17, 1957-1970
Minatare	736 (1)	300 (12)	140 (11)	92 (19)	72 (13)	- (0)	63 (5)	30 (11)	22 (19)	19 (13)
Bridgeport	440 (9)	261 (13)	149 (12)	110 (18)	91 (13)	83 (4)	67 (11)	38 (12)	31 (18)	28 (13)
Lisco	- (0)	311 (2)	116 (8)	107 (18)	84 (13)	- (0)	- (0)	31 (8)	34 (18)	31 (13)
Lewellen	- (0)	- (0)	- (0)	118 (17)	96 (13)	- (0)	- (0)	- (0)	39 (16)	33 (13)
Keystone	- (0)	575 (1)	- (0)	76 (16)	81 (13)	- (0)	- (0)	- (0)	11 (15)	8.4(13)
Sutherland	- (0)	575 (1)	152 (5)	59 (18)	68 (13)	- (0)	- (0)	26 (3)	9.8(18)	8.8(13)
North Platte	511 (14)	295 (18)	217 (13)	73 (18)	72 (13)	88 (13)	80 (18)	50 (13)	17 (18)	16 (13)
Brady	- (0)	- (0)	218 (2)	87 (18)	100 (13)	- (0)	- (0)	52 (1)	12 (18)	11 (13)
Cozad	- (0)	- (0)	204 (1)	79 (18)	84 (13)	- (0)	- (0)	- (0)	9.6(18)	8.8(13)
Overton	- (0)	443 (10)	293 (12)	150 (18)	140 (13)	- (0)	101 (13)	51 (12)	29 (18)	33 (13)
Odessa	- (0)	- (0)	196 (3)	145 (18)	165 (13)	- (0)	- (0)	38 (2)	25 (18)	31 (13)
Grand Island	- (0)	- (0)	312 (6)	169 (18)	174 (13)	- (0)	- (0)	28 (6)	26 (18)	33 (13)

Minatare's average mean annual discharge for 1909-27 was 63 m^3/s and for 1957-70 was only 19 m^3/s, or only 0.30 of the former value. Similar comparisons for the Bridgeport, North Platte, and Overton stations show the recent (1957-70) flows to have been 0.42, 0.20, and 0.33, respectively, of the 1909-27 values.

In general then, both peak discharges and mean annual discharges have decreased significantly over the years at most stations. Table 2 shows that many of these reductions correlate with the appearance of upstream dams.

DAYS OF NO FLOW

Long-time residents in the downstream part of the study reach say that the river was often completely dry in late summer. For the period of record (at least the last 35 years or so), all stations within the study reach except the two farthest downstream (Odessa and Grand Island) have, with rare exceptions, carried water throughout the year (table 5).

The Overton station had no flow at times in 1919, 1922, 1925, 1927-28, and 1930-41. In 1941 the Tri-County Canal system began routing water back into the Platte River about 11 km upstream from the Overton gaging station, and since then the Platte at Overton has always had some flow.

The Odessa and Grand Island stations do have some rather dry years, at times. For these stations, the meager data of table 5 indicate fewer days of no flow after 1941 than before, with Grand Island usually having more such days than Odessa.

Because of the upstream dams and the decrease in water discharge, the sediment loads in the study reach probably have decreased also.

THEORETICAL CHANNEL CHANGES

The response of a channel to a decrease in both water and sediment discharge can be predicted qualitatively but not quantitatively. Schumm (1969, p. 261) presents the following relation, in which (+) designates increase and (-) designates decrease:

$$Q_w^- \cdot Q_t^- \simeq \frac{W^- L^- (W/D)^-}{P^+} S^{\pm} D^{\pm}$$

where Q_w=water discharge, Q_t=percentage of total sediment that is bedload, W=bankfull width, L=meander wavelength, D=maximum channel depth, S=slope, and P=sinuosity.

Compared with the channel of the latter part of the 19th century, the present channel therefore should show a decrease in width, a decrease in meander wavelength, a decrease in the width/depth ratio, and an increase in sinuosity. Slope and maximum depth today could be greater than, equal to, or less than their former values.

The meander wavelength is not applicable to the study reach because the river tends to be braided rather than meandering. The next section describes changes in the remaining dependent variables and in other channel features.

CHANNEL CHARACTERISTICS

Photographs are an excellent way to compare the general nature of the river channel at different times. Unfortunately, old pictures of the North Platte and Platte Rivers are scarce. I did find a few, however, and took or obtained pictures of the same sites as they look today (figs. 3-10).

Comparison of the old and new pictures of the same sites reveals that the 1977 channel is radically different from that of 70-100 years ago. The most striking changes apparent from the photographs are a decrease in channel width and an increase in vegetation.

Historical accounts, in addition to the above photographs, verify that the North Platte and Platte Rivers were very wide in the 19th century. Estimates of six different explorers, from Robert Stuart in 1813 to Jesse Gove 1857, indicate that the river width at various points along the study reach ranged from about ½ to 3 miles (800-4,800 m). Fremont (1843, p. 19), in the report on his 1842 scientific exploration of the Platte, stated that the channel was 5,350 feet (1,630 m) wide immediately below the junction of the North Platte and South Platte Rivers. The Union Pacific Railroad survey of 1866 agrees with this figure and also indicates that the Platte River from Kearney to North Platte was about ¾ to 1¼ miles (1,200-2,000 m) wide. The U.S. Government survey of 1865-70, discussed in more detail below, shows about these same widths in this reach. As the present photographs (figs. 3-10) show, the 1977 channel is considerably narrower.

From about 1938 to about 1969 the U.S. Department of Agriculture has taken aerial photographs of much of the study reach. A comparison of the photographs of a given area shows what general changes, if any, have taken place over that recent 31-year period. This comparison probably is most useful for the reach from Lake McConaughy downstream, because the first set of aerial photographs was taken just before construction of the dam and lake.

Figures 11-16 show the 1938 channel compared to the 1969 channel at selected reaches. All photographs shown here were taken during July. These photographs, while not chosen randomly for presentation, are fairly representative. Once again a general decrease in channel width and an increase in vegetation appear. To describe these and other features more completely, detailed measurements or additional observations were made, as described in the following paragraphs.

WIDTH

DATA AND PROCEDURE

Measurements of channel width were made from the original U.S. Government plats of Nebraska (about 1865-75), U.S. Department of Agriculture 1938 aerial photographs, and U.S. Geological Survey topographic maps (various years generally within the period 1962-72). These three major sources of data permitted a determination of channel width at three different times (hereafter referred to as 1865, 1938, and 1965). In addition, some measured cross sections were provided by the Burlington Northern Railroad (formerly Chicago, Burlington, and Quincy Railroad), Nebraska Department of Roads, U.S. Geological Survey, Union Pacific Railroad, Central Nebraska Public Power and Irrigation District, and the U.S. Bureau of Reclamation.

Channel-width determinations were made simply by measuring the bank-to-bank width at the cross section of interest on the particular map or aerial photograph. In computing channel width, the width of stabilized islands (those covered by perennial vegetation) was subtracted from the bank-to-bank width of the general channel. Where the Platte River separates into several distinct channels, the channel width was taken as the sum of the various individual channels. Thus the width data presented here approximately represent the width of flowing water at bankfull flow.

Most of the available measured cross sections are at bridges. These sections do not necessarily reflect the kinds of channel changes that occur in more natural reaches. A selection of natural cross sections was made by measuring channel width at the eastern edge of every other range (R. 54 W., R. 52 W., and so forth). This provided 23 sites within the study reach. (Two range lines happened to fall at bridges, and for these cases the measuring site was moved 0.5 km upstream.)

RESULTS

Table 3 and figure 17 show the channel width in 1865, 1938, and 1965. The widths at any one time do not show any systematic change in the downstream direction. However, the graphs clearly show the overall decrease in channel width that has occurred over the past 100 years. The channel in 1938 was somewhat narrower than it was in 1865 at those sites for which 1938 aerial photographs were available. By 1965 the channel at all measuring sites was still narrower. Figure 18, which depicts the proportional decrease in width from 1865 to 1965, shows that in

FIGURE 3.—Site of old Bayard bridge. *A*, bridge used from about 1900-1913. Photo from Nebraska State Board of Irrigation, Highways, and Drainage, 1914, p. 172. *B*, 1977 view of same cross section. *C*, piers of 1900-1913 bridge several hundred meters from present (1977) left bank.

1965 the channel at many cross sections was only about 0.1-0.2 as wide as it was in 1865. Recent field measurements of the channel width at several sites agree reasonably well with widths measured on recent topographic maps.

The lesser decrease in width that has occurred in the downstream 115 km or so of the study reach (fig. 18) probably is due to the Johnson Power Plant returns to the Platte at about kilometer point 408, about 11 km upstream from Overton.

The process of channel narrowing has been accelerated locally at railroad and highway crossings. Here the builders usually try to reduce construction expenses by constricting the channel at the time of construction by dumping in artificial fill along the travel route. At some crossings additional fill was dumped on subsequent occasions after the original completion of the crossing (fig. 19).

Such artificial constrictions of the channel typically interrupt the flow and cause the river to deposit sediment along both banks just upstream and downstream from the bridge, especially downstream (figs. 12-15, 20). The deposit seems to extend only for about a distance of one or two channel widths (original channel) from the bridge. Bridges, therefore, have had only local effects on the overall narrowing of the Platte and are not the major cause of the narrowing.

The size of a river channel depends to a significant extent on the water discharge. Large discharges create big channels; whereas, small flows carve small channels. The North Platte and Platte Rivers in the late 1800's carried high discharges and were very wide, as the hydrology and channel width discussions have shown. The present channels carry low and sustained flows and are relatively narrow compared to the early days. Figures 21-26 show the general trend by which the channel width has decreased as a function of the water flow at two sites—North Platte River at North Platte (1.4 km upstream from the Union Pacific Railroad bridge) and the Platte River near Overton (2 km upstream from the gaging station). The procedure in constructing these figures for each station was as follows:

1. The flow data of table 5 were condensed into 5-year arithmetic averages and were plotted against year (figs. 21*A*, 21*B*, 24*A* and 24*B*). (The average discharge of each 5-year period was plotted against the mid-year of that respective period.)
2. A line was sketched by eye to represent the approximate long-term general trend of the discharges. (I considered the abnormally high flows of 1971, 1973 and 1974 to be atypical, that is, not representative of the general trend since 1940.)
3. A plot of channel width versus year was made by plotting the measured width against the corresponding year for that width (figs. 21*C* and 24*C*). For this purpose two width values for each station were obtained from the original plats of Nebraska (about 1868) and the 1938 aerial photos, mentioned earlier. Additional widths for the North Platte site were measured from the 1899 15-minute U.S. Geological Survey topographic map, a 1965 U.S. Dept.

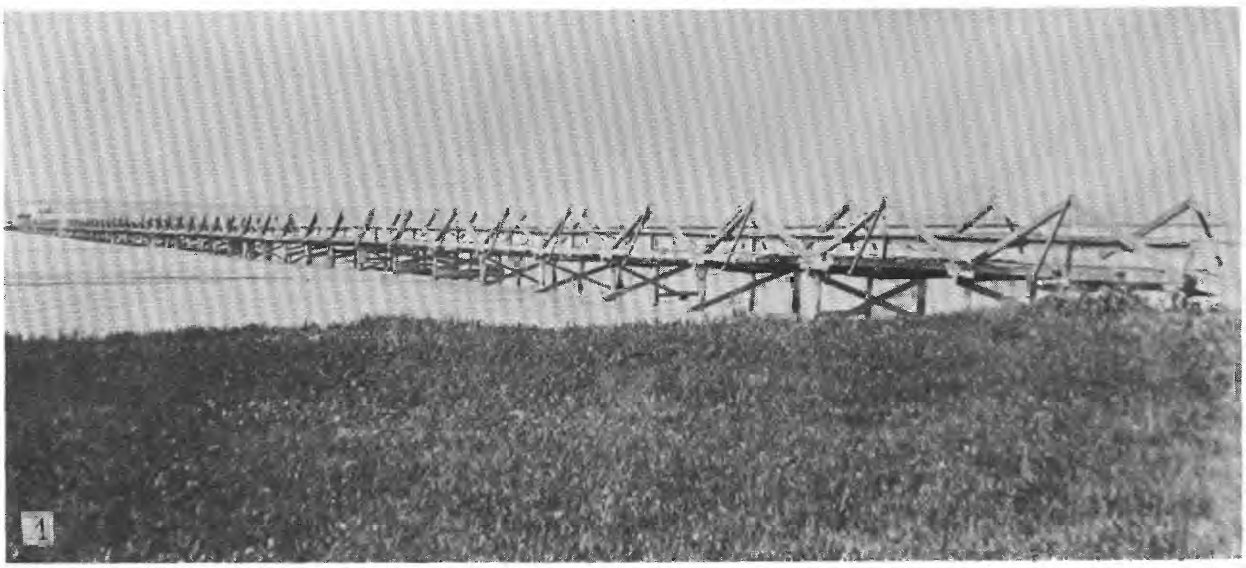

FIGURE 4.—Site of old Camp Clark bridge about 8 km west of Bridgeport. *A*, bridge used from about 1876-1903. View may be from an island in the river. Photograph from Paul Henderson. *B*, view of site in 1968. Present bank of river is just below lower edge of photograph. Arrows point to remaining piers of old bridge. Photograph from Joe Fairfield.


B

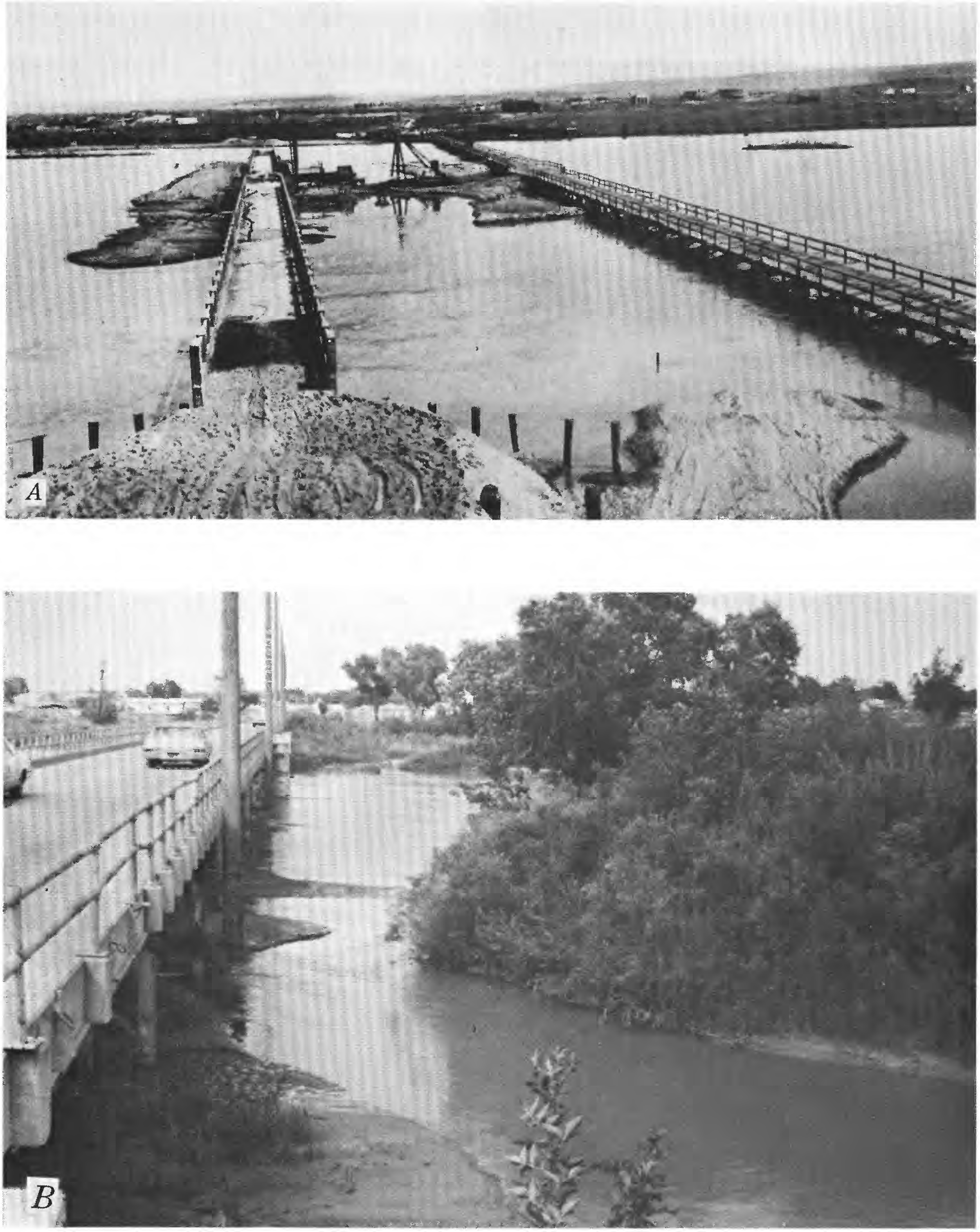

FIGURE 5.—North Platte River at Bridgeport, looking north. *A*, old bridge (right), with newer bridge under construction, about 1913. Photograph from Nebraska State Board of Irrigation, Highways, and Drainage, 1914, p. 188. *B*, the same cross section in 1977.

FIGURE 6.—Union Pacific Railroad bridge, North Platte River at North Platte, looking northeast. *A*, 1869 view (W. H. Jackson photograph, from U.S. Geological Survey files); *B*, 1977 view taken from about same location as *A*; *C*, the main channel in 1977.

FIGURE 7.—Platte River bridge at Kearney, probably about 1900. Photograph from Nebraska State Historical Society.

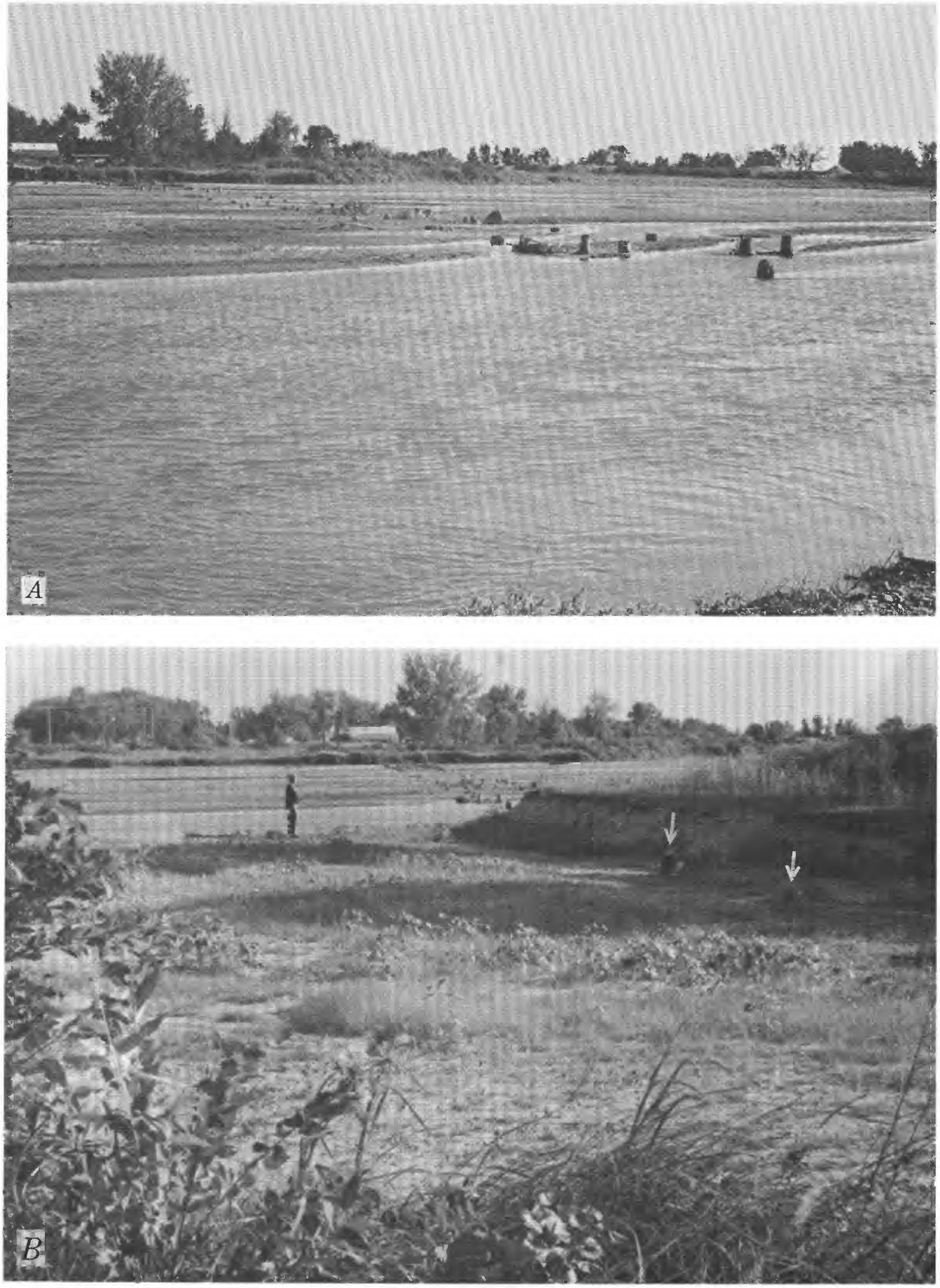

FIGURE 8.—Site of old Platte River bridge at Kearney—1977 views, looking north. *A*, scene from right bank, showing old bridge piers; *B*, view showing old piers (arrows) on present flood plain, as well as piers in channel. Woman standing on top edge of right bank.

FIGURE 9.—Platte River bridge about 8 km southeast of Grand Island (location of present U.S. Highway 34 bridge), looking southeast, about 1900. Photograph from the Stuhr Museum of the Prairie Pioneer.

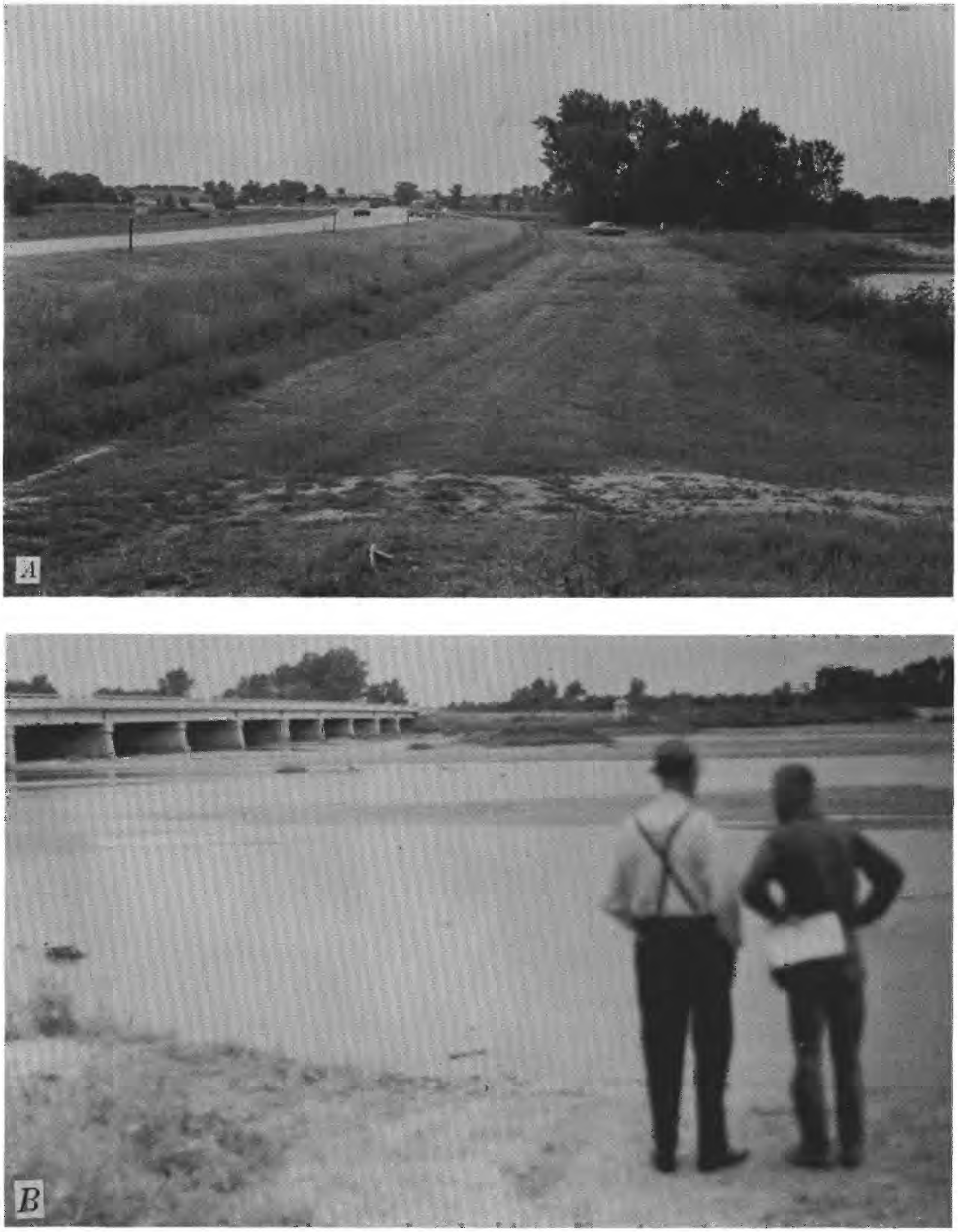

FIGURE 10.—Site of old Platte River bridge (fig. 9) southeast of Grand Island—1977 views. *A*, view of cross section from about same point as fig. 9; *B*, present channel, looking northwest.

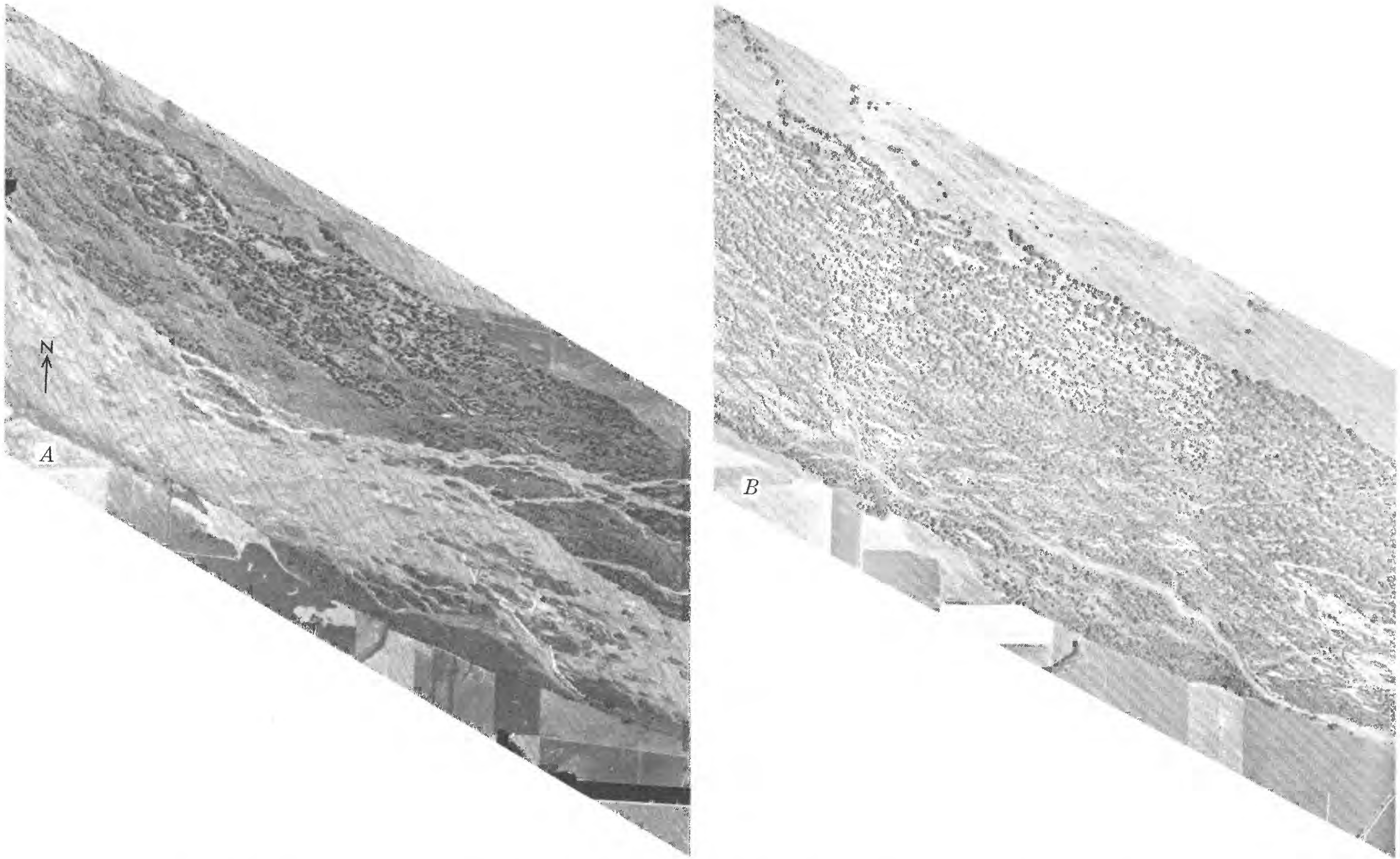

FIGURE 11.—Comparative aerial views of 1938 (*A*) and 1969 (*B*) channels of Platte River about 6 km west of Cozad and about 368 river km from Nebraska-Wyoming line. Photos from U.S. Dept. Agriculture.

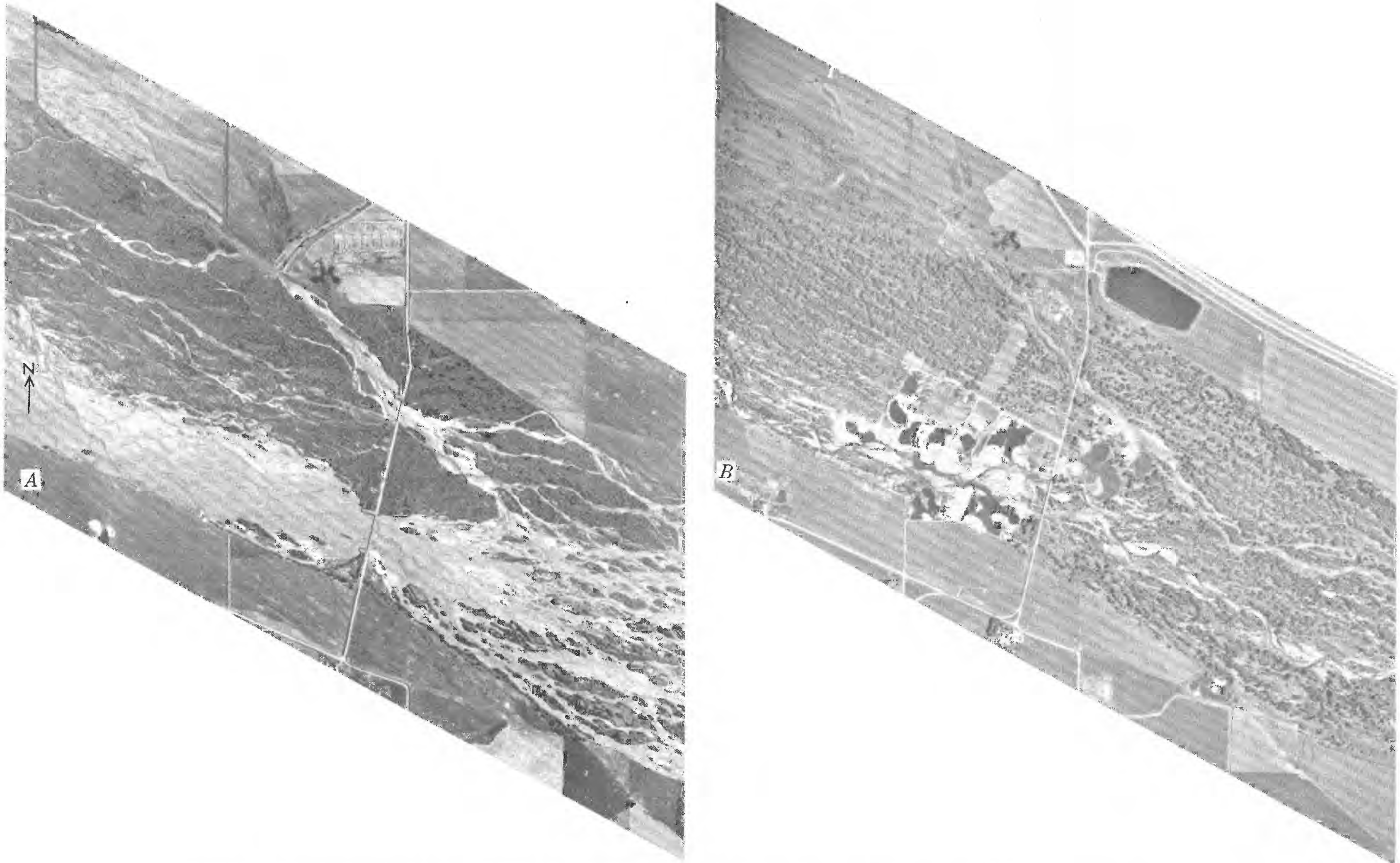

FIGURE 12.—Comparative aerial views of 1938 (*A*) and 1969 (*B*) channels of Platte River about 2 km south of Cozad and about 374 river km from Nebraska-Wyoming line. Photos from U.S. Dept. Agriculture.

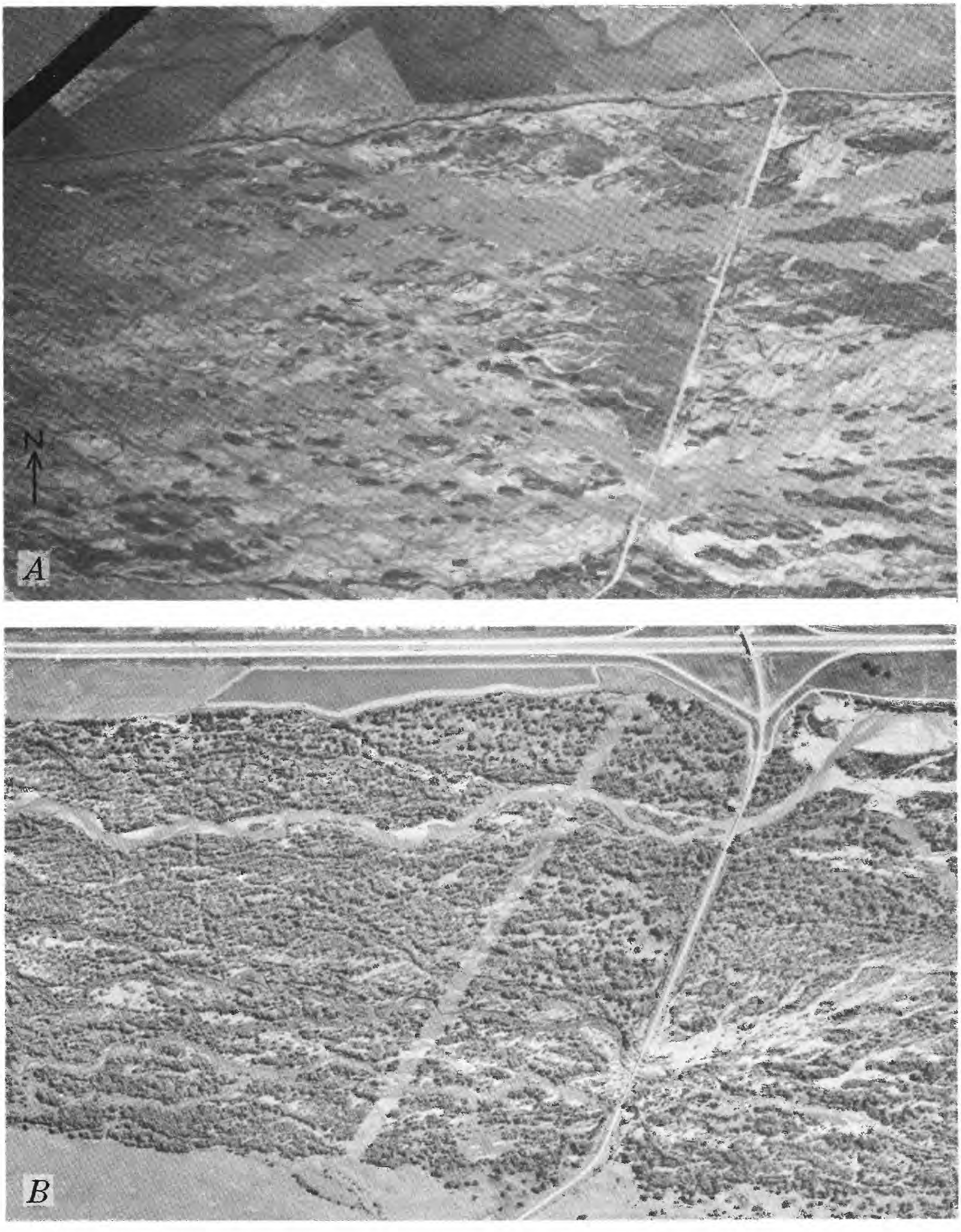

FIGURE 13.—Comparative aerial views of 1938 (*A*) and 1969 (*B*) channels of Platte River about 7 km west of Lexington and about 384 river km from Nebraska-Wyoming line. Photos from U.S. Dept. Agriculture.

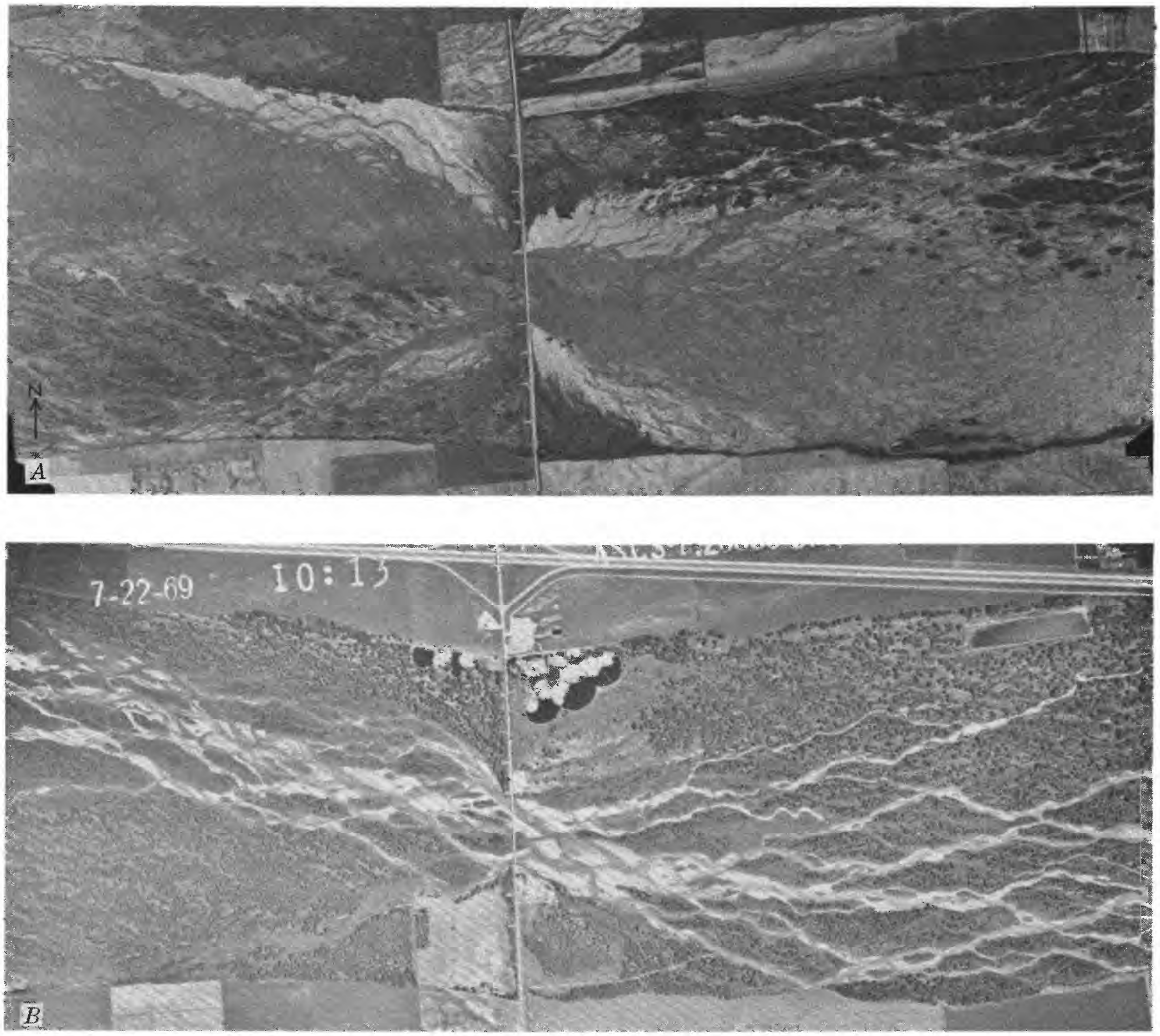

FIGURE 14.—Comparative aerial views of 1938 (*A*) and 1969 (*B*) channels of Platte River, about 12 km west of Kearney, at the U.S. Geological Survey gaging station near Odessa (river km 443). Photos from U.S. Dept. Agriculture.

Agriculture aerial photo (same type and scale as the 1938 photo) and the U.S. Geological Survey's 1970 7½-minute topographic map. For the Overton site additional widths were obtained from a 1951 U.S. Dept. Agriculture aerial photo, 1962 U.S. Geological Survey 7½-minute topographic map and 1969 U.S. Dept. Agriculture aerial photo (same scale as the 1938 photo).

4. A line was drawn by eye to show the approximate long-term general trend of the channel width (figs. 21*C* and 24*C*).

5. At the mid-year of each successive 5-year period, values of width and associated discharge were read from the appropriate curves.

6. For each station and type of discharge (peak flow and mean annual flow), a graph of width versus discharge was constructed, consisting of the plotted points for all 5-year periods (figs. 22, 23, 25 and 26).

Figures 22, 23, 25 and 26 show the circuitous trend which the width-discharge relations have followed at the North Platte and Overton reaches, during the period of record. The figures also give a perspective of the reductions in width and flow that have occurred at these sites. For example, by 1965-69 the average annual peak flows at the North Platte site were only about 0.15 of their 1895-99 values. Mean annual flows

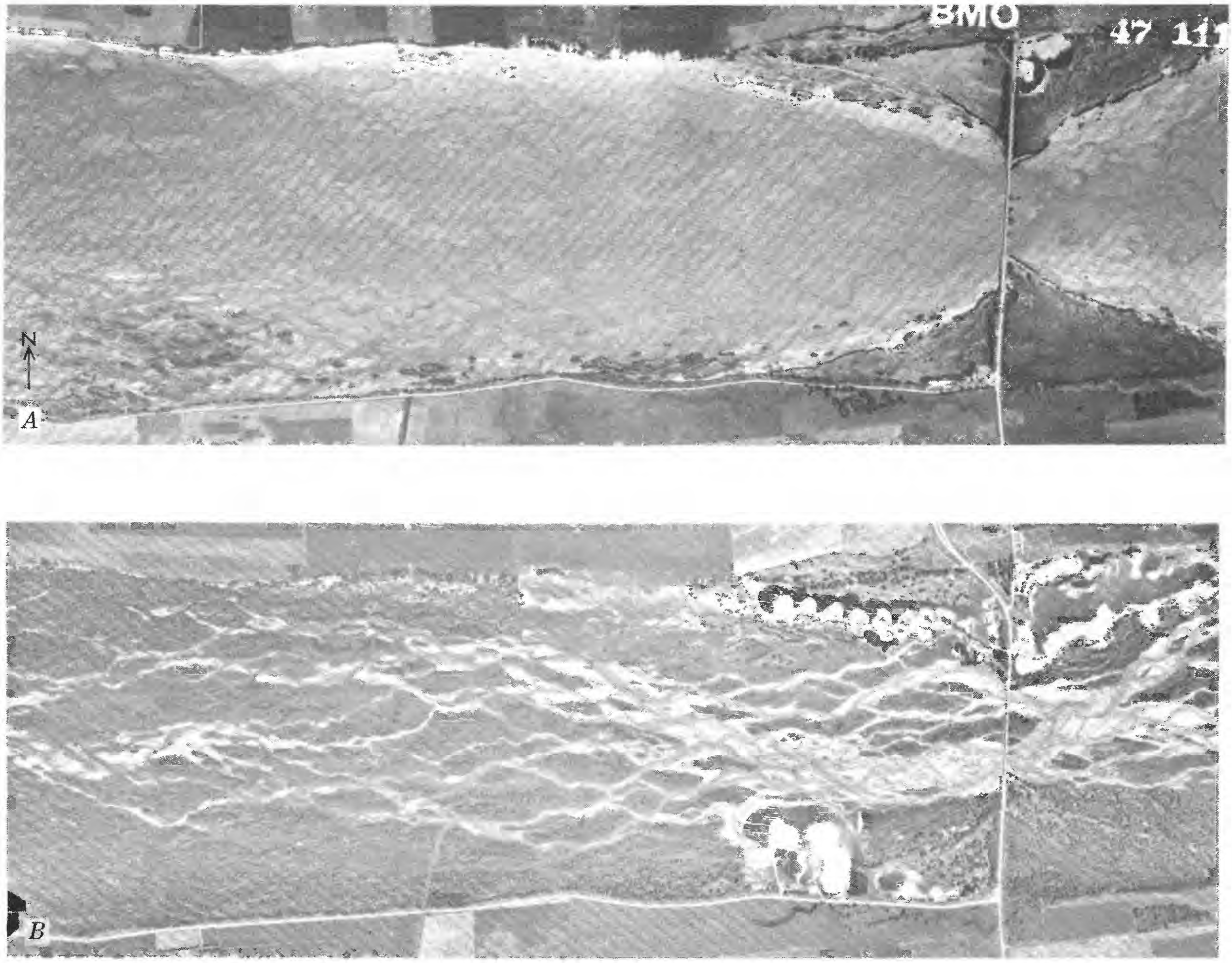

FIGURE 15.—Comparative aerial views of 1938 (*A*) and 1969 (*B*) channels of Platte River, directly south of Kearney (bridge of State Routes 10 and 44), at river km 457. Photos from U.S. Dept. Agriculture.

by 1965-69 were about 0.2 of what they were at the turn of the century at North Platte, and the channel was only 0.14 as wide. At the Overton site the 1965-69 peak flows, mean annual flows and channel width were each about 0.3 of their 1915-19 values. Other sites in the study reach have undergone comparable reductions, as the flow and width data presented above have shown.

VEGETATION

Explorers' reports generally agree on the amount of vegetation along the North Platte and Platte River in the 1800's. The numerous islands in the river for the most part were heavily wooded in those days, usually with cottonwood and willow trees. The river banks, on the other hand, only rarely had any trees. The shorelines of the North Platte River within the study reach, especially the left bank, were particularly barren: "...not a twig to be seen..." (Robert Stuart, 1813 in Rollins, 1935, p. 210); "You will find no more timber on the north side of the river for 200 miles except one lone tree" [starting up the North Platte] (Clayton, 1848, p. 8).

In spite of the agreement on the scarcity of trees and shrubs along the North Platte and Platte's banks during much of the 19th century, there is little agreement as to the cause of this. Some of the theories are that the trees didn't like the growing conditions, Indians and white travelers chopped down the trees for firewood, prairie fires destroyed the trees, big floods periodically washed out the young trees, and buffalo and other animals ate all the available vegetation. The trees certainly were cut down in some areas, such as near Kearney in 1848-49 for the construction of Fort Kearney.

FIGURE 16.—Comparative aerial views of 1938 (*A*) and 1969 (*B*) channels of Platte River south of Shelton about 1 km east of Buffalo County-Hall County line and at river km 490. Photos from U.S. Dept. Agriculture.

Today's channel seems to have more trees along the banks than during most of the 19th century. More striking, however, is the lush vegetation, including trees of all sizes, that occupies much of the zone that used to be stream channel (figs. 3-16).

The development of vegetation on sandbars within the old channel typically begins with sedges (Carex sp.). Grasses follow, and finally dense willows and other trees take hold (Ruby, 1952). Field observations, other studies (Sutherland, 1974; Bunde and others, 1975), and U.S. Geological Survey gaging station descriptions indicate that the kinds of trees within the study reach today are mainly willow, cottonwood, elm, ash, elder, and hackberry. Grasses, ragweed, sunflowers, dogwood, and mulberry bushes plus many other plants complement the tree growth.

BRAIDING

DEFINITION

Braiding is the formation of two or more alluvial channels, separated by one or more islands, within a main channel. The process tends to produce a network of small interlaced channels separated by islands or bars.

The present evaluation of braiding considers only islands and omits bars. For this purpose, an island is defined as a land mass which is located within the main

TABLE 3.—*Basic data for channel width, braiding, and sinuosity*

Number	Station[a]	River distance from Nebr.-Wyo. line (km)	Total channel width (m)			Braiding index		Sinuosity	
			1865	1938	1965	1938	1965	1938	1965
1	Minatare	53.3	975	-	55	-	-	-	-
2	R52W	78.8	810	-	105	-	-	-	-
3	Bridgeport	90.8	1140	-	120	-	-	-	-
4	R50W	98.4	810	-	130	-	-	-	-
5	R48W	120.3	1255	-	170	-	-	-	-
6	Lisco	135.6	1280	-	150	-	-	-	-
7	R46W	141.6	1060	-	185	-	-	-	-
8	R44W	166.3	545	-	200	-	-	-	-
9	Lewellen	182.9	885	-	150	-	-	-	-
10	R42W	187.5	810	-	165	-	-	-	-
11	R40W[b]	206.9	710	-	-	-	-	-	-
12	Keystone	225.4	950	-	-[c]	1.21	0.0[c]	1.06	1.00[c]
13	R38W	226.8	940	200	45	1.21	0.0	1.06	1.00
14	R36W	247.4	850	815	45	8.13	2.58	1.00	1.11
15	R34W	266.9	750	325	195	2.23	0.26	1.06	1.11
16	Sutherland	270.8	-	410	75	2.13	2.20	1.05	1.30
17	R32W	286.8	740	460	45	3.48	1.91	1.03	1.05
18	North Platte	302.6	790	520	90	3.44	1.76	1.06	1.11
19	R30W	312.9	1200	560	120	1.26	0.80	0.97	1.05
20	R28W	332.0	1145	975	185	-	-	-	-
21	Brady	338.8	1250	340	45	0.18	0.51	1.12	1.18
22	R26W	353.5	1405	1215	90	10.93	4.09	1.05	1.16
23	R24W	375.5	1070	435	140	7.35	4.70	1.05	1.08
24	Cozad	376.3	920	440	40	-	-	-	-
25	R22W	397.0	1380	1155	60	2.92	2.02	1.01	1.05
26	Overton[d]	418.6	1610	1520	335	2.03	1.53	1.11	1.05
27	Overton (R20W)	419.1	1465	880	335	-	-	-	-
28	R18W	438.5	1660	1335	1135	6.71	5.17	1.00	1.08

TABLE 3.—*Basic data for channel width, braiding, and sinuosity*—Continued

Number	Station[a]	River distance from Nebr.-Wyo. line (km)	Total channel width (m)			Braiding index		Sinuosity	
			1865	1938	1965	1938	1965	1938	1965
29	Odessa	442.6	1250	930	490	-	-	-	-
30	R16W	458.7	1405	1185	940	0.78	5.85	1.00	1.05
31	R14W	478.2	950	700	495	0.48[e]	0.60[e]	0.98[e]	0.985[e]
32	R12W	499.0	1220	1090	885	0.98	4.55	1.00	1.00
33	R10W[d]	518.6	655	655	465	1.06[e]	0.71[e]	1.00[e]	1.005[e]
34	R9W (Approx.)	527.2	-	-	-	0.66	1.34	1.00	1.00
35	Grand Island	529.6	-	730	760	-	-	-	-

[a]Name, location of USGS gaging station; range, cross section where river crosses eastern edge of designated range.

[b]Middle of Lake McConaughy.

[c]Artificially straightened sometime between 1938 and 1969.

[d]One-half km upstream, to avoid bridge section.

[e]Braiding index and sinuosity = average of two channels.

channel, is surrounded by water channels, and is stabilized by perennial vegetation.

The degree of braiding is here measured by a "braiding index" (B.I.), defined as

$$\text{B.I.} = \frac{\text{sum of length of islands in reach}}{\text{length of reach, measured midway between banks}}$$

This definition is patterned after, and similar to, that which Brice (1964, p. D27) proposed. The difference is that Brice multiplied the numerator by 2, thus obtaining for the numerator an approximation of the sum of island perimeters, rather than their lengths.

With the present definition, a B.I. of zero means the stream is not braided (has no islands). A B.I. of 0.5 means that island lengths amount to one-half the length of the reach measured. Similarly, if the sum of the island lengths equals the length of the reach, the B.I. is 1.0; if the sum is 10 times the length of the reach, the B.I. is 10.0.

The braiding index is not perfect in that a reach with many small islands could produce a braiding index that is less than, equal to, or greater than the same reach distance with one large island. A complete braiding index probably should include not only the lengths of the islands but also their number and density. The latter two features are reflected only indirectly in the braiding index used here. In many situations, however, the present braiding index should be generally indicative of anastomosing tendencies within a channel.

MEASUREMENTS

Braiding indices were measured from Keystone to Grand Island, a distance of about 300 km. Reaches measured within this stretch were those analyzed in the channel width aspect of this study plus those at U.S. Geological Survey gaging stations, if not already included in the former.

All braiding indices were determined from aerial photographs (1938-39 and 1965-69). Islands stabilized

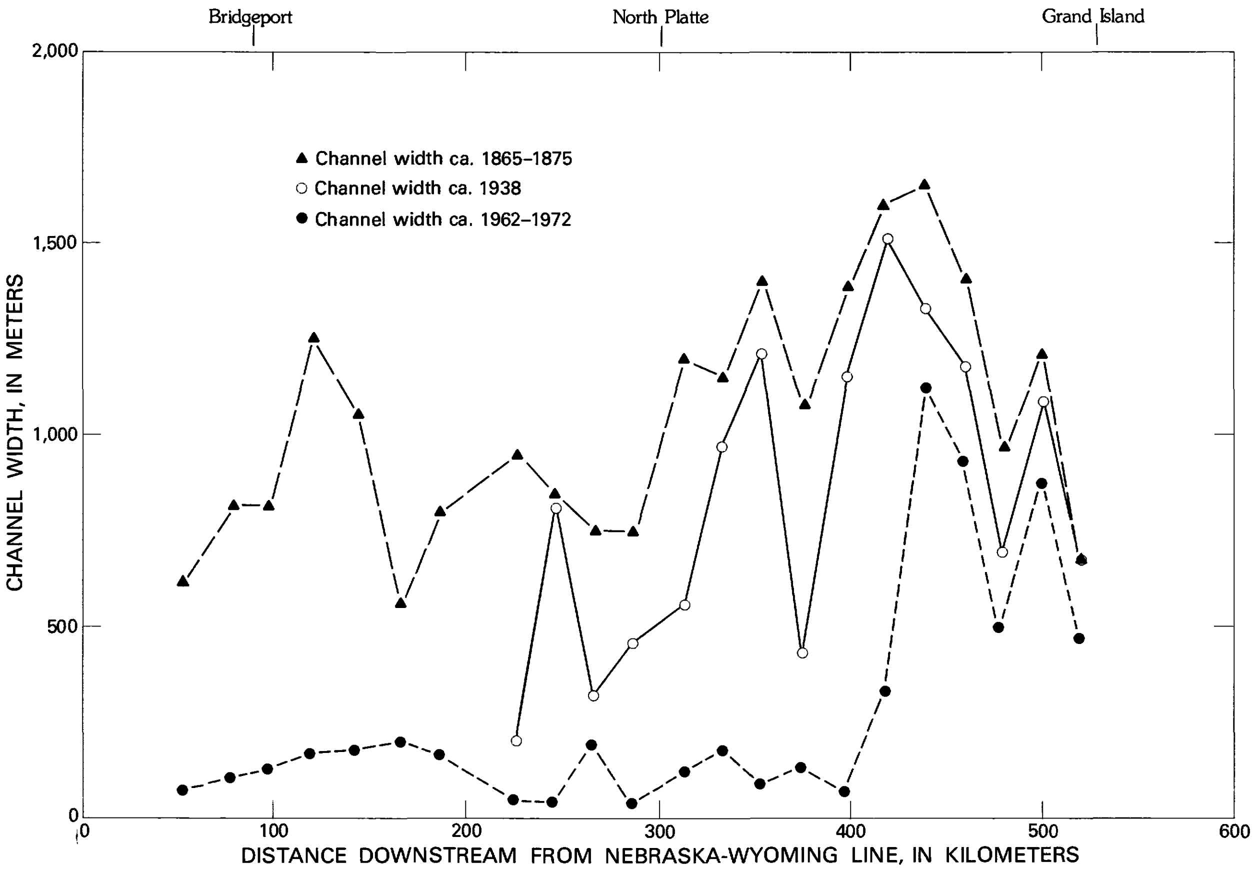

FIGURE 17.—Channel width at different time periods.

by perennial vegetation show up very clearly on such photographs. The length of reach examined was 2 km (1 km upstream from the cross section and 1 km downstream).

The braiding indices determined here involve only those islands located within the main channel. Excluded were islands within the former channel but which, on the aerial photograph examined, were essentially outside the existing main channel. Such old islands usually are surrounded by a distinct paleochannel or by a trickle of water. The existing main channel on aerial photographs usually is readily identifiable as a broad, sandy, generally unvegetated swath.

RESULTS

Table 3, presented earlier, lists all the computed braiding indices. Figure 27 shows how these indices vary with distance downstream. Nearly all reaches sampled are braided to varying extents.

Throughout most of the reach from Lake McConaughy to Grand Island, the river was somewhat less braided (had fewer and/or smaller islands) in 1969 than in 1938. The chief exception to this tendency is the downstream 100 km or so of the reach where the braiding either was greater in the 1969 channel or is about the same for both time periods.

In 1969, the flow in many channels was only a trickle, and the islands were so large relative to this small channel that I decided such islands should not be considered part of the general watercourse. This subjective decision lowers the corresponding braiding index and may account for some (but not all) of the reduction in braiding index in the pertinent 1969 channels.

I tried without success to find some relation between the changes in braiding and the changes in average water discharge (average peaks and average mean annual flow) from 1938 to 1969.

SINUOSITY

DEFINITION

Sinuosity is the ratio of channel length to valley length. Valley length, however, is impractical for use in defining the sinuosities of short (2 km) reaches of the Platte because the valley is many times as wide as the measuring reach. The ideal standard for the Platte, rather than valley length, is the length of the original (1865) channel as measured midway between the banks. This original channel, as shown above, was much wider than later channels and is readily identifiable on aerial photographs. In many reaches, it is fairly straight or only slightly curving for distances of several kilometers or more. Channels which evolved later were almost never straighter than the original channel in the cases examined. The adapted definition of sinuosity (Si) therefore was:

$$Si=\frac{\text{Length of existing channel}}{\text{Length of original channel}},$$

in which channel length was measured midway between the banks. This definition actually provides the sinuosity of the existing channel relative to that of the 1865 channel. In braided reaches, the most prominent channel was measured for sinuosity. Reaches examined were the same ones analyzed for the braiding index described above.

RESULTS

Table 3 gives the data, and figure 28 shows the sinuosity changes with distance downstream.

The channel was only slightly more sinuous in 1969 than in 1938, for most of the study reach. The exceptions are: (1) the very beginning of the study reach immediately downstream from Kingsley Dam and the Sutherland Canal (Keystone) diversion dam, which was artificially straightened sometime between 1938 and 1969, (2) the reach just downstream from the Johnson Power Plant return flow (kilometer point 408), which was straighter in 1969, and (3) the last 50 km or so (about Gibbon to Grand Island) for which the

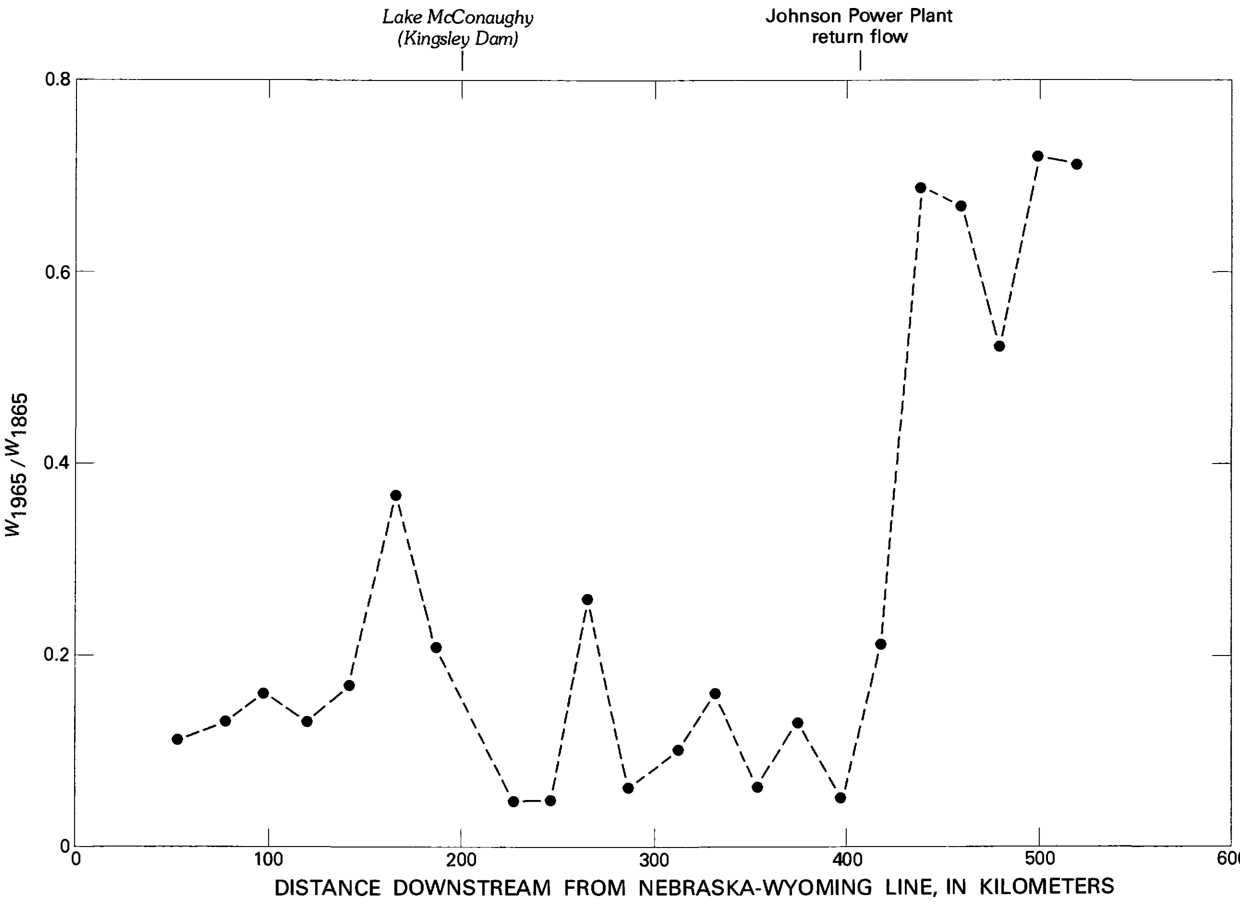

FIGURE 18.—Proportion of 1865 width occupied by 1965 channel.

data show no particular change from 1938 compared to 1969.

The changes in sinuosity from 1938 to 1969 were not large enough to show any noticeable relation to the respective average water discharges.

BED AGGRADATION AND DEGRADATION

METHOD OF ANALYSIS

A bed elevation for a wide, sandy channel is not a precise concept. The shifting nature of small- and large-scale bed forms causes a continuous fluctuation in the elevation of the bed at any one spot. However, in a stable channel, the average bed elevation should be reasonably constant if measured over a long enough time relative to the passage of bed forms. Changes in such a mean bed elevation should reflect a general aggradation or degradation.

The method adopted here for estimating the bed elevation is far from perfect but is probably the only method available in view of the historical data. That method is to estimate bed elevation using the rating curve and gage at U.S. Geological Survey gaging stations. (Such gages themselves are nearly always surveyed in to elevations above mean sea level.) Bed elevation is here taken as the elevation at which zero discharge occurs, as indicated by the rating curve (gage height versus discharge). This involves extrapolating the rating curve to zero discharge, reading the corresponding gage height on the rating-curve graph, and finally transferring this gage height into elevation above mean sea level.

Besides the uncertainty in equating bed level to the level of zero discharge, an unmeasurable amount of error stems from extrapolating the rating curve.

With this system, the bed theoretically stays at the same level as long as the same rating curve remains in effect.

Gaps in the data gathered in this way appear when (1) the station was temporarily not in operation, (2) the station was moved to another site upstream or

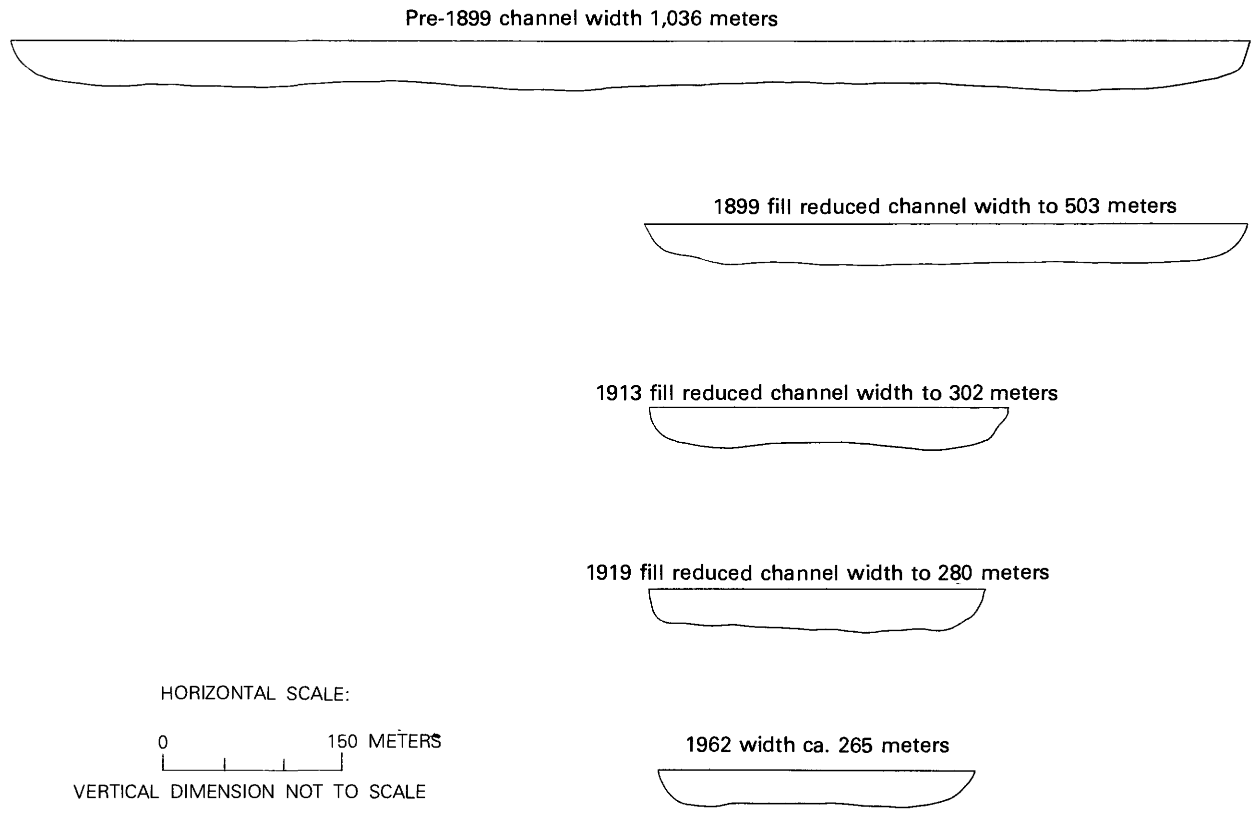

FIGURE 19.—Channel width changes at the Chicago, Burlington, and Quincy (Burlington Northern) Railroad bridge, Platte River, near Grand Island, Nebr. Data sources: Chicago, Burlington, and Quincy Railroad channel drawings, 1899-1919; U.S. Geological Survey 7½-minute topographic map, 1962, Grand Island Quadrangle.

downstream, or (3) the lowest measured discharges were sufficiently greater than zero discharge as to make an extrapolation to zero too unreliable.

The complete records of the 12 U.S. Geological Survey gaging stations within the study reach were examined. Most of these records begin in the mid-1930's, as mentioned above, which means that most stations have records for about the past 40 years. (Several stations actually were established around the turn of the century but not at the present site. Such data were acceptable for the hydrology analysis presented earlier but can't be used for present purposes.) Bed elevations, in meters above mean sea level, were determined as described above. Relative elevation changes with time were then computed for each station to reveal any aggradation or degradation.

RESULTS

Table 4 lists, and figure 29 shows, the data obtained. The complex history of water regulation and diversion upstream from and within the study reach, together with the shifting and unstable sand bed, complicate the interpretation of the data. Comments will be restricted to pointing out major changes in bed elevation with time at each station.

From 1936 to 1976 the streambed at the Minatare station has gradually degraded. The amount of degradation for this period is about 0.7 m.

At Bridgeport the bed eroded about 0.5 m from 1931 to 1967 but seems to have filled about 0.2 m around 1967 and has not changed much since.

The Lisco station has remained essentially stable since 1933.

The Lewellen station is only about eight kilometers upstream from Lake McConaughy. The bed at this station (two channels) has aggraded noticeably since about the mid-1940's. (Lake McConaughy, formed by Kingsley Dam, was created in 1941.) Fill in the north channel at Lewellen has amounted to about 0.6 m and in the south channel to about 0.3 m.

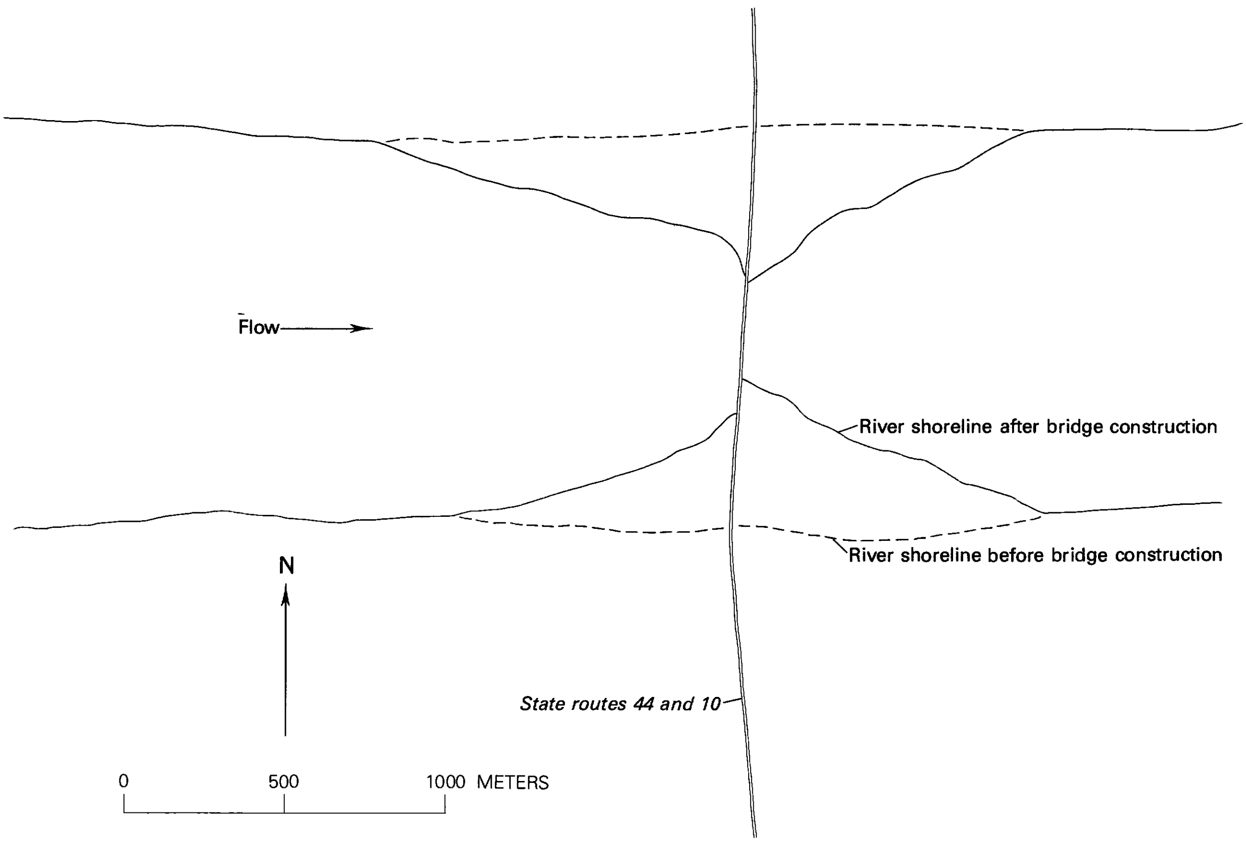

FIGURE 20.—Channel width changes due to bridge, Platte River, 2.4 km south of Kearney. Data from U.S. Dept. Agriculture aerial photographs of 1938. Shoreline evolution shown here probably not yet completed.

TABLE 4.—*Basic data for mean bed elevation, in meters above mean sea level, at various time periods*

[Gaps in data in most cases mean station was not in operation or too much extrapolation of rating curve needed to estimate gage height of zero flow]

Inclusive dates	Elevation (m)
North Platte R nr Minatare	
07/21/36–09/30/36	1162.42
05/01/37–09/30/37	1162.42
05/01/38–09/30/38	1162.42
05/01/39–09/30/39	1162.26
05/01/40–10/07/40	1162.26
06/12/41–09/30/42	1162.19
10/01/42–04/30/45	1162.11
05/01/45–05/31/47	1162.26
06/01/47–07/19/55	1162.11
07/20/55–03/21/56	1162.05
10/01/65–09/30/67	1161.96
10/01/67–06/06/68	1162.11
06/07/68–07/31/69	1162.02
10/01/69–06/10/70	1162.08
06/11/70–06/02/71	1161.93
10/01/74–	
North Platte R at Bridgeport	
10/01/31–04/30/33	1115.87
05/01/33–09/30/33	1115.84
10/01/33–05/31/34	1115.81
06/01/34–09/30/34	1115.69
10/01/34–06/30/35	1115.81
10/01/35–05/01/37	1115.60
05/01/37–09/30/39	1115.72
05/01/40– ?	1115.75
04/21/41–09/30/41	1115.66
10/01/42–09/30/43	1115.60
10/01/43–05/31/46	1115.69
06/01/46–05/31/47	1115.75
06/01/47–05/13/48	1115.75
05/14/48–06/07/54	1115.42
06/08/54–07/01/56	1115.57
07/02/56–09/30/67	1115.35
10/01/67–09/30/69	1115.63
10/01/69–	1115.60
North Platte R at Lisco	
9/08/31–04/30/33	1059.58
North Platte R at Lisco—Continued	
10/01/33–03/31/37	1059.39
10/01/37–03/31/40	1059.42
04/01/40–09/30/42	1059.39
10/01/42–06/28/55	1059.33
06/29/55–09/30/63	1059.39
10/01/63–09/30/67	1059.45
10/01/67–06/18/70	1059.39
06/03/71–06/11/73	1059.26
05/29/74–	1059.48
North Platte R nr Lewellen–north channel	
11/30/40–09/30/42	1001.82
10/01/42–05/31/54	1001.57
06/01/54–09/30/58	1001.73
10/01/58–09/30/61	1001.85
10/01/61–09/30/64	1001.91
10/01/64–09/30/67	1001.97
10/01/67–05/04/69	1002.00
05/05/69–02/12/70	1002.06
02/13/70–06/04/71	1002.18
North Platte R nr Lewellen–south channel	
11/30/40–09/30/42	1001.48
10/01/42–06/30/50	1001.45
07/01/50–07/27/54	1001.54
07/28/54–09/30/58	1001.69
10/01/58–09/30/64	1001.79
North Platte R nr Keystone	
05/12/45–06/30/45	947.32
07/01/45–09/30/45	947.50
10/01/45–04/29/49	947.47
04/30/49–11/04/50	947.11
11/05/50–05/31/51	947.14
06/01/51–09/30/51	947.01
10/01/51–09/30/52	946.86
North Platte R nr Keystone—Continued	
10/01/52–02/04/53	946.77
02/05/53–04/14/54	946.80
04/15/54–06/11/54	947.07
10/01/55–02/28/56	946.92
02/29/56–09/30/57	946.98
10/01/57–06/30/58	947.01
05/01/62–10/31/63	946.89
11/01/63–09/30/67	946.77
03/02/68–03/03/70	946.98
03/04/70–05/18/71	947.03
11/27/71–03/07/72	947.03
03/08/72–09/30/72	947.11
10/01/72–05/09/74	947.20
North Platte R nr Sutherland	
10/01/36–12/12/40	892.32
12/13/40–10/01/42	892.29
10/02/42–03/31/53	892.18
04/01/53–03/14/56	892.00
03/15/56–08/27/56	892.06
03/07/57–09/30/58	892.09
10/01/58–10/24/67	891.94
10/25/67–05/06/68	891.88
05/07/68–04/08/69	891.83
04/09/69–07/22/69	891.81
07/23/69–09/30/69	891.88
10/01/69–06/07/71	891.84
North Platte R at North Platte	
10/01/31–09/30/33	851.49
10/01/33–03/31/37	851.55
04/01/37–09/30/38	851.40
10/01/38–04/03/40	851.64
04/23/40–07/13/41	851.46
07/14/41–09/30/42	851.43
10/01/42–06/30/44	851.55
07/01/44–05/31/46	851.40
07/01/46–10/31/47	851.34
North Platte R at North Platte—Continued	
11/01/47–09/30/57	851.40
02/28/65–09/30/67	851.37
Platte R at Brady—No. channel	
03/01/39–09/30/42	804.98
10/01/42–03/31/43	804.92
04/01/43–04/30/45	804.73
05/01/45–06/15/49	804.89
06/16/49–04/30/52	804.67
05/01/52–08/04/53	804.73
08/05/53–05/10/55	804.95
05/11/55–02/27/56	805.10
02/28/56–05/27/56	804.85
05/28/56–09/30/56	805.10
10/01/56–05/15/57	804.92
05/16/57–05/31/59	805.04
06/01/59–06/21/65	804.92
06/25/65–09/30/67	804.66
10/01/67–06/24/69	804.67
06/25/69–02/20/70	804.70
08/07/70–02/27/71	804.92
02/28/71–07/05/71	804.85
07/06/71–09/30/72	804.55
10/01/72–06/05/73	804.52
10/01/73–	804.53
Platte R at Brady–So. channel	
03/08/39–09/30/40	805.34
10/01/40–09/30/41	805.28
10/01/42–02/04/49	805.22
02/05/49–04/30/51	805.07
05/01/51–04/30/59	805.13
05/01/59–09/30/61	805.22
10/01/61–06/23/65	805.25
06/24/65–09/30/67	805.19
10/01/67–04/27/70	805.25
04/28/70–09/30/70	805.28
10/01/70–06/20/71	805.22

TABLE 4.—*Basic data for mean bed elevation*—Continued

Inclusive dates	Elevation (m)
Platte R at Brady--So. channel Continued	
06/21/71-05/12/73	805.19
05/16/73-	805.22
Platte R nr Cozad--No. channel	
10/01/40-09/30/42	755.45
10/01/42-03/21/43	755.26
03/22/43-05/31/47	755.48
06/01/47-04/30/48	755.23
05/01/48-06/22/49	755.26
06/23/49-05/01/55	755.20
10/01/55-06/30/57	755.14
07/01/57-04/24/63	755.26
04/25/63-03/31/68	754.96
04/01/68-06/16/70	755.08
06/17/70-10/05/70	754.90
10/06/70-06/15/71	754.87
06/16/71-02/04/72	754.90
02/05/72-09/30/72	754.87
10/01/72-05/15/73	754.90
05/16/73-09/30/74	754.84
10/01/74-	754.90
Platte R nr Cozad--So. channel	
10/01/40-09/30/42	755.36
10/01/42-03/31/43	755.26
04/01/43-06/21/47	755.17
06/22/47-04/02/48	754.59
04/07/48-06/23/49	754.81
06/24/49-03/31/50	754.26
04/01/50-09/30/50	754.47
10/01/50-09/30/53	754.72
10/01/53-05/01/55	754.90
05/02/55-09/30/56	754.75
10/01/56-05/14/57	754.68
05/15/57-03/24/58	754.11
05/26/58-09/30/59	754.87
10/01/59-02/25/63	754.84
02/26/63-05/03/65	754.62

Inclusive dates	Elevation (m)
Platte R nr Cozad--So. channel Continued	
05/04/65-06/22/65	754.41
06/23/65-02/12/66	754.20
02/13/66-09/30/67	754.01
10/01/67-09/30/68	754.17
05/17/69-02/03/70	754.01
02/04/70-06/22/70	754.14
06/23/70-08/10/70	753.89
08/11/70-02/11/71	753.92
02/12/71-04/12/71	753.95
04/13/71-station moved	
Platte R nr Overton--South channel	
01/01/31-11/30/31	701.53
02/28/32-05/12/33	701.59
05/13/33-03/31/36	701.53
04/01/36-04/15/38	701.41
04/16/38-09/30/41	701.50
10/01/41-09/30/43	701.44
10/01/43-09/30/46	701.53
10/01/46-05/31/48	701.56
06/01/48-05/31/49	701.53
06/01/49-09/30/52	701.28
10/01/52-08/16/55	701.41
05/20/57-09/30/57	701.22
10/01/58-06/23/65	701.19
05/07/66-01/31/67	701.19
02/01/67-07/31/68	701.25
Platte R nr Odessa	
10/01/38-09/30/40	670.07
10/01/40-03/23/42	670.16
10/01/42-09/30/43	669.98
10/01/43-05/31/46	670.29
06/01/46-04/30/48	670.19
05/01/48-03/31/56	670.10
04/01/56-07/02/65	670.04
05/08/66-09/30/67	670.04

Inclusive dates	Elevation (m)
Platte R nr Odessa--Continued	
01/27/68-02/07/70	669.95
02/08/70-05/05/71	669.89
07/02/71-05/26/72	669.86
05/27/72-05/21/73	669.89
10/01/73-	669.89
Platte R nr Grand Island	
06/01/35-09/30/35	558.82
10/01/35-09/30/39	558.88
10/01/39-09/30/40	558.91
03/18/41-09/30/43	558.97
10/01/44-09/30/51	558.91
10/01/51-03/28/60	558.79
03/29/60-09/30/60	558.82
05/22/61-09/30/62	558.82
10/01/62-06/22/65	558.88
06/23/65-09/30/66	558.82
06/07/67-05/22/70	558.82
05/23/70-03/11/71	558.67
03/12/71-06/30/71	558.82
04/18/72-06/21/73	558.82
06/22/73-07/26/73	558.67
05/29/74-06/30/76	558.67

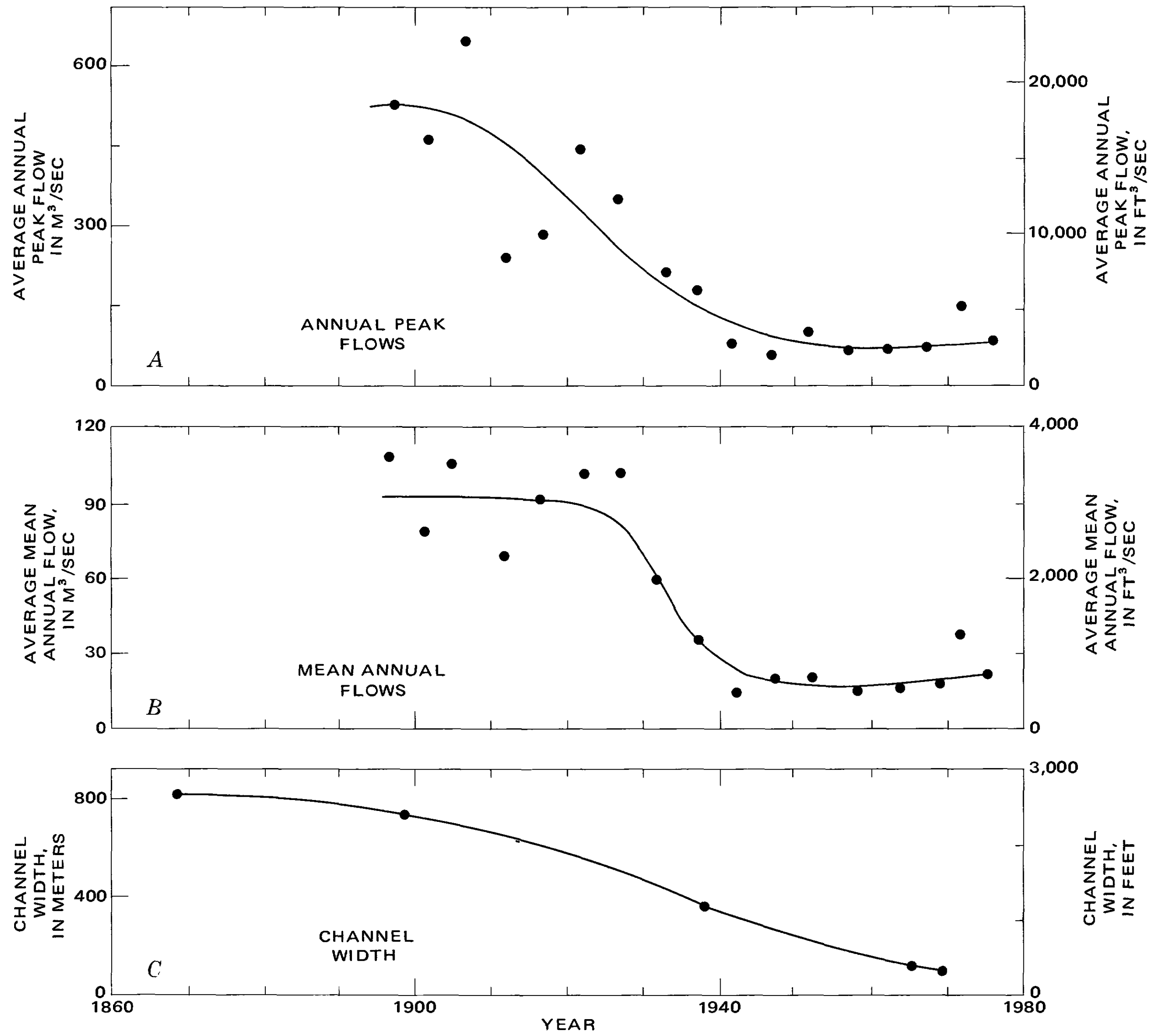

FIGURE 21.—Historical trends of annual peak flows, mean annual flows and channel width, North Platte River at North Platte.

The gaging station near Keystone is located just downstream from Kingsley Dam and from the diversion dam of the Sutherland Reservoir supply canal, which began operation in November 1937. The station has been at its present site since mid-1944. During the 10 years from 1944-54, the bed scoured about 0.6-0.8 m. (The channel had also been degrading during the previous several years, according to U.S. Geological Survey notes.) The bed level fluctuated over a range of about 0.2 m from the mid-1950's until the late 1960's. Since the late 1960's, it seems to have gradually aggraded about 0.4 m.

The channel of the North Platte near Sutherland has gradually eroded approximately 0.5 m since about 1940.

At North Platte the riverbed elevation seems to have been fairly stable over the past 45 years.

The North Platte at Brady today flows mainly in two channels. The bed level in the north channel has undergone periodic fluctuations of several tenths of a meter during the period of record (1939-present). Today (1977) the bed is about 0.5 m lower than it was in 1939-40. The south channel scoured about 0.3 m from 1939-49, then regained 0.1-0.2 m of this over the

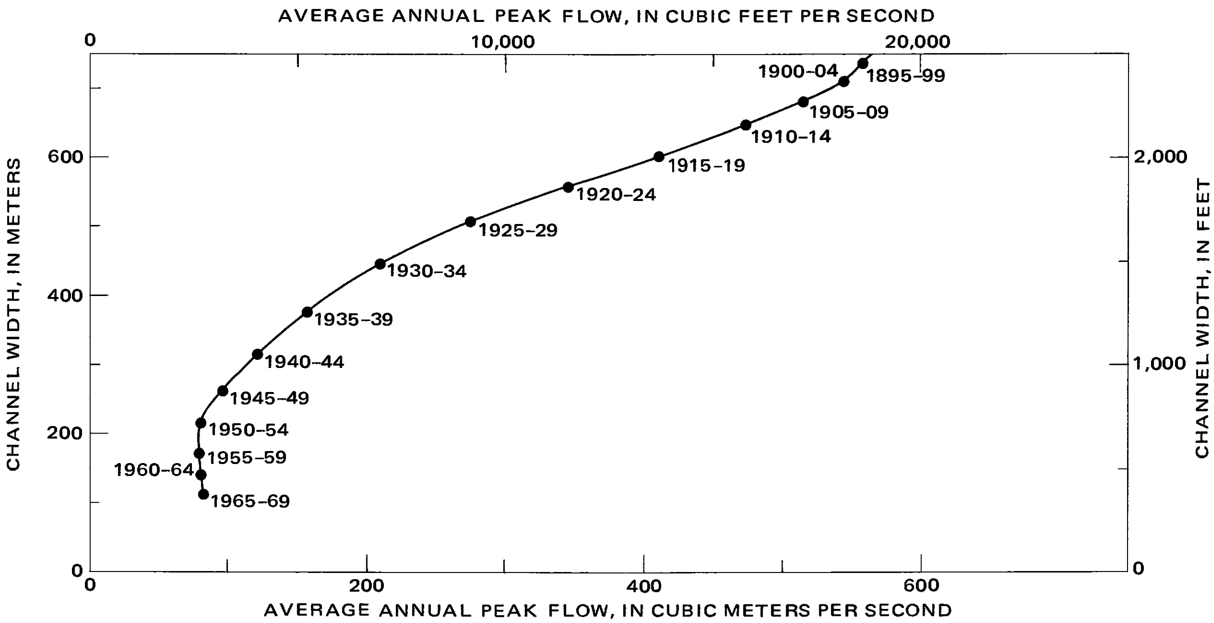

FIGURE 22.—Relation of channel width to 5-year-averaged annual peak flows, North Platte River at North Platte.

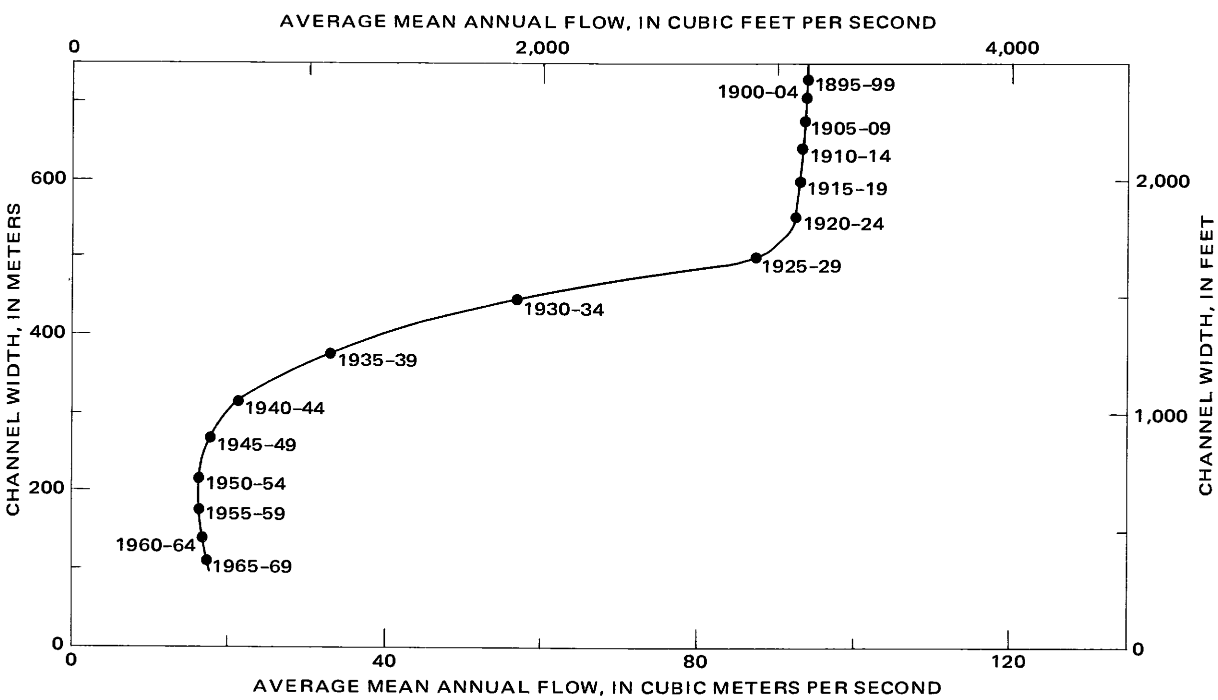

FIGURE 23.—Relation of channel width to 5-year-averaged mean annual flows, North Platte River at North Platte.

next 10 years (to 1959) and has remained fairly stable since 1959.

Near Cozad the Platte also flows in two channels. Both of these have scoured over the period of record

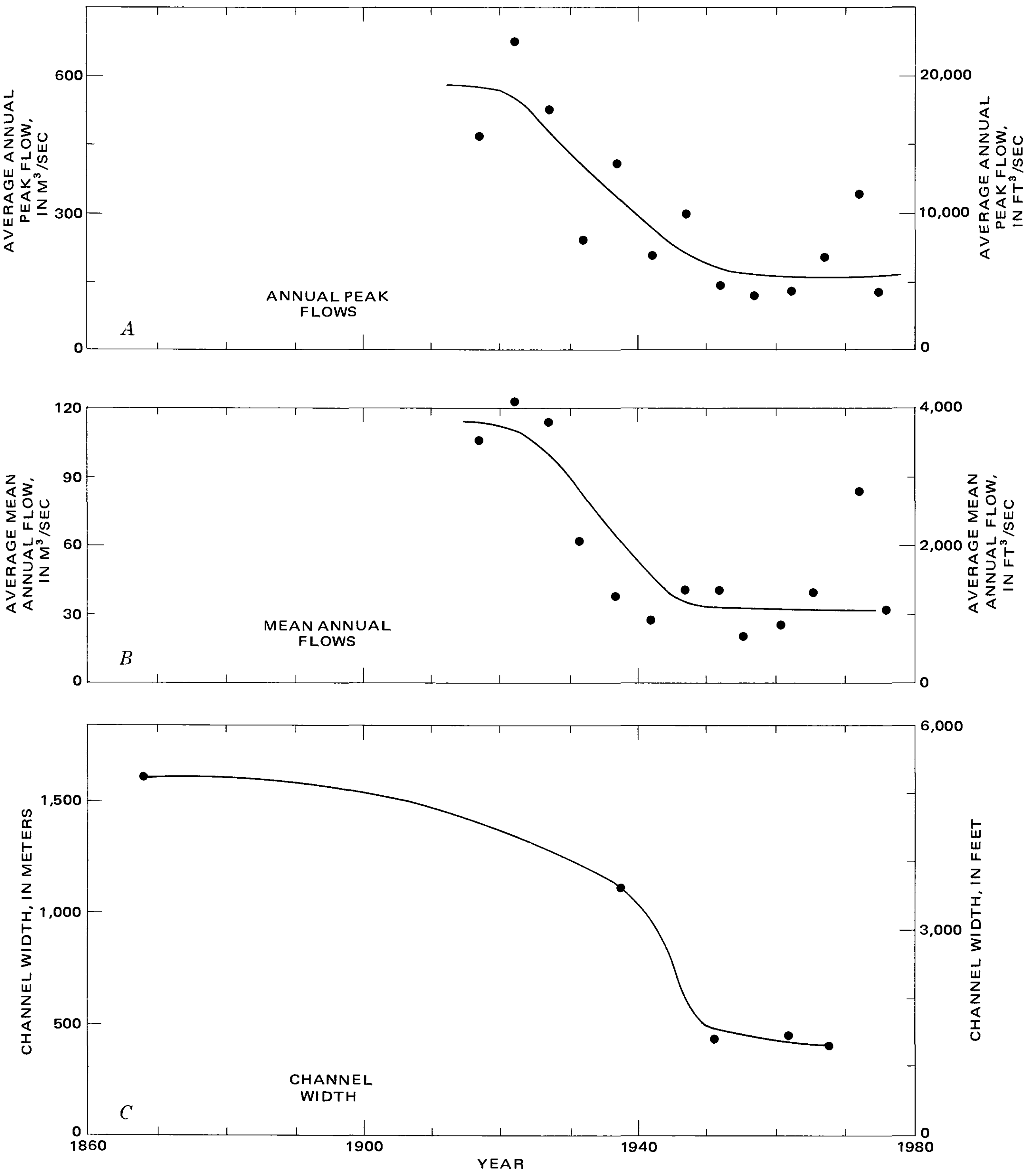

FIGURE 24.—Historical trends of annual peak flows, mean annual flows and channel width, Platte River near Overton.

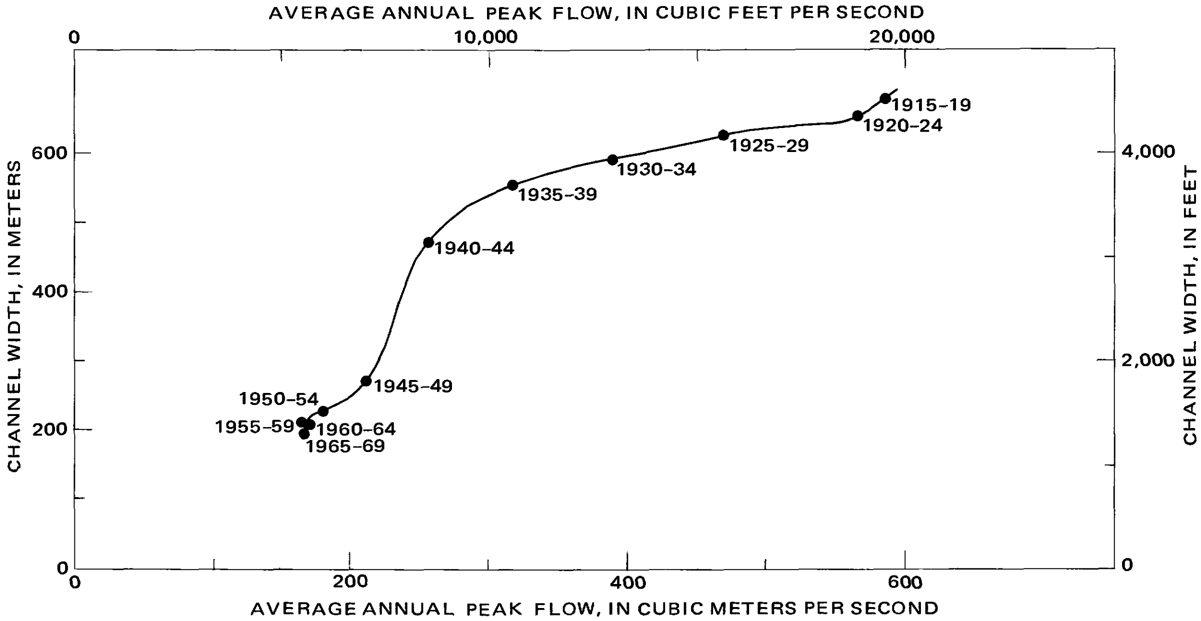

FIGURE 25.—Relation of channel width to 5-year-averaged annual peak flows, Platte River near Overton.

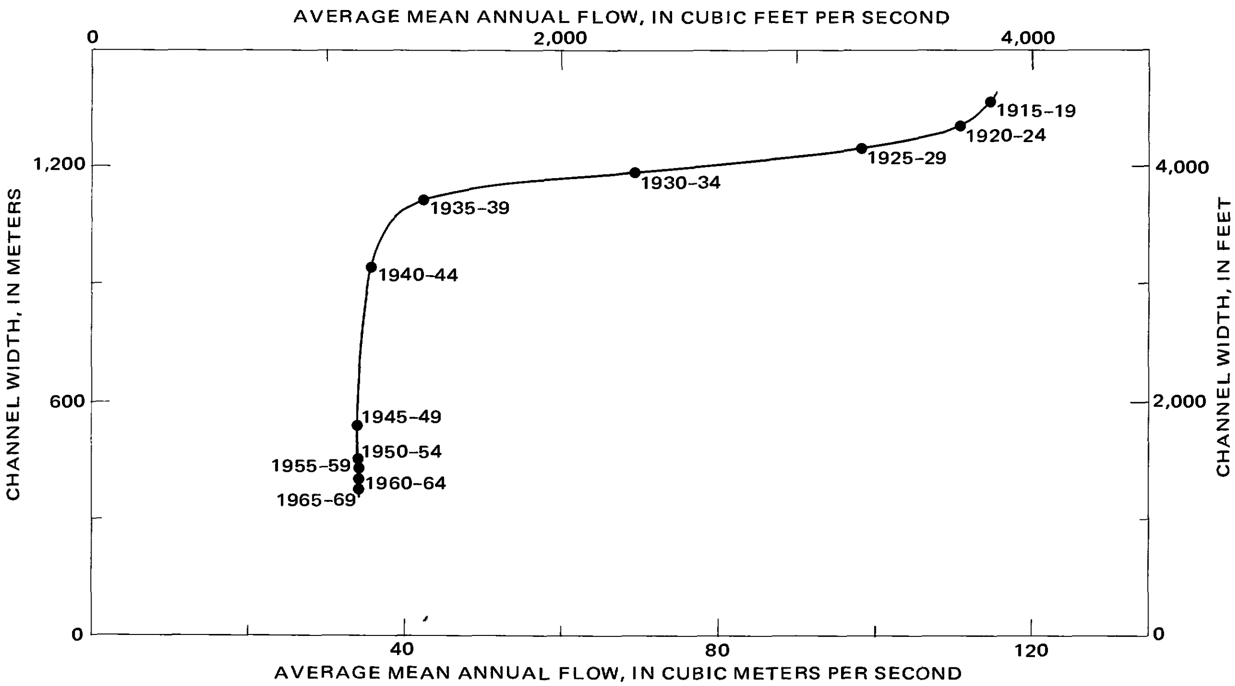

FIGURE 26.—Relation of channel width to 5-year-averaged mean annual flows, Platte River near Overton.

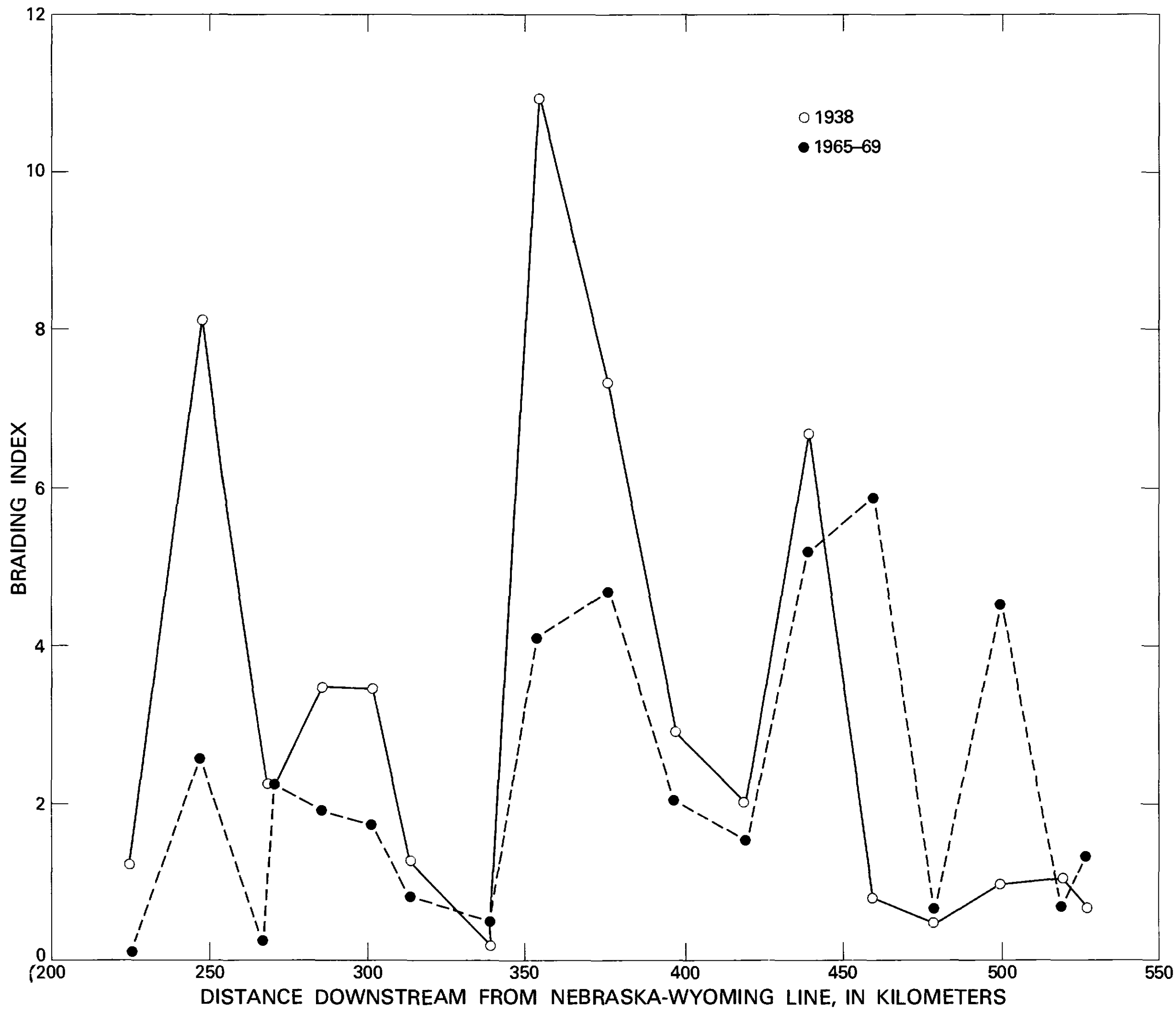

FIGURE 27.—Changes in braiding index with distance downstream.

(1940-present). The north channel has degraded about 0.7 m, the south channel about 1.5 m. The latter degradation represents the largest amount of change of the 12 stations studied.

The Platte River near Overton was reasonably stable from 1930-49. From 1949-57 it scoured about 0.3 m and has remained at about that same elevation since.

Near Odessa the bed of the river has fluctuated about ±0.2 m since 1938.

At Grand Island the river bed has been fairly stable, fluctuating within ±0.1 m since 1936.

The various and inconsistent changes of bed elevation with time mean that the gradient of the river bed has also changed with time in a similarly complex way. The same is true of the channel depth, although any changes have not been very large.

CONCLUSIONS

The channels of the North Platte and Platte Rivers in western and central Nebraska have changed considerably since about 1865.

The changes are most pronounced in the upstream 365 km of the study reach (Minatare to Overton). Within this reach, the channel in 1969 (and 1977) was only about 0.1-0.2 as wide as the 1865 channel. A significant part of this reduction in width has occurred since 1940. In the downstream 150 km of this reach, a reduction in braiding and a minor increase in sinuosity

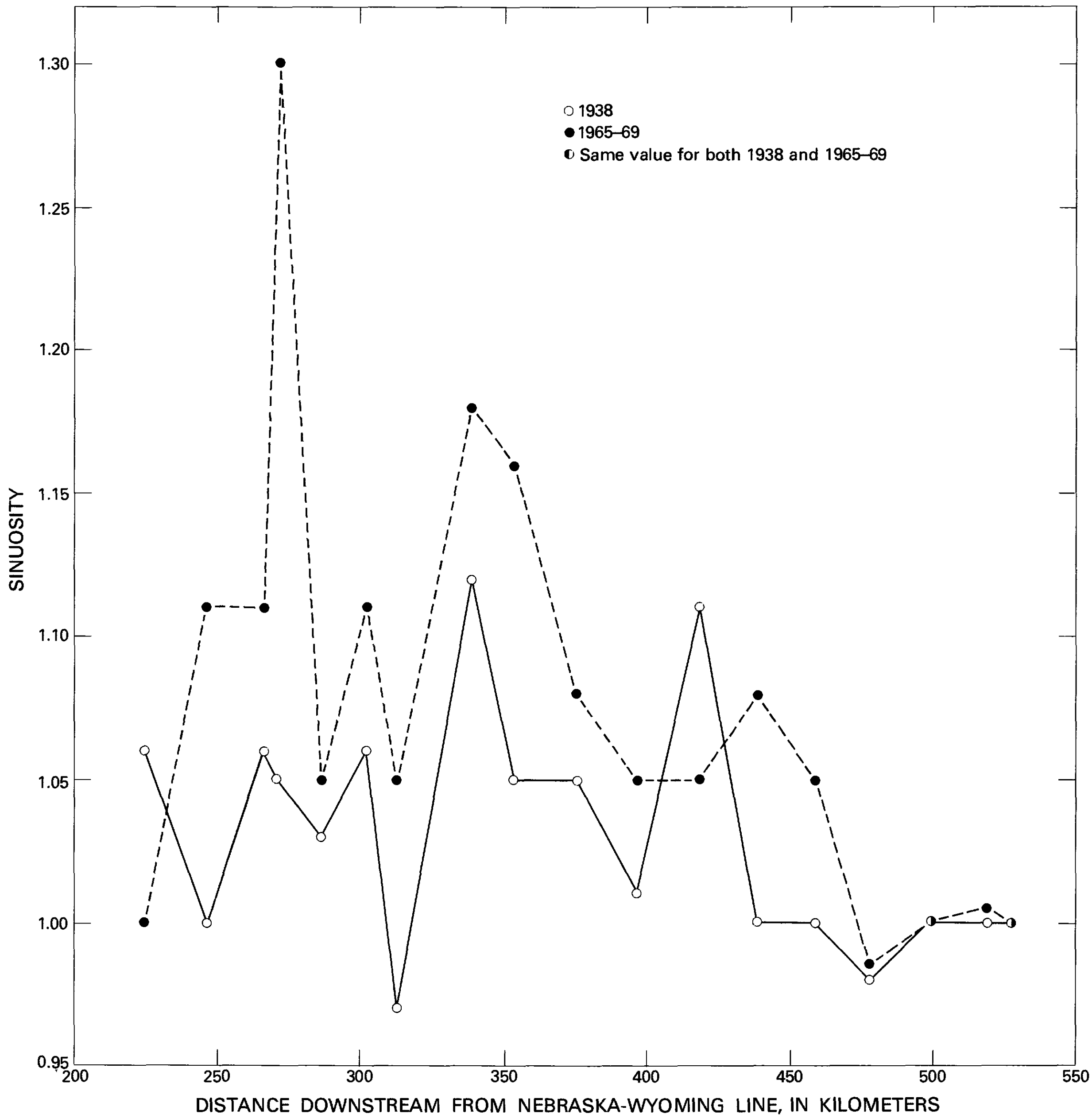

FIGURE 28.—Changes in channel sinuosity with distance downstream.

have taken place between 1938 and 1969. From Overton to Grand Island (a distance of about 115 river km) the channel in 1969-77 was about 0.6-0.7 as wide as it was in 1865. The 1969 channel in some reaches was more braided than in 1938, and for other reaches there was no significant change. Sinuosity was a little greater in 1969 than in 1938 for about the first 40 or 50 km of this reach, but in the remaining distance to Grand Island the degree of sinuosity was about the same in both 1938 and 1969.

Over the entire 480-km reach, vegetation, including many trees, has become firmly established in the part of the former channel which now carries no water.

Since about 1935-40 the estimated mean bed elevation has fluctuated at the 12 U.S. Geological Survey gaging stations along the 480-km study reach. These fluctuations probably reflect the complex regulation of water and sediment delivery to the river.

In the absence of any significant climatic shifts, the various channel changes described above most likely

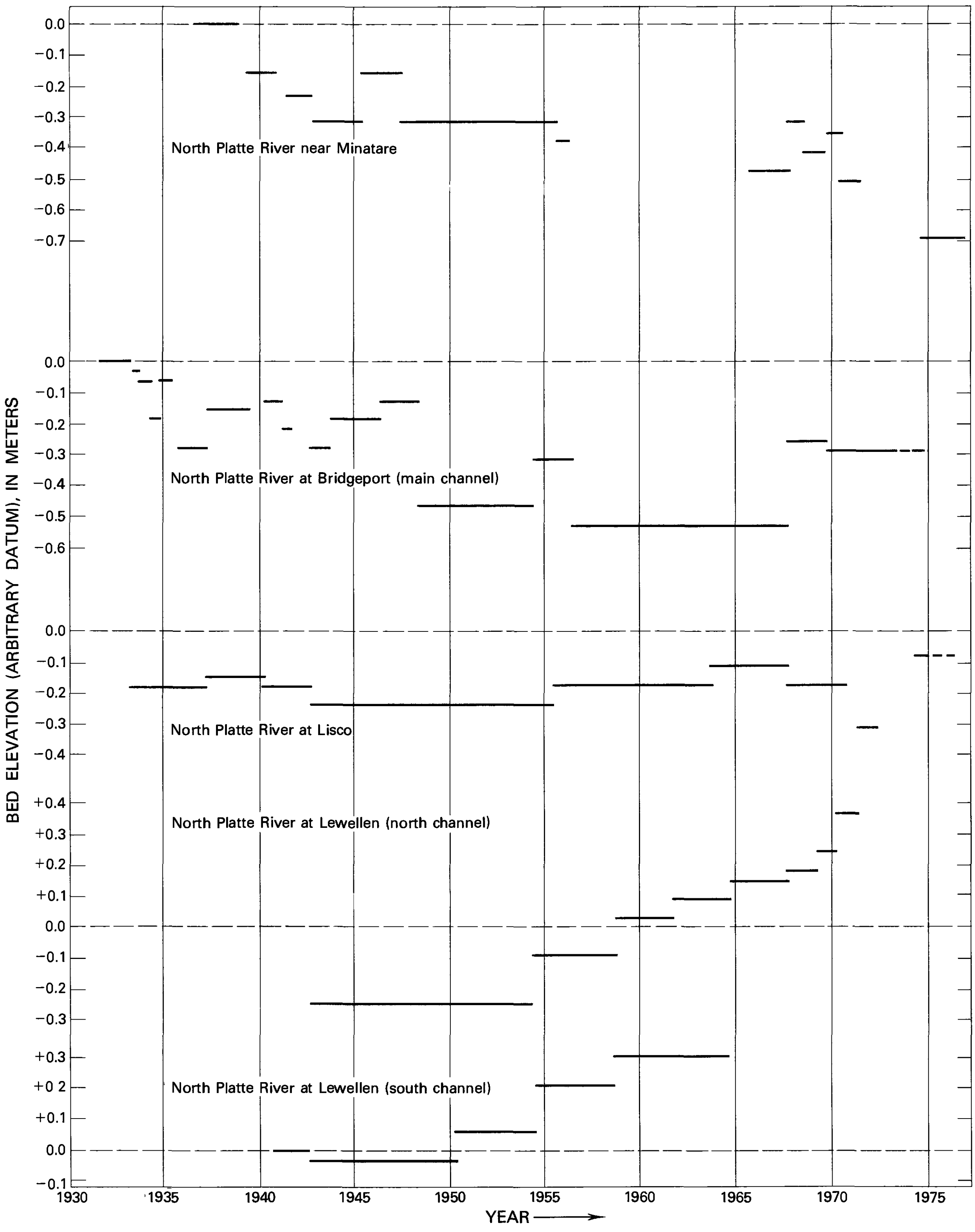

FIGURE 29.—Changes in bed elevation during the past 45 years at 12 U.S. Geological Survey gaging stations within the study reach. Dashed reference line drawn at earliest known elevation.

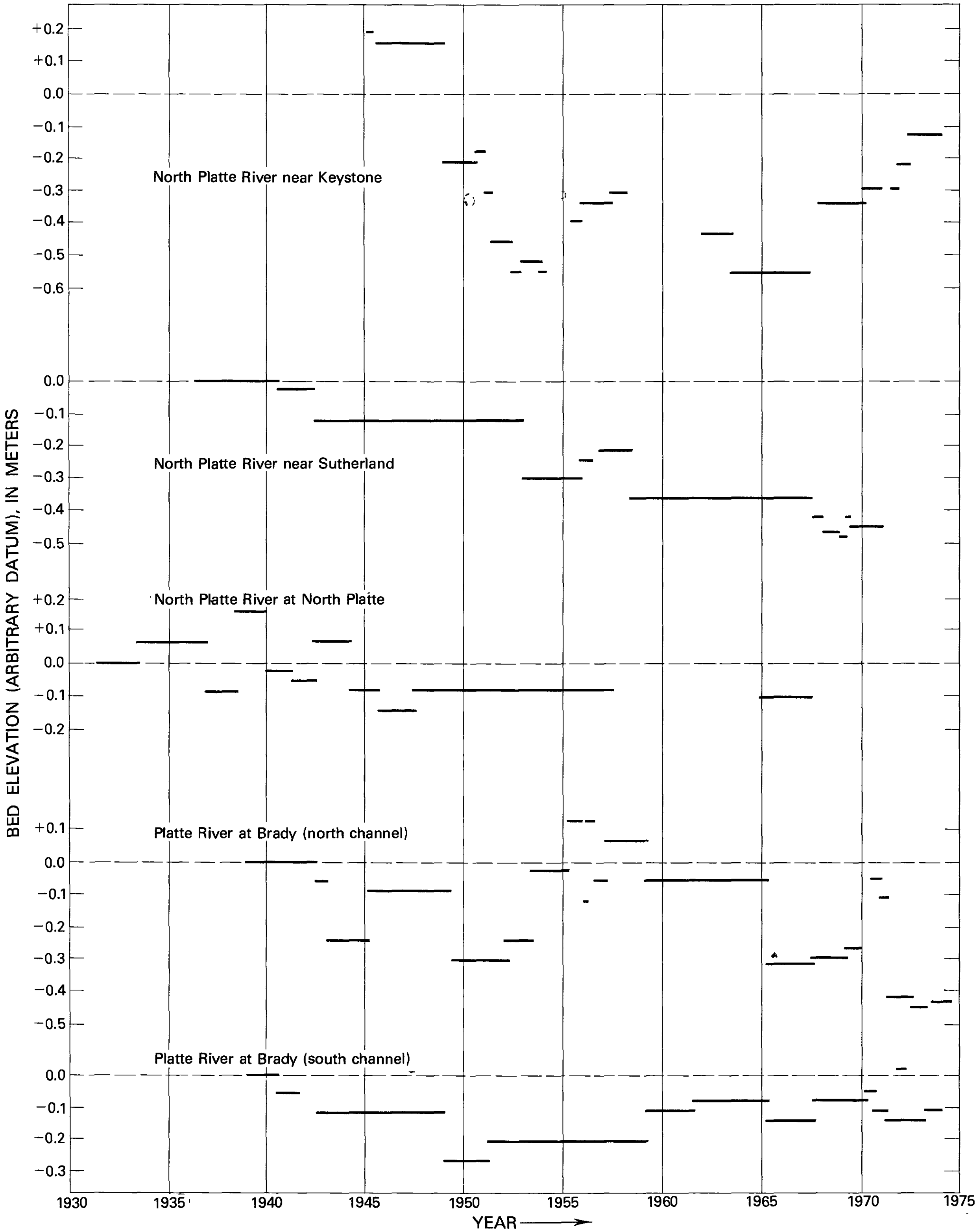

FIGURE 29.—Changes in bed elevation—Continued

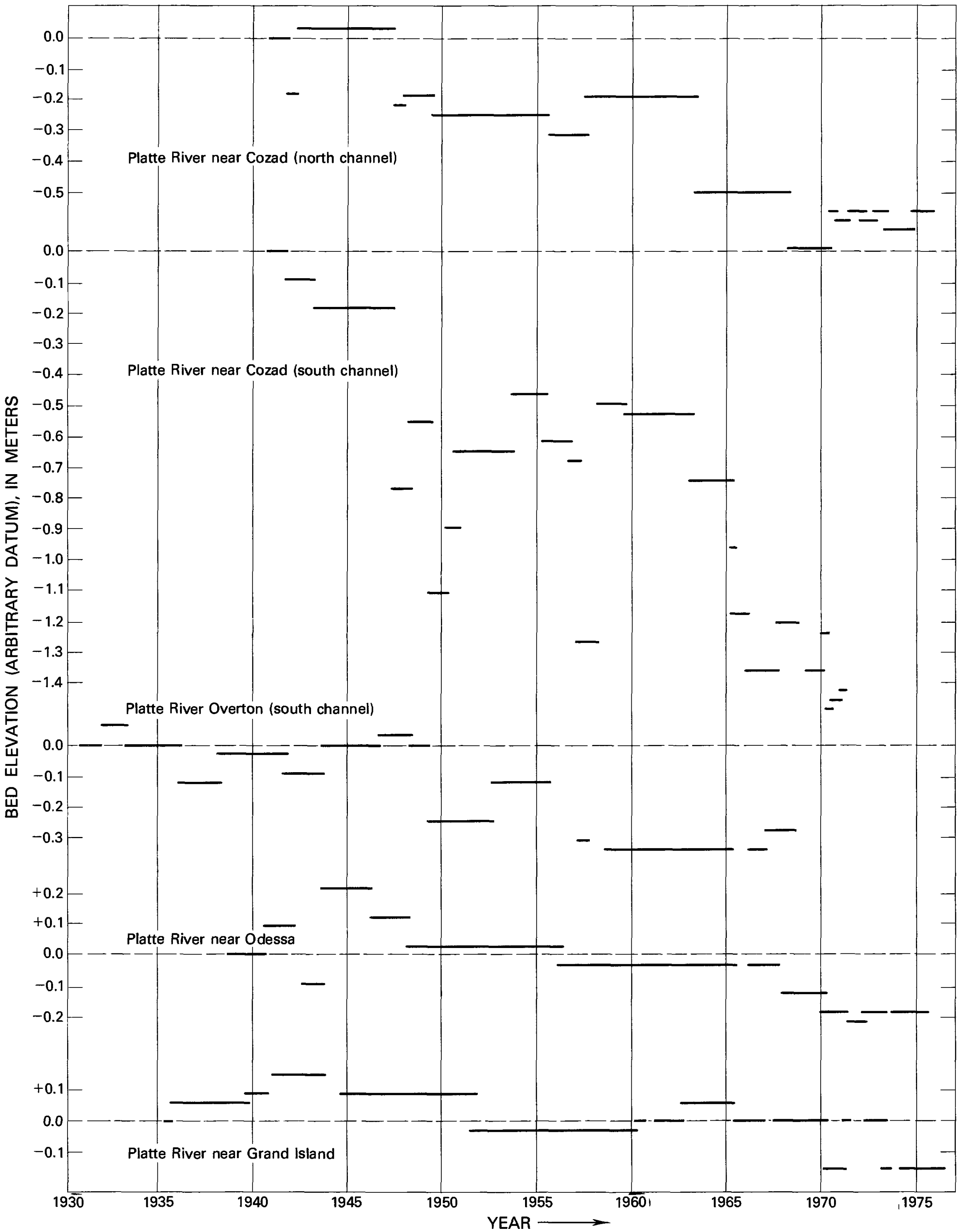

FIGURE 29.—Changes in bed elevation —Continued

are due to the rather systematic decrease in water discharge (and possibly sediment discharge) that has occurred. If this is the case, the changes agree qualitatively with the theoretical predictions of Schumm (1969). The decrease in water discharge (both peak flows and mean annual flows) probably is due to the creation of on-stream reservoirs and the greater consumptive use of river water.

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TABLE 5.—*Historical discharge data for North Platte and Platte gaging stations within the study reach*

[All data are for water years October 1-September 30]

	MINATARE				BRIDGEPORT				LISCO			
Year	Maximum discharge		Mean annual discharge	Number of no-flow days	Maximum discharge		Mean annual discharge	Number of no-flow days	Maximum discharge		Mean annual discharge	Number of no-flow days
	Flow (m^3/s)	Date	(m^3/s)	days	Flow (m^3/s)	Date	(m^3/s)	days	Flow (m^3/s)	Date	(m^3/s)	days
1895-96	---	--------	--	-	---	--------	---	-	---	--------	--	-
1897	---	--------	--	-	643	06/06/97	---	-	---	--------	--	-
1898	---	--------	--	-	481	05/28/98	---	-	---	--------	--	-
1899	---	--------	--	-	705	06/26/99	---	-	---	--------	--	-
1900	---	--------	--	-	411	06/05/00	---	-	---	--------	--	-
1901	---	--------	--	-	---	--------	---	-	---	--------	--	-
1902	---	--------	--	-	187	06/07/02	---	-	---	--------	--	-
1903	---	--------	--	-	306	06/23/03	69	-	---	--------	--	-
1904	---	--------	--	-	402	06/09/04	60	-	---	--------	--	-
1905	---	--------	--	-	515	06/15/05	110	-	---	--------	--	-
1906	---	--------	--	-	578	05/29/06	102	-	---	--------	--	-
1907	---	--------	--	-	---	--------	---	-	---	--------	--	-
1908	736	06/04/08	--	-	---	--------	---	-	---	--------	--	-
1909	793	06/04/09	--	-	---	--------	---	-	---	--------	--	-
1910-14	---	--------	--	-	---	--------	---	-	---	--------	--	-
1915	---	--------	--	-	171	06/10/15	---	-	---	--------	--	-
1916	147	07/16/16	--	-	125	06/16/16	---	-	170	05/22/16	--	-
1917	552	07/02/17	--	-	572	06/26/17	101	-	569	06/27/17	--	-
1918	249	06/25/18	59	-	278	06/27/18	67	-	---	--------	--	-
1919	113	09/14/19	--	-	130	09/13/19	43	-	---	--------	--	-
1920	---	--------	--	-	329	05/15/20	79	-	---	--------	--	-
1921	680	06/18/21	--	-	680	06/19/21	77	-	---	--------	--	-
1922	289	05/20/22	--	-	215	05/22/22	54	-	---	--------	--	-
1923	331	09/30/23	--	-	227	05/25/23	55	-	---	--------	--	-
1924	459	04/17/24	84	0	396	04/18/24	86	-	---	--------	--	-
1925	215	05/18/25	45	0	283	05/19/25	51	-	---	--------	--	-
1926	227	06/19/26	62	0	218	06/16/26	69	-	---	--------	--	-
1927	198	06/23/27	69	0	221	06/23/27	78	-	---	--------	--	-
1928	416	06/06/28	73	0	425	06/06/28	84	-	---	--------	--	-
1929	481	06/03/29	80	0	680	06/03/29	91	-	---	--------	--	-
1930	266	10/01/29	49	0	263	10/01/29	63	-	---	--------	--	-
1931	103	10/07/30	33	0	130	10/07/30	43	0	---	--------	--	-

TABLE 5.—*Historical discharge data*—Continued

Year	MINATARE				BRIDGEPORT				LISCO			
	Maximum discharge		Mean annual discharge	Number of no-flow days	Maximum discharge		Mean annual discharge	Number of no-flow days	Maximum discharge		Mean annual discharge	Number of no-flow days
	Flow (m^3/s)	Date	(m^3/s)		Flow (m^3/s)	Date	(m^3/s)		Flow (m^3/s)	Date	(m^3/s)	
1932	60	08/03/32	26	0	62	08/04/32	33	0	60	06/18/32	35	0
1933	180	05/25/33	35	0	186	05/26/33	44	0	231	05/26/33	48	0
1934	56	10/06/33	19	0	69	10/02/33	26	0	101	05/03/34	29	0
1935	258	06/02/35	17	0	351	06/02/35	23	0	343	06/15/35	25	0
1936	50	06/09/36	15	0	62	06/09/36	21	0	74	06/10/36	22	0
1937	111	07/15/37	19	0	100	07/16/37	24	0	95	07/18/37	27	0
1938	84	05/20/38	25	0	138	09/05/38	33	0	162	04/26/38	38	0
1939	49	06/16/39	19	0	50	11/03/38	26	0	61	11/03/38	30	0
1940	61	06/06/40	15	0	50	06/07/40	21	0	59	06/08/40	23	0
1941	129	06/11/41	16	0	153	06/12/41	21	0	145	06/13/41	24	0
1942	197	05/14/42	29	0	286	05/15/42	38	0	240	05/16/42	44	0
1943	57	04/01/43	24	0	70	04/03/43	33	0	78	10/14/42	37	0
1944	65	05/17/44	23	0	71	06/12/44	33	0	88	07/11/44	37	0
1945	95	06/11/45	29	0	121	06/12/45	41	0	123	06/13/45	43	0
1946	61	10/01/45	25	0	80	10/02/45	33	0	83	10/02/45	36	0
1947	191	06/26/47	32	0	239	06/30/47	41	0	221	06/29/47	44	0
1948	91	06/17/48	28	0	91	06/17/48	38	0	89	06/18/48	42	0
1949	84	06/13/49	27	0	79	06/14/49	37	0	91	06/15/49	40	0
1950	60	09/19/50	24	0	76	09/20/50	33	0	80	09/19/50	36	0
1951	89	06/25/51	26	0	133	09/04/51	37	0	145	09/04/51	41	0
1952	129	06/22/52	34	0	120	06/01/52	42	0	108	06/03/52	45	0
1953	103	06/07/53	25	0	106	06/08/53	34	0	103	07/30/53	38	0
1954	48	05/22/54	16	0	45	10/21/53	22	0	51	10/21/53	25	0
1955	267	06/28/55	15	0	236	06/29/55	21	0	167	07/01/55	23	0
1956	95	07/03/56	13	0	196	07/03/56	19	0	115	07/05/56	21	0
1957	109	05/20/57	19	0	119	05/20/57	27	0	112	05/21/57	30	0
1958	148	06/09/58	20	0	138	07/18/58	28	0	91	07/22/58	33	0
1959	40	09/30/59	17	0	63	09/28/59	25	0	61	09/26/59	28	0
1960	41	10/01/59	15	0	64	10/01/59	22	0	65	10/02/59	24	0
1961	37	05/15/61	14	0	51	07/31/61	20	0	46	05/14/61	22	0
1962	96	06/30/62	19	0	91	07/14/62	28	0	94	07/15/62	30	0
1963	106	05/30/63	17	0	113	06/14/63	26	0	89	06/16/63	29	0

TABLE 5.—*Historical discharge data*—Continued

Year	MINATARE				BRIDGEPORT				LISCO			
	Maximum discharge		Mean annual discharge	Number of no-flow days	Maximum discharge		Mean annual discharge	Number of no-flow days	Maximum discharge		Mean annual discharge	Number of no-flow days
	Flow (m^3/s)	Date	(m^3/s)		Flow (m^3/s)	Date	(m^3/s)		Flow (m^3/s)	Date	(m^3/s)	
1964	50	06/22/64	15	0	58	10/01/63	24	0	65	10/21/63	26	0
1965	131	06/18/65	24	0	170	06/24/65	34	0	161	06/11/65	38	0
1966	38	10/19/65	18	0	64	10/01/65	30	0	69	10/19/65	33	0
1967	97	06/07/67	22	0	120	06/15/67	33	0	112	06/16/67	35	0
1968	110	06/16/68	23	0	113	06/17/68	34	0	90	06/18/68	36	0
1969	43	04/13/69	19	0	78	05/05/69	28	0	77	05/06/69	31	0
1970	124	06/17/70	26	0	154	06/18/70	38	0	131	06/20/70	38	0
1971	422	06/02/71	67	0	464	06/03/71	82	0	374	06/03/71	77	0
1972	79	03/20/72	33	0	89	06/25/72	43	0	91	03/21/72	45	0
1973	245	05/27/73	69	0	297	05/28/73	82	0	274	05/29/73	85	0
1974	157	04/03/74	54	0	170	03/18/74	61	0	170	04/08/74	64	0
1975	54	07/05/75	24	0	66	06/30/75	31	0	61	07/01/75	35	0
1976	---	--------	23	0	---	--------	29	0	---	--------	32	0

Year	LEWELLEN				KEYSTONE				SUTHERLAND			
	Maximum discharge		Mean annual discharge	Number of no-flow days	Maximum discharge		Mean annual discharge	Number of no-flow days	Maximum discharge		Mean annual discharge	Number of no-flow days
	Flow (m^3/s)	Date	(m^3/s)		Flow (m^3/s)	Date	(m^3/s)		Flow (m^3/s)	Date	(m^3/s)	
1895-1916	---	--------	--	-	---	--------	-----	-	---	--------	----	-
1917	---	--------	--	-	575	06/30/17	-----	-	575	06/29/17	----	-
1918-32	---	--------	--	-	---	--------	-----	-	---	--------	----	-
1933	---	--------	--	-	---	--------	-----	-	283	05/29/33	----	-
1934	---	--------	--	-	---	--------	-----	-	---	--------	----	-
1935	---	--------	--	-	---	--------	-----	-	340	06/18/35	----	-
1936	---	--------	--	-	---	--------	-----	-	---	--------	----	-
1937	---	--------	--	-	---	--------	-----	-	86	03/07/37	21	0
1938	---	--------	--	-	---	--------	-----	-	107	04/29/38	40	0
1939	---	--------	--	-	---	--------	-----	-	91	03/12/39	21	0
1940	---	--------	--	-	---	--------	-----	-	55	03/01/40	13	9
1941	140	06/14/41	--	-	---	--------	-----	-	40	07/28/41	3.5	0
1942	237	05/16/42	48	0	74	08/03/42	-----	-	65	09/02/42	5.3	0
1943	80	03/12/43	41	0	61	08/04/43	11	0	55	07/23/43	10	0
1944	94	07/12/44	40	0	105	07/31/44	8.1	0	70	08/24/44	7.9	0
1945	137	06/16/45	48	0	75	07/30/45	12	0	57	08/02/45	14	0

TABLE 5.—*Historical discharge data*—Continued

Year	LEWELLEN				KEYSTONE				SUTHERLAND			
	Maximum discharge		Mean annual discharge (m^3/s)	Number of no-flow days	Maximum discharge		Mean annual discharge (m^3/s)	Number of no-flow days	Maximum discharge		Mean annual discharge (m^3/s)	Number of no-flow days
	Flow (m^3/s)	Date			Flow (m^3/s)	Date			Flow (m^3/s)	Date		
1946	87	10/03/45	39	0	75	07/22/46	12	0	57	07/24/46	12	0
1947	259	06/29/47	49	0	89	08/18/47	9.2	0	84	08/20/47	10	0
1948	102	02/19/48	45	0	88	07/28/48	13	0	86	07/29/48	12	0
1949	92	06/16/49	44	0	86	07/26/49	9.9	0	73	07/28/49	11	0
1950	97	08/06/50	41	0	47	10/10/49	9.0	0	42	05/06/50	10	0
1951	159	09/06/51	46	0	58	08/12/51	6.6	0	35	05/15/51	8.9	0
1952	114	06/04/52	49	0	104	07/04/52	27	0	87	06/10/52	27	0
1953	93	06/10/53	40	0	88	07/06/53	11	0	67	07/09/53	10	0
1954	63	10/21/53	28	0	80	07/29/54	9.9	0	59	07/20/54	8.7	0
1955	147	07/02/55	25	0	69	08/09/55	10	0	56	07/28/55	9.7	0
1956	136	07/06/56	23	0	81	07/17/56	9.4	0	52	07/19/56	8.0	0
1957	108	05/22/57	32	0	64	08/07/57	8.8	0	56	07/22/57	9.3	0
1958	150	07/20/58	36	0	114	07/02/58	4.8	0	115	08/17/58	6.6	0
1959	65	01/27/59	30	0	75	07/21/59	8.9	0	60	07/21/59	8.5	0
1960	101	03/19/60	27	0	70	07/24/60	8.7	0	60	08/09/60	9.3	0
1961	61	05/22/61	24	0	81	07/17/61	8.1	0	59	07/19/61	8.4	0
1962	99	07/17/62	34	0	104	05/16/62	5.0	0	95	05/17/62	6.7	0
1963	85	06/02/63	31	0	87	07/09/63	10	0	72	07/11/63	10	0
1964	79	10/21/63	28	0	81	07/04/64	9.1	0	58	07/09/64	9.1	0
1965	144	06/12/65	40	0	50	08/18/65	5.7	0	50	08/21/65	6.7	0
1966	85	10/19/65	35	0	86	07/13/66	9.1	0	71	07/15/66	10	0
1967	108	06/17/67	37	0	67	07/26/67	9.2	0	54	07/28/67	9.3	0
1968	113	05/06/68	38	0	103	08/09/68	12	0	86	08/11/68	11	0
1969	79	05/07/69	33	0	63	07/16/69	12	0	55	07/22/69	11	0
1970	133	06/22/70	41	0	91	06/19/70	11	0	80	06/21/70	10	0
1971	382	06/04/71	80	0	251	06/10/71	38	0	257	06/08/71	38	0
1972	142	06/26/72	47	0	88	05/15/72	20	0	82	05/16/72	20	0
1973	277	05/27/73	87	0	216	06/03/73	43	0	195	06/12/73	41	0
1974	173	04/11/74	66	0	117	03/28/74	38	0	110	03/21/74	37	0
1975	65	04/28/75	38	0	86	07/30/75	11	194	68	07/31/75	11	0
1976	---	--------	35	0	---	--------	18	135	---	--------	18	0

Year	NORTH PLATTE				BRADY				COZAD			
	Maximum discharge		Mean annual discharge	Number of no-flow days	Maximum discharge		Mean annual discharge	Number of no-flow days	Maximum discharge		Mean annual discharge	Number of no-flow days
	Flow (m^3/s)	Date	(m^3/s)	days	Flow (m^3/s)	Date	(m^3/s)	days	Flow (m^3/s)	Date	(m^3/s)	days
1895	493	06/07/95	-----	-	---	--------	----	-	---	--------	----	-
1896	462	06/06/96	60	-	---	--------	----	-	---	--------	----	-
1897	708	06/08/97	132	-	---	--------	----	-	---	--------	----	-
1898	433	05/30/98	71	-	---	--------	----	-	---	--------	----	-
1899	518	06/27/99	152	-	---	--------	----	-	---	--------	----	-
1900	549	06/08/00	91	-	---	--------	----	-	---	--------	----	-
1901	549	06/12/01	76	-	---	--------	----	-	---	--------	----	-
1902	280	05/16/02	61	-	---	--------	----	-	---	--------	----	-
1903	453	03/16/03	81	-	---	--------	----	-	---	--------	----	-
1904	470	06/14/04	71	-	---	--------	----	-	---	--------	----	-
1905	680	06/16/05	114	-	---	--------	----	-	---	--------	----	-
1906	544	06/05/06	105	-	---	--------	----	-	---	--------	----	-
1907	453	06/16/07	112	-	---	--------	----	-	---	--------	----	-
1908	756	06/04/08	64	-	---	--------	----	-	---	--------	----	-
1909	838	06/11/09	99	-	---	--------	----	-	---	--------	----	-
1910	195	10/16/09	44	-	---	--------	----	-	---	--------	----	-
1911	101	02/13/11	39	-	---	--------	----	-	---	--------	----	-
1912	425	04/05/12	103	-	---	--------	----	-	---	--------	----	-
1913	256	10/14/12	81	-	---	--------	----	-	---	--------	----	-
1914	231	05/03/14	57	-	---	--------	----	-	---	--------	----	-
1915	309	05/27/15	80	-	---	--------	----	-	---	--------	----	-
1916	142	05/22/16	59	-	---	--------	----	-	---	--------	----	-
1917	592	06/29/17	141	-	---	--------	----	-	---	--------	----	-
1918	283	06/30/18	96	-	---	--------	----	-	---	--------	----	-
1919	122	06/09/19	64	-	---	--------	----	-	---	--------	----	-
1920	425	06/25/20	108	-	---	--------	----	-	---	--------	----	-
1921	683	06/20/21	105	-	---	--------	----	-	---	--------	----	-
1922	306	05/24/22	77	-	---	--------	----	-	---	--------	----	-
1923	297	05/29/23	71	-	---	--------	----	-	---	--------	----	-
1924	524	10/03/23	118	-	---	--------	----	-	---	--------	----	-
1925	178	05/21/25	74	-	---	--------	----	-	---	--------	----	-
1926	306	06/19/26	101	-	---	--------	----	-	---	--------	----	-

TABLE 5.—*Historical discharge data*—Continued

Year	NORTH PLATTE				BRADY				COZAD			
	Maximum discharge		Mean annual discharge	Number of no-flow days	Maximum discharge		Mean annual discharge	Number of no-flow days	Maximum discharge		Mean annual discharge	Number of no-flow days
	Flow (m^3/s)	Date	(m^3/s)	days	Flow (m^3/s)	Date	(m^3/s)	days	Flow (m^3/s)	Date	(m^3/s)	days
1927	261	08/08/27	97	-	---	--------	----	-	---	--------	----	-
1928	442	06/12/28	103	-	---	--------	----	-	---	--------	----	-
1929	592	06/05/29	102	-	---	--------	----	-	---	--------	----	-
1930	312	10/04/29	75	-	---	--------	----	-	---	--------	----	-
1931	195	04/03/31	55	-	---	--------	----	-	---	--------	----	-
1932	179	03/19/32	45	0	---	--------	----	-	---	--------	----	-
1933	283	05/29/33	64	0	---	--------	----	-	---	--------	----	-
1934	109	05/06/34	40	0	---	--------	----	-	---	--------	----	-
1935	331	06/18/35	37	0	---	--------	----	-	---	--------	----	-
1936	181	03/05/36	22	0	---	--------	----	-	---	--------	----	-
1937	110	02/24/37	27	0	---	--------	----	-	---	--------	----	-
1938	142	04/29/38	46	0	193	09/14/38	----	-	204	09/15/38	----	-
1939	111	03/12/39	28	0	246	03/16/39	52	-	---	--------	----	-
1940	66	06/07/40	17	0	82	03/03/40	27	0	156	06/09/40	19	-
1941	45	07/29/41	9.4	0	48	12/03/40	7.7	3	39	11/22/40	7.2	-
1942	187	09/03/42	13	0	436	05/07/42	38	0	470	05/10/42	38	0
1943	69	06/15/43	17	0	67	06/16/43	10	0	119	06/28/43	8.1	0
1944	71	08/25/44	14	0	52	05/16/44	7.6	0	56	05/12/44	7.2	0
1945	75	08/05/45	21	0	44	08/22/45	8.1	0	57	06/10/45	7.6	0
1946	58	07/22/46	19	0	34	07/25/46	7.3	0	16	01/11/46	5.3	0
1947	74	08/21/47	17	0	295	07/01/47	16	0	343	06/23/47	17	0
1948	95	07/29/48	19	0	87	02/17/48	11	0	103	07/29/48	10	0
1949	73	08/02/49	18	0	411	06/22/49	24	0	385	06/23/49	23	0
1950	54	05/06/50	17	0	26	07/22/50	5.4	0	67	11/11/49	9.1	0
1951	153	05/15/51	17	0	193	05/16/51	11	0	174	05/17/51	11	0
1952	86	06/11/52	34	0	129	03/25/52	25	0	93	03/26/52	21	0
1953	71	07/10/53	17	0	53	07/10/53	9.1	0	22	01/09/53	5.5	0
1954	61	07/21/54	15	0	47	07/23/54	7.6	0	15	02/01/54	4.4	0
1955	61	08/09/55	15	0	44	07/21/55	8.9	0	17	03/11/55	4.8	0
1956	60	06/18/56	15	0	71	06/19/56	7.5	0	52	06/20/56	4.0	0
1957	56	07/23/57	17	0	185	05/24/57	12	0	176	05/25/57	9.3	0
1958	105	08/18/58	14	0	141	06/04/58	14	0	133	05/26/58	14	0

TABLE 5.—*Historical discharge data*—Continued

Year	NORTH PLATTE Maximum discharge Flow (m^3/s)	NORTH PLATTE Maximum discharge Date	NORTH PLATTE Mean annual discharge (m^3/s)	NORTH PLATTE Number of no-flow days	BRADY Maximum discharge Flow (m^3/s)	BRADY Maximum discharge Date	BRADY Mean annual discharge (m^3/s)	BRADY Number of no-flow days	COZAD Maximum discharge Flow (m^3/s)	COZAD Maximum discharge Date	COZAD Mean annual discharge (m^3/s)	COZAD Number of no-flow days
1959	59	07/22/59	14	0	40	08/05/59	7.6	0	23	05/21/59	5.7	0
1960	59	08/10/60	16	0	74	03/23/60	9.6	0	103	03/23/60	8.5	0
1961	58	07/22/61	14	0	88	08/17/61	10	0	57	08/18/61	7.4	0
1962	100	05/18/62	14	0	69	05/19/62	7.9	0	117	06/08/62	9.5	0
1963	71	07/13/63	17	0	55	07/12/63	11	0	41	02/05/63	7.5	0
1964	72	07/10/64	15	0	59	07/11/64	8.5	0	28	04/27/64	6.4	0
1965	54	08/22/65	14	0	476	06/23/65	13	0	447	06/24/65	13	0
1966	79	06/09/66	17	0	58	07/19/66	11	0	61	03/01/66	8.8	0
1967	71	07/09/67	16	0	112	07/09/67	11	0	101	07/10/67	9.1	0
1968	90	08/12/68	18	0	91	08/20/68	8.2	0	43	08/20/68	5.2	0
1969	61	07/24/69	18	0	186	06/29/69	13	0	173	06/30/69	10	0
1970	84	06/24/70	17	0	226	06/24/70	19	0	220	06/25/70	15	0
1971	271	06/10/71	44	0	360	06/10/71	57	0	357	06/11/71	51	0
1972	94	05/12/72	26	0	88	05/13/72	19	0	82	05/13/72	16	0
1973	196	06/13/73	49	0	527	05/14/73	74	0	521	05/29/73	72	0
1974	124	04/13/74	46	0	180	03/21/74	57	0	179	03/20/74	55	0
1975	85	08/01/75	17	0	68	08/02/75	10	0	46	06/22/75	6.6	0
1976	---	--------	24	0	---	--------	11	0	---	--------	5.6	0

Year	OVERTON Maximum discharge Flow (m^3/s)	OVERTON Maximum discharge Date	OVERTON Mean annual discharge (m^3/s)	OVERTON Number of no-flow days	ODESSA Maximum discharge Flow (m^3/s)	ODESSA Maximum discharge Date	ODESSA Mean annual discharge (m^3/s)	ODESSA Number of no-flow days	GRAND ISLAND Maximum discharge Flow (m^3/s)	GRAND ISLAND Maximum discharge Date	GRAND ISLAND Mean annual discharge (m^3/s)	GRAND ISLAND Number of no-flow days
1895-1914	----	--------	---	---	---	--------	----	---	---	--------	-----	---
1915	555	05/29/15	119	---	---	--------	----	---	---	--------	-----	---
1916	147	05/24/16	50	---	---	--------	----	---	---	--------	-----	---
1917	830	06/02/17	173	---	---	--------	----	---	---	--------	-----	---
1918	----	--------	88	---	---	--------	----	---	---	--------	-----	---
1919	255	10/10/18	66	---	---	--------	----	---	---	--------	-----	---
1920	609	05/18/20	139	---	---	--------	----	---	---	--------	-----	---
1921	1048	06/14/21	107	---	---	--------	----	---	---	--------	-----	---
1922	266	05/23/22	79	---	---	--------	----	---	---	--------	-----	---

TABLE 5.—*Historical discharge data*—Continued

Year	OVERTON				ODESSA				GRAND ISLAND			
	Maximum discharge		Mean annual discharge	Number of no-flow days	Maximum discharge		Mean annual discharge	Number of no-flow days	Maximum discharge		Mean annual discharge	Number of no-flow days
	Flow (m^3/s)	Date	(m^3/s)		Flow (m^3/s)	Date	(m^3/s)		Flow (m^3/s)	Date	(m^3/s)	
1923	623	06/17/23	98	---	---	--------	----	---	---	--------	-----	---
1924	----	--------	159	---	---	--------	----	---	---	--------	-----	---
1925	----	--------	77	---	---	--------	----	---	---	--------	-----	---
1926	439	06/20/26	111	---	---	--------	----	---	---	--------	-----	---
1927	362	04/19/27	116	---	---	--------	----	---	---	--------	-----	---
1928	651	06/12/28	120	---	---	--------	----	---	---	--------	-----	---
1929	538	06/07/29	113	---	---	--------	----	---	---	--------	-----	---
1930	282	05/13/30	92	---	---	--------	----	---	---	--------	-----	---
1931	300	04/04/31	69	---	---	--------	----	---	---	--------	-----	---
1932	173	03/18/32	38	41	---	--------	----	---	---	--------	-----	---
1933	239	04/23/33	59	61	---	--------	----	---	---	--------	-----	---
1934	148	02/01/34	35	134	---	--------	----	---	215	03/05/34	32	---
1935	1065	06/05/35	48	106	---	--------	----	---	850	06/06/35	38	145
1936	173	03/05/36	23	96	---	--------	----	---	425	03/06/36	23	135
1937	200	03/20/37	22	124	164	03/21/37	----	---	153	03/07/37	14	215
1938	217	02/28/38	44	9	215	02/28/38	37	---	283	03/02/38	35	64
1939	274	03/18/39	42	48	214	03/18/39	38	---	275	03/19/39	36	81
1940	253	03/02/40	18	95	190	03/03/40	12	186	227	03/05/40	12	169
1941	66	03/16/41	6.9	66	28	04/03/41	2.3	156	53	02/06/41	4.5	158
1942	430	05/10/42	46	0	496	05/10/42	43	30	433	05/06/42	44	121
1943	109	04/12/43	33	0	132	04/11/43	27	35	140	07/05/43	29	51
1944	115	05/12/44	28	0	143	04/25/44	26	9	154	05/13/44	30	30
1945	157	06/11/45	34	0	182	06/10/45	32	1	182	06/11/45	32	0
1946	99	03/16/46	28	0	89	03/17/46	25	3	118	03/17/46	26	10
1947	530	06/23/47	46	0	643	06/24/47	51	0	575	06/23/47	49	0
1948	170	06/23/48	36	0	156	06/24/48	37	0	450	03/19/48	34	4
1949	428	06/24/49	54	0	419	06/25/49	53	0	399	06/26/49	54	0
1950	91	11/14/49	36	0	116	05/30/50	36	0	122	05/09/50	33	0
1951	214	05/18/51	48	0	218	06/26/51	46	0	200	05/19/51	46	0
1952	162	03/27/52	57	0	201	03/27/52	51	0	221	03/27/52	53	0
1953	131	01/09/53	27	0	79	03/06/53	25	48	84	03/06/53	27	92
1954	83	11/06/53	22	0	75	11/07/53	20	45	98	02/22/54	20	100
1955	67	03/10/55	19	0	79	03/22/55	18	34	127	03/10/55	16	103
1956	56	03/31/56	16	0	47	03/16/56	13	83	53	03/01/56	12	130

TABLE 5.—*Historical discharge data*—Continued

Year	OVERTON				ODESSA				GRAND ISLAND			
	Maximum discharge		Mean annual discharge (m^3/s)	Number of no-flow days	Maximum discharge		Mean annual discharge (m^3/s)	Number of no-flow days	Maximum discharge		Mean annual discharge (m^3/s)	Number of no-flow days
	Flow (m^3/s)	Date			Flow (m^3/s)	Date			Flow (m^3/s)	Date		
1957	213	05/25/57	23	0	201	05/26/57	20	49	165	05/27/57	20	65
1958	164	05/26/58	37	0	152	05/28/58	36	0	133	04/03/58	38	0
1959	84	03/29/59	25	0	100	07/04/59	24	0	113	03/26/59	25	43
1960	197	03/24/60	30	0	227	03/24/60	31	0	286	03/27/60	33	52
1961	99	06/19/61	24	0	165	05/22/61	22	0	154	05/23/61	23	15
1962	201	06/09/62	38	0	262	06/09/62	37	0	198	06/11/62	39	0
1963	86	02/15/63	28	0	93	02/15/63	26	3	96	02/18/63	27	46
1964	67	04/07/64	24	0	61	04/07/64	21	0	96	04/26/64	20	14
1965	413	06/26/65	35	0	394	06/26/65	34	0	348	06/29/65	36	0
1966	97	03/02/66	41	0	138	10/19/65	41	0	140	10/01/65	40	20
1967	173	07/08/67	34	0	396	06/14/67	35	0	510	06/14/67	40	0
1968	72	02/22/68	31	0	79	02/24/68	26	0	108	06/25/68	29	0
1969	206	06/30/69	38	0	202	07/01/69	37	0	210	03/20/69	39	0
1970	245	06/26/70	49	0	230	06/26/70	49	0	196	06/28/70	48	0
1971	445	06/13/71	89	0	385	06/13/71	84	0	334	06/14/71	76	0
1972	135	05/14/72	53	0	117	05/16/72	49	0	135	05/06/72	46	0
1973	541	05/15/73	109	0	524	05/31/73	105	0	504	06/01/73	105	0
1974	249	03/21/74	94	0	254	03/22/74	89	0	220	04/14/74	92	11
1975	156	06/21/75	33	0	137	06/23/75	28	0	163	06/23/75	31	0
1976	----	--------	32	0	---	--------	26	0	---	--------	28	27

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