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# Effects of water development on the hydrology and morphology of Platte River channels, south-central Nebraska

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ABSTRACT The channels of the Platte River and its major tributaries, the North Platte and South Platte Rivers in Colorado, Wyoming, and Nebraska have undergone major changes in hydrologic regime and morphology since about 1860. These changes are attributed here to water development for agricultural, municipal, and industrial uses. Prior to water development in the nineteenth century, the Platte River was a wide (∿2 km), shallow (1.8-2.4 m) river characterized by bankfull spring floods and low summer flows. Since development, the channels have changed significantly. Channel widths in the 1970's at six locations between Cozad and Ashland, Nebraska, ranged from 9 to 92% of the 1860 widths. Flow regulation by onstream dams and reservoirs, diversions of surface water, power generation, and other uses have also had a significant effect on the hydrology of the basin.

## INTRODUCTION

The Platte River and its tributaries, the North Platte and South Platte Rivers (Fig.1) are typical of many Great Plains streams that originate along the Continental Divide in the Rocky Mountains. The plains are semiarid to subhumid; thus, most of the flow has been appropriated for irrigation of crops, municipal use, industrial development, and power generation. Water development, primarily for agricultural use, began in the middle of the nineteenth century and has continued to increase to the present time. In 1979, a study was begun in the Platte River basin that included hydrologic and geomorphic investigations by the US Geological Survey. The objective of these investigations was to determine the effects of water development and land use on changes in the riverine environment since 1860, which is about the time of settlement in the basin.

## STUDY AREA

The Platte River basin has a drainage area of about 223 000 $km^2$ 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

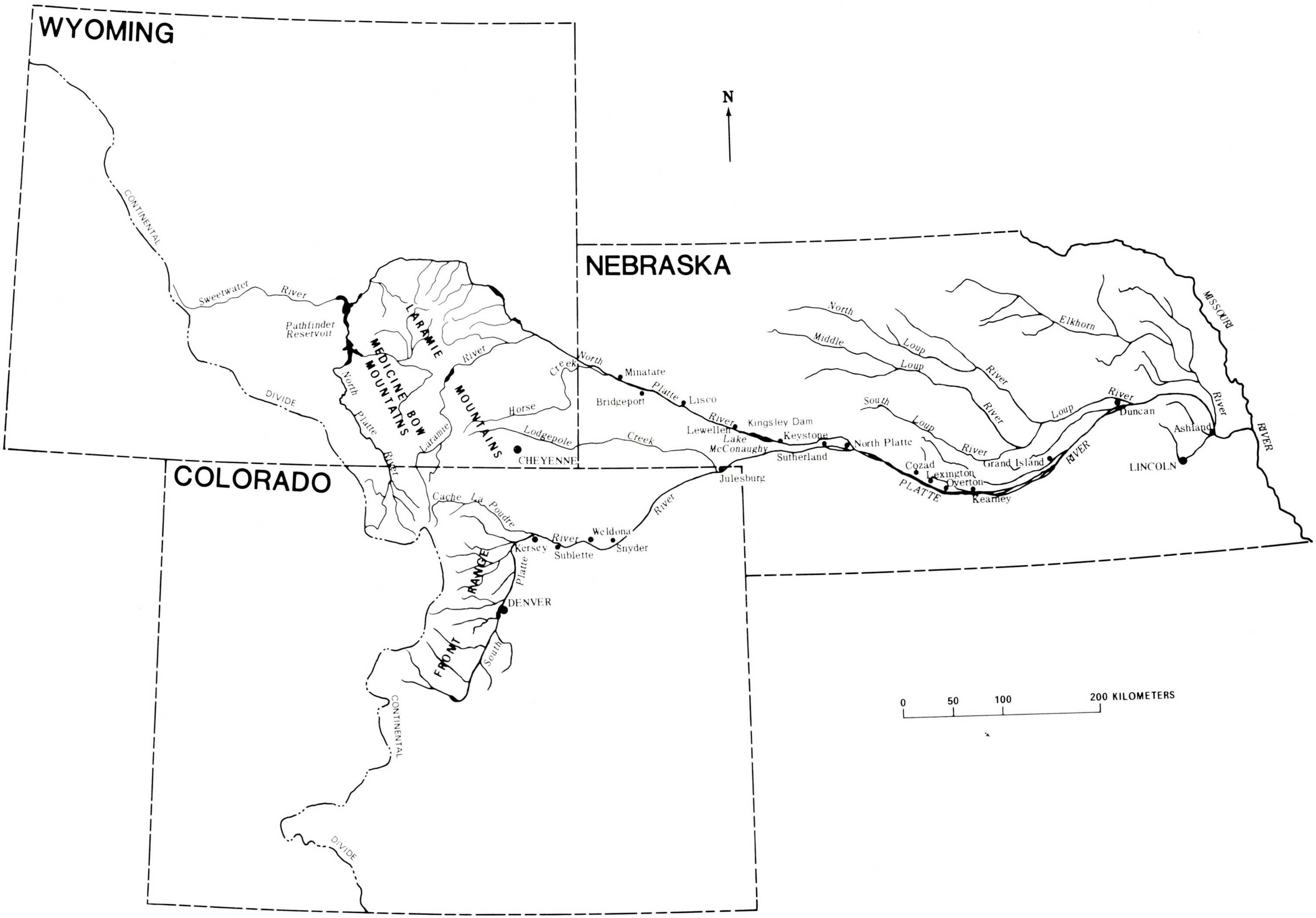


*FIG.1 The Platte River basin in Colorado, Wyoming, and Nebraska.*

plains into Nebraska to join the North Platte River (Fig.1).

Most of the flow in the Platte River system upstream from the Loup River (Fig.1) is derived from spring snowmelt in the Rocky Mountains. Annual precipitation on the Great Plains, which ranges from 330 to 635 mm, contributes additional water to the channels. Surface water is stored in reservoirs and diverted from stream channels for irrigation and other uses.

## EFFECTS OF WATER DEVELOPMENT ON HYDROLOGY

In the early 1840's during the large migrations west, the Platte River valley served as a natural route linking the eastern part of the United States with the unexplored and unsettled west. Between 1800 and 1860, many observations were recorded regarding the geology, topography, geomorphology of the valley, and hydrology of the river. The accounts of early expeditions were drawn upon for hydrologic observations of the Platte River prior to water development on a large scale. Most of these observations are qualitative as records of streamflow were not begun until 1891.

Floods that flowed bankfull occurred almost every year before river regulation began in the North Platte basin in 1892 (McKinley, 1938). 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 the lowest parts; the rise of the water, on such occasions, being no more than five or six feet |1.5-1.8 m|." High flows began in the months of April or May and generally lasted until July. For the remainder of the year, it was common for the Platte River to go nearly dry, and in years of low precipitation there was no flow in many reaches.

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

Peak flows on the North Platte River in Nebraska since 1935 have been decreased by construction of dams (Williams, 1978; Kircher & Karlinger, 1981). Impoundment of flows in the South Platte River basin has been less extensive than in the North Platte River basin. As a result, peak flows of the South Platte River have not decreased significantly with time, except near North Platte, Nebraska (Kircher & Karlinger, 1981).

Annual mean discharges of the North Platte River near North Platte, Nebraska (1895-1980) and of the Platte River near Overton, Nebraska (1914-1980) have decreased during the period of record, probably as a result of flow regulation by upstream reservoirs. Annual mean discharge near Grand Island, Nebraska, has increased only slightly since 1935 although annual mean discharge upstream from Grand Island has changed significantly (Kircher & Karlinger, 1981).

The shape of a flow duration curve, which is a plot of the probability distribution of mean daily flows at a gauged site, has changed with time for many gauging stations on the Platte River and its major tributaries (Eschner, 1981; Kircher & Karlinger, 1981). The shape of the flow duration curve graphically represents the variability of streamflow, and the position of the curve represents magnitude of streamflow. The curves for the Overton, Nebraska, gauging station (Fig.2), computed for short intervals of the period

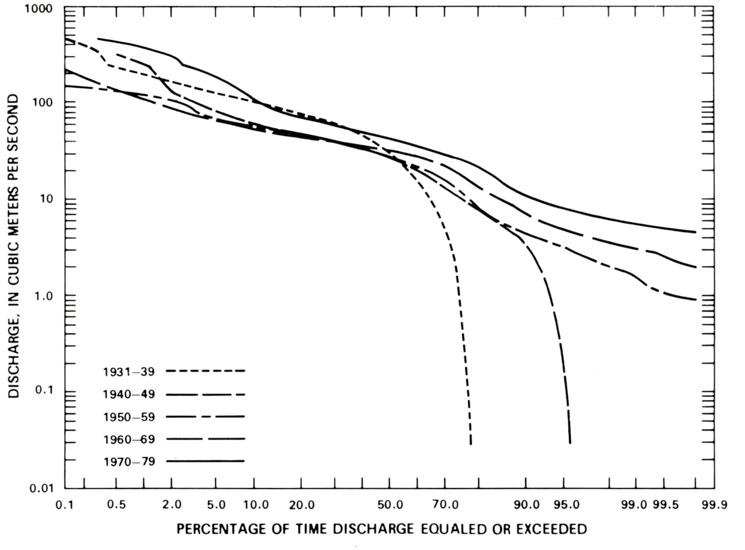


*FIG.2 Flow-duration curves for 10-year periods, Platte River near Overton, Nebraska (from Kircher & Karlinger, 1981).*

of record, show a reduction in short-duration flows; this reflects the effects of dam construction. An increase in the magnitude of long-duration flows has occurred because of temporal redistribution of flow by river regulation, and return flows to the river, both as surface water and groundwater. These changes indicate that the flow of the Platte River is becoming less variable and has a greater baseflow component than it did before regulation by dams.

## EFFECTS OF HYDROLOGIC CHANGES ON CHANNEL MORPHOLOGY

Channel width was the most prominent characteristic of the Platte River in the nineteenth century. 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. In 1832, Captain Bonneville (Irving, 1837) measured the width of the Platte River 40 km below the head of Grand Island to be 2.0 km. Fremont (1845, p. 21) measured the width of the Platte River below the confluence of the North and South Platte Rivers at 1.6 km.

Channel depth of the Platte River in the nineteenth century was generally very shallow throughout its length and could be forded almost anywhere except during spring floods. Most observations of depth range from 0.3 to 1.2 m depending on river stage. Long (James, 1823) reported that the depth of the flow was seldom more than 1.8-2.4 m, and in many places even less.

In general, early descriptions indicate that the bed material of the Platte River consisted of sand and gravel. However, James (1823), the botanist and geologist of the Long Expedition, described the alluvial deposits as consisting of particles of mud and sand which implies that the bed may have been composed of finer material. James (1823) also described the presence of shifting sand-bars and turbid or muddy flows.

The changes in hydrology that have been recorded were accompanied by major changes in channel morphology. These changes can be documented by comparison of aerial photographs taken between 1938 and 1979. In addition, early government maps provide relatively accurate measurements of river width from about 1860. Changes in the intervening years must be inferred from hydrologic data and records of canal and dam construction that indicate when changes were initiated.

Measurements of channel width taken from 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 1. Channel widths were measured at six cross sections, at 1 km intervals, for each of six reaches, and averaged for the entire reach. A visual comparison of the width changes at the six reaches is plotted in Fig.3 as percentages of the General Land Office map widths. For convenience, the map widths are

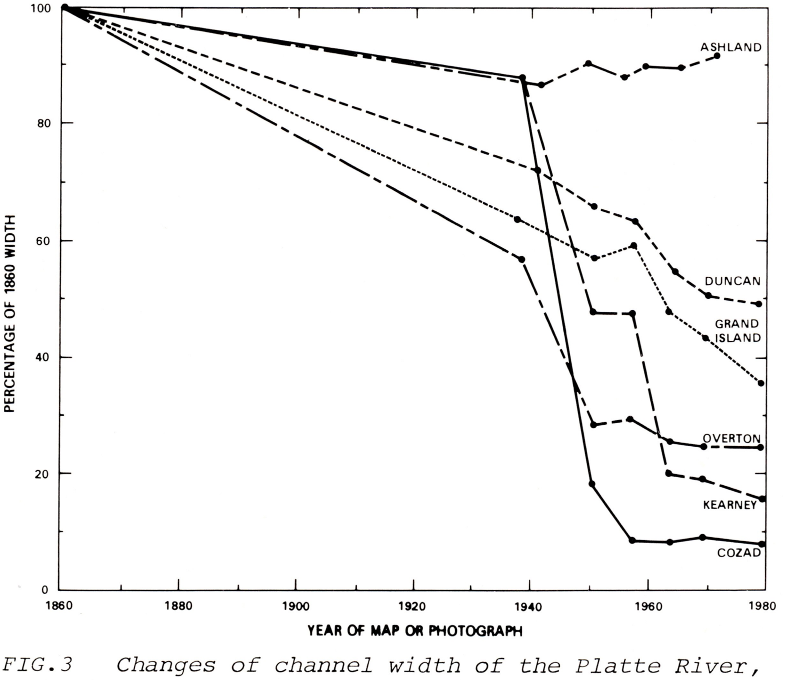


*FIG.3 Changes of channel width of the Platte River, Nebraska, with time.*

*TABLE 1 Channel widths of the Platte River, Nebraska, in downstream order, measured from General Land Office maps (1860) and aerial photographs (1938-1979)*

| *Year* | *Channel width (m)* | | | | | |
|---|---|---|---|---|---|---|
| | *Cozad* | *Overton* | *Kearney* | *Grand Island* | *Duncan* | *Ashland* |
| *1860* | *1161* | *1545* | *1484* | *1100** | *826* | *594* |
| *1938* | *1015* | *890* | *1298* | *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* | - | - |

** From 1898 edition, 30-minute US Geological Survey topographic map (General Land Office map, incomplete).*

called "1860 width" in Fig.3.

Channel widths during the periods 1938-1941, 1957-1959, 1969-1971, and 1978-1979, expressed as percentages of the 1860 channel widths, are plotted against distance downstream from the Wyoming-Nebraska State Line in Fig.4. 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% of the 1860 channel width. Also, the magnitude of change in channel width between the periods 1938-1941 and 1957-1959 decreases downstream. The reach farthest downstream, Ashland, actually shows an increase of width of 3% between these periods.

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, changes in channel width in the period between the General Land Office surveys, about 1860, and the advent of aerial photography can only be conjecture.

## PROCESSES OF WIDTH REDUCTION

Aerial photographs used in this study allow documentation of channel

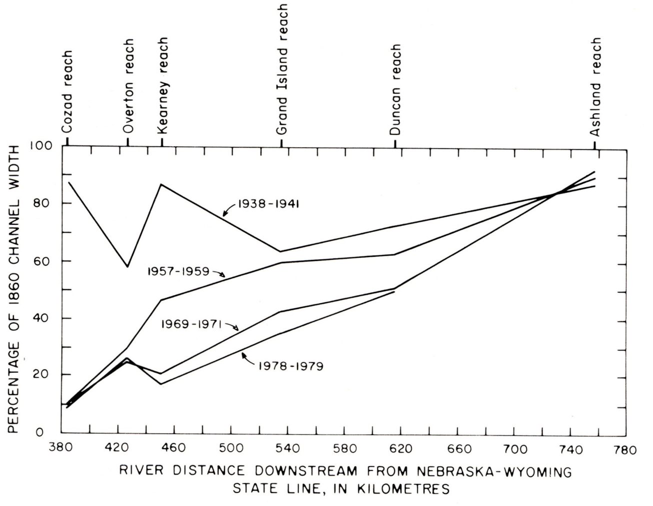


*FIG.4 Percentage of 1860 channel width of the Platte River occupied by the channel in 1938-1941, 1957-1959, 1969-1971, and 1978-1979.*

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 with few vegetated islands, most of which were large. By 1938, width decreased by island formation. In addition, bank locations had shifted towards the centre 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 in the study reaches are wedge- or lobe-shaped; they are oriented with the pointed end downstream. Comparison of these islands with adjacent sand bars 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 favourable 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 was 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 & 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).

## SUMMARY

Documented changes in the channels of the Platte River are attributed to water development. Water use for irrigation in the basin and water demands for municipal, industrial, and hydropower uses have significantly changed streamflow characteristics. These water uses have affected annual mean flows, peak flows, low flows, flow distribution, and sediment transport. New discharge and sediment transport regimes have resulted in sand bars that are not scoured annually and that have become stabilized by vegetation. These processes have been a major factor in changing the riverine environment.

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