Changes in Streamflow Rates of the Lower Platte River, Nebraska, 1895-2006

Interpretive Summary

[Based on USGS Scientific Investigations Report 2007-5267]

Introduction

The cumulative effects of water and channel management practices on stream and riverbank ecology are of interest to resource managers involved with new proposals to develop water, recreation, wildlife, and fisheries resources of the lower Platte River. As part of the Lower Platte River Cumulative Impact Study, the U.S. Geological Survey (USGS) compiled, analyzed, and summarized streamflow information from five gaging stations with long-term records on the Platte River (Duncan, number 06774000; North Bend, number 06796000; Leshara, number 06796500; Ashland, number 06801000; and Louisville, number 06805500; fig. 1) to identify any significant changes in streamflow rates among six discrete periods during 1895-2006. A second objective of this cooperative study with the Lower Platte South Natural Resources District was to relate changes in streamflow to changes in climatic conditions or other factors.

Approach

Streamflow rates vary through time in relation to differences in both upstream supply and patterns of use. For example, in the lower Platte River, there are daily fluctuations in streamflow rates that correspond to variable hydropower production at the Loup River Hydroelectric Project (Loup Power District, written commun., 2008), in response to consumer demands. There are also longer-term, natural fluctuations of streamflow rates caused by seasonal, annual, and decadal changes in climate.

Patterns of streamflow rates can be described through five basic characteristics: magnitude, duration, frequency, timing, and rate of change. Magnitude refers to how low or high a particular streamflow ranks relative to another streamflow or reference that may be separated in space or time. Duration describes the temporal length of a defined streamflow condition. Frequency refers to how often a defined streamflow rate or condition is repeated through time. Timing refers to the season(s) when a defined streamflow condition is more or less likely to occur. Rate of change can refer to either how quickly streamflow rates rise or fall, or how frequently a rising rate changes to a falling rate or vice versa.

Hydrologists have created many different ways to measure these five basic characteristics of streamflow. For this study, we used an approach based on 171 hydrologic indices that describe the pattern of streamflow rates. We used records of daily average streamflow rates and the annual maximum streamflow rates from 1895 through 2006 at five streamflow gaging stations to calculate the 171 indices. We analyzed those results statistically to select a subset of 27 indices that retained most of the desired information about streamflow characteristics yet minimizing redundancy.

We also compiled monthly climate data for the four climate reporting areas within Nebraska that roughly encompass the lower Platte River drainage. These data included precipitation and a calculated drought index, and were used to measure the association between streamflow rates and climatic conditions. The streamflow and climate data were divided into six discrete 11-year periods that corresponded to the years when aerial photography or historical maps were available, as identified for a larger cumulative-effects study of the lower Platte River. The discrete periods used were: 1895-1905, 1934-44, 1951-61, 1966-76, 1985-95, and 1996-2006. However, streamflow records during 1895-1905 were seasonal and somewhat discontinuous; therefore, monthly summaries of streamflow were used instead of the hydrologic indices for 1895-1905, because many of the indices could not be calculated from seasonal data. The results from applying these approaches are presented in USGS Scientific Investigations Report 2007-5267 (see Appendix __).

Discussion of Results

Changes in streamflow rates or indices for the five streamflow gaging stations used in this study generally related to upstream reservoir development and climatic conditions. Differences between gages corresponded to differences in upstream water management and basin geography.

Water-storage reservoirs have the potential to affect streamflow rates downstream by reducing the magnitude and frequency of high streamflow events, such as those that are caused by spring snow melt or intense precipitation. The only period in the study that preceded the construction of most large-storage reservoirs in the Platte River basin was 1895-1905. Thus, it was not unexpected that monthly average and monthly maximum streamflow rates were highest during this period for the wet season of April through July. In contrast, for the low-flow months of August through November, average streamflow rates during 1895-1905 were either less than or similar to those in more recent periods. There were no differences among the five post-1950 time periods in terms of the monthly maximum flows for April through June. However, the frequency of high-flow events per year was greater during 1934-44 at the Duncan, Ashland, and Louisville gages than it was during the two subsequent periods (1951-61 and 1966-76), as indicated by at least one streamflow index per gage.

Most of the flow in the lower Platte River originates from the ground-water fed Loup River and other tributaries downstream from Duncan, the westernmost stream gage in this study. This resulted in contrasting streamflow index values between the gage near Duncan and those downstream from the confluence of the Platte and Loup Rivers, where index values for streamflow magnitude were less variable. Among the indicators of streamflow magnitude at Duncan that demonstrate effects of the contrast in basin geography were greater variability during all five post-1930 time periods in base flow, monthly minimum, and annual average streamflow magnitude; higher frequency of low streamflow conditions; and greater variation in daily streamflow rates for the 1934-44, 1951-61, and 1996-2006 periods.

Monthly streamflow rates were correlated with monthly values of the Palmer hydrologic drought index for all five stream gages. Climate conditions during 1934-44 were characterized as moderate to severe drought, whereas the 1895-1906, 1966-76, and 1985-95 periods were characterized as mildly to moderately wet. These climate differences explain the consistently lower median monthly streamflow during 1934-44 than during 1985-95 at Duncan and Louisville, and the same result at North Bend and Ashland for 6 of the 12 months of the year. Mixed conditions ranging from incipient drought to mildly wet occurred in 1951-61 and 1996-2006. Although these periods each had mixed climate conditions, annual maximum flow rate, expressed as a ratio with median flow for each period, was consistently larger during 1951-61 than during 1996-2006 for the two downstream gages, Ashland and Louisville.

Two of the five stream gages, North Bend and Leshara, showed an increased frequency of days when a sequence of increasing or decreasing streamflow rates changed to the opposite trend (fluctuations in the daily series; fig. 2). This increased unsteadiness in short-term (daily) changes in streamflow rates may be associated with the proximity of these gages to the Platte River confluence with the Loup River Hydroelectric Project tailrace canal, which carries highly variable flows resulting from variable hydropower production.

Implications

The finding that the 1895-1905 pattern of streamflow rates was significantly different from that during the subsequent time periods may have implications for native aquatic biota. There may be limits to their ability to successfully respond to altered hydrology and associated habitat conditions, in terms of maturation and reproductive success. Altered hydrology also has implications for ecological resilience and susceptibility to exotic invasive species.

Increased short-term unsteadiness in streamflow rates potentially could have a negative effect on any aquatic organisms that expend substantial energy to move some distance to reach a refuge where they wait while a pulse (that is, a short period of relatively extreme streamflow) of either high or low flows passes by. Even though the actual frequency of those pulses may not have increased, the increased unsteadiness in the streamflow-rates pattern may increase the frequency of cues or signals that such pulses might be about to occur. Fish and other highly mobile organisms may not require much time to respond successfully to changes in the streamflow rate, but slow-responding organisms might be adversely affected by increased short-term unsteadiness in streamflow rates.

Another implication of more frequent changes in streamflow rates involves possible effects on sandbar erosion. The lower Platte River is generally wide and exposed to the wind, and wave action tends to erode unvegetated sandbars readily, whereas the riverbanks have been frequently protected structurally from the typically low-level erosive power of such waves. When streamflow rates, and associated water levels, change more frequently, the level at which wave erosion is active also shifts more frequently and may as a consequence erode bare sandbars or undercut vegetated sandbars more rapidly than otherwise. However, frequent rises and falls of water levels also could help maintain more moisture within the root zone on exposed sandbars, thereby promoting establishment and growth of vegetation on bars. Bare sandbars are known to provide nesting and foraging areas for some species of special concern in the lower Platte River, including least terns and piping plovers. Whereas a reduction in vegetation on bars may benefit these species, reduced size and elevation of sandbars might be detrimental. Further study is needed to verify whether the potential implications of the types of hydrologic changes that have occurred within the lower Platte River are actual concerns affecting ecosystem health and resiliency.

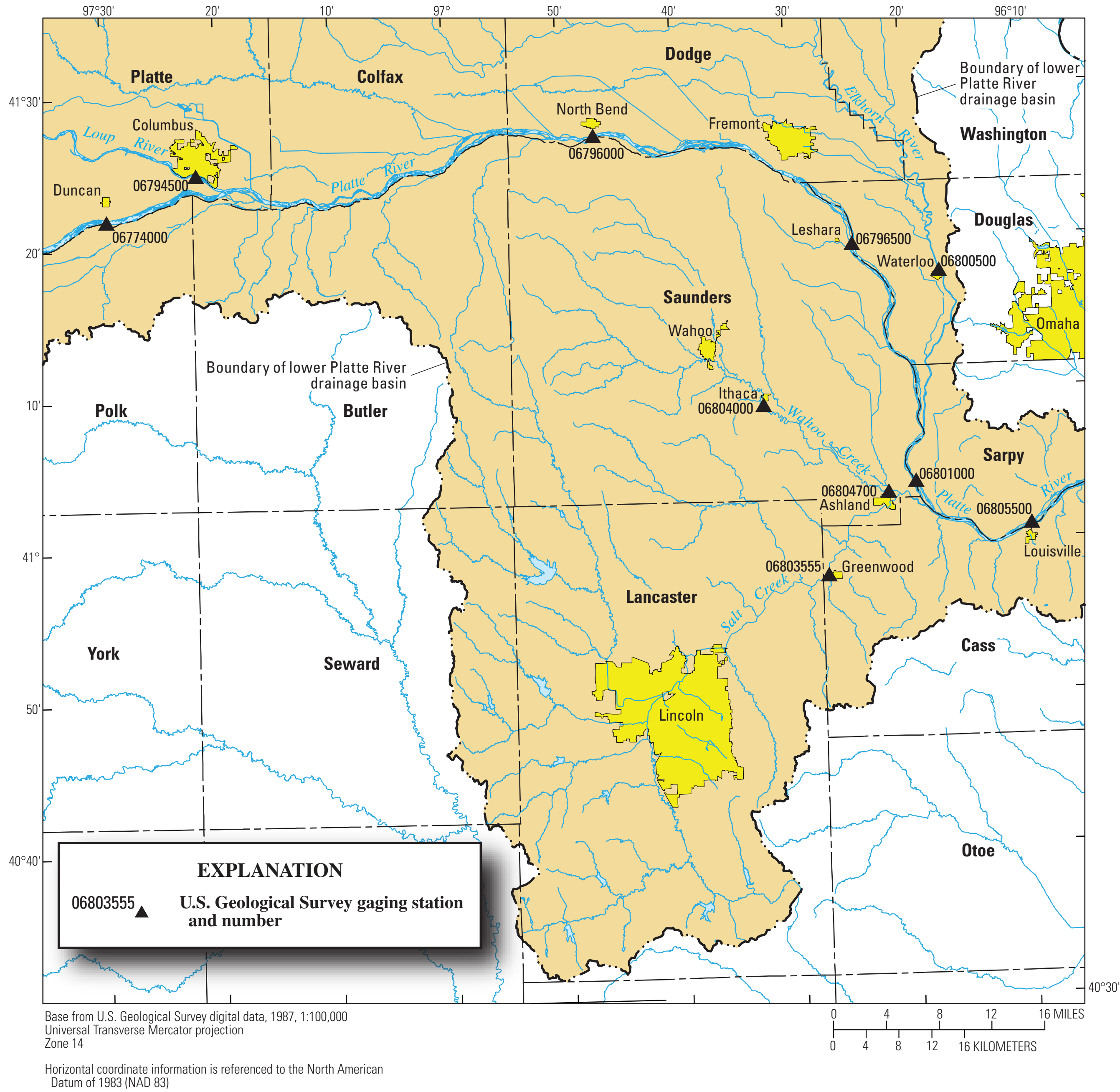

Figure 1. Location of study area and gaging stations on Platte River and tributaries, Nebraska.

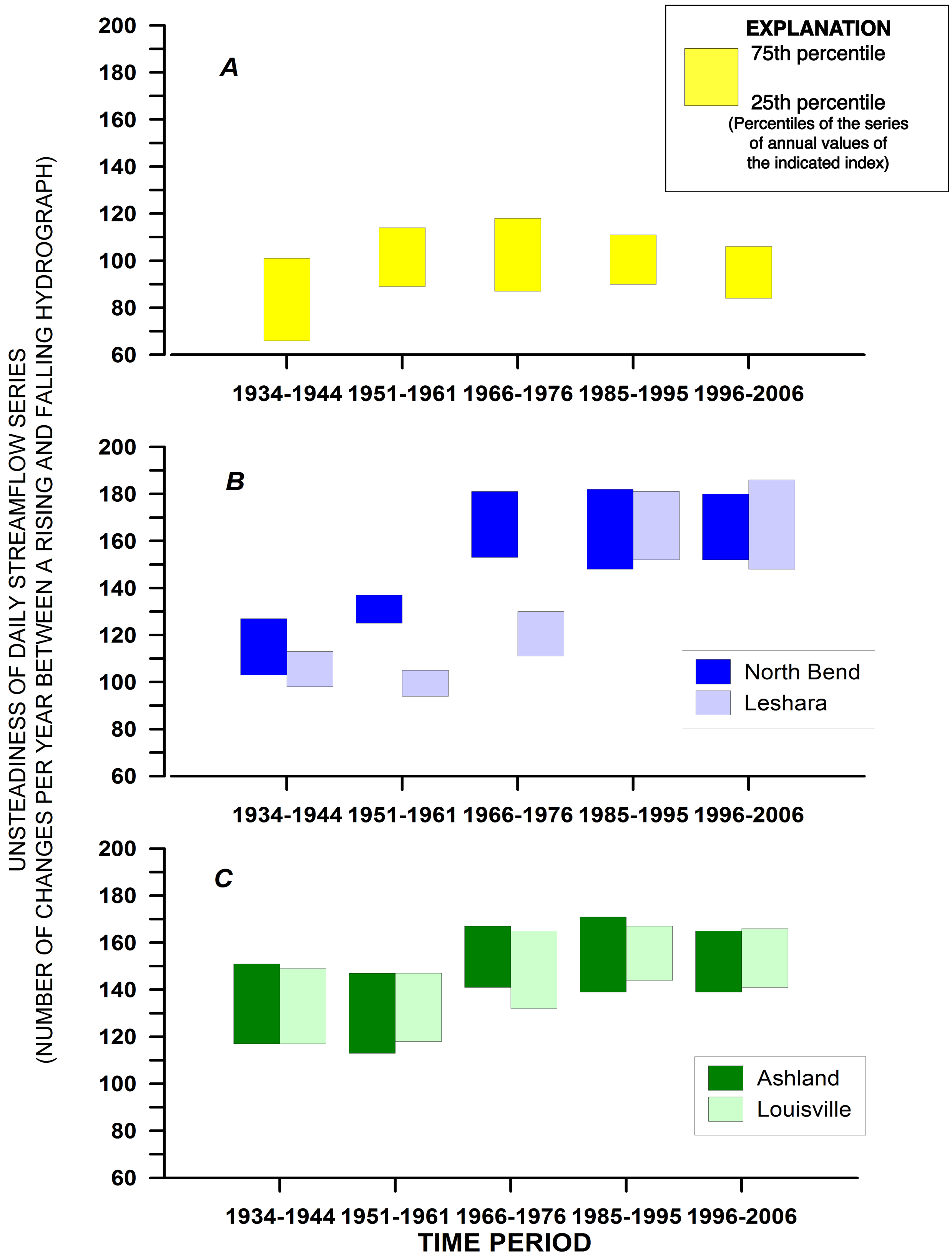

Figure 2. Temporal patterns in unsteadiness of daily streamflow series for lower Platte River stream-gaging stations near (A) Duncan (number 06774000); (B) North Bend and Leshara (numbers 06796000 and 06796500, respectively); and (C) Ashland and Louisville (numbers 06801000 and 06805500, respectively), Nebraska.