HYDROLOGIC AND MORPHOLOGIC CHANGES IN CHANNELS OF THE PLATTE RIVER BASIN: A HISTORICAL PERSPECTIVE

UNITED STATES
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GEOLOGICAL SURVEY

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Cover illustration -- A 2-km reach of the Platte River channel near Kearney, Nebraska from an aerial photograph taken in 1957.

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by T. R. Eschner, R. F. Hadley, and K. D. Crowley

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HYDROLOGIC AND MORPHOLOGIC CHANGES IN THE CHANNELS OF THE PLATTE RIVER BASIN: A HISTORICAL PERSPECTIVE

By

T. R. Eschner, R. F. Hadley, and K. D. Crowley

ABSTRACT

The channels of the Platte River and its major tributaries, the South Platte and North Platte Rivers in Colorado, Wyoming, and Nebraska, have undergone major changes in hydrologic regime and morphology since 1860. These changes are attributed here to agricultural, municipal, and industrial water use.

Although water-resource development varied temporally throughout the basin, the history of development along the Platte River and tributaries followed four stages: (1) Construction of small, crude ditches to irrigate flood plains; (2) construction of larger canals to irrigate bench lands; (3) construction of reservoirs to store snowmelt runoff; and (4) accelerated development of ground-water resources. Despite differences in rates of development, diversion and storage of water for irrigation, municipal, and industrial use have changed streamflow patterns throughout the basin. At some stations, significant changes in flood peaks, annual mean discharges, and shapes of flow-duration curves have been recorded.

Changes in streamflow patterns are manifested by changes in appearance of channels of the Platte River. Prior to water development in the 19th century, the Platte was a wide (~2 kilometers), shallow (1.8 to 2.4 meters) river characterized by bankfull spring flows and low summer flows. Although timber generally was scarce in the valley, the Platte channels contained hundreds of small, timbered islands. Since development, the channels have changed radically. Comparing surveyor's maps (General Land Office), drawn during the 1860's, with six sets of aerial photographs, taken between 1938 and 1979, for six 5-kilometer reaches of the river shows that the channels have narrowed considerably above the confluence with the Loup River. The width of the channels in 1979 ranged from 8 to 50 percent of the channel width in 1860. Below the confluence with the Loup River, the width of the river in 1979 was about 92 percent of the channel width in 1860. Above the confluence with the Loup River, width reduction has occurred by progressive encroachment of vegetation and consequent vertical and horizontal accretion on sand bars in the channel. Vegetative encroachment on sand bars has occurred because (1) the present hydrologic regime provides more favorable conditions for germination and growth on sand bars, and (2) since development of the basin, flood peaks are no longer capable of scouring vegetation from the sand bars. Overbank flows evidently have become more common, probably because channel narrowing and vegetative encroachment have increased the hydraulic roughness of the channels. Moreover, the magnitude of low flows has increased and the days of no flows has decreased giving the channels a more perennial character.

INTRODUCTION

The Platte River and its tributaries in Colorado, Wyoming, and Nebraska (fig. 1) are typical of many Great Plains streams that originate in the Rocky Mountains. Much of the flow in the North Platte, South Platte, and Platte Rivers is derived from spring snowmelt in the mountains. Because the plains are semiarid to subhumid, most of the flow has been appropriated for irrigation of agricultural crops, municipal use, and industrial development. These rivers have been an integral part of the economy in the Platte River basin since the middle of the 19th century.

Migratory waterfowl also use the river and adjacent farmlands in the Platte River valley of central Nebraska during their annual migration stopover in February and March. An estimated 70 to 80 percent of the world's lesser sandhill cranes and a small number of rare whooping cranes use the river valley between Overton and Grand Island, Nebraska, on their way to Canada and Siberia each year (Frith, 1974).

Concern for the habitat of sandhill cranes, whooping cranes, and other migratory-bird species prompted wildlife managers to document the changes that have occurred in the river channels since settlement of the valley and the effects of these changes on wildlife habitat. In 1979, a study was begun in the Platte River basin that included hydrologic investigations by the U.S. Geological Survey. An integral part of these investigations is this review of the history of water development in the basin and the effects of water use and land use on the hydrology and morphology of the Platte River and its major tributaries. Site-specific investigations were centered on the critical migratory-bird habitat in a 96-km (kilometer) reach of the Platte River between Overton and Grand Island, in south-central Nebraska. This paper presents an overview of the channel changes along the Platte River.

Acknowledgments

The historical information in this report was excerpted from emigrant journals, expedition accounts, early photographs, and maps. The authors wish to thank the Grand Island, Nebraska Office of the U.S. Bureau of Reclamation; U.S. Geological Survey, Water Resources Division, Nebraska District; Burlington Northern Railroad; the Nebraska State Engineers Office; the Smithsonian Institution; and the Union Pacific Railroad for their assistance in locating maps, photographs, and river cross sections. Joseph Jeffrey, Norman Jeffrey, Emil Roeser, and personnel from the Colorado Historical Society, Denver Public Library, and Nebraska State Historical Society assisted in obtaining early written descriptions of the Platte River valley. F. B. Shaffer provided unpublished information about reservoir capacity.

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DESCRIPTION OF THE AREA

The Platte River and its major tributaries, the North Platte and South Platte Rivers, have a drainage area of about 222,740 km^2 (square kilometers) in Colorado, Wyoming, and Nebraska. The North Platte River originates in the mountains of northern Colorado, flows northward into central Wyoming, then southeastward to Nebraska. In west-central Nebraska, the river joins the South Platte River to form the Platte River (fig. 1). The South Platte River originates in the mountains of central Colorado and flows northeastward across the eastern Colorado plains into Nebraska to meet the North Platte River (fig. 1).

Most of the flow in the Platte River system above the Loup River is derived from spring snowmelt in the Rocky Mountains. Precipitation on the Great Plains, which ranges from 330 to 635 mm (millimeters), contributes additional water to the channels. Irrigation of agricultural lands is the major water use in the basin; surface water is stored in reservoirs and diverted from channels to canals for irrigation, for municipal use, and for power generation. Ground water is developed extensively in the basin.

DEVELOPMENT OF IRRIGATION IN THE PLATTE RIVER BASIN

Introduction

Development of irrigation in the Platte River basin has had significant effects on the hydrology of the river. Not all of these effects have been documented owing to a lack of long-term hydrologic records. The earliest streamflow records date from 1891. Systematic flow records date from 1930. To understand the changes in hydrology that occurred prior to 1930, the history of irrigation development in the basin is reconstructed from records of canal construction and other available information.

Although irrigation development varied temporally throughout the basin, the history of development along the Platte River and tributaries followed four general stages. Each stage produced a different effect on river hydrology. The first stage represents the earliest period of irrigation. It was characterized by construction of small, crude ditches to irrigate irregular patches of land on the flood plains. The second stage was characterized by construction of larger and more sophisticated canals and ditches to irrigate lands on benches above the valley floor. The amount of water appropriated to these canals usually exceeded the summer flows of the river. Thus, canals with later water rights were unable to divert water during the irrigation season. Many canals were abandoned, and the number of new appropriations granted was reduced or eliminated.

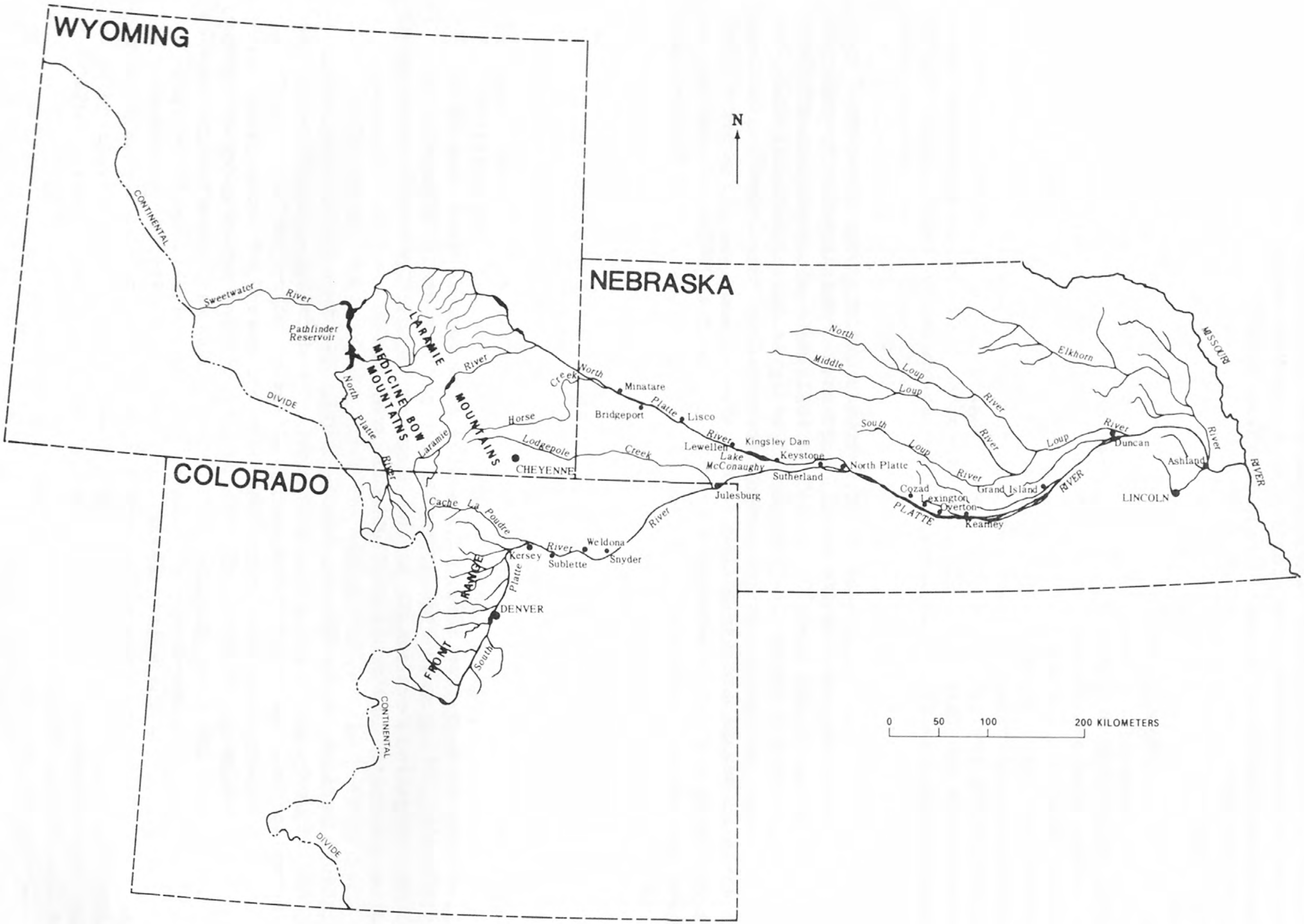

Figure 1.--The Platte River basin in Colorado, Wyoming, and Nebraska.

The third stage was characterized by the construction of reservoirs to store water from snowmelt runoff. During this stage, many of the canals abandoned previously were reopened. Many new canals were constructed, and existing canals were enlarged. Summer flows were overappropriated during most of stage 3, and new claims for water each year exceeded the amount of water available in the basin. The fourth stage marked the end of canal construction in the basin. Dam construction continued, but at a slower pace, and water impounded above these structures was used to satisfy existing water rights and new municipal demands for water and power. New demands for irrigation water were satisfied with ground water; stage 4 marked the beginning of large-scale ground-water withdrawals in the basin.

Irrigation development has been documented in the reports of the State Engineers of Colorado, Nebraska, and Wyoming (State of Colorado, 1883/1884 to 1925/1926; State of Nebraska, 1913/1914 to 1917/1918; State of Nebraska, 1919/1920 to 1931/1932; State of Wyoming, 1889-1931). Early record keeping was sporadic, and few diversion data are available prior to 1930. Water-right adjudication records (which list the date of appropriation for each canal, usually coincident with the date of construction or enlargement) and the amount of water appropriated to each canal can be used to infer in a qualitative sense when changes in streamflow occurred. For example, during a period when hundreds of canal appropriations were granted in the basin, more consumptive use of surface water would be expected. When streamflow became overappropriated, the number of new appropriations granted should decrease. Thus, canal-appropriation records should indicate: (1) When streamflow changes caused by canal diversions began; and (2) the approximate date when summer flows were overappropriated in the basin. Comparisons of adjudication and dam-construction records with several written reports of the State Engineers suggest that canal-construction activity can be used to indicate these changes.

Similarly, few storage data exist for most of the reservoirs that were constructed in the basin prior to 1910. However, the date of closure and the usable storage capacity of each reservoir can be used to reconstruct streamflow trends. For example, the beginning of large-scale reservoir construction in the basin probably marks the date of streamflow overappropriation. This date serves as a reliable check on the overappropriation date indicated by canal-appropriation records. Moreover, certain streamflow parameters, such as peak flows, are affected by reservoir construction.

South Platte River and Tributaries

The South Platte River and tributaries were the focus of the earliest and most extensive irrigation development in the Platte River basin. Irrigation in the basin was first practiced by Antoine Janis, who diverted water from the Cache la Poudre River in 1838 (Steinel and Working, 1926) or 1844 (Rohwer, 1953). The first ditches were small and crude; irrigated lands were confined to the flood plain. Construction of the small canals proceeded at a slow pace until about 1860. Prior to 1860, 28 appropriations were granted for canals in the South Platte River basin (table 1). The period 1840-1860 may be considered stage 1 in the development of irrigation in the South Platte River basin.

Table 1.--*History of canal construction in the Platte River basin, 1851-1930*[1]

River basin	River	Number of new canals constructed or existing canals enlarged[2]								Earliest canal[3]
		1851-1860	1861-1870	1871-1880	1881-1890	1891-1900	1901-1910	1911-1920	1921-1930	
South Platte basin	Cache la Poudre River and tributaries	1	37	85	37	1	46	14	7	1860
	Lodgepole Creek and tributaries	0	0	31	75	28	26	10	13	1873
	Big Thompson River and tributaries	0	32	29	6	0	8	3	2	1861
	Bear Creek and tributaries	2	22	4	3	0	3	7	14	1859
	South Platte River and tributaries below mouth of the Cache la Poudre River, except Lodgepole Creek	0	21	61	104	28	126	55	32	1868

Table 1.--*History of canal construction in the Platte River basin, 1851-1930*[1]--Continued

River basin	River	Number of new canals constructed or existing canals enlarged[2]								Earliest canal[3]
		1851-1860	1861-1870	1871-1880	1881-1890	1891-1900	1901-1910	1911-1920	1921-1930	
South Platte basin--continued	South Platte River and minor tributaries above mouth of the Cache la Poudre	25	264	323	139	6	104	52	28	1860
Total, South Platte basin		28	376	533	364	63	313	141	96	
North Platte basin	Big Laramie River and tributaries	0	8	98	467	148	263	119	29	1868
	Sweetwater River and tributaries	0	0	2	43	55	117	46	17	1880
	North Platte River, Nebraska	0	0	0	16	36	5	7	1	1888
	Tributaries to North Platte River, Nebraska	0	0	0	19	51	30	24	13	

Table 1.--*History of canal construction in the Platte River basin, 1851-1930*[1]--Continued

River basin	River	Number of new canals constructed or existing canals enlarged[2] 1851-1860	1861-1870	1871-1880	1881-1890	1891-1900	1901-1910	1911-1920	1921-1930	Earliest canal[3]
North Platte basin--continued	North Platte River, Wyoming	0	0	2	32	15	47	25	17	1875
	Tributaries to North Platte River, Wyoming, except Sweetwater and Big Laramie River	0	9	91	740	410	801	436	161	
	North Platte River and minor tributaries, Colorado	0	0	1	310	10	128	75	11	1880
Total, North Platte basin		0	17	194	1,627	725	1,391	732	249	

Table 1.--*History of canal construction in the Platte River basin, 1851-1930*[1]--Continued

River basin	River	Number of new canals constructed or existing canals enlarged[2]								Earliest canal[3]
		1851-1860	1861-1870	1871-1880	1881-1890	1891-1900	1901-1910	1911-1920	1921-1930	
Platte basin (except North and South Platte River basins)	Platte River tributaries above the Loup River	0	0	0	1	3	0	6	53	
	Platte River above the Loup River	0	0	0	2	7	0	3	16	1882
Total, Platte basin above the Loup River		0	0	0	3	10	0	9	69	

[1]Data compiled from Biennial Reports of the State Engineer of Colorado, 1883-1926; unpublished data from the files of the State Engineer of Colorado in Denver; Biennial Reports of the Department of Water Resources, Nebraska, 1913-1932; 2nd Annual Report of the Territorial Engineer, Wyoming, 1889; Biennial Reports of the State Engineer of Wyoming, 1893-1930; Tabulation of Adjudicated Water Rights, State of Wyoming, Water Divsion Number One, 1965.

[2]Numbers are based on appropriations to new canals or additional appropriations to existing canals exceeding 0.3 cubic meter per second.

[3]Based on recorded date of appropriation decree.

The initial impetus for large-scale development of irrigation was the influx of population at the time of the discovery of gold in the mountains west of Denver in 1858. Water-right number one in the South Platte River basin dates from 1859 on Bear Creek (table 1). In the next decade, numerous small projects were begun and irrigation was important enough by 1861 that the legislature passed a law allowing landowners access to water whether or not their land was immediately adjacent to the stream. The establishment of the Greeley Colony in 1870 marked the beginning of construction of large canals (McKinnon, 1952). This experiment demonstrated the potential value of bench or terrace land, and it may have served as a catalyst for the formation of other large canal companies. Beginning in 1874, corporations were formed to finance large-scale canal projects. A period of increased construction began that lasted until 1890. Between 1861 and 1870, 376 canals were constructed; 533 canals were constructed between 1871 and 1880, and 364 canals were constructed between 1881 and 1890 (table 1).

Appropriations granted to these canals exceeded the available water in the basin during the summer. However, it is difficult to pinpoint the exact year in which summer flows in the South Platte River basin were overappropriated, because development activity varied between the tributaries. For example, the earliest record of overappropriation occurred in the Cache la Poudre basin in 1876. Irrigation reports by the State Engineer of Colorado during the early 1880's indicate that most of the canals holding appropriation decrees received water during all but the driest years. By 1885, approximately 710 m^3/s (cubic meters per second) were appropriated in the South Platte River basin (State of Colorado, 1886). Although not all canals granted appropriations were diverting water, summer flows were nevertheless overappropriated. Thus, overappropriation of summer flows in the South Platte River basin occurred between 1880 and 1885, marking the end of stage 2.

Dams were built to increase available irrigation water. The earliest reservoirs impounded less than 6.2 hm^3 (cubic hectometers) in the basin in 1868. The dams were small structures built in natural depressions along or across small tributaries. Large-scale construction of dams in the basin began during the early 1880's (table 2). Canal-construction activity declined during the decade 1890-1900 (63 constructed) and increased again after 1900. Canal construction declined again after 1910. Construction of dams did not completely eliminate overappropriation of summer flows. In 1911-1912, for example, only canals with appropriation decrees of 1882 or older received water during the highest flows in June. In the same years, new claims for water totaling 784 m^3/s were made (State of Colorado, 1914).

Although present storage is double that of 1912 (fig. 2), only a minor amount of the increase has been for irrigation. Dam construction declined during the 1920's, increased slightly during the early 1930's, and declined afterward. Most of the reservoirs impounded after 1930 were for new municipal water supplies and for flood control and recreation. Little canal-construction activity occurred after 1930. New demands for irrigation water were satisfied with ground water. Thus, 1930 marks the end of stage 3 and the beginning of stage 4 in the South Platte River basin.

Table 2.--*History of reservoir capacity in the Platte River basin*[1]

Basin	New usable storage, in cubic hectometers												
	1851-1860	1861-1870	1871-1880	1881-1890	1891-1900	1901-1910	1911-1920	1921-1930	1931-1940	1941-1950	1951-1960	1961-1970	1971-1980
South Platte River basin	0	0	8.7	142.2	167.5	535.3	102.6	0	186.5	118.3	76.0	0	539.0
North Platte River basin	0	0	0	0	11.6	1,408.0	97.7	79.2	1,646.8	2,402.9	969.9	0	0
Platte River above Loup River	0	0	0	0	0	0	0	0	53.9	0	0	0	0

[1]Data from Martin and Hanson, 1966; F. B. Schaffer, Conservation and Survey Division, University of Nebraska, written commun., 1979. (For reservoirs in excess of 6.2 cubic hectometers.)

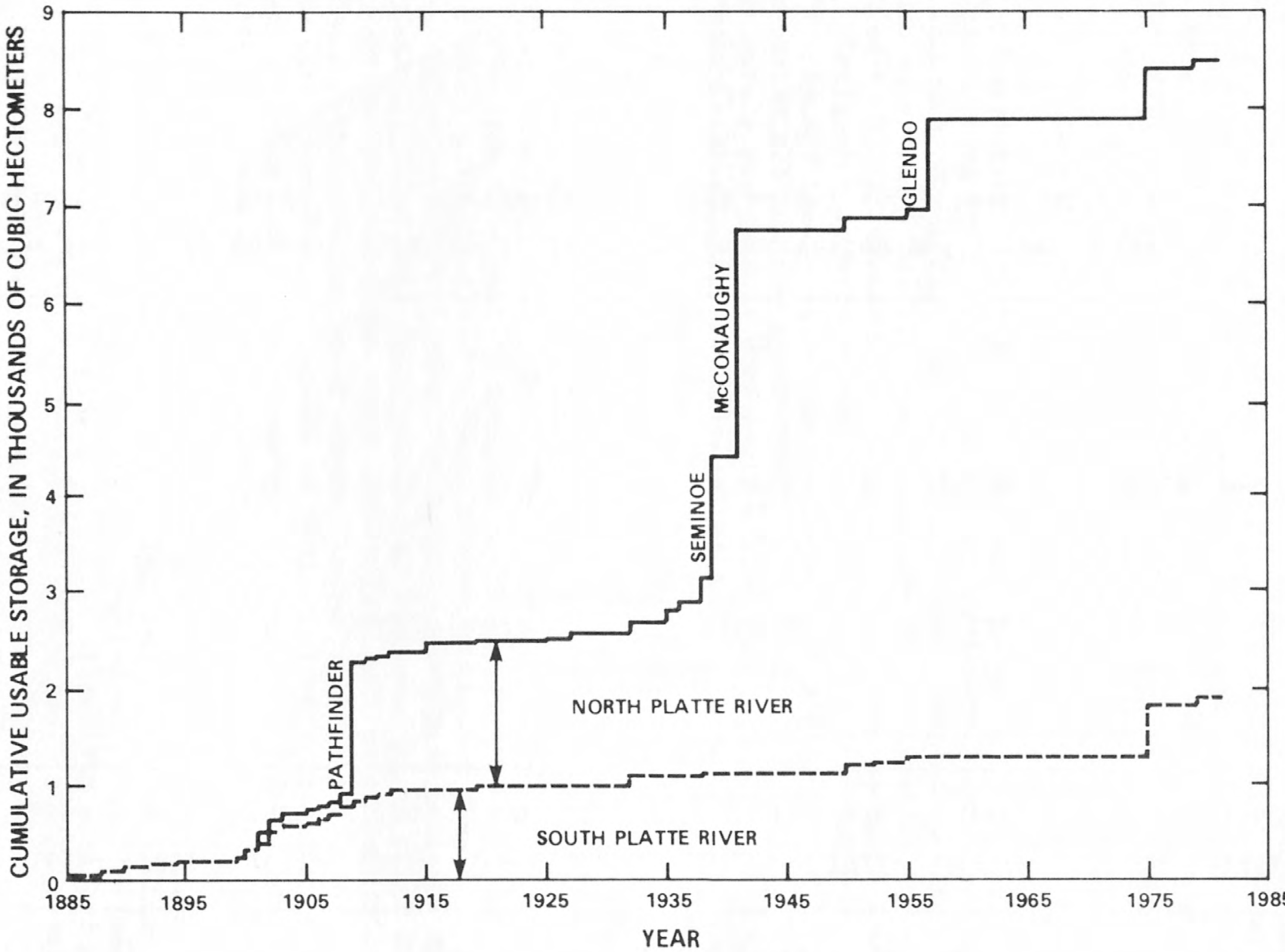

Figure 2.--Cumulative usable storage in reservoirs in the Platte River basin (modified from Bentall, 1975a).

Diversion of surface water from the Colorado River basin and North Platte River basin provided additional water for the South Platte River basin. The earliest of these transbasin diversions was begun in the early 1890's. Importation of water increased gradually from completion of the first structures to 1947, when the Alva B. Adams Tunnel, which imports water from the Colorado River basin, was completed. The large increase in imports of water after 1947 is shown in figure 3. Average annual diversions in 1974 totaled 460 hm^3 (Gerlek, 1977).

Use of ground water for irrigation dates from 1885, from an area near Eaton, Colorado (Rohwer, 1953). Extensive development of pump irrigation did not begin until 1910. The number of irrigation wells in the South Platte River basin increased slowly to a total of about 735 by 1933. The drought years of the mid-1930's saw the number of wells almost triple, to 2,000. The use of ground water for irrigation has continued to increase in importance with time (Hurr, 1975).

North Platte River and Tributaries

Irrigation development along the North Platte River and tributaries has an early history similar to that of the South Platte River basin. Irrigation was practiced in the vicinity of Fort Laramie as early as 1847 (McKinley, 1938). Throughout the 1850's and 1860's, small-scale irrigation projects flourished near military outposts, commonly to provide produce for emigrants.

Unlike Colorado, Wyoming did not experience a mineral-exploration boom in the late 1850's; the dominant industries in Wyoming during this period were grazing and agriculture. Although canals were built to irrigate farmland, grazing land did not require irrigation water. Thus, canal construction proceeded slowly during the 1860's and early 1870's. The period 1850-1870 may be considered stage 1 in the development of irrigation in the North Platte River basin.

The most rapid construction of canals occurred during the 1880's when cattlemen realized the benefits of irrigating grazing lands (McKinley, 1938, p. 91). In 1883, construction of the first large canals was completed on the Laramie River (Pioneer Canal) in Wyoming and the North Platte River (North Platte Canal) in Nebraska. By 1884, 22 firms, whose primary function was to supply water, existed in the North Platte River valley (McKinley, 1938). The severe winter of 1886-1887, during which the range-cattle industry experienced great losses for want of feed, provided the impetus for expansion of irrigation.

During the 1880's and early 1890's, several large canals were constructed on the North Platte River in Nebraska and on tributaries to the North Platte River in Wyoming. By 1889, Wyoming ranked third among the arid states in irrigated acreage and second in canal mileage following development in the North Platte basin above the Sweetwater River. The North Platte River in Wyoming below the mouth of the Sweetwater River was undeveloped as late as 1892 (U.S. Geological Survey, 1892), primarily because of the difficulty of diverting water from the North Platte River in the reach below the Sweetwater River.

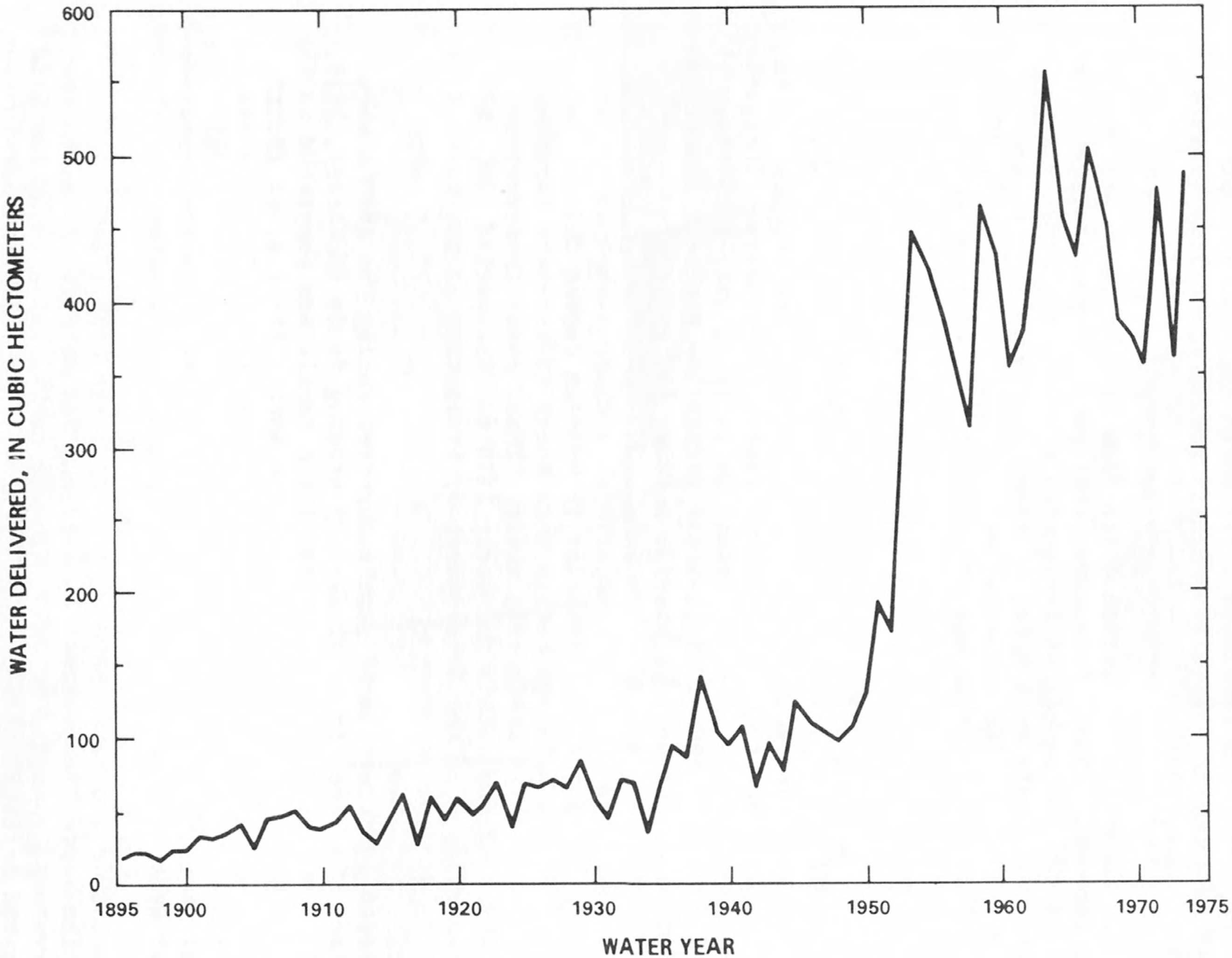

Figure 3.--Historical total yearly imports of water to the South Platte River basin since 1895 (modified from Gerlek, 1977).

Canal construction declined in the 1890's because by 1894, most of the available land in the North Platte River basin was being irrigated. The Carey Act, enacted in 1894, provided 1 million acres to the State on the condition that it be irrigated. Under this act, the largest private irrigation development within the basin was undertaken (McKinley, 1938). A second legislative act, the Federal Reclamation Act of 1902, enabled reclamation projects to be funded from the sale of public lands in the West. As a result of these legislative acts, canal construction increased during the period 1901-1910.

Overappropriation of summer flows in the North Platte River basin varied temporally along the tributaries. By 1889, summer flows of the smaller order streams in the basin were overappropriated (State of Wyoming, 1889); by 1899, flows of the Laramie River were overappropriated (State of Wyoming, 1899); by 1901, flows of Horse Creek and tributaries, Chugwater River and tributaries, Little Laramie River and tributaries, and upper North Platte River and tributaries in Colorado and Wyoming were overappropriated (State of Wyoming, 1902). Summer flows of the North Platte River in Nebraska were overappropriated sometime between 1914 and 1917 (State of Nebraska, 1914; State of Wyoming, 1918).

Flows of the North Platte River in Wyoming, below the mouth of the Sweetwater River, were not utilized until the construction of Pathfinder Dam in 1909 (fig. 2). The difficult terrain through which the river flowed offered few good sites for canal diversions, making the costs of diversion prohibitive. The Reclamation Act of 1902 provided public funds with which canals could be constructed along this section of the North Platte. Because of the lag in canal construction, overappropriation of summer flows in this section of the North Platte did not occur until much later than in the remainder of the basin. Overappropriation of summer flows in most of the North Platte River basin, however, occurred between 1900 and 1915. This period marks the end of stage 2 in the development of irrigation in the North Platte River basin.

Reservoir construction in the North Platte River basin began in 1892 (McKinley, 1938). The first reservoirs were natural lakes on the upper reaches of the tributaries that were modified to allow storage and release of water. In 1897, the Wyoming Development Company completed a reservoir on the Laramie River. By 1906, 27 reservoirs, with combined storage capacities of 3.0 hm^3, were operating in the basin (State of Wyoming, 1906).

The impoundment of Pathfinder Reservoir marked the beginning of stage 3 in the development of irrigation in the North Platte River basin. A renewed construction of canals occurred with the construction of reservoirs. During the period 1901-1910, 1,391 canals were constructed; during the period 1911-1920, 732 canals were constructed; and during the period 1921-1930, 249 canals were constructed. Canal construction declined after 1930. Dam construction for the purpose of irrigation in the North Platte River basin ended after 1939. The year 1939 marks the close of stage 3 in the development of irrigation in the North Platte River basin.

Platte River Valley

Development of irrigation along the Platte River lagged behind that of the North Platte and South Platte Rivers, partly because of the unwillingness of landowners to identify their land with more arid lands to the west (McKinley, 1938), and partly because irrigation was not essential for production of marginally profitable crops (Lugn and Wenzel, 1938).

Irrigation apparently was practiced as early as 1856 in the Platte River valley, near Wood River, about 18 km east of Fort Kearny (Carlson, 1963). Additionally, small irrigation projects were attempted during the dry years from 1859 to 1864. The project most commonly cited as the beginning of irrigation in the Platte River basin was a canal dug by John Burke in the year 1864 (Carlson, 1963) or 1866 (Willis, 1951), just east of North Platte. Little additional irrigation development occurred until 1882, when the Kearney canal was built for hydropower generation and irrigation. Further development occurred between 1891 and 1895, dry years in the Platte River valley, when six large canals were built on the Platte River between North Platte and Kearney. Between 1901 and 1930, one additional canal was constructed on the Platte River (1926), and several canals were constructed on the tributaries to the Platte River (table 1).

Construction of dams to supply canals on the Platte River did not result from overappropriation of flows on the river following canal construction. Rather, a shortage of water developed from the greater consumptive use of surface water upstream on the North Platte and South Platte Rivers. Three reservoirs, two of them offstream and Lake McConaughy on the North Platte with a combined usable storage capacity of 2,456 hm^3, were built after 1930 to supply canals and provide power.

Unreliability of streamflow in the Platte River encouraged development of ground water for irrigation. There is some historical evidence of pumping of ground water for irrigation beginning in the late 1880's (Willis, 1951), but this is not documented in the Platte River basin until 1893 (Lugn and Wenzel, 1938). Development of pump irrigation was slow initially, but it increased steadily, particularly after 1910. Between 1911 and 1920, 146 wells were constructed in the Platte River valley; between 1921 and 1930, 558 wells were constructed in the valley (Lugn and Wenzel, 1938). Most of the wells developed before 1930 were located west of Grand Island. The drought years of the 1930's hastened the development of ground-water irrigation, and its development continues to increase.

EFFECTS OF WATER DEVELOPMENT ON HYDROLOGY

Presettlement Hydrology

The Platte River valley served as a natural highway linking the eastern part of the United States with the unexplored and unsettled west. The first reliable reports of the river were written during journeys up the valley in the early 19th century. The number of reports increased during the large migrations west that began in the early 1840's, the California Gold Rush migrations in the late 1840's and early 1850's, and the Pikes Peak Gold Rush migrations in the late 1850's. Between 1800 and 1860, a substantial number of observations were recorded regarding the geology, topography, geomorphology of the valley, and hydrology of the river.

Accounts written during early explorations of the Great Plains and Rocky Mountains by scientific expeditions, as discussed below, probably furnish the most reliable information about the river and valley. Location of historic sites and migration trails are shown in figure 4. In most cases, these expeditions were commissioned for the purpose of observing and reporting on the lands and rivers of the region. Later accounts of the river and valley, written during westward migrations, probably are not as reliable. These accounts were written by travelers using the valley as a means of going west; their interest in the territory was secondary to the immediate task of surviving the journey. Usually, no attempts were made at systematic observation, and the prejudices of fellow travelers and travel guidebooks often were repeated in the journals. Movement of large numbers of settlers through the Platte River valley (estimated to be 350,000 persons between 1841 and 1866 by Mattes, 1969) had a significant impact on the land. For example, timber, a scarce commodity in the valley before the first migrations, all but disappeared in many parts of the valley because of use by settlers and railroads.

The most notable expeditions that touched the Platte River valley were the Lewis and Clark Expedition in 1804, the Long Expedition in 1820, the Fremont Expedition in 1842, and the Stansbury Expedition in 1850-1851. Other notable explorations were the Stuart Exploration in 1812-1813, the Ashley-Smith Explorations in 1822-1829, and the Bonneville Exploration in 1832. These and other accounts of the river and valley written during the period 1800-1860 by missionaries, trappers, naturalists, and settlers provide the first substantial historical description of the Platte River.

Floods

To clear the western passes before the first snowfall, travelers had to traverse the Platte River valley in the spring, during spring floods. Thus, most observations of the river were made during high flow. In approximately 70 years of written records of early explorations of the valley, from about 1800 to the construction of railroads and the subsequent cessation of the great westward migrations in 1870, there are no accounts of overbank floods on the Platte River. In 1820, the Long Expedition (James, 1823) reported that the river was so wide and the banks so high that "*** the highest freshets pass off without inundating the bottoms, except in their lowest parts; the rise of the water, on such occasions, being no more than five or six feet." In 1849, Pritchard (Morgan, 1959, p. 63) wrote in his journal, that the banks of the Platte near Grand Island:

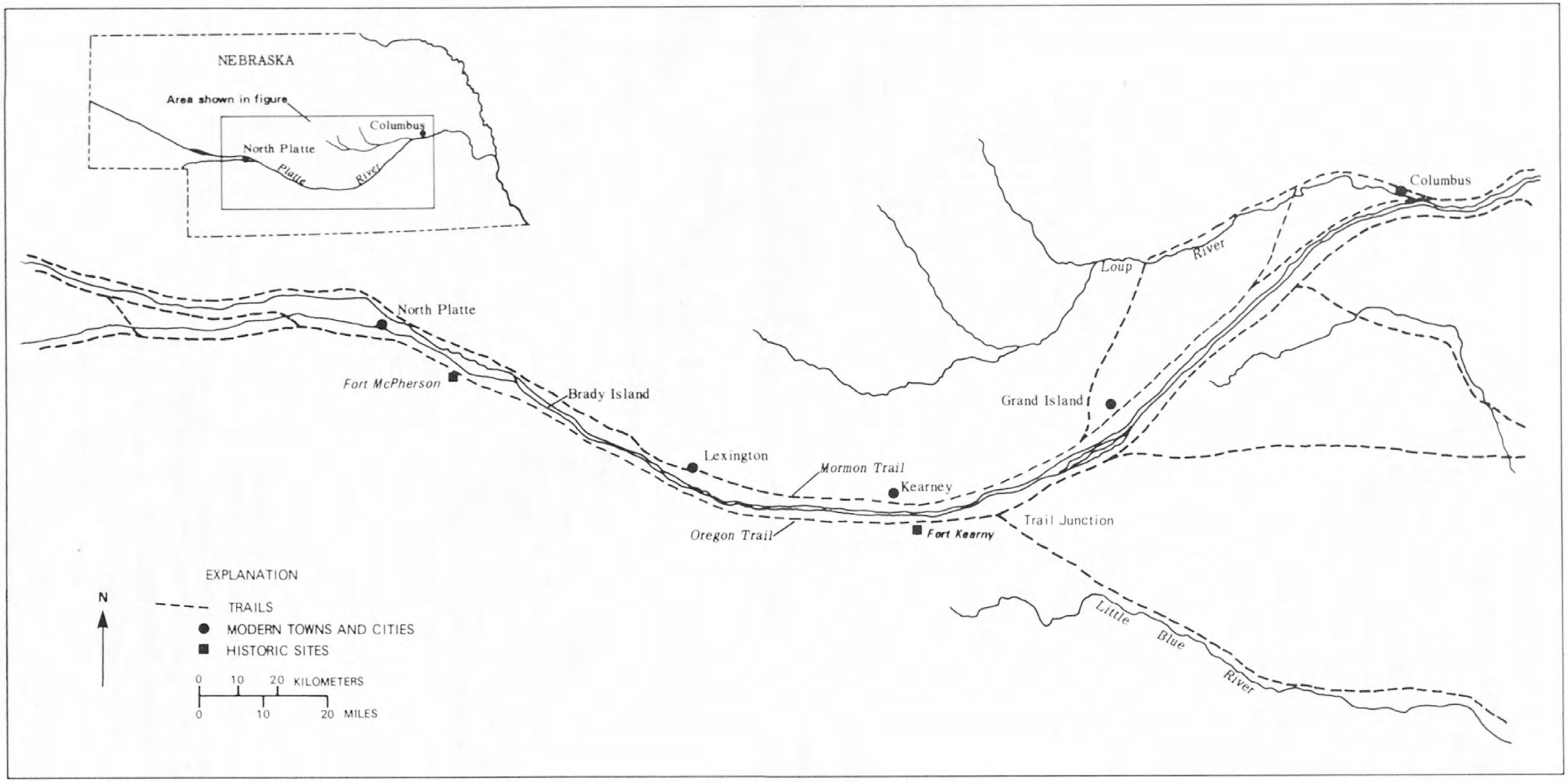

Figure 4.--Location of modern and historic sites in the Platte River valley.

> *** are low at this time (the river being high) [and] do not rise more than 18 inches or two feet above the surface of the water. I judge that the bottoms at this point are rarely, if ever inundated ***. Such is the breadth of the channel that an immense quantity of water would be required to raise it above its banks ***.

The only observation of flooding in the Platte River basin was noted by Fremont (1845, p. 110), on the South Platte upstream of Bijou Creek, who wrote "On the evening of the 3rd (July) as we were journeying along the partially overflowed bottoms of the Platte ***." The "bottoms" referred to in these accounts are probably the low, broken meadowlands that occur on either side of the river. These bottomlands usually contain abandoned channels, which, during high flow, may be filled with water from a rise in the ground-water table, rather than by overflow of the river. It is unclear from historical accounts, particularly the Fremont account, whether the bottomlands were inundated by overflow of the river or by a rise in the ground-water table.

Low Flows

Because most of the travels along the Platte River valley occurred in the spring, few historical accounts exist of the river during low flow. Of particular interest is the behavior of the river between the junction of the North Platte and South Platte Rivers and the confluence with the Loup River (fig. 2). The Loup has a fairly constant discharge (Brice, 1964, p. 35); therefore, the Platte River below this confluence probably was a perennial stream. Little is known about low-flow behavior of the river above the confluence with the Loup prior to irrigation, about 1860. Miller (1978) concluded that prior to irrigation the Platte River above the junction of the Loup rarely, if ever, went dry in the summer. This conclusion is based primarily on indirect evidence, such as construction of canals along the Platte to divert water during the summer months.

Several observations of the Platte River during low flow are notable. Clarke (1902, p. 301) reported that "*** In the summer of 1863, the Platte having so nearly dried up as to make it difficult to secure water for cattle *** We sank headless barrels in the Platte *** to secure water from an underflow." Ware (1911, p. 41) noted that during the summer of 1864:

> *** From Fort Kearney, for many miles up, there was no water in the river. The water seemed to be in "the underflow". We not infrequently rode down to the river, and with shovels dug watering places in the sand of the bed ***. We were told that 75 miles of the river were then dry, and that generally about 125 miles of it were dry in the driest season ***.

The year 1864, however, apparently was not unusually dry. In 1864, Ward (in Root and Connelley, 1901) wrote of the "*** unprecedented flood of 1864." McKinley (1938) also reported the river to be unusually high during the spring of 1864.

Fremont (1845, p. 77), descending the North Platte River (Sept. 3, 1845), wrote that the river was "*** merely a succession of sandbars, among which the channel was divided into rivulets a few inches deep." Upon reaching the Platte River, Fremont and his men constructed a bull boat which, when fully loaded with men and supplies, drew four inches of water; they attempted to navigate the river (Fremont, 1845, p. 78):

> *** On the morning of the 15th [September] we embarked in our hide boat, Mr. Preuss and myself, with two men. We dragged her over the sands for three or four miles, then left her on a bar and abandoned entirely all further attempts to navigate this river ***.

If the river did not go dry every summer, the flow became relatively insignificant, a "*** mere trickle of water among sandy shoals ***" (Ghent, 1929, p. 128). Between the junction of the North Platte and South Platte Rivers and the Loup River, the Platte may have gone dry during years of low precipitation and probably was reduced to a trickle in other years.

Postsettlement Hydrology

Surface Water

Diversion and storage of surface water for irrigation and hydropower generation have changed patterns of streamflow in some reaches in the Platte River basin. At some stations changes in flood peaks, annual mean discharge, the shape of flow-duration curves have been recorded. These changes are not found uniformly throughout the Platte River basin, because development of water resources has progressed differently along the North Platte, South Platte, and Platte Rivers.

Construction of large onstream reservoirs in Wyoming and Nebraska has decreased peak flows of the North Platte River. Four gaging stations on the North Platte River with long periods of record show that peak discharge decreased progressively after the closure of each of four major dams (Williams, 1978). Kircher and Karlinger (1981) determined statistically that changes in annual peak flows on the North Platte River at North Platte, Nebraska, are better described by two regression models, one corresponding to the period prior to construction of Kingsley Dam (1895-1935) and one corresponding to the period following construction (1936-1979), than by a single model. Kircher and Karlinger did not test the significance of differences in peak flows following each period of dam construction, but peak flows from 1895 to 1935 decreased with time. There has been no significant change in peak flows since 1935.

Reservoir development has been less extensive in the South Platte River basin than in the North Platte River basin. Total reservoir storage in the South Platte River basin increased about 100 percent from 1915 to the present (fig. 2) with the majority of storage in offstream reservoirs.

Kircher and Karlinger (1981) showed that peak flows of the South Platte River near Kersey and Julesburg, Colorado, have not changed significantly since 1902, the beginning of the record. However, a statistically significant decrease in peak flows with time was observed on the South Platte River at North Platte, Nebraska, probably due to surface-water diversions downstream of Julesburg.

Peak flows of the Platte River are influenced by flows from both the North Platte and South Platte Rivers. Since the reduction of flood peaks on the North Platte River, flood peaks on the South Platte River have become a more significant component of flow on the Platte River. Peak flows on the Platte River near Overton, Nebraska, have decreased over the period of record, 1915-1979, but have shown no statistically significant decrease since 1935 (Kircher and Karlinger, 1981). No long-term change is apparent in peak flows near Grand Island, Nebraska, since the record began in 1935. However, changes may have occurred prior to 1935.

If the entire period of record is considered, annual mean flows have decreased on the North Platte and Platte Rivers. However, since 1935, annual mean flows on these rivers have either not changed signficantly or have increased. Records for the North Platte River at North Platte and the Platte River near Overton show no statistically significant change in annual mean flows for the period 1935-1979 (Kircher and Karlinger, 1981). Annual mean flows of the Platte River near Grand Island have increased significantly since 1935. No long-term change is apparent in annual mean flows of the South Platte River although changes may have occurred prior to the period of record. Importation of water into the South Platte River basin apparently has counteracted the effects of water development within the basin.

The flow-duration curve is the frequency distribution of daily mean flows at a given site. The flow-duration curve graphically represents variability of streamflow by the shape of the curve. The position of the curve reflects the magnitude of the streamflow (Leopold, Wolman, and Miller, 1964). Curves with low slope and high minimum values generally indicate a large baseflow component of streamflow. High slope and low minimum values indicate a more ephemeral character and a quicker response to precipitation events. The flow-duration curve does not provide information about sequential relationships of flows (Hudson and Hazen, 1964). Thus, although the curve may reveal that a given flow is exceeded 50 percent of the time, it cannot indicate if the flows occurred consecutively, randomly, or in some pattern.

The shape of flow-duration curves for most stations on the North Platte, South Platte, and Platte Rivers has changed with time (Kircher and Karlinger, 1981; Eschner, 1981). In general, the curves show an increase in the magnitude of low-frequency discharges. A representative example of the type of changes that have occurred in flow duration over time is shown in figure 5. The position of the curve is dependent on the volume of water passing the gage during the period for which the flow duration is computed. However, the changes in the shape of the flow-duration curves with time reflect the cumulative effects of streamflow regulation and water use.

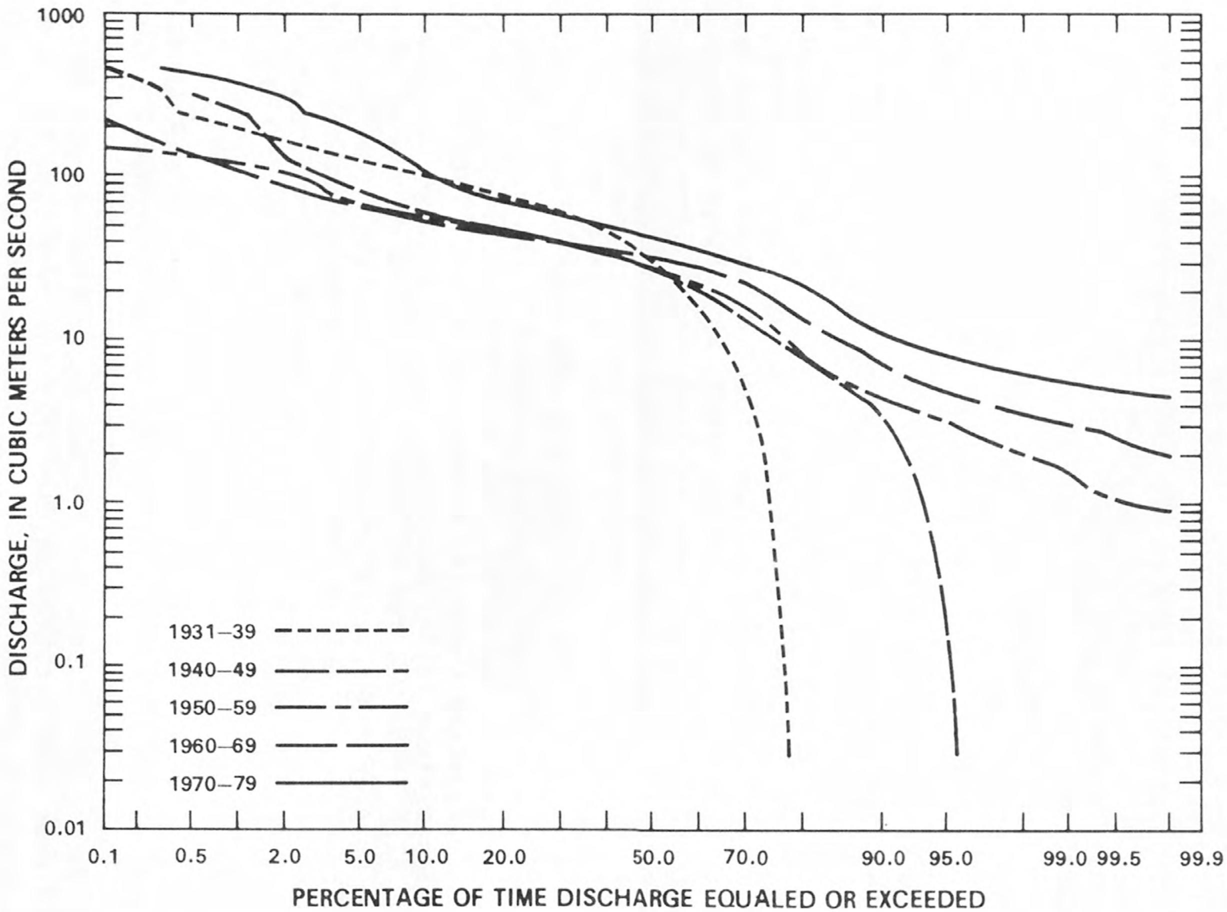

Figure 5.--Flow-duration curves for 10-year periods, Platte River near Overton, Nebraska (from Kircher and Karlinger, 1981).

Surface-Water - Ground-Water Relationships

Unconsolidated deposits of the Platte River valley in the study area comprises Holocene alluvium and Quaternary sediments. The Ogallala Formation of Tertiary age and Pierre Shale and Niobrara Formation of Cretaceous age underlie the Quaternary sediments in the Platte River valley. The Ogallala Formation thins to the east and pinches out between Kearney and Grand Island. The thickness of the Ogallala Formation is irregular due to deposition on an irregular Cretaceous surface and to subsequent erosion.

Quaternary sediments and, where present, the Ogallala Formation, are the principal aquifers in the Platte River valley. These two units act as a single aquifer in areas where the Quaternary materials overlie the Ogallala. The Quaternary sediments comprise the primary aquifer where these sediments directly overlie the Pierre Shale or Niobrara Formation. The Niobrara Formation is a source of ground water at some locations (Bentall, 1975b). Thickness of saturated alluvium varies from about 6 m to more than 122 m because of an irregular bedrock surface (Bentall, 1975a).

The Platte River is hydraulically connected with the aquifer in the valley (Lappala, Emery, and Otradovsky, 1979); water can move from the river to the ground water and from the ground water to the river. The river serves as a control on the ground-water system and can influence ground-water levels and reflect changes in those levels. A study near Grand Island indicates that ground-water levels within ½ mile of the river in that area respond within 24 hours to changes in river stage (Hurr, 1981). It is not known if this rate of change is typical for other areas within the Platte River valley.

In general, ground-water pumping lowers ground-water levels. This reduction may result from drawdown and change in water-table gradient, rather than from appreciable loss of storage. Evapotranspiration salvage, or the reduction of evapotranspiration by lowering the water table, would offset partially the decrease in water level brought about by ground-water pumping in areas where the ground-water table is close to the surface. Ground-water withdrawals in relatively close proximity to the Platte River may influence ground-water levels in two ways: (1) By initiating drawdown, and (2) by causing river-stage decline that may induce a further reduction in ground-water levels downstream (Hurr, 1981).

Net rises in ground-water level have resulted primarily from seepage water from canals and reservoirs. Lugn and Wenzel (1938) noted a rise in water level over 3 m since 1896 near Lexington, Nebraska. In general, rises of 3 m have occurred beneath the Central Nebraska Public Power and Irrigation District in Lincoln, Gosper, Dawson, Phelps, and Kearney Counties. The largest recorded rises in water levels have been 27 m for Phelps County, 19 m for Kearney County, and 25 m for Gosper County (Johnson and Pederson, 1980). Rises of more than 0.6 m were measured in those counties between October 1968 and October 1971 (Lappala, Emery, and Otradovsky, 1979).

Net declines in the water table have occurred over broad areas in the Platte River valley in response to ground-water pumping. The greatest water-table declines have occurred primarily in areas where depth to the water table prevents evapotranspiration salvage (Bentall, 1975a). Declines of less than 1.5 m have occurred extensively throughout Buffalo, Hall, and Merrick Counties. Net declines of up to 6.4 m since the beginning of development have been recorded in Buffalo County mainly in upland areas along the Platte River-Loup River divide (Johnson and Pederson, 1980). Declines of more than 1.2 m have been measured for the period 1968 to 1971 for other parts of Buffalo, Hall, and Merrick Counties (Lappala, Emery, and Otradovsky, 1979).

Water-level changes in the Platte River basin in Nebraska were simulated by Lappala and others (1979) for various development schemes. Projected water-level changes ranged from rises up to 6.1 m over some areas with no further development, to net declines up to 24.4 m over the entire upper Platte subbasin, if development of ground water continues at the rate that occurred from 1960 to 1970.

EFFECTS OF CHANGES IN HYDROLOGY ON THE CHANNEL

Presettlement Channel and Valley-Floor Characteristics

Channel Width

Channel width was the most obvious characteristic of the Platte River in the 19th century. Most travelers, comparing the Platte to rivers in the Eastern United States, found the width of the river remarkable; comments on channel width were recorded in most journals. Accurately estimating distances across a wide body of water is difficult. Accordingly, estimates of channel width from historical accounts must be used with caution. In 1849, Pritchard (Morgan, 1963, p. 63) noted that it "*** is hardly possible to guess at the width of the river as we seldom see the whole at once, on account of the numerous islands that are scattered from shore to shore ***." Many of the estimates of channel width included the width of the islands in the channel. In 1849 Gibbs (Settle, 1940, p. 306) noted "*** [the Platte] is a mile [1.6 km] in width. Where cut up by islands, as is often the case, it extends to double or treble [that distance], and in one place is seven miles [11.3 km] wide from shore to shore."

Estimates of the width of the Platte River during the period 1800-1860 vary from 1.2 to 4.8 km, with the most common estimates ranging from 1.6 to 3.2 km. There are two measured observations of channel width recorded in the literature. In 1832, Captain Bonneville (Irving, 1837) measured the width of the Platte River 40 km below the head of Grand Island and found it "*** twenty-two hundred yards [2.0 km] from bank to bank." Fremont (1845, p. 21) determined the width of the Platte River below the confluence of the North Platte and South Platte Rivers to be 1.6 km.

Channel Depth

The second most remarkable characteristic of the Platte River was its depth. The river could be forded anywhere at almost anytime of the year, except during spring floods. Observations of water depth are useful only to establish a range in flows. Most observations of depth range from 0.3 to 1.2 m, depending on river stage. Long (James, 1823) reported that the bed of the Platte "*** is seldom depressed more than six or eight feet [1.8 to 2.4 m] below the surface of the bottoms, and in many places even less." Jessup substantiates Long's report:

> *** The range of the Platte, from extreme low to extreme high water is very inconsiderable, manifestly not exceeding six or eight feet [1.8 to 2.4 m]. This is about the usual height of its banks above the surface of the sand which forms its bed ***.

Warren (1858) later reported that, "*** when the banks are full, it [Platte] is about six feet [1.8 m] deep throughout, having a remarkably level bed."

Bed Material and Bed Forms

In general, descriptions indicate that the bed material consisted of sand and gravel. However, James (1823), the botanist and geologist of the Long Expedition, stated, "The alluvial deposits of which the river bottoms are formed, consist of particles of mud and sand ***," implying that the bed was finer than other accounts indicated.

Quicksand was encountered in the channels of the Platte system. In 1812, Stuart (Rollins, 1935) wrote that the bed of the Platte River, near the present day Gosper-Phelps County border, was composed "*** of such quicksand that it was difficult for our horse to get over, though the water was in no place more than two feet [0.6 m] deep." Farther downstream near Fort Kearny, Taylor (Williams, 1969) in 1850 noted, "The bottom is composed of a fine quicksand ***." Fremont (1845) described the southern channel of the South Platte River near the confluence with the Platte River as being "*** generally quicksands."

The configuration of the channel bed and its ephemeral character were described in detail by several travelers. Bradbury (1819), recrossing the Platte, noted:

> *** in the same place where the day before it reached to our armpits, it did not now reach to our waists, although the river had not fallen. Such changes in the bottom of this river *** were very frequent, as it is composed of a moving gravel, in which our feet sank to a considerable depth.

Mattes (1969) cited two descriptions of the Platte River bed near Fort Kearny. In 1849, Pritchard (Mattes, 1969) noted the composition and character of the bed: "The bed of the river is composed of sand, and this is all the time shifting its position and fresh deposits are constantly being made." Evans (Mattes, 1969) wrote in 1849 that the Platte was a wide sheet of water "*** running over a vast level bed of sand and mica *** continually changing into short offsets like the shingled roof of a house ***."

The account of the Long Expedition (James, 1823) stated of the Platte, "*** its bed is composed almost exclusively of sand, forming innumerable bars, which are continually changing their positions and moving downward [downstream] ***." In their travels, members of the Long Expedition observed on the flood plain "*** extremely numerous natural elevations of earth, of some considerable degree of regularity *** of a more or less oval outline ***" with lengths of about 30 m and heights of 0.6 to 1.5 m. These elevations were presumed to have been former sandbars, "Their existence is doubtless due to the action of water. Should the rivers Platte and Arkansas be deprived of their waters, the sand islands of their beds would probably present a somewhat similar appearance."

The water of the Platte commonly was referred to as muddy or turbid. The "turbid waters of the Platte" were noted by the Long Expedition (James, 1823). McKinstry (1975), although calling the Platte a river of sand, stated that it was "*** nearly as muddy ***" as the Missouri. Taylor (Williams, 1969) wrote that the river was, at various points, "*** swift and muddy ***," "*** muddy and turbulent ***," and "*** broad swift and muddy ***." Kelly (1851) described the river as turbid. Ebey (Baydo, 1971) stated of the Platte: "The water is always muddy and turbid ***." Stagecoach drivers (Ghent, 1929) used to tell the story that the Platte never overflowed its banks because its flood waters carried so much mud, that as it rose, it built new banks.

Islands

Islands were a ubiquitous feature in the Platte River channels. In 1852, Cole (1905, p. 29) wrote:

> *** Looking out upon the long stretch of river either way were islands and islands of every size whatever, from three feet in diameter to those which contained miles of area, resting here and there in the most artistic disregard of position and relation to each other, the small and the great alike wearing its own mantle of the sheerest willow-green ***.

Islands of the Platte River can be divided into two groups based on size, elevation, and vegetation. The large, well-timbered islands were described and mapped by Fremont (1845, pl. 1); these are Brady Island, Willow Island, Elm Island, Grand Island, and five other unnamed islands. Grand Island, also called the "Great Island" or "Big Island," was the largest of the islands mapped, being 84 km long and 2.8 km wide by Fremont's estimate. Although no quantitative estimates were given of the elevation of the large islands, Fremont (1845, p. 78) described Grand Island as being "*** sufficiently elevated to be secure from the annual flood of the river."

In addition to the large islands, there were hundreds of smaller islands too numerous to map or name. These islands were as small as a few square meters in area; most supported shrubs, young willows, and cottonwoods. A particularly dense concentration of these smaller islands occurred between Fort Kearny and Grand Island: these were named "Thousand Islands" after the Thousand Islands of the St. Lawrence River (Meline, 1966, p. 21).

Vegetation

The valley of the Platte River supported a wide variety of plant species. The Fremont Expedition collected and cataloged over 90 plant species in the valley; the list included several species of trees, such as poplar (cottonwood), elm, hackberry, box elder, willow, and juniper. Other tree species found in the valley included cedar, dogwood, ash, and aspen.

Timber was a scarce commodity; however, it grew on the islands in the river and could be found in scattered groves between the Missouri and Loup Rivers (Fremont, 1845, p. 79). In 1820, according to Bell, the banks of the Elkhorn River and the Platte River near the Loup Fork were well-timbered (Fuller and Hafen, 1957, p. 107). The banks of the Platte River near Buffalo Creek also were timbered in 1812, according to Stuart (Rollins, 1935, p. 217). Timber also grew on the banks of the Platte River from the present site of Cozad to Brady Island (Fremont, 1845) and on the south bank of the Platte River along Brady Island (Rollins, 1935; Fremont, 1845; Palmer, 1847).

The scarcity of timber in the valley has been attributed to the effects of grazing buffalo and prairie fires (Stansbury, 1851, p. 32; Mattes, 1969). Accounts of prairie fires can be found in several reports. Wyeth (1833) noted that the ground "*** is covered with herbage for a few weeks of the year only, *** owing to the Indians burning the prairies regularly twice a year." Bradbury (1819) observed near the mouth of the Platte:

> *** the reflection of immense fires, occasioned by burning the prairies. At this late season (April 28), the fires are not made by hunters to facilitate their hunting, but by war parties; and more particularly when returning unsuccessful, or after a defeat to prevent their enemies from tracing their steps ***.

Several parties reported large areas of burned prairie along the Platte River valley. Stansbury (1851, p. 32) reported that the valley was burned for a distance of 480 km above Fort Kearny.

The influences of man and climate as regulators of tree growth in the valley have been underemphasized. The Indians used cottonwood as fodder for their horses and for firewood. Timber use by man increased during westward migrations up the valley. Fremont (1845, p. 17) noted that, near the head of Grand Island, "*** with the exception of a scattered fringe (of trees) along the bank, the timber *** is confined almost entirely to the island." Burnett (1904) reported that, in 1844, "*** near the head of Grand Island *** there was not a solitary tree on the south side of the river." It is likely that the few trees that grew along the banks of the Platte River were used for fodder and fuel by the Indians or settlers.

Distribution of timber in the valley was inconsistent with that expected based on the prairie-fire hypothesis. Timber grew along all the large tributaries to the Platte River, in many of the ravines in the bluffs along the valley margin, and in many hollows on the valley floor. It is unlikely that prairie fires sweeping across the valley would spare the timber along the rivers and in the ravines and hollows. A more likely explanation is that distribution of timber was controlled by availability of water; ravines, hollows, river banks, and islands are situated in topographically lower areas in close proximity to water. The conditions in these areas favor germination and growth. The remainder of the valley is topographically higher and drier. Conditions favoring the germination of seeds and growth of trees probably did not exist along most of the valley.

Aridity of the valley was observed by many travelers. In 1820, Long christened the area "The Great American Desert," a description of the valley that stuck through most of the 19th century. Several writers observed saline crusts on the surface over large areas of the valley. Townsend (1833) observed that the ground near Grand Island:

> *** is in many places encrusted with an impure salt, which by taste appears to be a combination of sulphate and muriate of soda [thenardite and halite]; there were also a number of little pools, only a few inches in depth, scattered over the plain, the water of which is so bitter and pungent, that it seems to penetrate into the tongue, and almost to produce decortication of the mouth ***.

Availability of water probably was the prime factor that determined the distribution of timber in the valley. Prairie fires and grazing buffalo may have been secondary regulators of growth and distribution.

Summary of Presettlement Characteristics

In the 1800's the Platte River averaged about 2 km in width; it may have been as wide as 5 km where it was cut by islands, or as narrow as 1.2 km where no islands were present in the channel. The two measured observations of width (Irving, 1837; Fremont, 1845), 2.0 and 1.6 km, fall within these average values. Flow depth varied between 0.3 and 1.2 m during most of the year; bankfull depth ranged between 1.8 and 2.4 m along most of the valley. Large sand deposits were common in the channel. The channel bed was very active; a change of bed elevation of 0.5 m was observed over a 1-day period.

The river was observed to flow at bankfull stages during the spring floods. There were no observations of overbank flow along the river. Above the confluence with the Loup, the Platte was an intermittent river. It carried little water during the late summer and dried up completely in some years.

The Platte channels contained nine large islands and hundreds of smaller islands; most supported timber. Timber grew along the banks of the Platte, along the banks of the tributary rivers, in the ravines cut in the bluffs along the margins of the river, and in hollows on the valley floor. Distribution of timber in the valley was controlled primarily by availability of water. Prairie fires and grazing buffalo probably were secondary regulators of timber growth and distribution.

Changes in Platte River Morphology

Changes in channel morphology of the Platte River can be documented by comparison of aerial photographs taken between 1938 and 1979. In addition, General Land Office maps provide relatively accurate measurements of river width from the 1860's. Changes in the intervening years must be inferred from hydrologic data and records of canal and dam construction that indicate when changes were initiated.

The development of islands in several reaches in the study area from 1860 to 1979 is shown in figures 6 through 10; the changes are summarized in figure 11. The same years are not shown for all the photo sets. These figures show representative island development that occurred throughout the study area.

Development of islands near Cozad, Nebraska, is shown in figure 6. The channel in 1860 was broad and open (fig. 6). By 1938, numerous islands had formed within the channel and had begun to attach to the flood plain (fig. 6). Between 1938 and 1979, significant narrowing of the channel occurred (fig. 6). Today, almost the entire channel of 1860 is covered with vegetation, and only two or three small meandering channels are present (fig. 6).

By 1938, some islands had formed and had become attached to the flood plain near Kearney (fig. 7a). A group of en echelon islands was present near the southern bank of the western edge (fig. 7a). Between 1938 and 1957, many new islands formed, and additional islands attached to the flood plain (fig. 7b). In 1957, almost the entire southern bank was lined with vegetation. In general, the islands present in 1938 are still present, but have enlarged, primarily in the downstream direction, or have coalesced with other islands. The dashed lines within the larger islands in figure 7b show the locations of channels that separated islands at one time. These abandoned channels have a

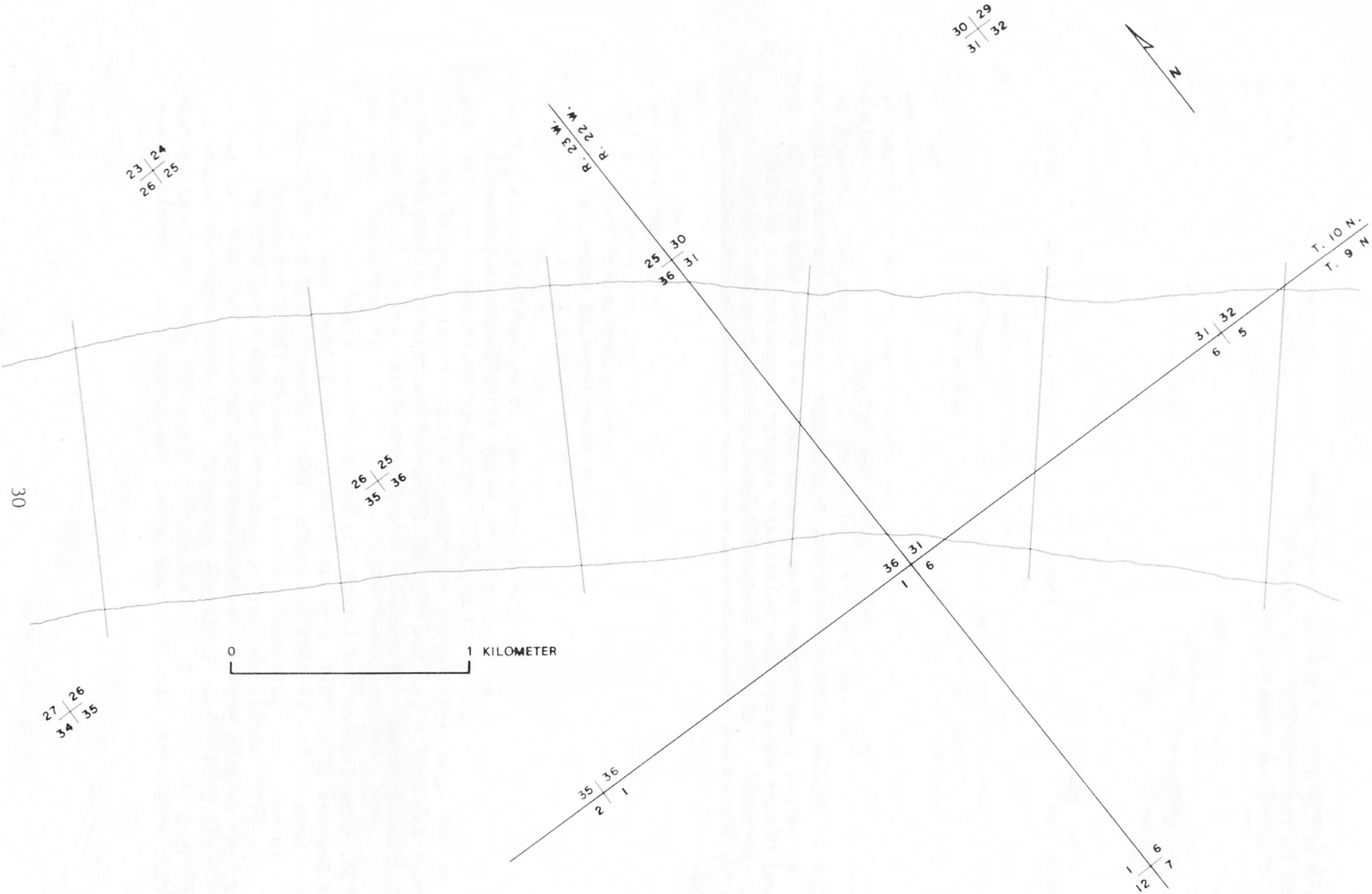

Figure 6a.--Channel of the Platte River near Cozad, Nebraska, in sections 25, 26, 35, and 36, T. 10 N., R. 23 W., section 31, T. 10 N., R. 22 W., and section 6, T. 9 N., R. 22 W., in 1860.

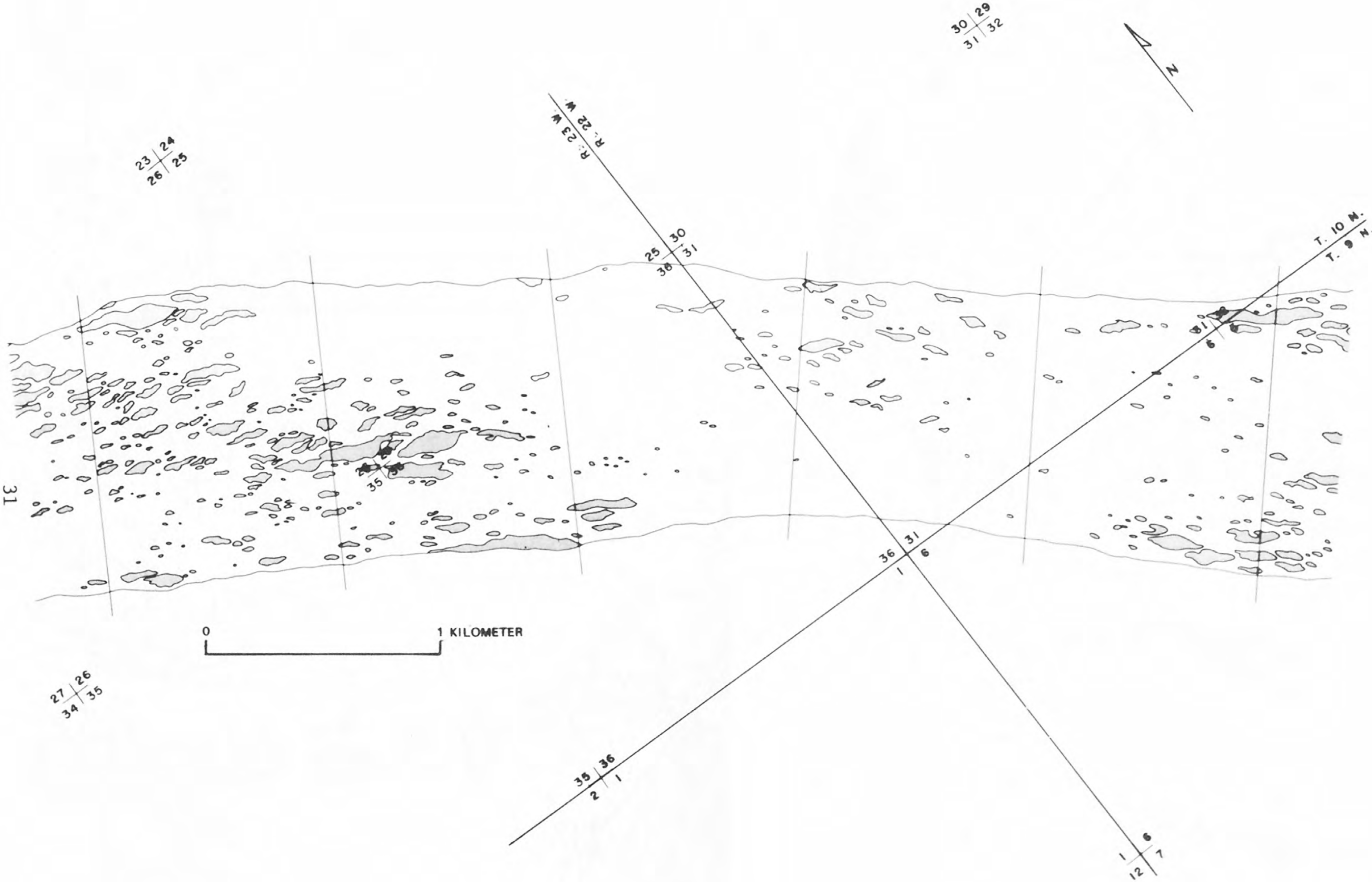

Figure 6b.--Channel of the Platte River near Cozad, Nebraska, in sections 25, 26, 35, and 36, T. 10 N., R. 23 W., section 31, T. 10 N., R. 22 W., and section 6, T. 9 N., R. 22 W., in 1938. Shaded areas are vegetated.

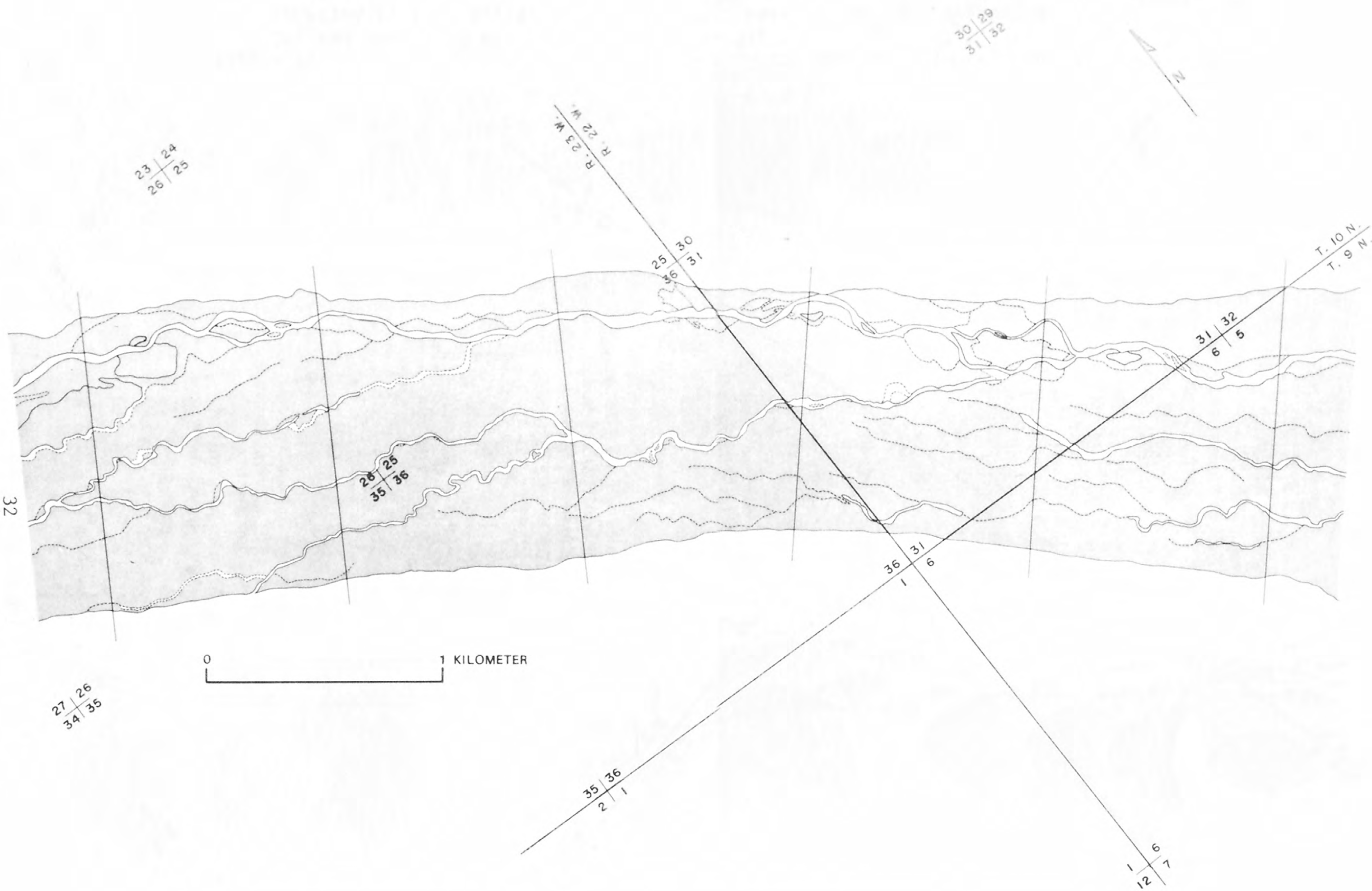

Figure 6c.--Channel of the Platte River near Cozad, Nebraska, in sections 25, 26, 35, and 36, T. 10 N., R. 23 W., section 31, T. 10 N., R. 22 W., and section 6, T. 9 N., R. 22 W., in 1979. Shaded areas are vegetated.

Figure 7a.--Channel of the Platte River near Kearney, Nebraska, in sections 7, 8, 9, 16, 17, and 18, T. 8 N., R. 16 W., and sections 12 and 13, T. 8 N., R. 17 W., in 1938. Shaded areas are vegetated.

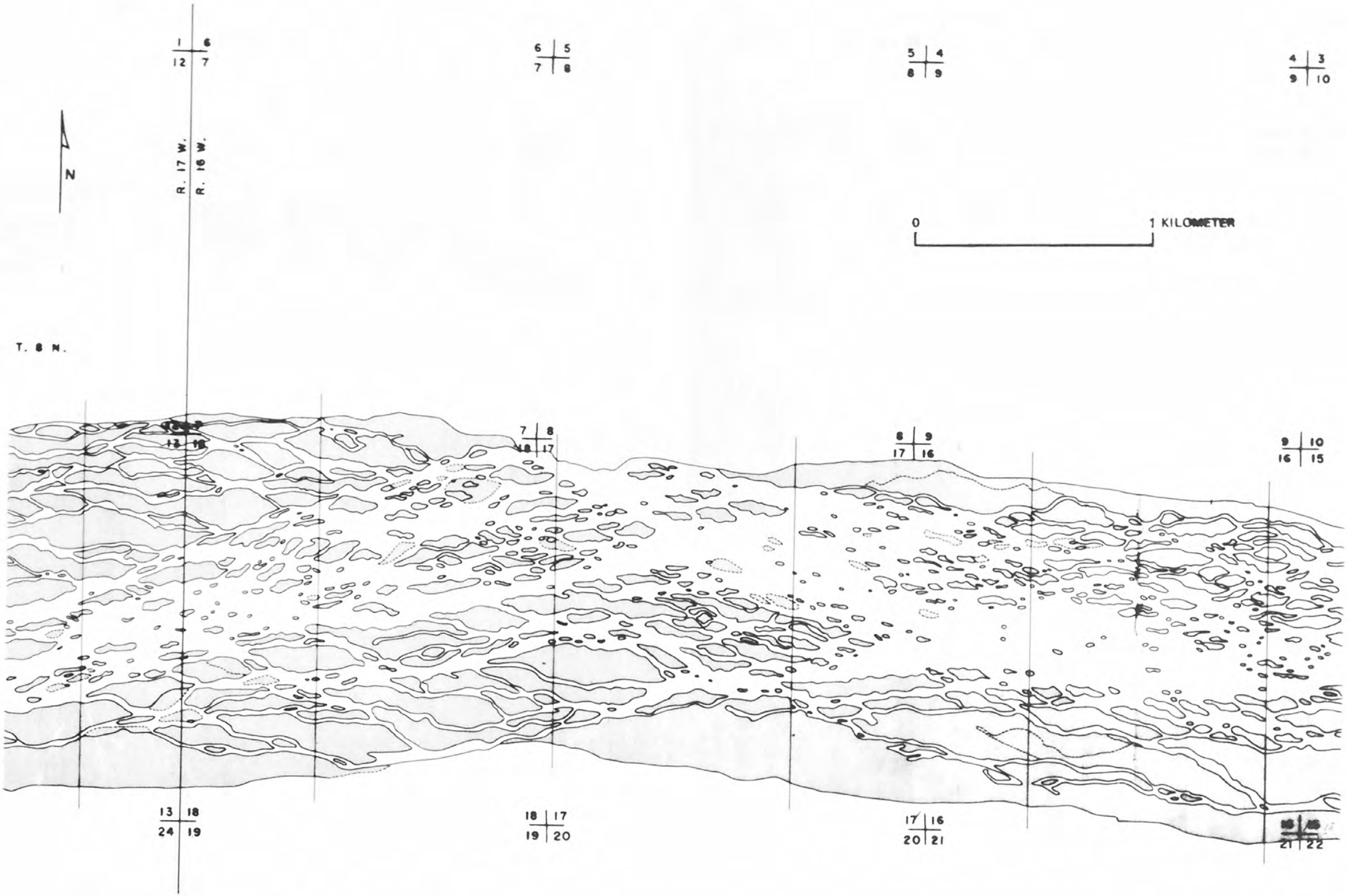

Figure 7b.--Channel of the Platte River near Kearney, Nebraska, in sections 7, 8, 9, 16, 17, and 18, T. 8 N., R. 16 W., and sections 12 and 13, T. 8 N., R. 17 W., in 1957. Shaded areas are vegetated.

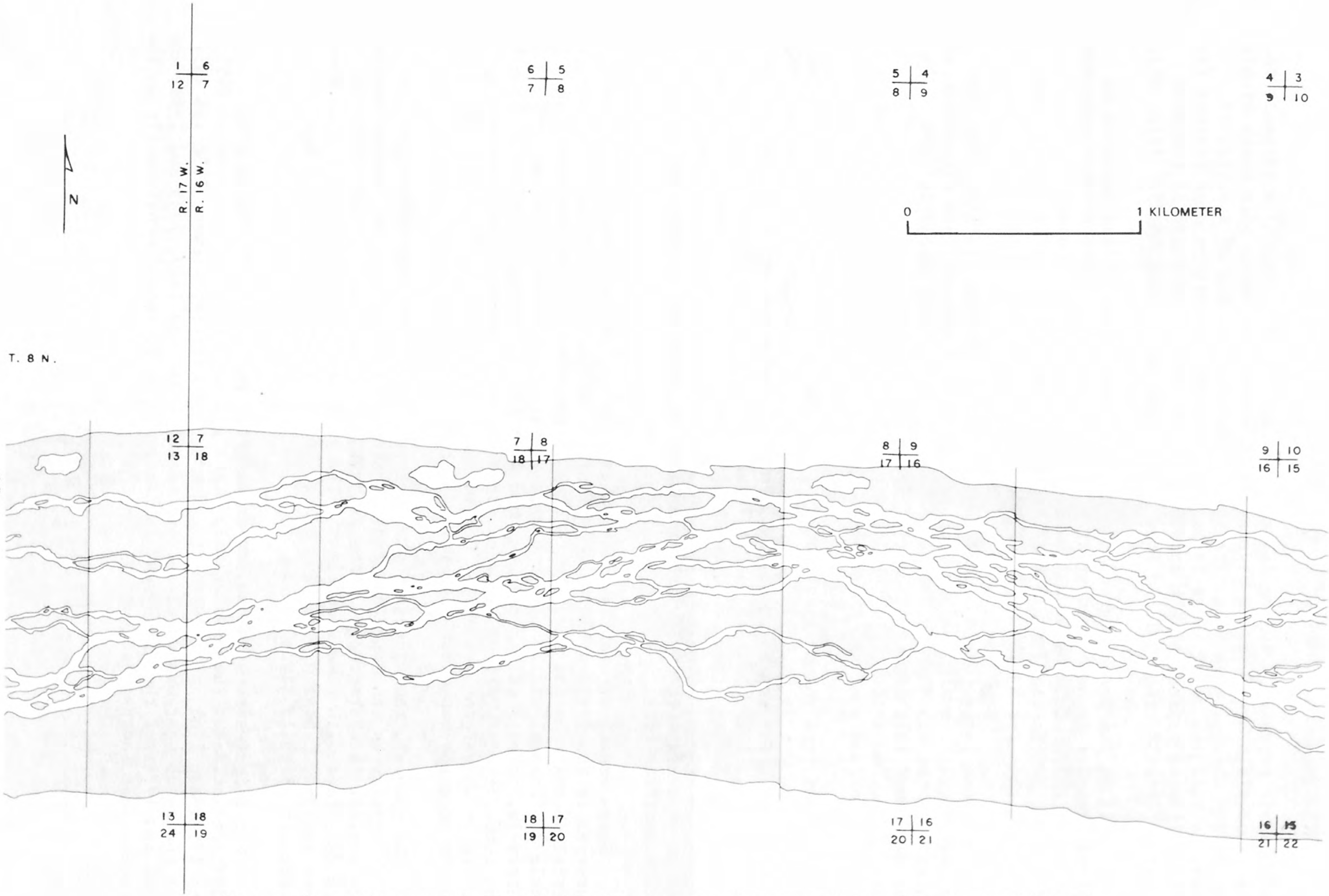

Figure 7c.--Channel of the Platte River near Kearney, Nebraska, in sections 7, 8, 9, 16, 17, and 18, T. 8 N., R. 16 W., and sections 12 and 13, T. 8 N., R. 17 W., in 1979. Shaded areas are vegetated.

topographic expression on the island surface. By 1979, island attachment to the flood plain had formed a wide swath of vegetation along both banks within the former channel area (fig. 7c) and the river consisted of a series of channels braiding among large islands. This channel pattern near Kearney (in 1979) differed appreciably in appearance from both the channel at the same location in 1938 (fig. 7a) and from the channel near Cozad in 1979 (fig. 6c).

In 1938, the percentage of channel area near Grand Island occupied by islands appears to have been greater than at the other river reaches observed for this study. Islands of all sizes were present in the channel, and attachment to the flood plain had begun (fig. 8a); by 1979, new islands had formed in this reach (fig. 8b).

Only one large island existed near Duncan, Nebraska, in 1860 (fig. 9a). By 1941, several small islands were present in the channel, and attachment of islands to the flood plain had begun. The large island mapped in 1860 had decreased slightly in size (fig. 9b). Most of the islands evident in 1941 had become attached to the flood plain by 1978 (fig. 9c). Although islands continue to form, the channel is relatively open.

In 1941, the channel near Ashland, Nebraska, contained four large islands (fig. 10a). One large island along the south bank already had become attached to the bank. The remainder of the 5-km reach had a few small islands in 1941. By 1971 (fig. 10b), only one large island existed in the channel. Two of the islands had become attached to the bank and one island not present in 1941 formed and became attached to the bank during the 30-year period. The net change in average channel width at Ashland was very small when compared to sites upstream (fig. 11).

Measurements of channel width taken from the General Land Office maps surveyed in the field during the approximate period 1859-1867 and six sets of aerial photographs for six 5-km reaches of the Platte River are listed in table 3. Channel widths were measured along six cross sections, at 1-km intervals, at each of six reaches, and averaged for the entire reach. To make the comparison of various cross sections easier, the widths are plotted in figure 11 as percentages of the General Land Office map widths. For convenience the map widths are called "1860 width" in figure 11.

In general, the widths of the Platte channels have decreased since 1860. Width changes in the Cozad, Overton, Kearney, Grand Island, and Duncan reaches are similar in character. On the average, the magnitude of width reduction has decreased with time since 1940. The decrease in width of the Platte River near Ashland, Nebraska, has been minor, however, and channel width has increased slightly since 1941.

Width increases of a smaller scale are superimposed on the long-term width reductions. These relatively minor width increases occur between 1951 and 1957, and 1969 and 1979 for the reach near Overton; between 1950 and 1957 for the reach near Grand Island; and between 1941 and 1949, 1955 and 1959, and 1965 and 1971 for the reach near Ashland. Width decreased consistently in the reaches near Kearney and Duncan.

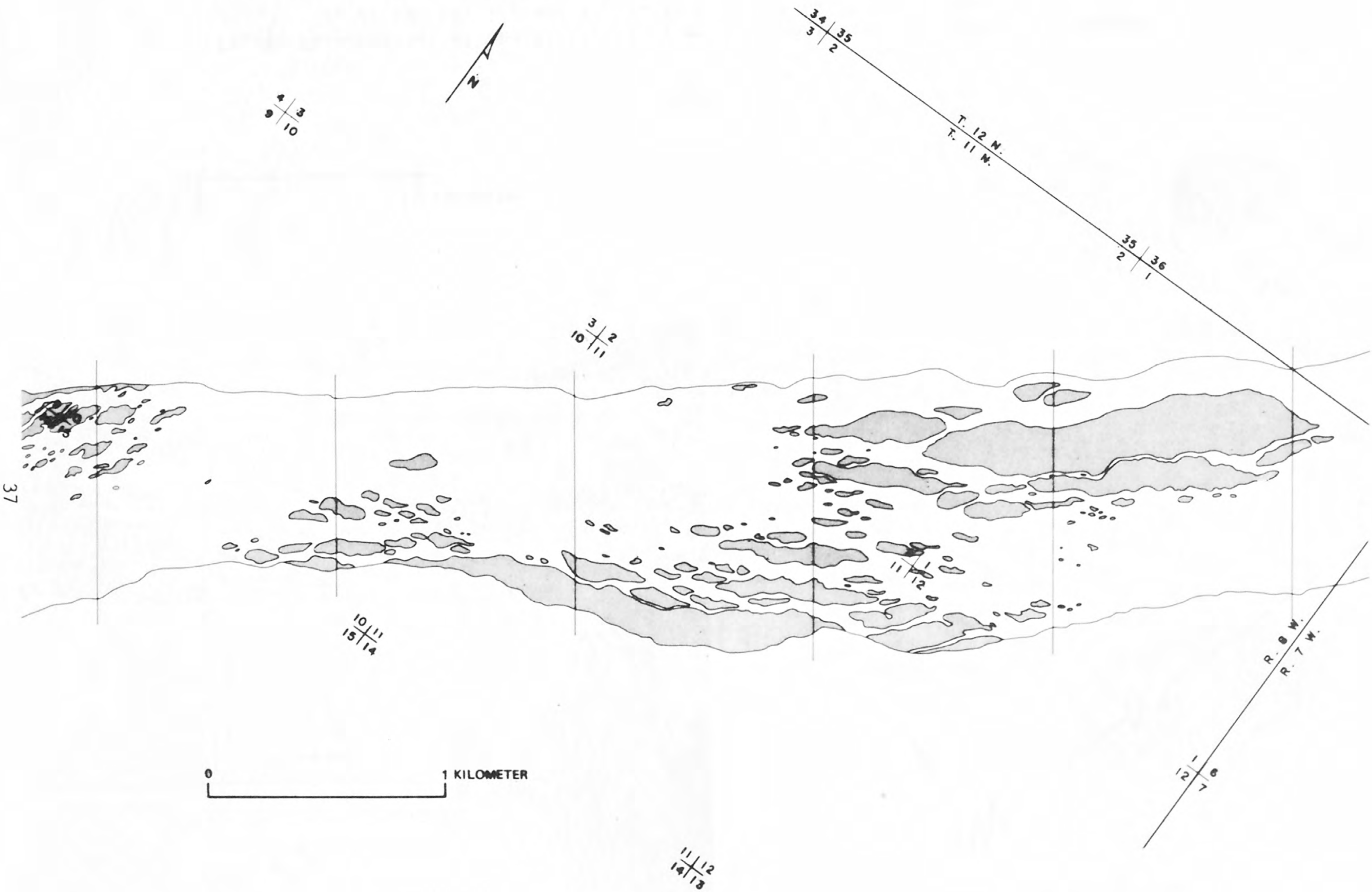

Figure 8a.--Channel of the Platte River near Grand Island, Nebraska, in sections 1, 2, 10, 11, 12, and 15, T. 11 N., R. 8 W., and section 36, T. 12 N., R. 8 W., in 1938. Shaded areas are vegetated.

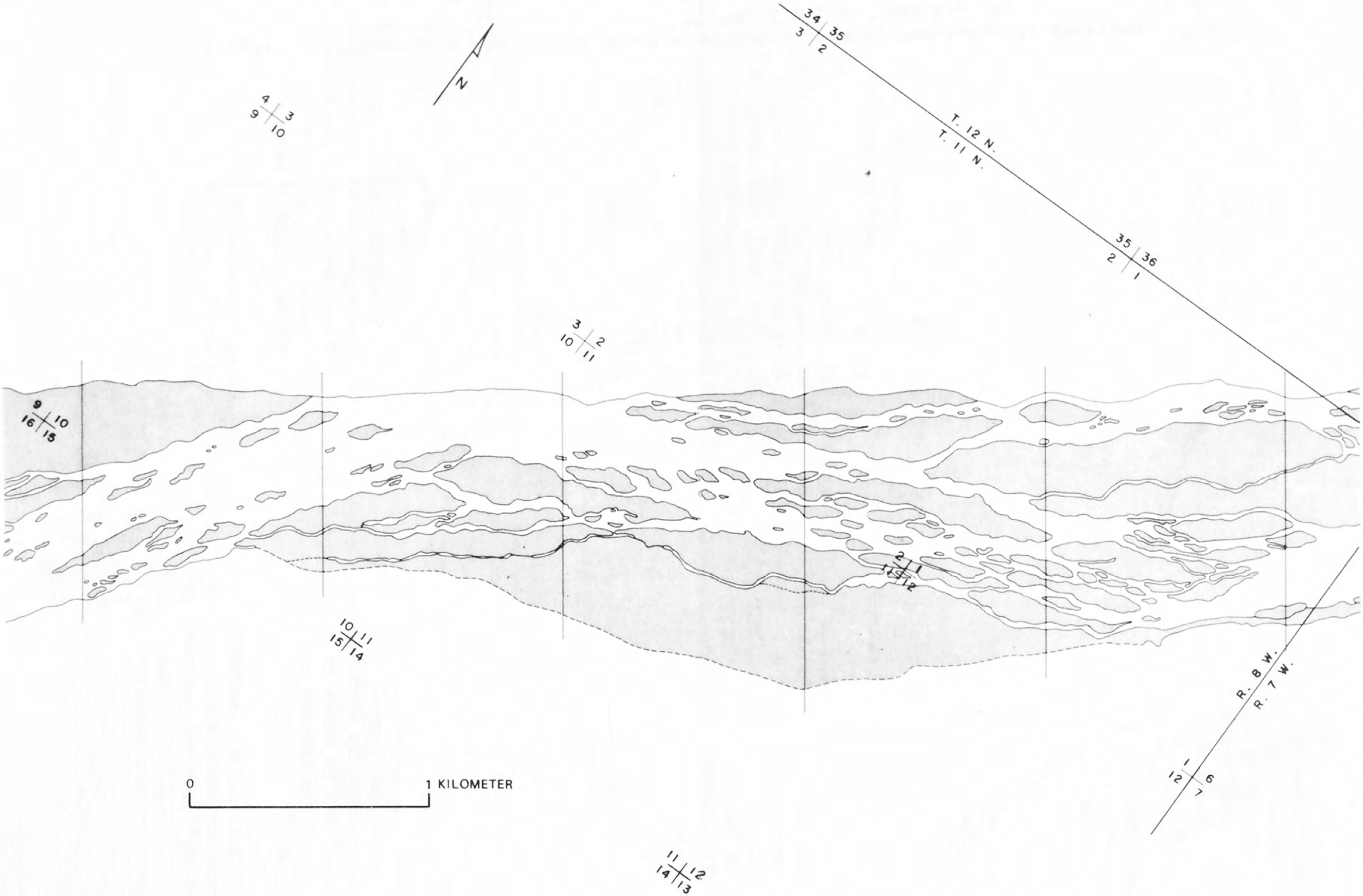

Figure 8b.--Channel of the Platte River near Grand Island, Nebraska, in sections 1, 2, 10, 11, 12, and 15, T. 11 N., R. 8 W., and section 36, T. 12 N., R. 8 W., in 1979. Shaded areas are vegetated.

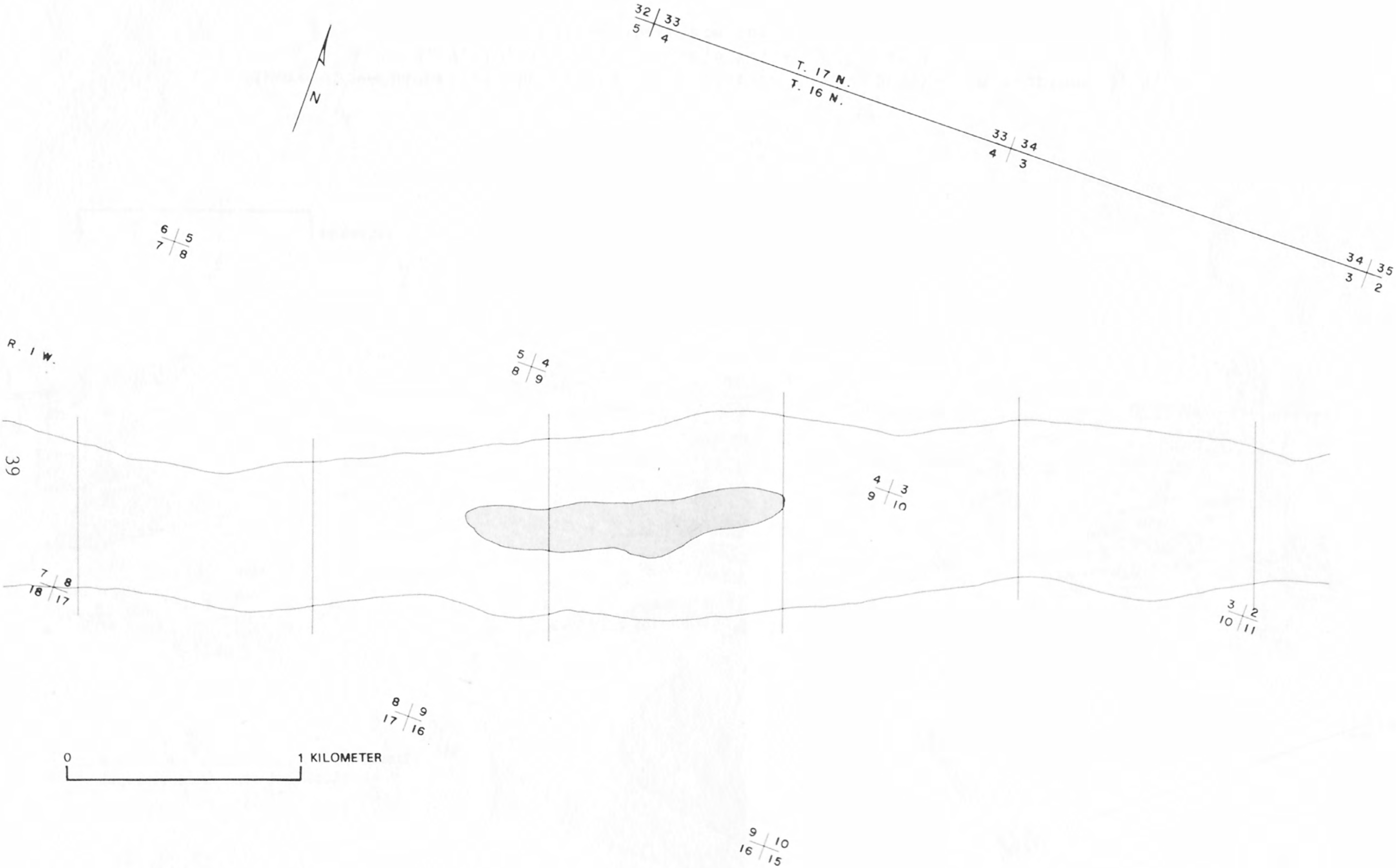

Figure 9a.--Channel of the Platte River near Duncan, Nebraska, in sections 3, 4, 8, 9, 10, 16, and 17, T. 16 N., R. 1 W., in 1860. Shaded areas are vegetated.

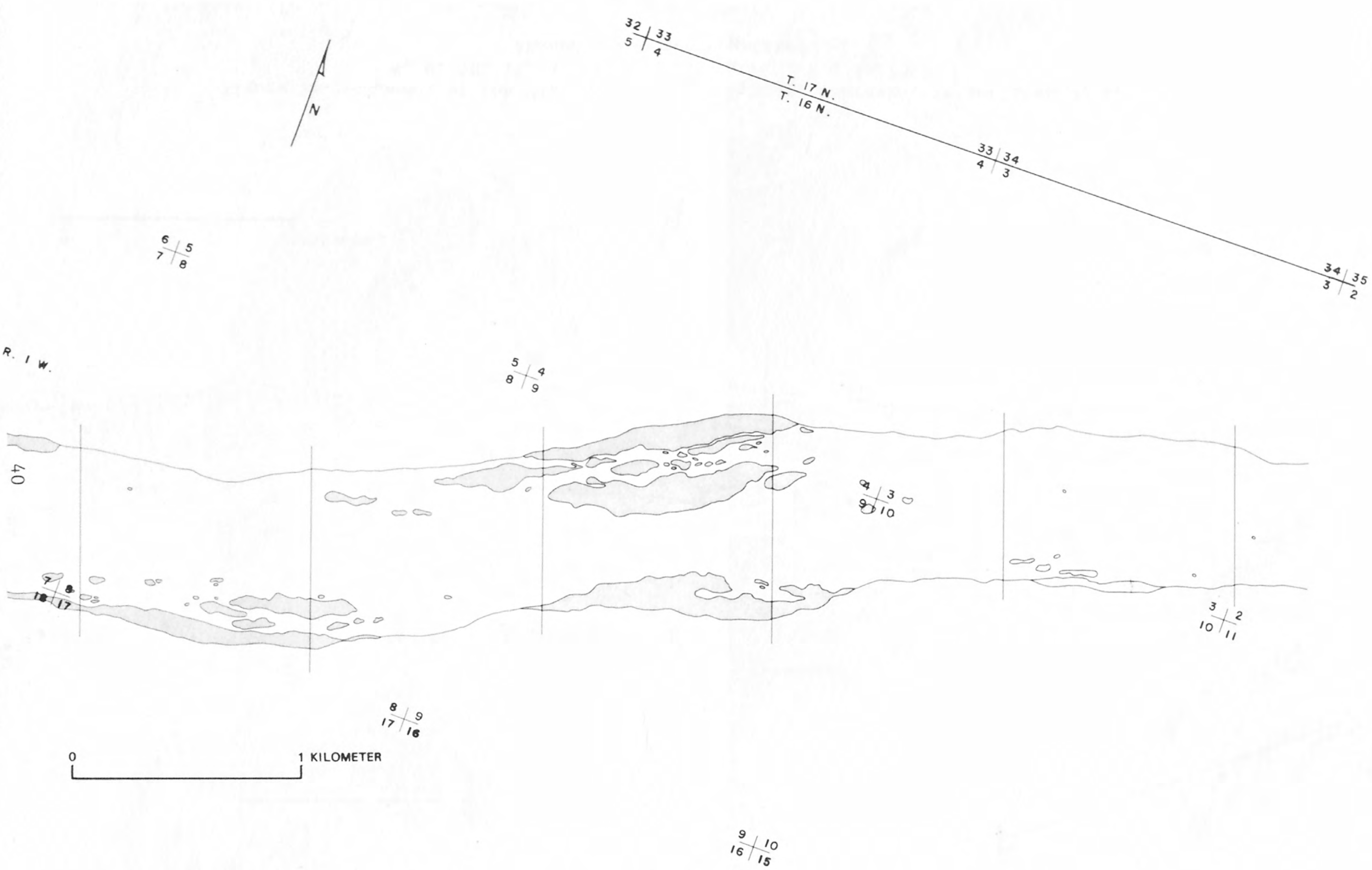

Figure 9b.--Channel of the Platte River near Duncan, Nebraska, in sections 3, 4, 8, 9, 10, 16, and 17, T. 16 N., R. 1 W., in 1941. Shaded areas are vegetated.

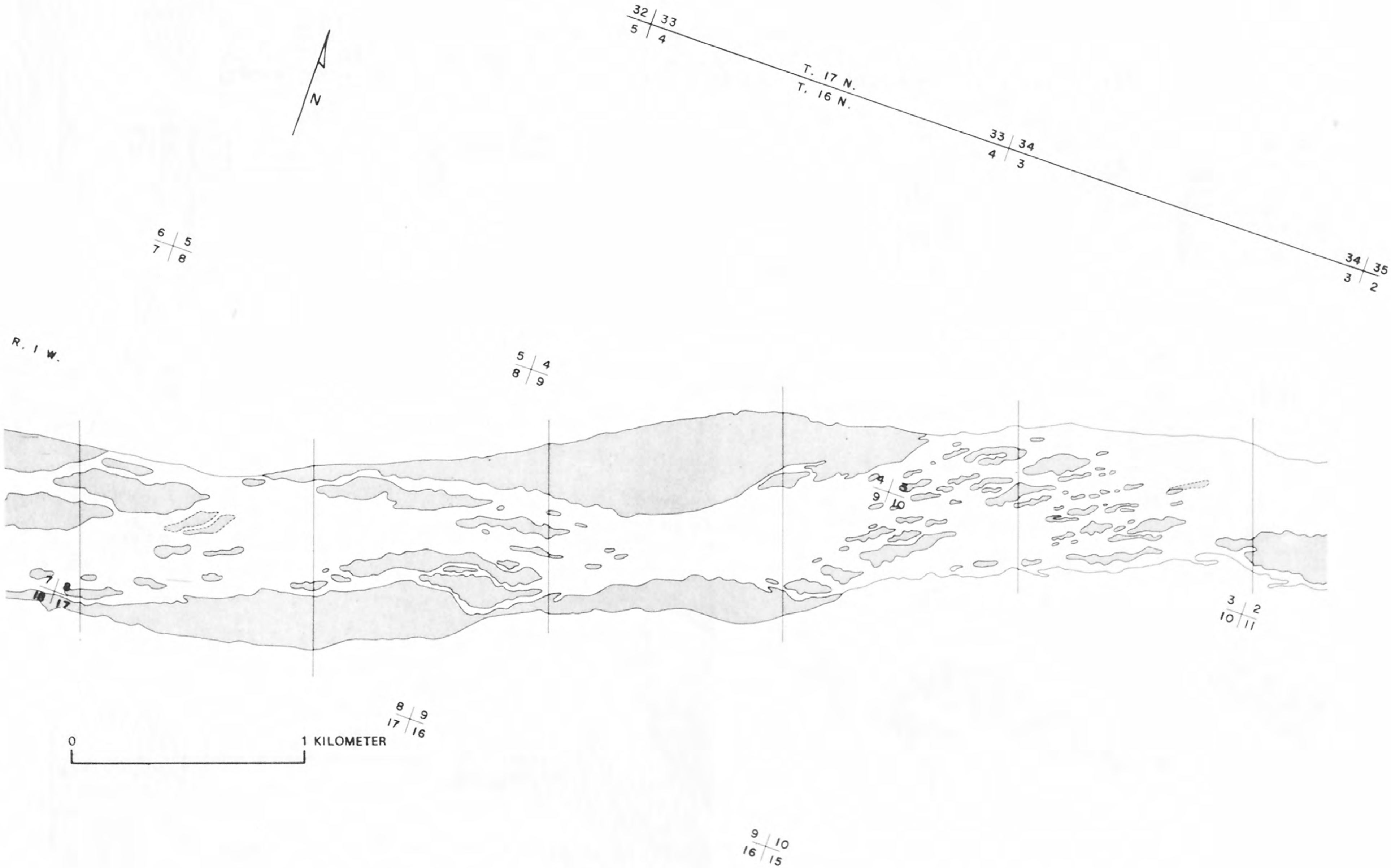

Figure 9c.--Channel of the Platte River near Duncan, Nebraska, in sections 3, 4, 8, 9, 10, 16, and 17, T. 16 N., R. 1 W., in 1978. Shaded areas are vegetated.

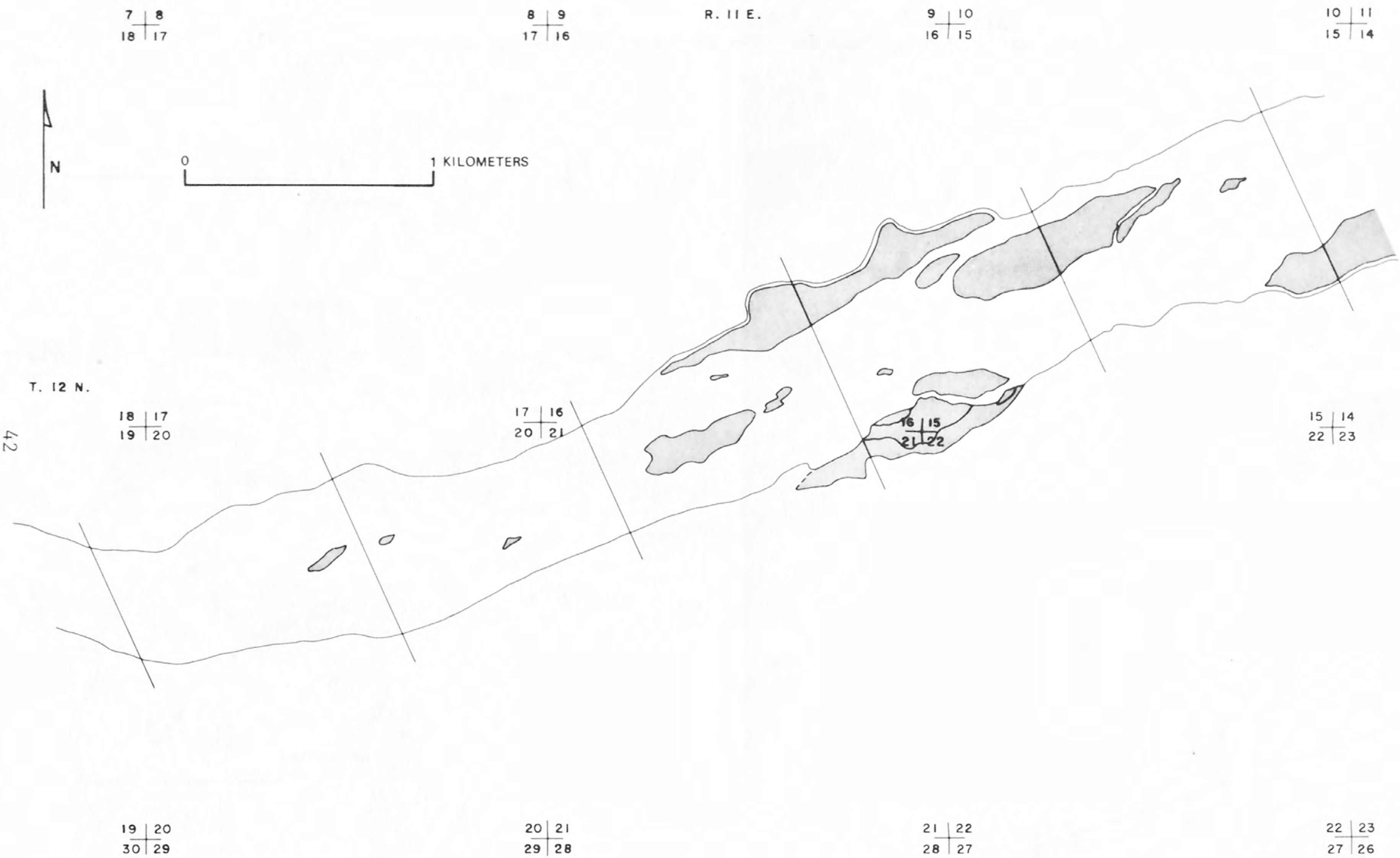

Figure 10a.--Channel of the Platte River near Ashland, Nebraska, in sections 15, 16, 17, 18, 19, 20, and 21, T. 12 N., R. 11 E., in 1941. Shaded areas are vegetated.

Figure 10b.--Channel of the Platte River near Ashland, Nebraska, in sections 15, 16, 17, 18, 19, 20, and 21, T. 12 N., R. 11 E., in 1971. Shaded areas are vegetated.

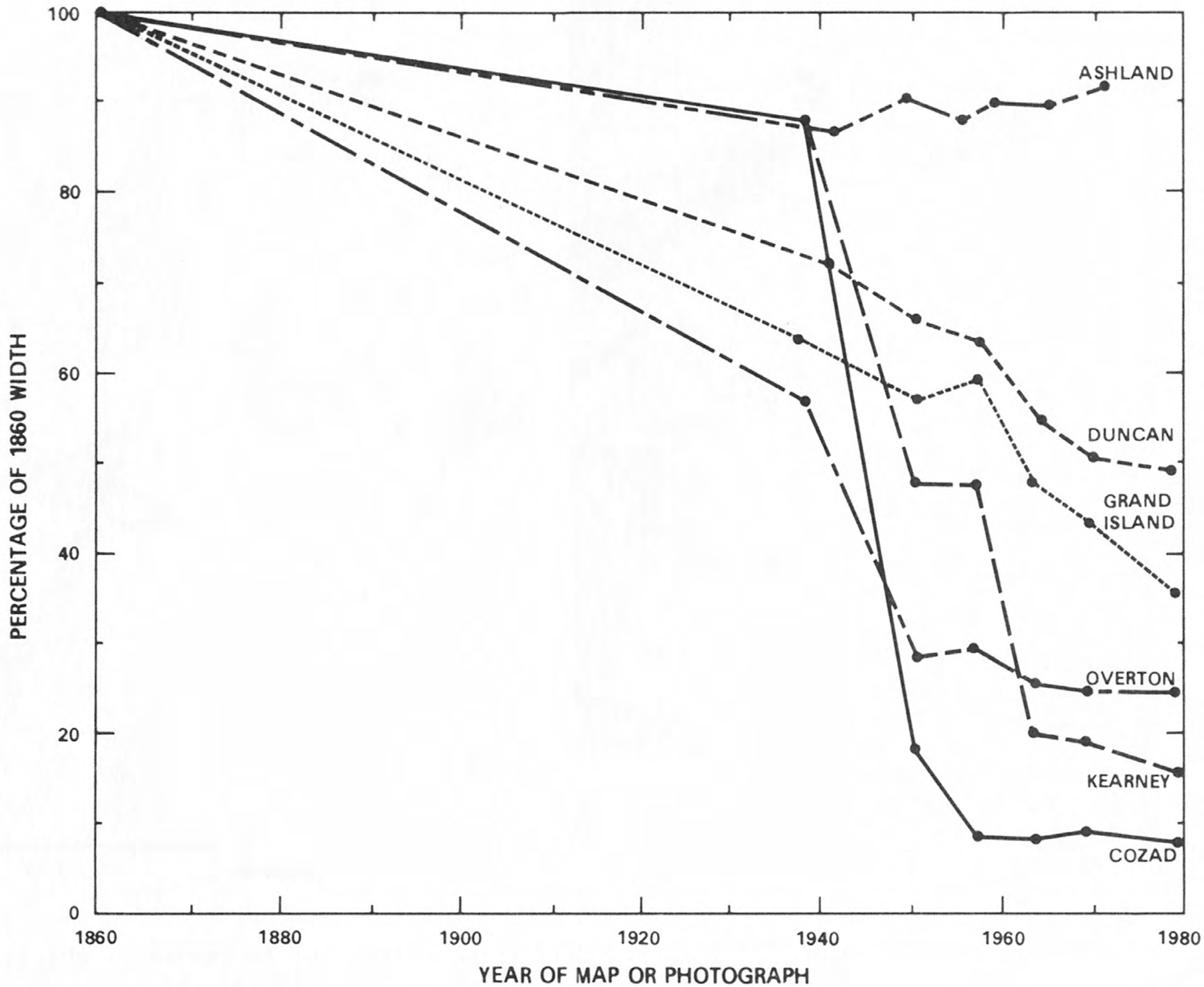

Figure 11.--Changes of channel width of the Platte River, Nebraska, with time.

Table 3.--*Channel widths of the Platte River, Nebraska, in a downstream order, measured from General Land Office maps (1860) and aerial photographs (1938-1979)*

Year	Channel width, in meters					
	Cozad	Overton	Kearney	Grand Island	Duncan	Ashland
1860	1,161	1,545	1,484	1,100[1/]	826	594
1938	1,015	890	1,298	704	---	---
1941	-----	-----	-----	---	600	515
1949	-----	-----	-----	---	---	539
1950	-----	-----	-----	643	543	---
1951	204	451	698	---	---	---
1955	-----	-----	-----	---	---	521
1957	113	460	695	664	521	---
1959	-----	-----	-----	---	---	533
1963	110	408	308	530	---	---
1964	-----	-----	-----	---	448	---
1965	-----	-----	-----	---	---	530
1969	113	387	293	472	---	---
1970	-----	-----	-----	---	424	---
1971	-----	-----	-----	---	---	549
1978	-----	-----	-----	---	411	---
1979	110	405	247	387	---	---

[1/] From 1898 edition 30' U.S. Geological Survey topographic map (General Land Office map incomplete).

Williams (1978) measured river widths at 35 locations on the North Platte and Platte Rivers from the Wyoming-Nebraska State line to Grand Island. He found that channel width was about 10 to 20 percent as wide in 1965 as it was in 1860 for most of the reach. The downstream 100 km of his study reach, from Overton to Grand Island, also showed a decrease in width, but to a lesser extent than upstream, being about 60 to 70 percent as wide in 1965 as it was in 1860.

Channel widths during the periods 1938-1941, 1957-1959, 1969-1971, and 1978-1979, expressed as percentages of the 1860 channel widths, are plotted with distance downstream from the Wyoming-Nebraska State line in figure 12. Generally, the greatest reductions in channel widths occurred between the periods 1938-1941 and 1957-1959. At Cozad, for example, the 1938-1941 channel occupied 87 percent of the 1860 channel width, whereas the 1957-1959 channel occupied only 10 percent of the 1860 channel width. Additionally, the magnitude of change in channel width between the periods 1938-1941 and 1957-1959 decreases downstream. The downstream-most reach, Ashland, actually shows an increase of width of 3 percent between these periods.

Channel width has decreased consistently for most of the reaches during the entire period of record (1860-1979). However, the rate of width reduction has decreased since 1957-1959. That is, there is relatively little change in channel width between 1957-1959 and 1961-1969 and almost no change between 1969-1971 and 1978-1979. During 1969-1971, the last period of complete aerial photograph coverage, channel widths ranged from 10 percent of the 1860 width at Cozad, the upstream-most reach, to 92 percent of the 1860 width at Ashland.

Reduction of channel width has been documented extensively and has been shown to coincide with a period of changing flow regime. Despite the abundance of information available from aerial photographs, channel changes in the period between the General Land Office surveys and the inception of aerial photography only can be conjectured.

Information from the gaging station formerly located south of Lexington, Nebraska, provides one precise morphologic description from this intervening period. The U.S. Geological Survey station description, prepared in 1902, states that both right and left banks were: "Low, not over four or five feet, but not subject to overflow-sparingly wooded." The description further states, "Bed is composed of shifting sand. Total width is 3720 feet [1,134 m]." The same cross section, as measured from the General Land Office maps, has a width of 1,134 m, the same width as that given in 1902. The 1938 aerial photograph shows the same cross section with a width about one-third of the width in 1860. Although the reduction at the gage station was largely because of fill around the bridge sections, areas of the river upstream and downstream from the bridge show that channel narrowing and island development already had occurred. Thus, morphologic change of the Platte River at this site began after 1902, but before 1938.

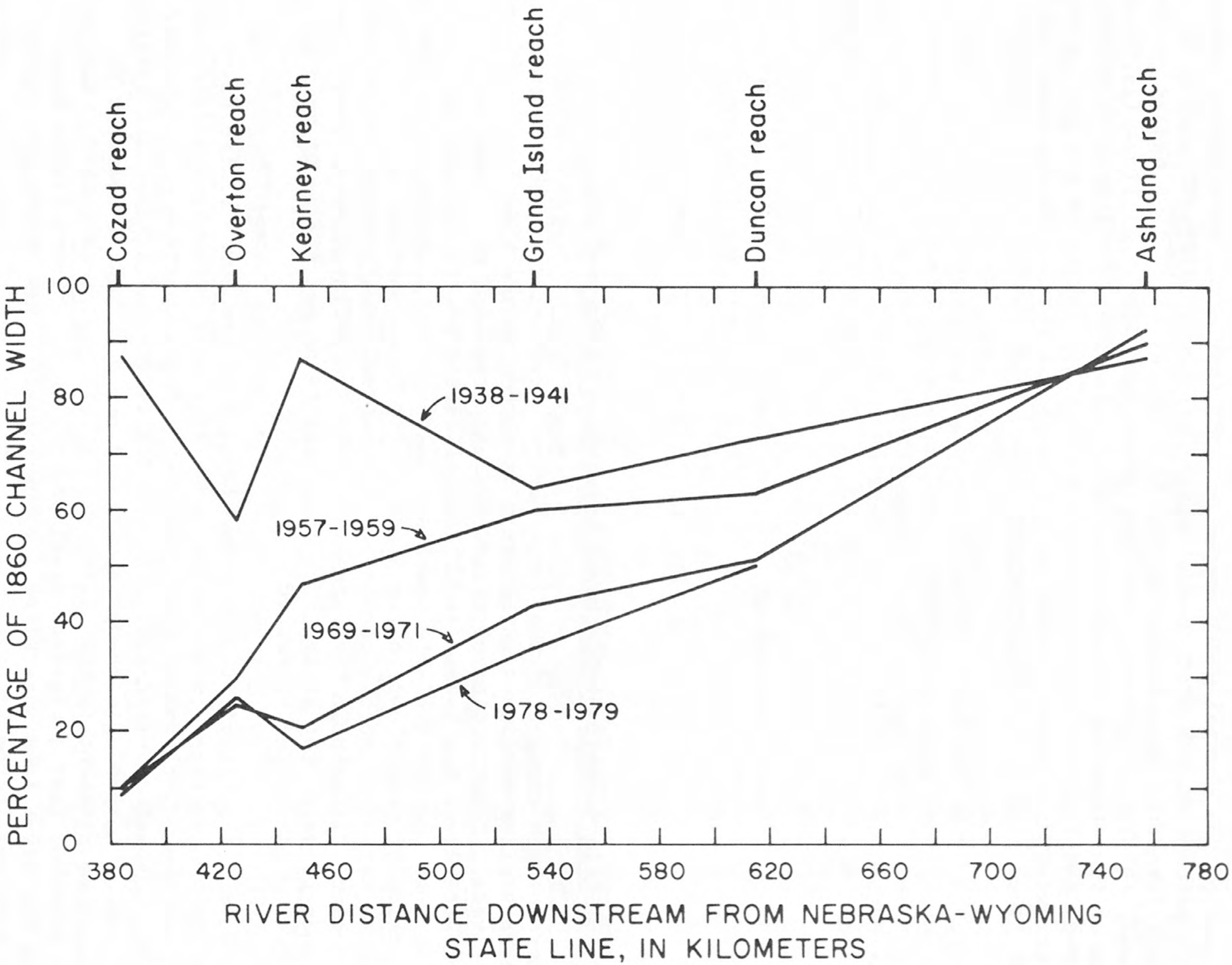

Figure 12.--Percentage of 1860 channel width of the Platte River occupied by the channel in 1938-1941, 1957-1959, 1969-1971, and 1978-1979.

Changes in North Platte and South Platte River Morphology

Changes of North Platte River morphology have been similar to changes that occurred on the Platte River. Channel width in 1965 ranged from 5 to 40 percent of the channel width mapped in 1860 (table 4); it probably averaged about 15 percent of the 1860 channel width (Williams, 1978). Braiding and sinuosity (table 4) were determined for the channel as of 1938 and as of 1965 (Williams, 1978). In general, braiding index, defined by Williams (1978) as the sum of the length of islands in a reach divided by the length of the reach, decreased, and sinuosity index, defined by Williams (1978) as the length of a reach of existing channel divided by the length of channel in the same reach in 1860, increased for the North Platte River in Nebraska.

Morphology of the South Platte River also has changed. Nadler (1978) found that channel width in 1952 averaged only about 15 percent of channel width in 1867. From 1867 to 1952, sinuosity of the South Platte River increased between 5 and 15 percent. Data from individual cross sections are listed in table 5.

The overall character of the channel in the Platte River basin changed with time from a broad channel dotted with numerous small islands (fig. 13) to a series of relatively narrow, well-defined channels intertwining among large islands (fig. 14). This change is effected by the coalescence of islands and loss of numerous small channels between the islands.

Relationship of Discharge Regulation to Channel Change

Morphologic changes of the North Platte, South Platte, and Platte Rivers have been similar despite significant differences in the hydrology of these three rivers. Construction of reservoirs and diversion of streamflow on the North Platte River has caused reductions of annual peak flows and mean annual flows of both the North Platte and Platte Rivers. In contrast, there has been no reduction of peak flows on the South Platte River upstream of Julesburg during the period of record because of a relatively small amount of reservoir construction. Transbasin diversions into the South Platte River have offset diversions of water for irrigation, resulting in no net change of mean annual flows during the period of record.

Schumm (1968) attributed decrease in size of the South Platte River channel to the decrease in the annual peak discharge. However, a decrease in the annual peak discharge of the South Platte River upstream of Julesburg, Colorado, has not occurred during the period of record (Kircher and Karlinger, 1981). Thus, morphologic change apparently has occurred in response to irrigation development in the basin prior to the period of record. Nadler (1978) proposed that irrigation development along the South Platte River changed the river from intermittent to perennial. This hydrologic change caused a change in the vegetation that stabilized the channel. The temporary reduction of discharge during the drought of the 1930's allowed vegetation to occupy and become established in areas of channel. Subsequent floods were not able to widen the channel, as they presumably might have, prior to the encroachment of vegetation.

Table 4.--*Data for channel width, braiding index, and sinuosity index for the North Platte River*[1]

Location, city name, or township and range	Total channel width (meters)				Williams' braiding index		Williams' sinuosity index	
	1865	1938	1965	Ratio of 1965 to 1865	1938	1965	1938	1965
Minatare	975	---	55	0.06	----	----	----	----
R. 52 W.	810	---	105	0.13	----	----	----	----
Bridgeport	1,140	---	120	0.11	----	----	----	----
R. 50 W.	810	---	130	0.16	----	----	----	----
R. 48 W.	1,255	---	170	0.14	----	----	----	----
Lisco	1,280	---	150	0.12	----	----	----	----
R. 46 W.	1,060	---	185	0.18	----	----	----	----
R. 44 W.	545	---	200	0.37	----	----	----	----
Lewellen	885	---	150	0.17	----	----	----	----
R. 42 W.	810	---	165	0.20	----	----	----	----
R. 40 W.	710	---	---	----	----	----	----	----
Keystone	950	---	---	----	1.21	0.00	1.06	1.00
R. 38 W.	940	200	45	0.05	1.21	0.00	1.06	1.00
R. 36 W.	850	815	45	0.05	8.13	2.58	1.00	1.11
R. 34 W.	750	325	195	0.23	2.23	0.26	1.06	1.11
Sutherland	-----	410	75	----	2.13	2.20	1.05	1.30
R. 32 W.	740	460	45	0.06	3.48	1.91	1.03	1.05
North Platte	790	520	90	0.11	3.44	1.76	1.06	1.11

[1]From Williams, 1978.

Table 5.--*Data for channel width, braiding index, and sinuosity for the South Platte River*[1]

Location, city name, or township and range	Total channel width (meters)					Braiding index[2]		Sinuosity[3]	
	1867	1952	1977	Ratio of 1952 to 1867	Ratio of 1977 to 1867	1867	1952	1867	1952
T. 5 N., R. 65 W.	415	34	---	0.08	----	----	----	----	----
Kersey	335	52	81	0.16	0.24	0.42	0.29	1.05	1.21
Kuner	335	91	107	0.27	0.32	0.40	0.25	1.04	1.11
Hardin	435	44	61	0.10	0.14	0.17	0.21	1.05	1.12
T. 4 N., R. 63 W.	360	56	---	0.16	----	----	----	----	----
Masters	425	81	107	0.19	0.25	0.27	0.76	1.00	1.09
T. 4 N., R. 62 W.	430	39	---	0.09	----	----	----	----	----
Sublette	---	36	119	----	----	0.29	0.30	1.13	1.19
T. 4 N., R. 61 W.	610	48	---	0.08	----	----	----	----	----
Goodrich	535	80	109	0.15	0.20	0.16	0.31	1.14	1.25
T. 5 N., R. 60 W.	430	73	---	0.17	----	----	----	----	----
Weldona	440	52	91	0.12	0.21	0.21	0.50	1.02	1.12
T. 4 N., R. 59 W.	380	55	---	0.14	----	----	----	----	----
T. 4 N., R. 58 W.	605	101	---	0.17	----	----	----	----	----
Hurley	425	75	93	0.18	0.22	0.79	0.49	1.01	1.10
T. 4 N., R. 57 W.	495	51	---	0.10	----	----	----	----	----
Snyder	375	60	91	0.16	0.24	0.18	1.78	1.02	1.12
T. 4 N., R. 56 W.	535	75	---	0.14	----	----	----	----	----

[1]From Nadler, 1978.

[2]Braiding index, after Brice (1964), not equivalent to Williams' braiding index in table 4.

[3]Sinuosity defined as length of channel divided by down-valley distance.

Figure 13.--Photograph of the Platte River near the present site of Cozad, Nebraska, taken in 1869 from the south bank toward the northwest. (Photograph from Union Pacific Railroad Museum Collection)

Figure 14.--Oblique photograph of the Platte River near the present site of Cozad, Nebraska, taken in 1979 toward the northwest.

Processes of Width Reduction

Six sets of aerial photographs used in this report (figs. 6-10) allow documentation of channel width reductions and the processes of width reduction. These processes are island formation and subsequent attachment of islands to either the flood plain or other islands. The channel in the 1860's was broad and open (figs. 6a and 13 near Cozad, Nebraska for example) with few vegetated islands, most of which were large.

By 1938, width decreased by island formation. In addition, bank locations had shifted toward the center of the channel, as a result of island formation and attachment to the flood plain. Island attachment resulted from channel abandonment or atrophication, rather than from a migration of the river course. Most of the small islands near these sections are wedge- or lobe-shaped; they are oriented with the pointed end downstream. Comparison of these islands with adjacent sandbars shows that they have the same form. Therefore, we conclude that the majority of the islands in the Platte River formed when vegetation established itself on these bars and stabilized them. Hydrologic changes, which began with irrigation development and were accelerated by large reservoir construction, evidently provided either more favorable growing conditions on the bars, or decreased flood peaks that formerly had removed vegetation.

Once an island formed, it tended to perpetuate itself. The presence of vegetation encouraged further aggradation by increasing roughness and decreasing flood-water velocity over the bar when the island is submerged. Thus, island elevation increased until it was at or above high-water stage.

Sets of maps and photographs made after 1938 show similar, continued development of islands. However, with time, the number of islands diminished, but their size increased. Sediment was accreted at the downstream ends of islands due to decreased flow velocity at their downstream end. This sand substrate is a likely place for vegetation establishment.

The coalescence of islands occurs as the channels between islands gradually lose their water- and sediment-carrying capabilities, becoming indistinguishable, both in appearance and function, from the islands they separate. This process has been documented in other studies. Nadler (1978) proposed vertical infilling of channel braids or branch channels, as the method by which the South Platte River was transformed from a multiple-thalweg to single-thalweg stream. Branch-channel aggradation is important in the abandonment of channels and subsequent attachment of islands to the flood plain on the Cimarron River (Schumm and Lichty, 1963). The attachment of islands to the flood plain of the Loup River in Nebraska by atrophication of narrow channels carrying water at high discharges has been documented by Brice (1964).

SOME IMPLICATIONS OF FUTURE WATER DEVELOPMENT

Documented changes in the channels of the Platte River and its major tributaries that have been discussed in this report are attributed primarily to water development. Water use for irrigation in the basin and water demands from municipal, industrial, and power generation uses have significantly changed streamflow characteristics. These water uses have affected mean annual flows, peak flows, low flows, and flow distribution (Kircher and Karlinger, 1981). Also, changes in surface-water hydrology probably have affected sediment transport in major streams. New discharge and sediment-transport regimes have resulted in sand bars that are not scoured or removed each year. Vegetation has stabilized channel sand bars and transformed them into islands. These processes have been a major factor in narrowing the channels, as shown by the sequence of maps (figs. 6 to 10). All of these changes have contributed to progressive deterioration of the riverine habitat of sandhill cranes, whooping cranes, and other migratory birds in the critical reach between Overton and Grand Island, Nebraska.

If the present migratory-bird habitat is to be preserved from further deterioration, further research is needed for the relationship between streamflow, sediment-transport characteristics, and channel geometry. For example, it will be useful to estimate the discharge necessary to maintain a desired channel width necessary for preservation of the habitat. This discharge must be of sufficient magnitude and duration to cause sand bar movement and removal of vegetation seedlings by scour.

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