Channel Morphology and Bed-Sediment Characteristics Before and After Riparian Vegetation Clearing in the Cottonwood Ranch, Platte River, Nebraska, Water Years 2001–2004

By Paul J. Kinzel, Jonathan M. Nelson, and Ashley K. Heckman

Prepared in cooperation with the
Platte River Endangered Species Partnership

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Conversion Factors

Multiply	By	To obtain
	Length	
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
meter (m)	1.094	yard (yd)
	Area	
square meter (m^2)	0.0002471	acre
square kilometer (km^2)	247.1	acre
square kilometer (km^2)	0.3861	square mile (mi^2)
	Volume	
cubic meter (m^3)	35.31	cubic foot (ft^3)
cubic meter (m^3)	1.308	cubic yard (yd^3)
	Mass	
gram (g)	0.03527	ounce, avoirdupois (oz)
kilogram (kg)	2.205	pound avoirdupois (lb)

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Water year: The 12-month period October 1 through September 30. The water year is designated by the calendar year in which it ends.

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Abstract

Riparian areas along a reach of Platte River passing through Nebraska Public Power District's Cottonwood Ranch Property were modified during 2002 to 2004 to enhance in-channel habitats for endangered and threatened avian species. A component of this alteration involved the removal of riparian vegetation from riverbanks and islands to provide roosting habitat for the endangered whooping crane and to provide nesting and foraging habitat for the endangered least tern and threatened piping plover. It was hypothesized that the removal of riparian vegetation could have the effect of stimulating channel widening in this reach by increasing the potential of these surfaces to erode under natural fluvial action. It also was hypothesized that as a direct or indirect consequence of the alterations, a local increase in sediment supply also might occur, potentially resulting in geomorphic change downstream and possibly initiating negative third-party effects. The cumulative effects of the management activities on the channel morphology and sediment transport in this reach were monitored during water years 2001–2004 by measuring transect elevation profiles and bed-sediment-size gradations upstream, within, and downstream from the managed area before and after the development activities.

An analysis of variance (ANOVA) was performed to determine if the geomorphic variables measured before and after the development activities were significantly different. Although statistically significant differences were detected in some of the variables, increases in mean bed elevation did not occur in a greater percentage of the monitoring sections measured downstream compared to upstream from the management activities. This result suggests that the management activities did not have a substantial effect on the downstream river channel morphology and sediment transport. However, it is important to place these short-term and site-specific results in the context that river flows following the management activities were at historical low rates, and therefore the potential to affect and the opportunity to detect possible geomorphic change within and downstream from the managed reach were limited.

Introduction

The central Platte River in Nebraska is an internationally recognized stopover for migratory water birds of the central North American flyway and also is important habitat for three avian species listed as endangered or threatened, collectively referred to hereinafter as the target species. The whooping crane (*Grus americana*) and interior least tern (*Sterna antillarum*) were listed as endangered species in 1967 and 1985, respectively (U.S. Fish and Wildlife Service, 1967; U.S. Fish and Wildlife Service, 1985b). The piping plover (*Charadrius melodus*) was listed as threatened in 1985 (U.S. Fish and Wildlife Service, 1985a).

Over the last century, upstream water-resource development has reduced the supply of water and sediment to the central Platte River (Williams, 1978; Eschner and others, 1983). Historically, annual snowmelt runoff from the Rocky Mountains resulted in high spring flows capable of scouring vegetation seedlings from midchannel sandbars. As these peak flows were removed from the hydrograph, sandbars were progressively stabilized by vegetation (Eschner and others, 1983; O'Brien and Currier, 1987). Vegetation on sandbars increases flow resistance during periods of inundation and can promote deposition of suspended sediment and vertical accretion of these surfaces. Furthermore, as side channels became silted and(or) the watercourse was rerouted, midchannel sandbars became connected to the flood plain. Over time, these processes have led to the progressive narrowing of the Platte River channels. The changes in flow and sediment regime, and ultimately their influence upon riparian vegetation and the morphology of the river channels, are believed to have negatively affected the quality and quantity of in-channel habitats for the target species along the central Platte River (U.S. Department of the Interior, 2003). The National Academy of Sciences' National Research Council also determined that current habitat conditions along the central Platte River were adversely affecting the survival and recovery of the target species (National Research Council, 2004).

Recently efforts have been directed toward establishing a long-term habitat recovery program to improve conditions for the target species. In 1997, a Cooperative Agreement was signed between the States of Colorado, Nebraska, and Wyoming and the U.S. Department of the Interior to reconcile endangered species issues with future water development in the Platte River Basin (Cooperative Agreement, 1997). The Platte River Endangered Species Partnership (PRESP) was formed to interpret and implement the Cooperative Agreement. The PRESP has proposed a recovery program for the target species (Platte River Recovery and Implementation Program, 2005). A component of the proposed recovery program will involve the acquisition of lands along the central Platte River. Over the first increment of the proposed program (13 years) approximately 40 km^2 of habitat are expected to be acquired. Some degree of habitat enhancement or management activities is expected to occur on these properties for the purpose of either increasing the suitability or maintaining the condition of these lands for the target species.

The first property incorporated into the 40 km^2 of PRESP-managed habitat was an 11-km^2 parcel owned by the Nebraska Public Power District (NPPD), hereinafter referred to as the Cottonwood Ranch Property. NPPD purchased the Cottonwood Ranch Property from private landowners in 1992 because they anticipated a future need to acquire land for endangered species management purposes. On July 29, 1998, the Federal Energy Regulatory Commission (FERC) issued a 40-year license for NPPD's Project 1835 (the North Platte River/Keystone Diversion Dam). Pursuant to granting the license, FERC required NPPD, under Article 407 of the license, to develop a plan to enhance the Cottonwood Ranch Property for endangered species. NPPD developed a management plan with consultation from the U.S. Fish and Wildlife Service, the Nebraska Game and Parks Commission, Central Nebraska Public Power and Irrigation District, and the Governance Committee of the PRESP (James Jenniges, Nebraska Public Power District, written commun., 1999).

An immediate concern of the PRESP is the potential for the management activities performed on program properties to inadvertently cause negative third-party effects to downstream landowners. One potential result of these activities was reported by Johnson (1997), who documented a reduction in downstream channel area of the Platte River near Grand Island, Nebraska, and implied that upstream vegetation clearing activities were a cause of excess sediment that led to local aggradation and vegetation recruitment downstream. Because the recovery program is committed to preventing third-party effects, a need was identified for establishing a monitoring and research framework to identify the potential effects from riparian management on the river channel on current and future recovery program lands. In 2000 the U.S. Geological Survey (USGS), in cooperation with representatives from the Technical Committee and the Executive Director's Office of the PRESP, developed a monitoring and research study to investigate and detect potential downstream effects of management activities performed by NPPD on the Cottonwood Ranch Property. The objective of the monitoring and research study was to collect the data necessary to detect possible downstream channel changes and sediment movement resulting from the integrated management activities conducted within the Cottonwood Ranch Property. In a more general sense, this study sought to develop a scientifically based and statistically robust methodology for monitoring the geomorphic effects of riparian management activities.

Purpose and Scope

This report describes channel morphology and bed-sediment characteristics before and after riparian vegetation clearing in the Cottonwood Ranch Property. An analysis of the geomorphic data collected between the beginning of water year 2001 and the end of water year 2004 (October 1, 2000, to September 31, 2004) is provided. These data have been published previously by the USGS and are available on CD–ROM for each water year (Kinzel and others, 2003a,b; Kinzel and others, 2004; and Kinzel and others, 2005). Geomorphic data were collected within the Cottonwood Ranch Property at and near the Input, Managed, and Output Reaches (fig. 2–4; see "Methods" section of this report for a description of transects and reaches).

Acknowledgments

This study was made possible with the permission and collaboration from NPPD and from Douglas Stunkle, a downstream landowner. The experimental design was developed in consultation with the Executive Director's office and members of the Technical Committee of the PRESP. The authors would like to acknowledge James Jenniges (NPPD) for input into the experimental design and logistical planning, assisting with the collection of field data, maintaining serial ground-photography stations, and providing topographic survey data and aerial photography used in this and previous reports. Dwain Curtis, Daniel Hitch, and John Miller (USGS, North Platte, Nebraska) installed, maintained, and conducted periodic discharge measurements at the Cottonwood Ranch streamflow-gaging station. Daniel Hitch also reviewed and published the streamflow record for this station. Sediment and topographic data collection at the field sites was assisted by James Bennett, John Elliott, and Stevan Gyetvai (USGS, Denver, Colorado). Judith Daniels and Heather Sproule (USGS, Denver, Colorado) performed laboratory analysis of sediment samples. Advice regarding statistical analysis was provided by Brent Troutman (USGS, Denver, Colorado). Lisa Fotherby (Bureau of Reclamation, Denver, Colorado) provided topographic survey data. Technical reviews of this report were kindly supplied by Waite Osterkamp (USGS, Tucson, Arizona) and Ronald Zelt (USGS, Lincoln, Nebraska).

Study Area

The Platte River is a tributary of the Missouri River that forms at the confluence of the North and South Platte Rivers near North Platte, Nebraska, and joins the Missouri River near Plattsmouth, Nebraska (fig. 1). The 130-km reach of the river between Lexington and Chapman, Nebraska, is commonly referred to as the central Platte River, or the "Big Bend," named after the general course of the river as it flows first to the southeast and then to the northeast. The study area includes about a 20-km reach of the central Platte River. The Cottonwood Ranch Property covers 11 km^2 and is located along the central Platte River between Overton and Elm Creek, Nebraska (fig. 1). The Platte River watershed upstream from the USGS streamflow-gaging station 06768000, Platte River near Overton (fig. 1), has a drainage area of about 145,816 km^2, of which approximately 133,695 km^2 contributes directly to surface runoff (Hitch and others, 2005).

The valley slope through the Cottonwood Ranch Property, computed from a 1961 USGS topographic quadrangle map, is approximately 0.0014. The alluvium of the river valley is composed of flood-plain sediment deposited during the Holocene period. The sediment consists of "unconsolidated gravel in a sandy or silty matrix interbedded with or overlain by sandy silt and silty sand" (Condon, 2005). The soil types outside the active river channel are predominantly the Gothenburg soils and corresponding loamy alluvial beds (Condon, 2005).

Geomorphology

The Platte River can be classified as a braided river on the basis of its general planform (flow in multiple channels around islands or midchannel bars). Braided rivers have been further classified by Schumm (1977) into those that at low stages have islands of sediment or islands of semipermanent vegetation and those that can be considered multiple-thread rivers or anastomosing channels. Because the Platte River exhibits characteristics of both at various spatial scales and flow stages, the general braided terminology seems appropriate. In the classification system of Leopold and Wolman (1957), as compared with undivided or straight river reaches, braided rivers are steeper, wider, and shallower. Other characteristics of braided rivers include rapid shifting of bed sediment and frequent shifting of the position of the river course (Leopold and others, 1964). O'Brien and Currier (1987) speculated that the central Platte River was trending toward a meandering form but would not achieve it because its banks lack silt and clay and are therefore noncohesive.

The historically wide, braided pattern of the Platte River within the Cottonwood Ranch Property is illustrated in a black and white aerial photograph taken on August 21, 1938, by the Soil Conservation Service (fig. 5*A*). The mean daily flow when this photograph was taken was approximately 9.0 m^3/s at the Overton streamflow-gaging station. For comparison purposes, figure 5*A* shows an overlay in blue of the wetted area of the channel digitized from color-infrared photography taken exactly 60 years later on August 21, 1998, also at a mean daily flow of approximately 9 m^3/s (Bureau of Reclamation, 2000). Over these 60 years, the river has become increasingly channelized through the Cottonwood Ranch Property, and presently conveys flow in three principal channels. Vegetation encroachment, island stabilization, and lateral accretion have affected the channel morphology as illustrated in a subsequent black and white aerial photograph taken November 18, 1951, by the U.S. Geological Survey when the mean daily flow at Overton was 56 m^3/s (fig. 5*B*). The extent of the vegetation clearing activities performed by NPPD along the middle channel during Phase 1 of their management activities can be seen (see "Management Activities" section of report) by comparing a photograph taken October 7, 2002, when the mean daily flow at Overton was 15 m^3/s (fig. 5*C*), with one taken March 31, 2003, when the mean daily flow at Overton was 19 m^3/s (fig. 5*D*). The area that was cleared of vegetation in Phase 1 of the management activities conducted late October through December of 2002 is outlined in green, and the area that was subsequently cleared in Phase 3 of the management conducted October 1, 2003, through September 30, 2004, is outlined in red on figures 5*C–D* (see "Management Activities" section of report).

The resistance to flow in alluvial rivers is made up of drag associated with the riverbanks, islands, and submerged and emergent bedforms, as well as vegetation on these surfaces (Guy, 1970). Bedforms are deformations in the riverbed resulting from the interaction of fluid and sediment transport in the channel. The hierarchy of bedforms in the central Platte River ranges from small-scale ripples and dunes that can have heights less than a few centimeters to sandbars with widths and lengths that approach the dimensions of the active river channel. Crowley (1981) referred to the large-scale bedforms observed east of Grand Island as macroforms. However, Crowley concluded that vegetation encroachment and the presence of multiple channels made the regular pattern of these macroforms much more difficult to distinguish upstream from Grand Island.

Hydrology

Flow in the central Platte River is influenced by upstream water-resource development on the North and South Platte Rivers as well as diversions along the main stem. Substantial regulation of the Platte River occurred in 1941, when Kingsley Dam on the North Platte River began impounding water, and the Tri-County Diversion Dam started diverting water into the Tri-County Supply Canal (Williams, 1978). Platte River water is diverted for a variety of uses including recreation, irrigation, hydropower generation, and off-channel storage. Irrigation return flows and hydropower releases replace water to the river, often many kilometers downstream from where it was withdrawn. The flow in the Platte River also is influenced by the underlying alluvial aquifer. Examples of studies of surface

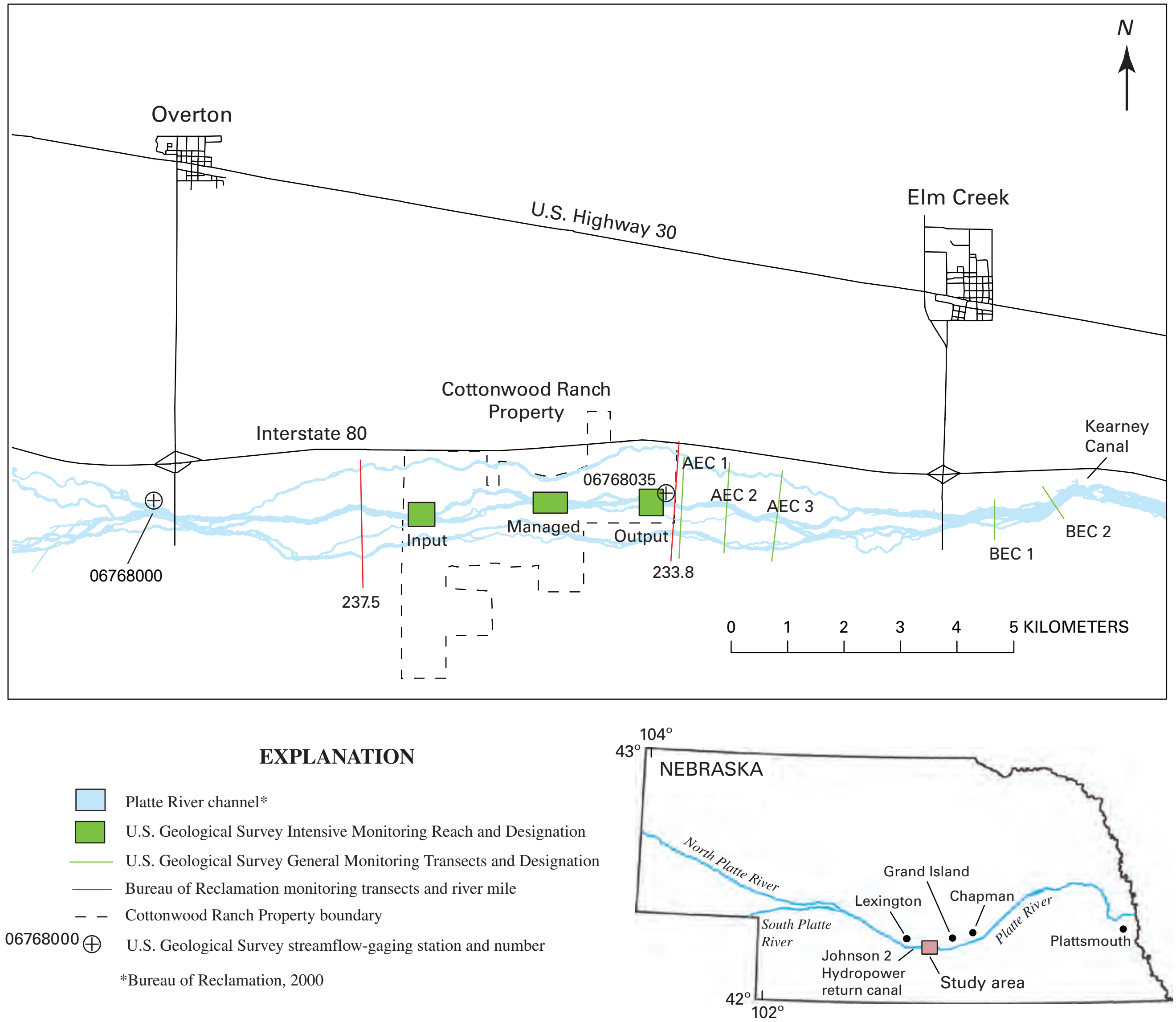

Figure 1. Map showing the Overton to Elm Creek reach of the Platte River, the Cottonwood Ranch Property, intensive monitoring reaches, monitoring transects, and streamflow-gaging stations.

and ground-water interactions include those of Burns (1983), who simulated the effects of various water-management alternatives by computing stream-depletion factors, and those of Stanton (2000), who mapped the areas of gain and loss to ground water along the central Platte River.

Management Activities

The habitat development and enhancement plan for the Cottonwood Ranch Property called for the removal of woody vegetation, primarily cottonwood (*Populus* ssp.) and willow (*Salix* ssp.), from the islands and riverbanks. The plan also included the excavation of 2,134 linear meters of abandoned channels that formerly conveyed flow but, due to sedimentation, had become separated from the river and accreted to the flood plain (James Jenniges, written commun., 1999). In the process of vegetation clearing, NPPD created potential habitat for least terns and piping plovers by exposing bare sand and gravel on the islands.

The management activities were executed in phases. Phase 1 of the management activities was anticipated to begin in the fall of 2000. Because an undetermined quantity of sediment could be introduced into the river channel as a consequence of the management activities conducted near the river channel, on December 7, 1999, NPPD applied to the U.S. Army Corps of Engineers (USACE) for a permit under section 404 of the Clean Water Act. On January 22, 2002, the USACE issued the permit for NPPD to "* * * clear up to 10.9 acres of river islands of vegetation, excavate and lower the elevation of the islands by 18 inches, and discharge up to 26,000 cubic yards of sediment into the river channel." NPPD also was granted permission to "* * * excavate up to 6.7 miles of sloughs and

1.5 miles of backwater with a bulldozer and spread the material evenly on adjacent uplands." Under the special-conditions section of the permit, NPPD was instructed during the construction of the tern and plover islands to distribute any excavated material "* * * in a manner conforming to existing contours that will not change the flow distribution among the various channels." Areas where sediment was discharged were to be "* * * kept clear of vegetation to facilitate downstream movement." (U.S. Army Corps of Engineers, 1999).

In late October 2002, NPPD began Phase 1 of the management plan. The activities conducted in Phase 1 included the removal of trees and understory vegetation along the north bank and on five islands in the middle river channel of the Platte River within the Cottonwood Ranch Property (figs. 5*C* and 5*D*). The management activities extended upstream from the Managed Reach to the first flow split where approximately 0.08 km^2 of a large island, hereinafter referred to as the West Tern and Plover Island, was cleared (figs. 5*C* and 5*D*). The management activities extended to the downstream end of the Output Reach. In Phase 1 approximately 0.36 km^2 of riparian area was cleared. This area is outlined in green in figures 5*C*–*D*.

A crawler loader was used to topple the trees, resulting in both the tree and associated root ball being removed. The trees were then gathered in large piles away from the riverbank and burned. In the middle of two islands in the upper end of the Managed Reach, a hole was dug and the cleared vegetation was pushed in and buried. The vegetation that was cleared on these islands was not burned because it consisted of understory vegetation that did not burn well if coated with sand (James Jenniges, written commun., 2004). Banks on these islands were sloped into the active river channel by pushing some sediment from the top of the island into the river, a process colloquially referred to as "island squishing."

At two locations in the Managed Reach, triangular segments of the riverbank that sharply protruded into the river were cut away to create a smooth bank. At the segment located near the north end of transect 17, a volume of approximately 250 m^3 was pushed into the river channel. At the segment near the north end of transect 21 (fig. 4), a volume of approximately 700 m^3 was pushed up onto the riverbank. Immediately downstream from the Managed Reach, NPPD's contractor dug a small channel along the north bank to create a small artificial island. This was to evaluate if the small artificial island would eventually erode into the river. Phase 2 was a wetland enhancement project conducted on the south side of the Cottonwood Ranch Property. Because this phase was conducted sufficiently far away from the river channel monitored as part of this study, the effects of this phase were not investigated.

During October 1, 2003 through September 30, 2004, Phase 3 of NPPD's management plan was initiated and completed (figs. 5*C*–*D*). It included the removal and disposal of trees in a manner similar to Phase 1. The remaining 0.20 km^2 of the West Tern and Plover Island was cleared, as were segments along the north and south banks in the Input Reach. The 0.42 km^2 of riparian area cleared in Phase 3 is outlined in red on figures 5*C*–*D*.

Methods

Streamflow

The USGS operates a network of streamflow-gaging stations along the central Platte River. Station 06768000, Platte River near Overton, is about 4 km upstream from the Cottonwood Ranch Property and has been operated as a daily streamflow-gaging station since 1930 (fig. 1). The gage at Overton measures the total flow in the Platte River. Downstream from the Overton gage the river flows in three major braids, or channels, under typical flow conditions. Because the management activities were to be carried out along the middle of these three channels, a new streamflow-gaging station (06768035, Platte River Middle Channel, Cottonwood Ranch, near Elm Creek) was installed in May 2001 to measure and record stage (figs. 1, 4, 5*C*–*D*). A stage-discharge relation, or rating curve, was developed for the Cottonwood Ranch gage by using 29 wading measurements of river discharge made from May 23, 2001, to September 30, 2004. Discharge measurements were made by using standard USGS methods (Carter and Davidian, 1968; Buchanan and Somers 1969). Due to the relatively short period of record and small range of discharges measured (3 to 27 m^3/s), the rating curve developed for this station is confidently applied only to this range of flows.

Geomorphic Monitoring

The monitoring design selected for the Cottonwood Ranch Property stratified the sampling of geomorphic variables into two relatively short time periods, those collected about 2 years before the management activities began (October 2000–October 2002, pretreatment) and about 2 years after the management activities began (November 2002–September 2004, posttreatment). Owing to the localized character of the management, this study required dividing the middle channel of the Platte River into three intensively monitored reaches: Input, Managed, and Output (figs. 2, 3, and 4). Spatially stratifying the river into these reaches allowed any management effects measured in the area to be compared or referenced to those measured upstream and downstream from the affected area. This is conceptually similar to a control in an experiment. True controls in field experiments, however, are not possible either in regard to replication or the factors influencing the measured variables. Each monitored reach was stratified further by a series of approximately equally spaced transects spanning the width of the middle channel. Geomorphic variables were measured along each transect. The majority of management activities were performed within and immediately upstream and downstream from the Managed Reach. However, in the interest of efficiency and scheduling, some riparian clearing was performed by NPPD along the Input Reach during Phase 3 as was clearing along the Output Reach during Phase 1.

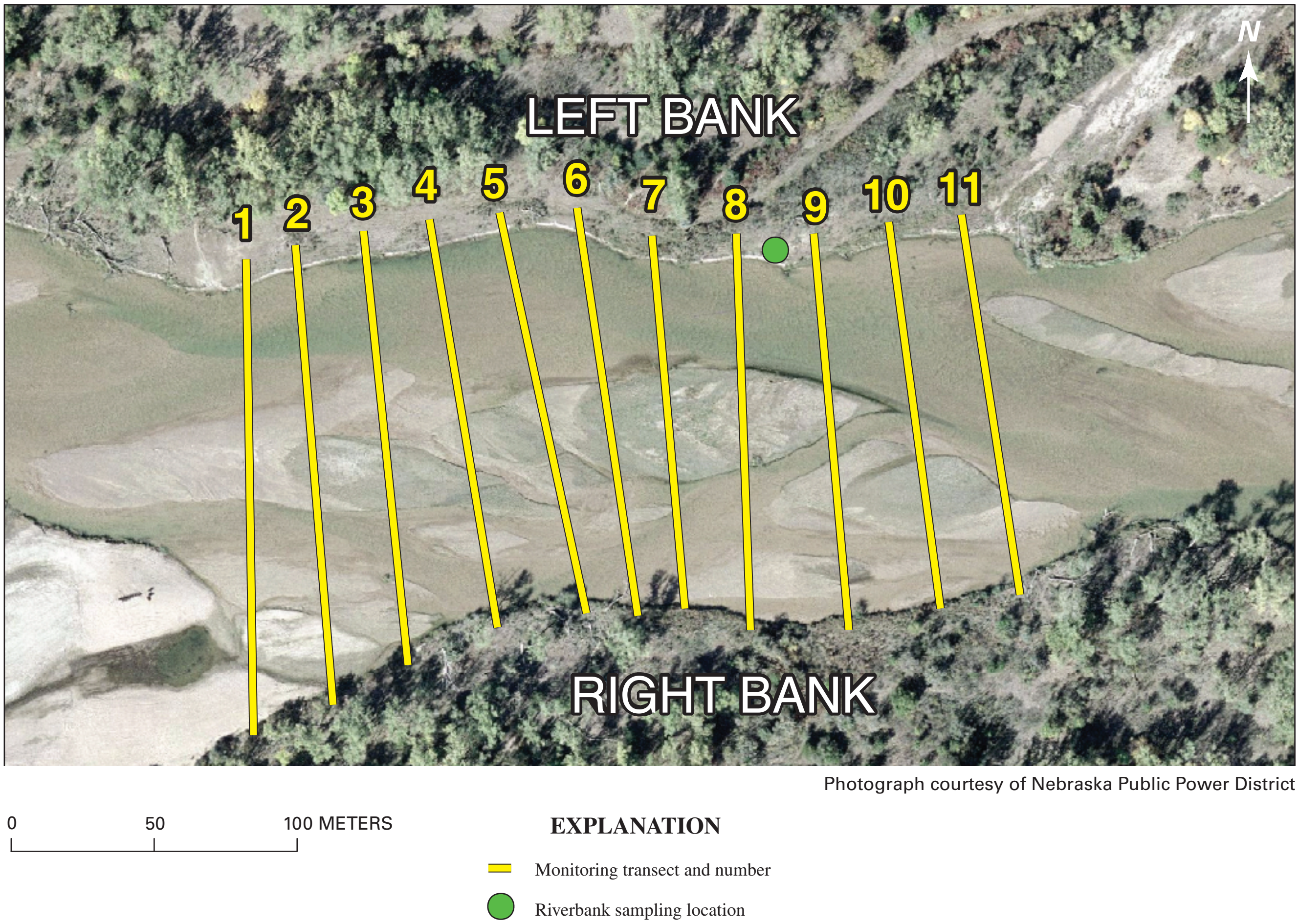

Figure 2. Natural-color aerial photograph taken October 7, 2002, showing the Input Monitoring Reach in the Cottonwood Ranch Property.

In these cases NPPD was informed that their contractors needed to keep some distance away from the riverbanks so as not to influence the measurements made along the monitoring transects. Examination of these riverbanks following the clearing in these areas indicated that they were not compromised as a result of these activities.

Geomorphic data were collected within NPPD's Cottonwood Ranch Property along transects traversing the middle channel of the Platte River and along five transects spanning the entire width of the Platte River (all channels) downstream from the Cottonwood Ranch Property. The transects within the Cottonwood Ranch Property are referred to as intensive-monitoring transects and were positioned in three intensive-monitoring reaches: an approximately 300-m-long reach upstream from the location where the management activities occurred (the Input Reach), an approximately 500-m-long reach within the area where the management occurred (the Managed Reach), and an approximately 450-m-long reach immediately downstream (the Output Reach) (fig. 1). The five downstream transects designated AEC 1, AEC 2, AEC 3, BEC 1, and BEC 2, referred to as General Monitoring transects, begin at the eastern boundary of the Cottonwood Ranch Property and extend downstream to the Kearney Canal (fig. 1). These General Monitoring transects extended the monitoring effort outside the Cottonwood Ranch Property and were intended to function in the future as a component of the PRESP's proposed general geomorphic monitoring program for the central Platte River (Platte River Recovery and Implementation Program, 2005).

Channel Morphology

The number of transects in each monitored reach was sufficient to characterize the longitudinal variation in the geomorphic variables measured along the transects and to provide a reasonable sample size. The transects were spaced approximately 20 m apart to allow the resolution of the spatial extent and temporal evolution of large-scale sandbars. Each transect was monumented by placing a wooden stake along the north bank of the middle channel and placing another stake along south bank, orienting the transect perpendicular to the principal flow direction in the channel. The wooden stakes served as semipermanent end-point locations for each transect.

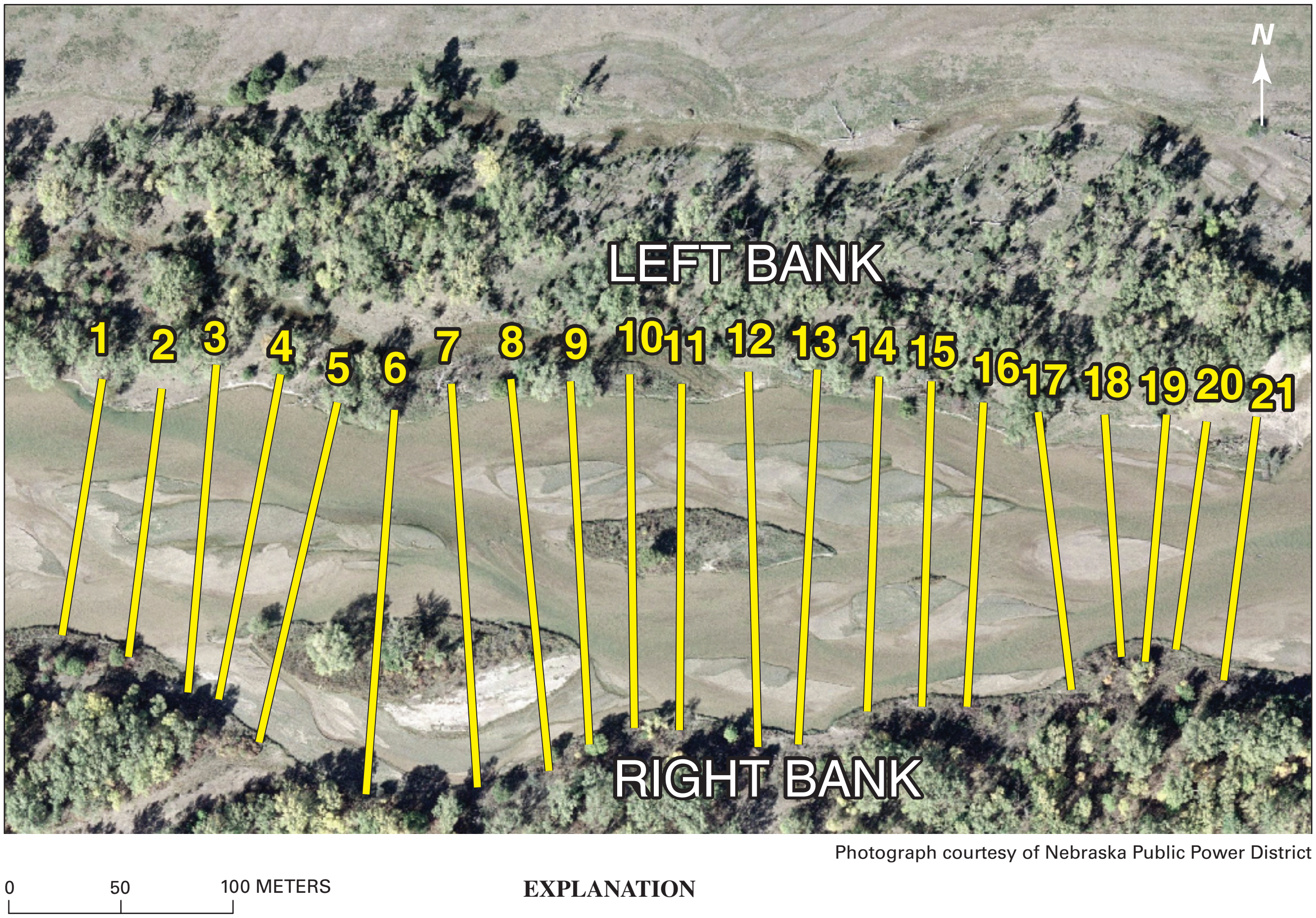

Figure 3. Natural-color aerial photograph taken October 7, 2002, showing the Managed Monitoring Reach in the Cottonwood Ranch Property.

A total of 11, 21, and 25 transects were established in the Input, Managed, and Output Reaches, respectively (figs. 2, 3, and 4). Following a protocol developed through the Technical Committee of the PRESP, these "spatial intensive" transects were surveyed and ground photographs were taken once per year in the time period between late October and November. Bed sediment also was sampled at approximately every other transect during the annual site visits.

To quantify and isolate the deviation in the variables due to seasonal variations in sediment supply and riverflow, measurements were made during two additional time periods in each water year at a subset of the transects in the intensively monitored reaches. Two transects in the Input Reach (transects 3 and 9), three in the Managed Reach (transects 2, 12, and 20), and three in the Output Reach (transects 8, 16, and 24) were designated for "temporal-intensive" monitoring. Each water year these transects were surveyed, and bed sediment was sampled once during the fall (October through November) with the rest of the spatial-intensive transects, once during the spring (late March to early May), and once during the summer (July). Spacing the measurements in this manner throughout a year allowed the patterns of natural variation in the variables to be quantified at these transects and within the monitored reaches. The General Monitoring transects were surveyed and sampled once a year during the summer (May to July) by using identical methods used in surveying and sampling those transects within the Cottonwood Ranch Property.

The channel morphology variables measured or calculated along the transects included distance from a reference mark to the left bank (LB) and right bank of the river (RB); channel width (Width), the distance between the right and left bank; and the mean (MeanBE), minimum (MinBE), maximum (MaxBE), and standard deviation (StdBE) of the riverbed elevations measured between the riverbanks on the monitoring section. Left bank and right bank are defined from the perspective of looking downstream.

The mean bed elevation of a series of river transects can be used to construct a longitudinal elevation profile of a river reach. Comparison of channel-elevation profiles through time can be used to elucidate changes in river gradient. Serial measures of the mean bed elevation at a transect in a sand

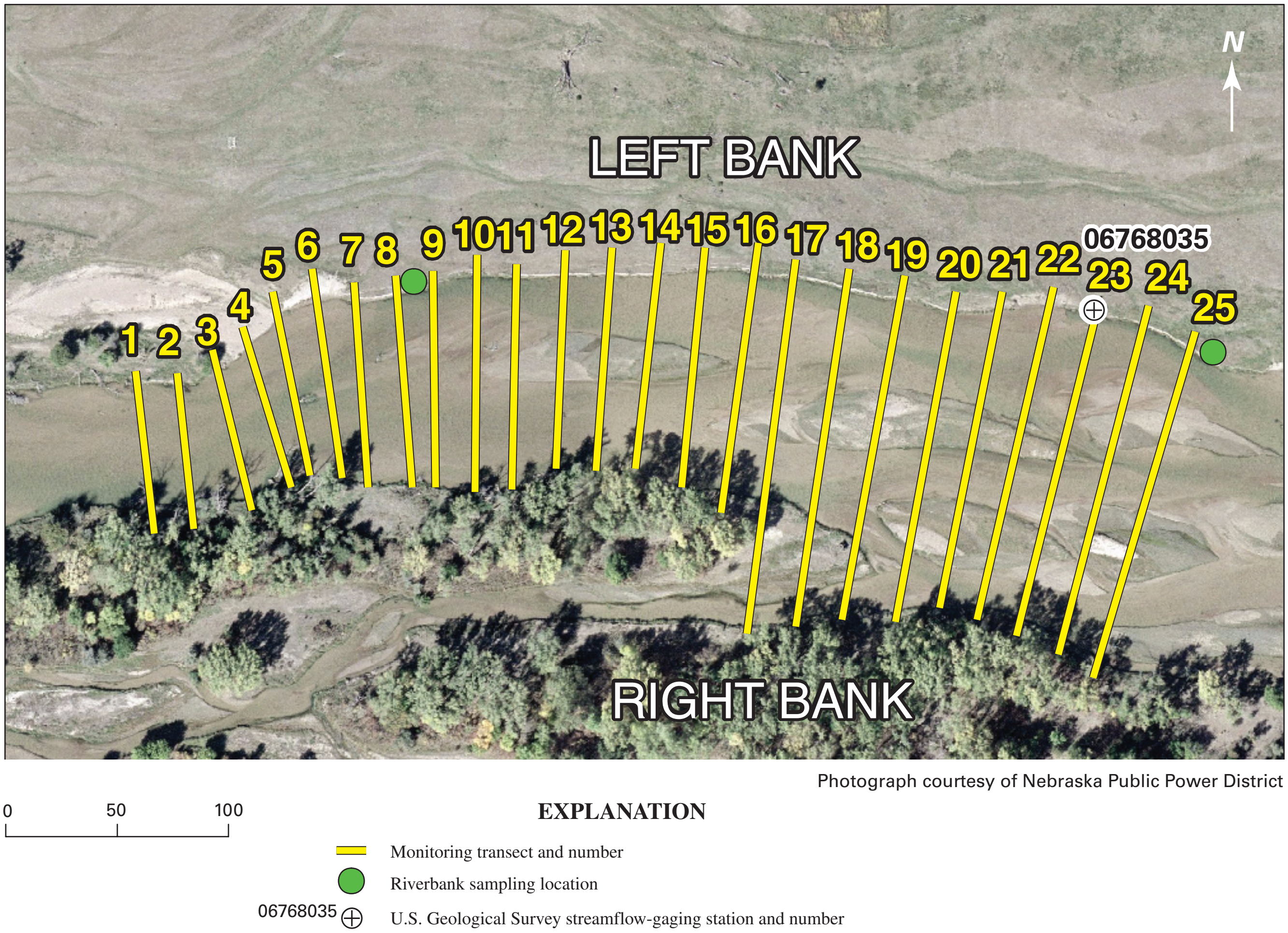

Figure 4. Natural-color aerial photograph taken October 7, 2002, showing the Output Monitoring Reach in the Cottonwood Ranch Property.

channel can document the natural variation in this variable due to the passage of bedforms. If the mean bed elevation at a transect increases or decreases through time, a disequilibrium between sediment supply and transport may be indicated, resulting either as erosion or deposition. In braided river reaches, depending on the water-surface elevation at the time of a survey, elevation measurements made along the active width of a transect might traverse a variety of surfaces including submerged channels, subaerial sandbars, and vegetated islands. The elevation measurements made on portions of the river channel not frequently exposed to fluvial action (the riverbanks and islands) are often excluded from the computation of the mean bed elevation. Although the mean bed-elevation parameter is an abstraction and simplification of the complex three-dimensional reality of river-reach adjustment, it is a useful metric for tracking the integrated topographic response at a river transect, as well as along and between river reaches.

Other variables derived from topographic surveys are useful for elucidating changes in channel geometry. The minimum bed elevation represents the lowest or deepest point in a transect. The course connecting the minimum elevation on successive transects is termed the river thalweg. The positions of thalwegs frequently shift in braided channels due to rerouting of flow around islands or midchannel sandbars. Thalwegs also deepen (decrease in elevation) or become shallower (increase in elevation) as a means to adjust to the quantity of water and sediment supplied. The maximum bed elevation corresponds to the highest point measured along a transect and frequently occurs on a midchannel sandbar. Tracking variations in the maximum bed elevation may identify the magnitude of deposition or erosion that occurs on these higher surfaces. The standard deviation of the elevations measured along a transect is an index of the vertical variation of the transect. This complexity may be due to the presence of high islands or vegetated sandbars that constrict flow through a transect. Measurement of this variable, like the others, was to reduce two-dimensional data sets (transverse distance and elevation) into single values that describe the geometry of each transect.

Elevations were measured along transects with a survey-grade global positioning system (GPS) operated in real-time kinematic (RTK) mode. In RTK mode a radio transmits data from a stationary GPS receiver (base) to a mobile GPS receiver (rover) (Trimble Navigation Limited, 1998). During each topographic survey, the base receiver was positioned over a benchmark located in proximity to the reach to be surveyed. In the Managed and Output Reaches, permanent benchmarks were placed by NPPD. The geographic coordinates of these two benchmarks in the North American Datum of 1983 (NAD 83) also were supplied by NPPD and computed with postprocessed differential GPS measurements. A permanent benchmark, set by NPPD in the Managed Reach, also was used to establish another benchmark in the Input monitoring reach. This was done to improve the chances for uninterrupted radio contact while surveying in RTK mode along the Input Reach.

The transects were displayed in the GPS rover data collectors as lines connecting the left and right bank end-point positions. While in the field, the surveyor was able to accurately follow each transect by adjusting the instantaneously computed and displayed position to align with the transect. As the surveyor traversed each river transect, the locations of substantial topographic slope changes along the channel were recorded, as were the points where the land intersected the water surface. In addition to recording the positions of these features, surveyors were instructed to collect a data point every few meters along each transect, even over relatively flat terrain. The positions surveyed with the roving receivers were stored in the data collectors.

The survey data collected in the field were later downloaded to an office computer. The geographic coordinates were projected into Universal Tranverse Mercator (UTM) coordinates. The surveyed ellipsoid heights were converted to North American Vertical Datum of 1988 (NAVD 88) elevations by using the 1999 geoid model for the conterminous United States (Geoid 99 [Conus]) (Smith and Roman, 2001). The horizontal coordinates of the points surveyed along the transect were converted to a transverse distance relative to the left bank end-point position with a Euclidean distance equation. Elevations at regular (1-meter) intervals along each transect were computed using a software program to linearly interpolate between the surveyed data points. This procedure was used to generate a common number of points in the monitoring transect because different surveyors could sample topography along a transect at somewhat different frequencies. The mean bed elevation was computed by averaging the interpolated elevation values between horizontal positions located in proximity to the riverbanks. The standard deviation and minimum and maximum bed elevation also were computed from the same set of elevation values as the mean bed elevation. In the Managed Reach, the elevations collected on the high islands, whose elevations were close to those of the riverbanks, also were included in the computation of these channel variables. This was done to document the effect of the management activities performed on these islands on the channel variables.

Another mechanism by which alluvial channels adjust in response to hydraulic forces or sediment loads is lateral migration. An extreme, punctuated example is when a channel avulses or changes course. Less dramatic adjustment occurs by bank erosion. Bank erosion at a transect was quantified by examining the variation in the distances from the left end point to the point that the surveyor identified as the top of the bank on the left and right sides of the river. In the Cottonwood Ranch Property, the majority of the riverbanks are nearly vertical, making this determination relatively straightforward and easily replicated. Along banks where erosion has occurred recently, the debris pile may form a slope that is more gradual than abrupt, in which case identifying the position of the top of bank may be arbitrary and subjective. Because of the inherent difficulty in defining the position of this edge, determining erosion at these banks is imprecise. Despite this difficulty, the density of topographic measurements made along the banks was sufficient to illustrate the progression of the river margin through time.

Sampling of Bed and Bank Sediment

The sediment that forms the bed of an alluvial river is an integrated result of the local geology, sediment transported upstream from the watershed, and local contributions from the flood plain as surface runoff or bank erosion. In the absence of significant tributary inputs or dams, the bed-particle sizes of a river should decrease from the headwaters to the mouth (Leopold and others, 1964). Most rivers are no longer natural in the sense that the contributions from headwaters, tributaries, and runoff have been altered by some degree of water-resource development and(or) land use. Similarly, the sizes of sediment making up the banks of an alluvial river are reflective of the geological record, which is a product of the depositional and erosional history of the watershed.

The downstream effects of dams on alluvial rivers have been well documented (Williams and Wolman, 1984; Collier and others, 1996). Dams generally interrupt the supply of sediment from upstream and return water to the river that is sediment deficient. The immediate effects of these returns to a river may be local degradation and winnowing of the fines from the riverbed sediment. In the Platte River system, upstream sediment supplies have been affected by dams, irrigation channel diversions and returns, and likely, by changes in land cover and land use. Comparison of bed-sediment size gradations of samples collected by the U.S. Army Corps of Engineers in 1931 along the central Platte River to gradations of samples taken in 1998 showed the median grain size of riverbed sediment has coarsened from approximately 0.4 mm to 1.2 mm over a nearly 70-year period (Kinzel and others, 1999). Clear-water returns from the Johnson 2 Hydropower return (fig. 1) upstream from the Overton bridge also may have contributed to channel incision and coarsening of the bed sediment (Murphy and Randle, 2001).

The particle-size distribution of the riverbed was determined by collecting samples along the transects at regular intervals (stations) from the right bank to left bank. A “can on a stick” bed-sediment sampler (Edwards and Glysson, 1999, p. 24) consisting of a steel cylinder 0.07 m in diameter, sealed on one end and welded to a steel pipe 1.55 m long, was used to scoop sediment from the top 0.05 m of the riverbed. Each bed-sediment sample was placed in a separate bag and labeled with the date, time, transect, and sample station number (Edwards and Glysson, 1999, p. 70).

Sediment samples also were collected from the riverbanks to determine the range in grain sizes that could be supplied to the channel from erosion. The riverbanks were sampled at three locations in the Cottonwood Ranch Property: in the Input Reach along the north bank near transect 9 on September 9, 2000, and in the Output Reach along the north bank near transects 9 and 25 on November 1, 2001 (figs. 2 and 4). At each sampling location photographs were taken of the bank after a shovel was used to shave the bank back vertically (fig. 6*A–C*). Differences in color or texture of sediment were used to separate the bank into stratagraphic layers or units. The sediment in each unit was sampled and the vertical thickness measured. Finally, a sketch was made in a field notebook to show the sampling locations, unit thicknesses, and sediment types.

The sediment samples from the bed and banks were dry sieved in ½ phi increments (a phi unit is defined as the negative base 2 logarithm of the grain diameter in millimeters) by using a series of sieves and a mechanical “Rotap” to agitate the sieve stacks (Guy, 1969). The cumulative particle-size distribution curve generated for each sample was interpolated to compute four sediment parameters. These sediment parameters were the median grain size of the bed sediment (D_{50}); sediment size for which 16 percent of the sample is finer by mass (D_{16}); the sediment size for which 84 percent of the sample is finer than (D_{84}); and the gradation parameter, defined as the square root of the ratio of the D_{84} and D_{16} (σ_g). Composite bed-sediment parameters were computed for each monitoring transect by averaging the individually computed bed-sediment parameters for each sample in that transect. For example, if *n* bed-sediment samples were collected across a transect, the composite or mean D_{50} for that transect was $\overline{D_{50}} = \sum_{i=1}^{n} \frac{D_{50i}}{n}$.

Ground Photography

A 35-mm camera with a 24-mm single-action reflex lens and slide film was used to take ground photographs at all spatial-intensive monitoring transects once per year and at all temporal-intensive transects three times per year. These photographs help to document the changes in riparian and in-channel vegetation and record the progress of the management activities. The photographer stood near each transect end point on the north bank and took a photograph facing the end point on the south bank as well as one upstream and downstream from the transect, making sure to sight the river bank in the center of the view frame. The film was developed onto slides and then scanned at 200 dots per inch resolution to create digital images. The digital images were organized and catalogued according to the transect and are included in the USGS Open-File Reports (Kinzel and others, 2003a, b; Kinzel and others, 2004; and Kinzel and others, 2005).

Oblique photographs taken daily from elevated 35-mm stationary cameras were used to observe the downstream migration of sandbar slipfaces. These serial time-lapse images documented the effect of flow variation on sandbar formation, emergence, and dissection. The time periods associated with growth of annual vegetation on these surfaces also could be determined from these images.

Aerial Photography

Aerial photography along the Platte River has been used to identify changes in river planform and vegetation patterns through time (Williams, 1978; Eschner and others, 1983; Peake and others, 1985; Johnson, 1997). As part of the Cooperative Agreement, PRESP has contracted for annual aerial photography of the central Platte River. The imagery collected alternates each year between color infrared and panchromatic black and white photography. Color-infrared imagery from 1998, black and white imagery from 2001, and color-infrared images from 2003 have been digitized and orthorectified. In addition, NPPD collected natural color photography over the Cottonwood Ranch Property in October of 2002 and in March of 2003 (fig. 5*C–D*). The areas where riparian vegetation was removed can be clearly seen in figure 5*D* as they appear lighter from the reflectivity of bare sand. Detecting subtle changes in channel planform due to bank erosion is somewhat more difficult when using aerial photography if vegetation is present on the banks. However, change along the banks was easily delineated along the areas that have undergone substantial mechanical alteration (for example, near transects 17 and 21 in the Managed Reach, figure 3).

Statistical Analysis

An analysis of variance (ANOVA) was performed on the measured channel-morphology variables to determine if statistically significant differences existed following management activities. The measurements were classified as pretreatment if they were collected before November 2002 and posttreatment if they occurred afterward. The ANOVA compared the statistical distribution of the sampled variable before the treatment to its statistical distribution after the treatment. Because only two groups were used, this is the same analysis as a t-test. The procedure tests the null hypothesis that the means of the distributions (pre and post) are the same against the alternative hypothesis that the means are different. A 95-percent confidence interval was used to determine significance.

An analysis of variance also was used to examine the bed-sediment-size gradations along the temporal intensive transects before and after the management activities. The same time stratification was used as for channel morphology variables, with those samples collected before November 2002 classified

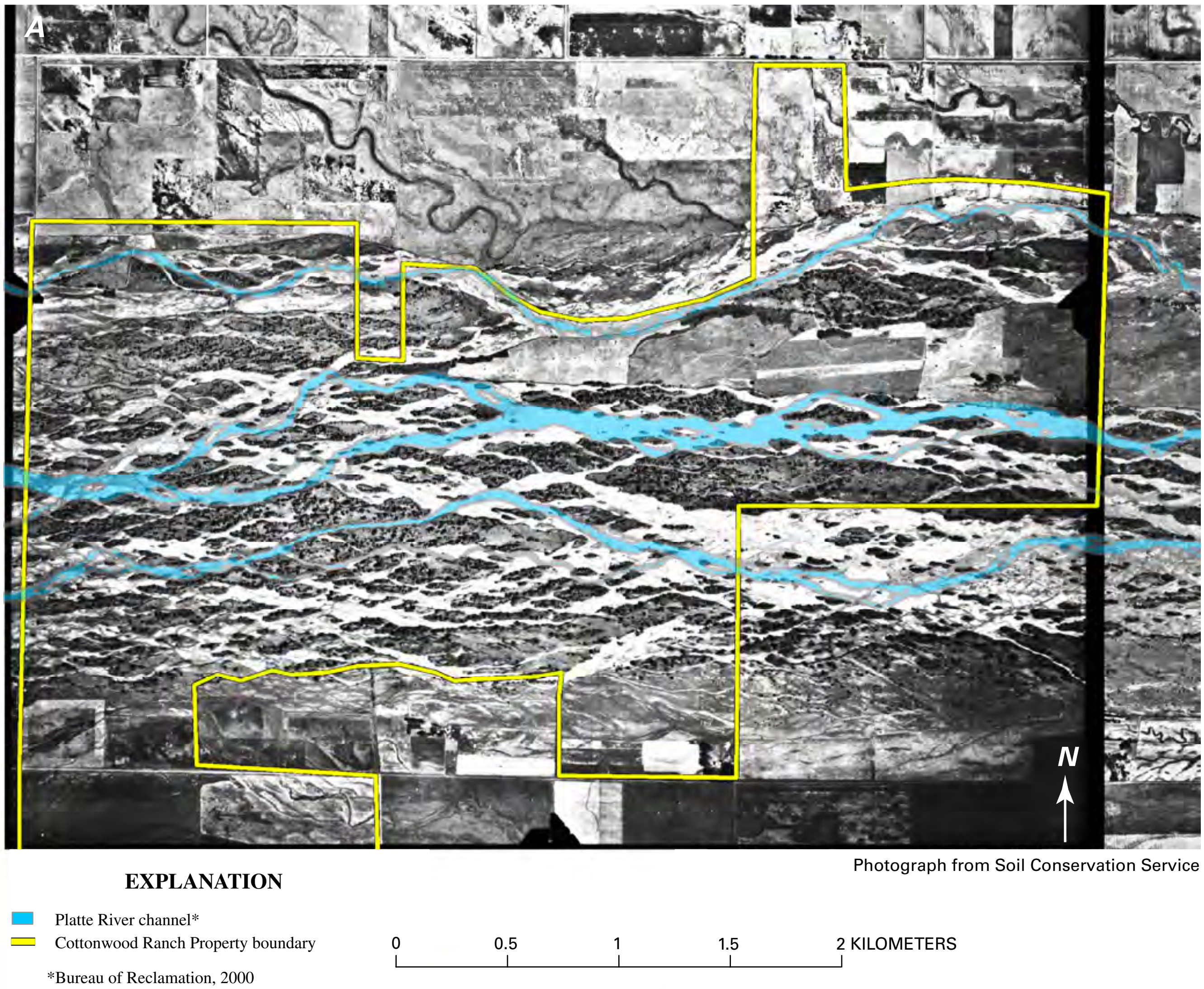

Figure 5. Aerial photography taken of the Cottonwood Ranch Property: (*A*) August 21, 1938, mean daily flow at the Overton streamflow-gaging station, 9 cubic meters per second; (*B*) November 18, 1951, mean daily flow at Overton, 56 cubic meters per second; (*C*) October 7, 2002, mean daily flow at Overton, 15 cubic meters per second; and (*D*) March 31, 2003, mean daily flow at Overton, 19 cubic meters per second.

as pretreatment and those collected after that date classified as posttreatment. Sufficient data were not available to compare pre- and posttreatment data for the spatial-intensive samples; only one posttreatment bed-sediment size data set was collected at these transects.

Channel Morphology

The results of the t-test for the channel morphology variables are shown in tables 1–3 along with the pre- and posttreatment means and sample sizes. In the Input Reach, significant differences were observed in the left-bank positions between transects 3 through 7 and transect 9 (table 1). These differences were due to erosion along the left bank that was likely stimulated from flow being directed toward the bank by a midchannel sandbar (fig. 2). A similar process was demonstrated in a laboratory flume by Leopold and Wolman (1957). The standard deviation of the bed elevation showed a statistically significant increase at transects 6 and 10. In addition, the increase in mean bed elevation at transect 9 was statistically significant.

In the Managed Reach, significant differences were observed for the maximum bed elevation of transect 2, which increased, and transects 5, 7, 8, 9, 12, 13, and 15, which all decreased following the management (table 2). All of the sections where decreases occurred following the management were directly affected by the mechanical excavation process described previously. This practice tended to decrease the maximum bed elevation and decrease the standard deviation along these transects. The mean bed elevation decreased

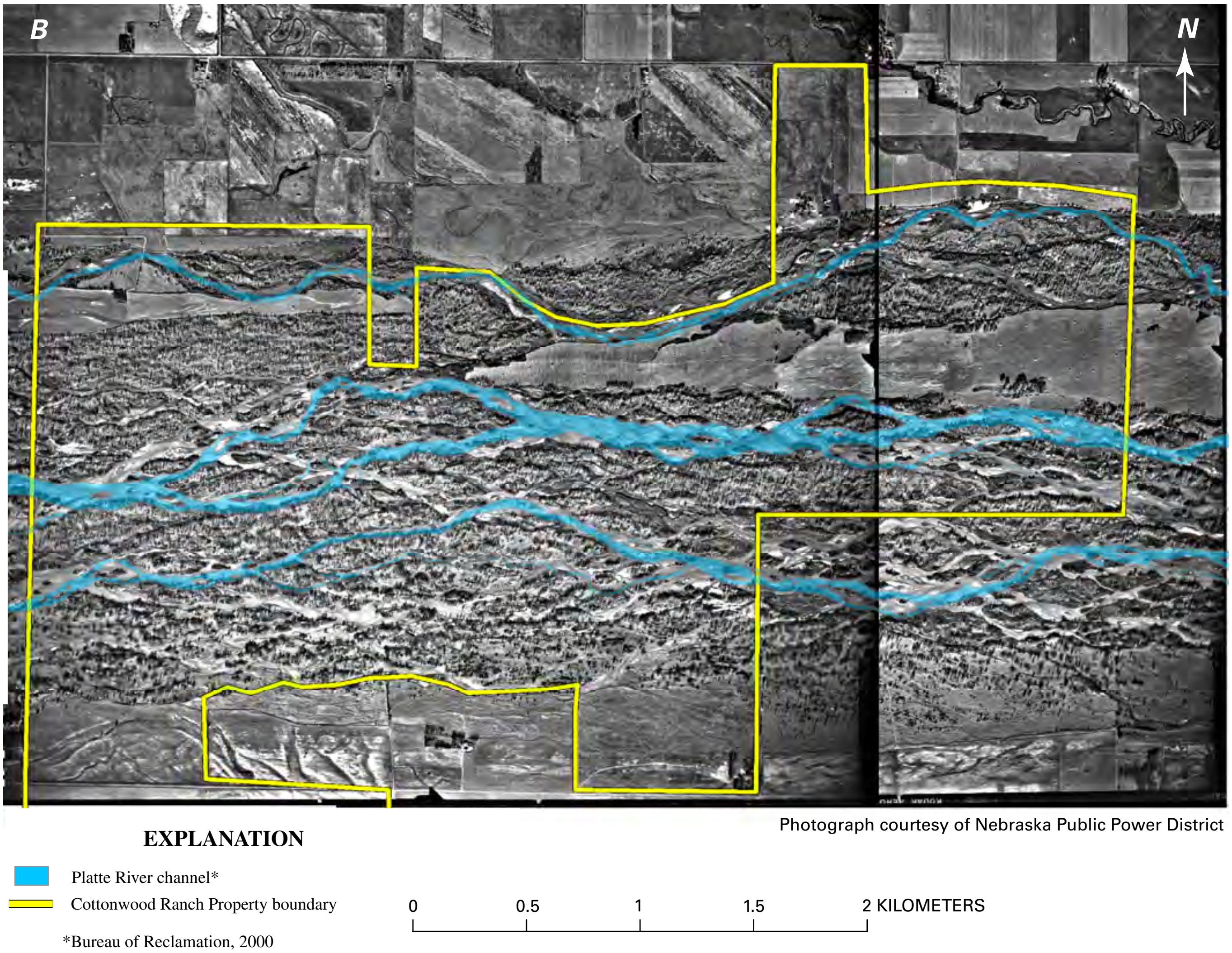

Figure 5. Aerial photography taken of the Cottonwood Ranch Property: (*A*) August 21, 1938, mean daily flow at the Overton streamflow-gaging station, 9 cubic meters per second; (*B*) November 18, 1951, mean daily flow at Overton, 56 cubic meters per second; (*C*) October 7, 2002, mean daily flow at Overton, 15 cubic meters per second; and (*D*) March 31, 2003, mean daily flow at Overton, 19 cubic meters per second.—Continued

significantly at three transects and increased significantly at three transects. Clearing by NPPD along the left bank of the river with machinery appears to be predominantly responsible for the magnitude of bank erosion and the widening measured. We investigated if the rates of erosion along the left bank of the Managed Reach were greater after the management than before for the 12 transects that showed significant differences. This was done to test the assumption that banks cleared of vegetation would be more erodible. Only four of the 12 transects (33 percent) showed greater rates of bank erosion after the management than before. However, this could be explained by the observation that the streamflows were lower after the management and therefore the opportunity to cause lateral erosion also was less.

It was inferred that if significant sediment was liberated from the managed area and if this supply exceeded the transport capacity downstream, it would produce and be detected by statistically significant increases in the mean bed elevation of the Output Reach transects. However, statistically significant increases in the mean bed elevation were only observed at two transects, 1 and 5 (table 3). The standard deviation of bed elevation decreased and minimum bed elevation also increased significantly at transect 1. Significant differences in the left-bank positions were observed at seven transects along the left bank and four along the right bank. At the downstream end of the Output Reach, four sections showed significant increases in the standard deviation of bed elevation. Because significant increase in the mean bed elevation occurred at one of 11 transects in the Input Reach (9 percent of the transects measured) and only two of 25 transects in the Output Reach (8 percent of the transects measured), it can be concluded that the management activities did not have a greater effect in increasing the mean bed elevations in the downstream transects as compared to the upstream transects.

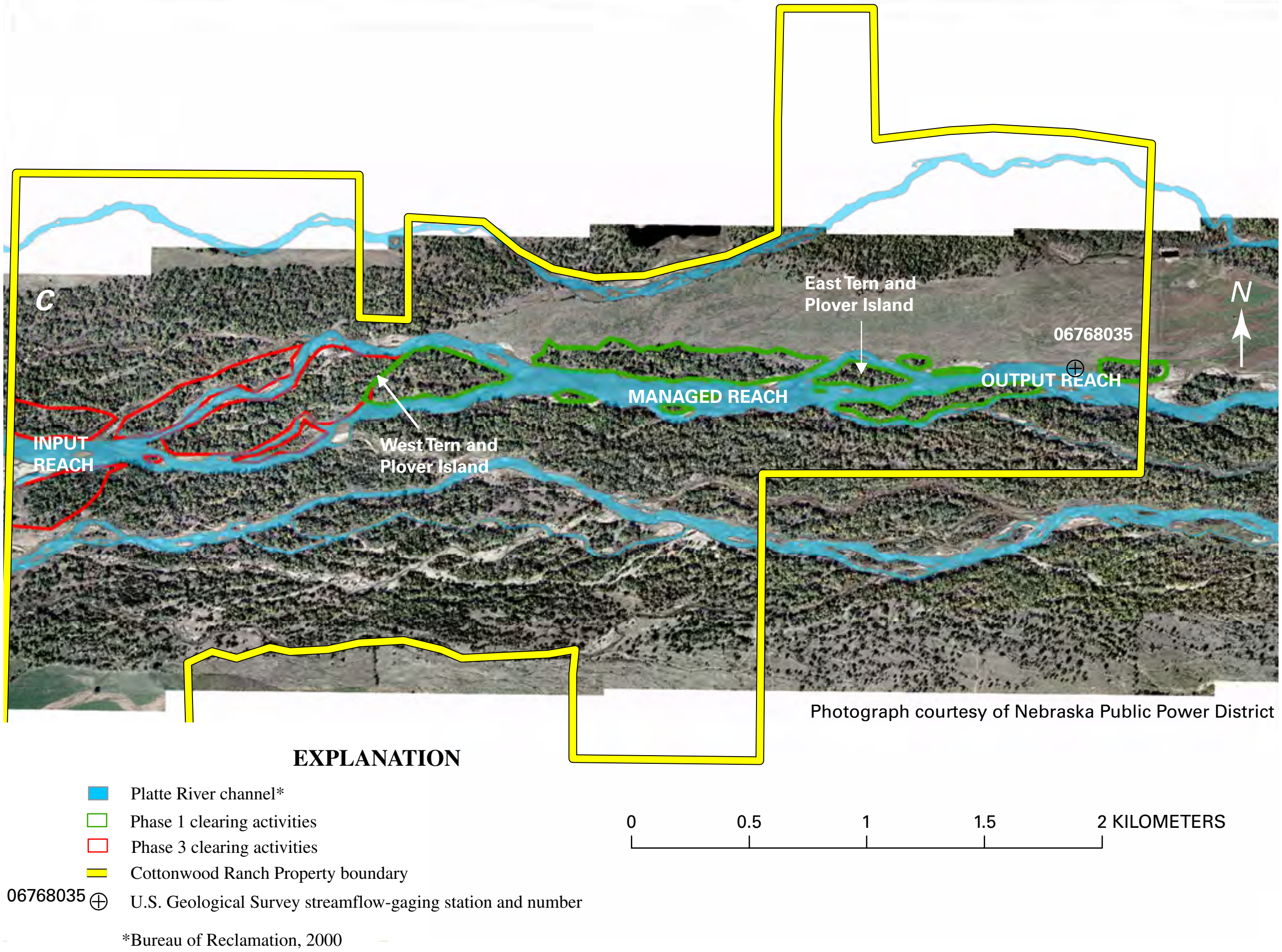

Figure 5. Aerial photography taken of the Cottonwood Ranch Property: (*A*) August 21, 1938, mean daily flow at the Overton streamflow-gaging station, 9 cubic meters per second; (*B*) November 18, 1951, mean daily flow at Overton, 56 cubic meters per second; (*C*) October 7, 2002, mean daily flow at Overton, 15 cubic meters per second; and (*D*) March 31, 2003, mean daily flow at Overton, 19 cubic meters per second.—Continued

Bed-Sediment Characteristics

The results of the ANOVA for the sediment variables are listed in tables 4–6 along with the pre- and posttreatment means and sample sizes. The bed-sediment grain-size data in the Input Reach did not show significant differences either at transect 3 or 9 (table 4). In the Managed Reach, none of the differences in the bed-sediment parameters before compared to after the treatment were determined to be significant in transects 2, 12, and 20 (table 5). In the Output Reach no significant differences in the bed-sediment variables were observed in transects 8, 16, and 24 (table 6).

Bank-sediment gradations were generally finer than those sampled from the riverbed but also were variable. The average D_{50} in the Input Reach sampling location at transect 9 was 0.47 mm with a standard deviation of 0.20 mm (fig. 6*A*). In the Output Reach sampling locations, the average D_{50} near transect 9 was 0.59 mm with a standard deviation of 0.74 mm (fig. 6*B*). The sampling location near transect 25 had an average D_{50} of 0.66 mm with a standard deviation of 0.76 mm (fig. 6*C*). A wide variation in gradations of bank sediment was observed ranging from very fine sand with silt and clay up to large cobbles.

Additional Analysis

As part of this study it was important to place the small-scale geomorphic changes measured within the Cottonwood Ranch Property over a relatively short period of time into a broader context of changes that may be occurring over larger spatial and temporal scales. In this section, stage-discharge relations to infer stage trends and trends in mean bed elevation from historical surveys are used as indicators of changes in channel morphology in the study area. An analysis of streamflow at USGS streamflow gages in the study area was done to place the flows measured during 2001–2004 into a historical perspective.

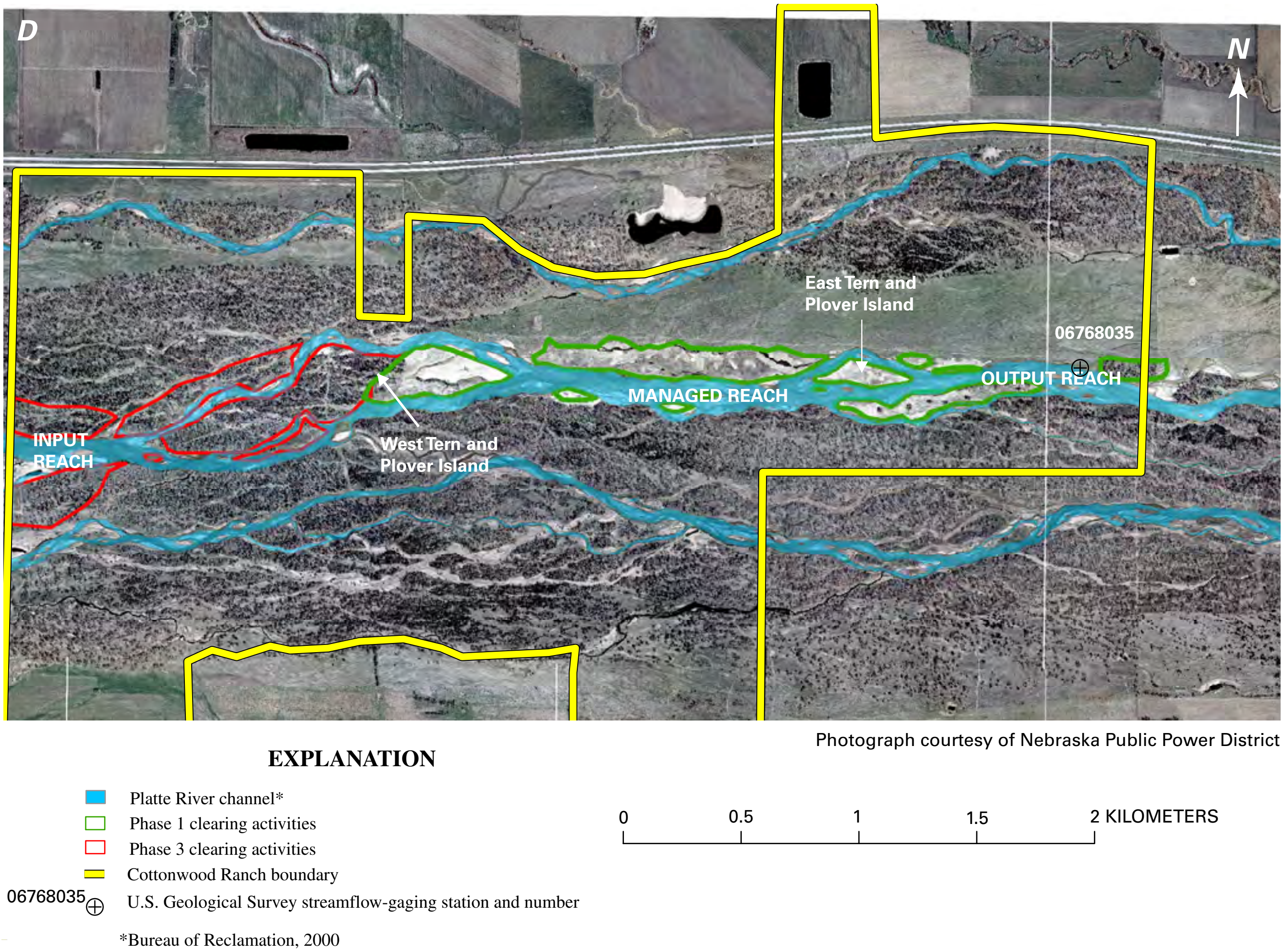

Figure 5. Aerial photography taken of the Cottonwood Ranch Property: (*A*) August 21, 1938, mean daily flow at the Overton streamflow-gaging station, 9 cubic meters per second; (*B*) November 18, 1951, mean daily flow at Overton, 56 cubic meters per second; (*C*) October 7, 2002, mean daily flow at Overton, 15 cubic meters per second; and (*D*) March 31, 2003, mean daily flow at Overton, 19 cubic meters per second.—Continued

Stage Trend

Stage-discharge relations developed at streamflow-gaging stations over long time periods provide a means to infer changes in channel gradation from stage trends. This approach does not have the accuracy of measured transects because the water-surface elevation can be influenced by the channel geometry, hydraulic roughness, or downstream effects (Williams and Wolman, 1984). However, by comparing how the stage or water-surface elevation at a particular discharge (typically at zero or low flow) of a rating changes through time, one can infer if and how the bed elevation may be changing. A downward trend in the water-surface elevation through time may be an indication that the riverbed near the gage location is scouring. Conversely, an upward trend in the water-surface elevation may be an indication that the riverbed is aggrading. Shifts in ratings are also observed at Platte River gages in the summer months when vegetation growing along the channel increases the flow resistance, resulting in a higher stage for a particular discharge (John Miller, U.S. Geological Survey, North Platte, Nebr., oral commun., 2005).

Williams (1978) extrapolated rating curves for streamflow-gaging stations along the Platte River to the point of zero discharge. He found that the south channel of the Platte River near Overton was stable from 1930 to 1949, but from 1949 to 1957 it was scoured about 0.3 m and then was constant until the late 1960s. More recently, Chen and others (1999) examined trends in stream channel gradation for 145 sites across Nebraska by examining stage at a median discharge. At the Cozad USGS streamflow-gaging station (06766500), which is approximately 47 km upstream from the Cottonwood Ranch Property, they found that between 1940 and 1987 the trend slope of the water-surface elevation associated with the median discharge was –0.013 m/yr for a flow of 9.06 m^3/s. At the Odessa streamflow-gaging station (06770000), which is 20 km downstream from the Cottonwood Ranch Property, they found that between 1938 and 1988 the trend slope of the water-surface elevation was –0.007 m/yr for a flow of 33.1 m^3/s.

Table 1. Results of the analysis of variance between pre- and postclearing channel-morphology variables in the Input Reach.

[Results of the analysis of variance (ANOVA) or t-test between pre- and posttreatment means for the following variables: MinBE (the minimum bed elevation in meters [m] measured along the transect), MaxBE (the maximum bed elevation in meters [m] measured along the transect), StdBE (the standard deviation in meters [m] of the bed elevations measured along the transect), MeanBE (the mean elevation in meters [m] measured along a transect), LB (the distance in meters [m] from reference marker to the left bank of the transect), RB (the distance in meters [m] from the reference marker to the right bank of the transect), and Width (the distance in meters [m] between the left and right bank position on the transect). If the t-test was significant at 95-percent confidence, the p-value was less than 0.05 and is listed in green. If the t-test was not significant at 95-percent confidence, the p-value was greater than 0.05 and is listed in red. Sample sizes (n) for pre- and posttreatment means also are listed]

Input reach transect	Channel morphology variables																						
	Sample (n)		MinBE (m)			MaxBE (m)			StdBE (m)			MeanBE (m)			LB (m)			RB (m)			Width (m)		
	Pre	Post	Pre	Post	p-value	Pre	Post	p-value	Pre	Post	p-value	Pre	Post	p-value	Pre	Post	p-value	Pre	Post	p-value	Pre	Post	p-value
1	3	3	695.49	695.61	0.255	696.89	696.83	0.259	0.32	0.33	0.280	696.18	696.17	0.522	4.72	3.13	0.086	164.02	163.16	0.094	160.03	159.29	0.291
2	3	3	695.44	695.63	0.349	696.69	696.58	0.189	0.25	0.25	0.872	696.06	696.06	0.462	4.28	2.18	0.059	154.76	154.75	0.862	152.56	150.48	0.059
3	7	4	695.56	695.60	0.627	696.30	696.33	0.065	0.17	0.20	0.279	695.99	696.00	0.169	5.09	3.97	0.001	145.61	145.60	0.943	141.64	140.51	0.000
4	3	3	695.50	695.55	0.780	696.16	696.24	0.167	0.14	0.18	0.238	695.93	695.94	0.655	5.53	4.58	0.047	137.18	137.17	0.607	131.65	132.59	0.044
5	3	3	695.51	695.53	0.813	696.18	696.27	0.145	0.17	0.21	0.109	695.91	695.91	0.833	3.74	2.37	0.011	137.91	137.91	0.951	135.53	134.17	0.008
6	3	3	695.54	695.43	0.052	696.21	696.24	0.522	0.17	0.22	0.013	695.89	695.91	0.527	3.59	0.32	0.019	138.66	138.99	0.216	135.07	138.68	0.014
7	3	3	695.46	695.14	0.164	696.23	696.24	0.709	0.23	0.26	0.174	695.88	695.91	0.313	3.41	2.11	0.008	128.41	128.00	0.126	124.59	126.30	0.010
8	3	3	695.41	695.38	0.660	696.39	696.28	0.380	0.25	0.27	0.281	695.86	695.87	0.582	4.98	3.88	0.085	133.35	133.40	0.347	128.37	129.52	0.094
9	7	4	695.33	695.39	0.624	696.29	696.31	0.163	0.23	0.25	0.186	695.82	695.85	0.007	4.80	4.57	0.016	132.90	133.02	0.116	128.10	128.45	0.006
10	3	3	695.40	695.38	0.666	696.03	696.15	0.050	0.14	0.21	0.031	695.77	695.75	0.231	3.41	2.93	0.159	132.41	132.42	0.963	129.00	129.49	0.182
11	3	3	695.44	695.40	0.721	696.02	696.05	0.435	0.13	0.18	0.054	695.71	695.69	0.261	3.17	2.70	0.261	130.58	129.80	0.066	127.89	126.63	0.066

Table 2. Results of the analysis of variance between pre- and postclearing channel-morphology variables in the Managed Reach.

[Results of the analysis of variance (ANOVA) or t-test between pre- and posttreatment means for the following variables: MinBE (the minimum bed elevation in meters [m] measured along the transect), MaxBE (the maximum bed elevation in meters [m] measured along the transect), StdBE (the standard deviation in meters [m] of the bed elevations measured along the transect), MeanBE (the mean elevation in meters [m] measured along a transect), LB (the distance in meters [m] from reference marker to the left bank of the transect), RB (the distance in meters [m] from the reference marker to the right bank of the transect), and Width (the distance in meters [m] between the left and right bank position on the transect). If the t-test was significant at 95-percent confidence, the p-value was less than 0.05 and is listed in green. If the t-test was not significant at 95-percent confidence, the p-value was greater than 0.05 and is listed in red. Sample sizes (n) for pre- and posttreatment means are also listed]

Managed reach transect	Channel morphology variables																						
	Sample (n)		Min(BE) (m)			MaxBE (m)			StdBE (m)			MeanBE (m)			LB (m)			RB (m)			Width (m)		
	Pre	Post	Pre	Post	p-value	Pre	Post	p-value	Pre	Post	p-value	Pre	Post	p-value	Pre	Post	p-value	Pre	Post	p-value	Pre	Post	p-value
1	3	3	692.41	692.48	0.718	693.67	693.21	0.156	0.21	0.19	0.381	692.90	692.91	0.545	2.49	1.27	0.072	110.86	111.18	0.384	108.37	109.90	0.120
2	7	4	692.40	692.53	0.096	693.15	693.26	0.028	0.17	0.19	0.558	692.85	692.89	0.069	3.69	3.51	0.035	114.91	114.99	0.019	111.23	111.48	0.016
3	3	3	692.49	692.51	0.831	693.31	693.36	0.680	0.15	0.17	0.156	692.86	692.89	0.020	3.22	3.06	0.157	140.12	141.25	0.025	136.90	138.18	0.023
4	3	3	692.52	692.52	0.953	693.16	693.22	0.211	0.17	0.16	0.379	692.86	692.88	0.313	1.89	1.05	0.079	152.33	152.45	0.008	150.44	151.40	0.063
5	3	3	692.18	692.40	0.146	694.10	693.44	0.008	0.41	0.27	0.008	692.97	692.90	0.008	2.41	1.86	0.365	154.85	155.13	0.156	152.44	153.27	0.194
6	3	3	692.36	692.47	0.098	694.11	693.89	0.055	0.46	0.42	0.070	693.00	693.00	0.872	2.39	1.91	0.293	174.73	174.77	0.725	172.34	172.86	0.299
7	3	3	692.42	692.37	0.255	694.22	693.91	0.009	0.51	0.45	0.051	693.03	693.00	0.019	3.45	3.27	0.244	181.08	180.79	0.282	177.63	177.52	0.737
8	3	3	692.31	692.16	0.086	693.94	693.87	0.016	0.43	0.38	0.014	692.91	692.87	0.132	1.74	1.11	0.009	173.20	173.09	0.427	171.46	171.99	0.007
9	3	3	692.23	692.32	0.384	693.92	693.33	0.008	0.41	0.25	0.008	692.82	692.76	0.014	2.88	1.65	0.008	163.66	164.45	0.043	160.78	162.80	0.008
10	3	3	692.27	692.33	0.503	693.95	693.77	0.149	0.45	0.36	0.011	692.78	692.76	0.558	3.35	3.00	0.008	154.92	154.92	0.931	151.57	151.92	0.015
11	3	3	692.33	692.31	0.589	693.79	693.63	0.324	0.48	0.38	0.027	692.81	692.79	0.536	1.90	1.65	0.321	149.37	149.29	0.519	147.47	147.64	0.530
12	7	4	692.17	692.24	0.242	693.70	693.43	0.000	0.40	0.31	0.000	692.72	692.70	0.169	4.40	4.00	0.246	164.27	164.88	0.033	159.87	160.89	0.043
13	3	3	692.20	692.27	0.275	693.67	693.26	0.008	0.28	0.20	0.008	692.62	692.61	0.656	4.20	2.86	0.008	165.64	166.07	0.180	161.44	163.21	0.008
14	3	3	692.01	692.05	0.834	692.84	692.89	0.262	0.22	0.20	0.564	692.54	692.55	0.062	4.23	2.67	0.008	150.99	150.97	0.857	146.74	148.32	0.008
15	3	3	692.02	692.17	0.074	693.67	692.89	0.008	0.27	0.19	0.008	692.50	692.52	0.012	2.82	0.00	0.008	137.78	138.07	0.213	134.96	138.07	0.008
16	3	3	692.03	692.08	0.646	692.74	692.75	0.319	0.17	0.17	0.865	692.43	692.47	0.094	3.71	–2.32	0.008	132.22	132.22	0.974	128.51	134.54	0.008
17	3	3	691.87	691.89	0.907	692.64	692.69	0.360	0.16	0.20	0.462	692.33	692.38	0.149	3.14	–6.69	0.008	112.65	113.33	0.107	109.51	120.02	0.008
18	3	3	691.83	691.86	0.852	692.60	692.69	0.107	0.20	0.20	0.881	692.30	692.34	0.036	2.24	0.62	0.008	105.37	105.37	1.000	103.12	104.74	0.007
19	3	3	691.90	691.94	0.795	692.64	692.63	0.780	0.19	0.17	0.633	692.28	692.30	0.355	3.67	3.37	0.063	105.01	105.17	0.012	101.34	101.80	0.038
20	7	4	691.93	691.96	0.669	692.43	692.45	0.635	0.13	0.12	0.592	692.21	692.23	0.166	1.66	–15.29	0.000	91.45	91.41	0.583	89.75	106.74	0.000
21	3	3	691.90	691.92	0.897	692.53	692.51	0.822	0.15	0.16	0.896	692.21	692.24	0.211	1.50	–15.20	0.008	94.36	94.20	0.297	92.86	109.40	0.008

Table 3. Results of the analysis of variance between pre- and postclearing channel-morphology variables in the Output Reach.

[Results of the analysis of variance (ANOVA) or t-test between pre- and posttreatment means for the following variables: MinBE (the minimum bed elevation in meters [m] measured along the transect), MaxBE (the maximum bed elevation in meters [m] measured along the transect), StdBE (the standard deviation in meters [m] of the bed elevations measured along the transect), MeanBE (the mean elevation in meters [m] measured along a transect), LB (the distance in meters [m] from reference marker to the left bank of the transect), RB (the distance in meters [m] from the reference marker to the right bank of the transect), and Width (the distance in meters [m] between the left and right bank position on the transect). If the t-test was significant at 95-percent confidence, the p-value was less than 0.05 and is listed in green. If the t-test was not significant at 95-percent confidence, the p-value was greater than 0.05 and is listed in red. Sample sizes (n) for pre- and posttreatment means are also listed]

Output reach transect	Sample (n)		Channel morphology variables																					
			Min(BE) (m)			MaxBE (m)			StdBE (m)			MeanBE (m)			LB (m)			RB (m)			Width (m)		
	Pre	Post	Pre	Post	p-value	Pre	Post	p-value	Pre	Post	p-value	Pre	Post	p-value	Pre	Post	p-value	Pre	Post	p-value	Pre	Post	p-value
1	4	3	690.73	690.86	0.015	692.02	691.82	0.275	0.19	0.13	0.011	691.00	691.06	0.009	2.68	2.20	0.017	59.71	59.77	0.754	57.03	57.57	0.036
2	4	3	690.64	690.63	0.940	691.19	691.24	0.560	0.12	0.14	0.707	690.98	691.01	0.356	1.91	1.63	0.095	58.28	57.65	0.391	56.37	56.02	0.622
3	4	3	690.69	690.85	0.181	691.16	691.17	0.899	0.10	0.08	0.522	690.95	691.01	0.135	1.72	0.67	0.059	61.46	61.79	0.062	59.74	61.12	0.046
4	4	3	690.43	690.70	0.069	691.40	691.22	0.428	0.20	0.12	0.070	690.95	691.01	0.081	1.40	0.38	0.170	67.83	68.22	0.011	66.43	67.83	0.057
5	4	3	690.64	690.73	0.332	691.23	691.30	0.110	0.16	0.15	0.599	690.99	691.04	0.039	4.33	5.80	0.258	82.23	82.34	0.384	77.90	76.54	0.257
6	4	3	690.72	690.77	0.409	691.28	691.29	0.927	0.13	0.13	0.983	691.00	691.03	0.153	2.63	2.05	0.228	94.20	94.14	0.536	91.57	92.09	0.215
7	4	3	690.78	690.77	0.918	691.18	691.19	0.761	0.11	0.10	0.582	690.98	691.01	0.092	2.87	2.21	0.063	87.73	87.49	0.394	84.62	85.52	0.058
8	7	4	690.67	690.69	0.731	691.18	691.18	0.952	0.12	0.12	0.984	690.98	690.99	0.275	2.97	2.24	0.003	90.27	90.51	0.484	87.30	88.27	0.058
9	4	3	690.66	690.72	0.272	691.15	691.23	0.194	0.12	0.13	0.275	690.97	691.00	0.073	2.13	2.03	0.533	95.83	95.79	0.582	93.71	93.76	0.714
10	4	3	690.49	690.70	0.176	691.24	691.23	0.953	0.14	0.13	0.747	690.99	690.99	0.918	1.26	0.66	0.090	102.26	102.35	0.302	101.00	101.69	0.113
11	4	3	690.52	690.58	0.560	691.23	691.28	0.627	0.15	0.15	0.786	690.97	690.97	0.901	1.54	0.68	0.092	98.66	98.97	0.138	97.12	98.28	0.080
12	4	3	690.51	690.52	0.910	691.22	691.26	0.140	0.18	0.18	0.857	690.94	690.94	0.924	3.07	1.84	0.063	95.17	95.46	0.199	92.10	93.62	0.069
13	4	3	690.54	690.56	0.839	691.28	691.28	0.901	0.20	0.19	0.646	690.92	690.92	0.966	3.53	2.39	0.043	94.05	94.58	0.059	90.52	92.19	0.044
14	4	3	690.53	690.62	0.439	691.21	691.25	0.090	0.17	0.17	0.815	690.91	690.89	0.552	3.90	3.32	0.048	96.65	97.11	0.135	92.75	93.79	0.075
15	4	3	690.60	690.60	0.990	691.21	691.22	0.766	0.14	0.14	0.820	690.87	690.87	0.930	2.37	2.01	0.226	103.11	103.61	0.245	100.74	101.60	0.221
16	7	4	690.51	690.45	0.350	691.13	691.06	0.037	0.15	0.13	0.269	690.86	690.84	0.248	2.83	2.25	0.001	103.74	104.24	0.014	100.91	102.00	0.002
17	4	3	690.54	690.52	0.759	691.12	691.10	0.395	0.14	0.13	0.791	690.84	690.81	0.075	2.79	2.16	0.176	162.57	162.64	0.602	159.78	160.48	0.234
18	4	3	690.43	690.50	0.414	691.17	691.19	0.157	0.17	0.19	0.426	690.82	690.82	0.834	6.15	5.48	0.128	157.19	157.58	0.003	151.04	152.10	0.042
19	4	3	690.47	690.35	0.020	691.28	691.21	0.688	0.19	0.21	0.069	690.82	690.83	0.324	4.67	4.14	0.068	149.34	149.13	0.146	144.67	144.99	0.331
20	4	3	690.45	690.32	0.085	691.36	691.34	0.480	0.22	0.24	0.012	690.82	690.82	0.895	6.66	6.27	0.045	145.28	145.42	0.313	138.62	139.15	0.006
21	4	3	690.45	690.36	0.114	691.36	691.34	0.108	0.22	0.23	0.060	690.80	690.79	0.650	3.27	2.73	0.039	142.87	143.13	0.069	139.60	140.39	0.041
22	4	3	690.47	690.27	0.004	691.14	691.15	0.488	0.18	0.21	0.004	690.77	690.77	0.954	1.71	0.91	0.055	143.14	143.70	0.029	141.44	142.79	0.018
23	4	3	690.40	690.27	0.296	691.12	691.12	0.941	0.15	0.19	0.006	690.73	690.72	0.259	1.60	1.47	0.365	145.05	145.02	0.790	143.45	143.55	0.660
24	7	4	690.39	690.39	0.919	691.59	691.59	0.711	0.21	0.23	0.052	690.73	690.72	0.435	5.87	5.49	0.068	153.23	153.06	0.183	147.36	147.58	0.230
25	4	3	690.30	690.35	0.572	691.38	691.42	0.666	0.19	0.23	0.048	690.71	690.72	0.786	3.43	2.16	0.063	150.66	150.66	0.958	147.23	148.50	0.077

Table 4. Results of the analysis of variance between pre- and postclearing bed-sediment variables for transects sampled in the Input Reach.

[Results of the analysis of variance (ANOVA) or t-test between pre- and posttreatment means for the following variables: D_{16} (bed-sediment size in millimeters [mm] for which 16 percent of the sample is finer by mass), D_{50} (bed-sediment size in millimeters [mm] for which 50 percent of the sample is finer by mass), D_{84} (bed-sediment size in millimeters [mm] for which 84 percent of the sample is finer by mass), σ_g, the gradation parameter defined as the square root of the ratio of D_{84} and D_{16}. If the t-test was not significant at 95-percent confidence, the p-value was greater than 0.05 and is listed in red. Sample sizes (n) for pre- and post-treatment means are also listed]

Input reach transect	Bed-sediment variables														
	Sample sizes (n)		D_{16} (mm)			D_{50} (mm)			D_{84} (mm)			σ_g unitless		
	Pre	Post	Pre	Post	p-value	Pre	Post	p-value	Pre	Post	p-value	Pre	Post	p-value
3	7	3	0.40	0.37	0.078	1.22	1.28	0.643	3.49	3.81	0.625	2.87	2.86	0.985
9	7	3	0.42	0.43	0.734	1.70	2.04	0.082	5.01	5.88	0.182	3.20	3.34	0.462

Table 5. Results of the analysis of variance between pre- and postclearing bed-sediment variables for transects sampled in the Managed Reach.

[Results of the analysis of variance (ANOVA) or t-test between pre- and posttreatment means for the following variables: D_{16} (bed-sediment size in millimeters [mm] for which 16 percent of the sample is finer by mass), D_{50} (bed-sediment size in millimeters [mm] for which 50 percent of the sample is finer by mass), D_{84} (bed-sediment size in millimeters [mm] for which 84 percent of the sample is finer by mass), σ_g, the gradation parameter defined as the square root of the ratio of D_{84} and D_{16}. If the t-test was not significant at 95-percent confidence, the p-value was greater than 0.05 and is listed in red. Sample sizes (n) for pre- and post-treatment means are also listed]

Managed reach transect	Bed-sediment variables													
	Sample sizes (n)		D_{16} (mm)			D_{50} (mm)			D_{84} (mm)			σ_g unitless		
	Pre	Post	Pre	Post	p-value	Pre	Post	p-value	Pre	Post	p-value	Pre	Post	p-value
2	7	3	0.39	0.35	0.129	1.23	1.08	0.188	3.77	3.15	0.100	3.04	2.90	0.483
12	7	3	0.38	0.36	0.323	1.21	0.91	0.144	3.41	2.87	0.378	2.94	2.72	0.321
20	7	3	0.44	0.42	0.452	1.19	1.13	0.676	3.15	3.32	0.752	2.64	2.69	0.769

Table 6. Results of the analysis of variance between pre- and postclearing bed-sediment variables for transects sampled in the Output Reach.

[Results of the analysis of variance (ANOVA) or t-test between pre- and posttreatment means for the following variables: D_{16} (bed-sediment size in millimeters [mm] for which 16 percent of the sample is finer by mass), D_{50} (bed-sediment size in millimeters [mm] for which 50 percent of the sample is finer by mass), D_{84} (bed-sediment size in millimeters [mm] for which 84 percent of the sample is finer by mass), σ_g, the gradation parameter defined as the square root of the ratio of D_{84} and D_{16}. If the t-test was not significant at 95-percent confidence, the p-value was greater than 0.05 and is listed in red. Sample sizes (n) for pre- and post-treatment means are also listed]

Output reach transect	Bed-sediment variables													
	Sample sizes (n)		D_{16} (mm)			D_{50} (mm)			D_{84} (mm)			σ_g unitless		
	Pre	Post	Pre	Post	p-value	Pre	Post	p-value	Pre	Post	p-value	Pre	Post	p-value
8	7	3	0.42	0.42	0.893	1.03	1.16	0.402	2.82	3.26	0.302	2.55	2.76	0.245
16	7	3	0.40	0.39	0.527	1.43	1.37	0.782	4.48	4.26	0.679	3.17	3.15	0.936
24	7	3	0.36	0.36	0.875	1.37	1.13	0.289	4.35	4.04	0.739	3.35	3.22	0.749

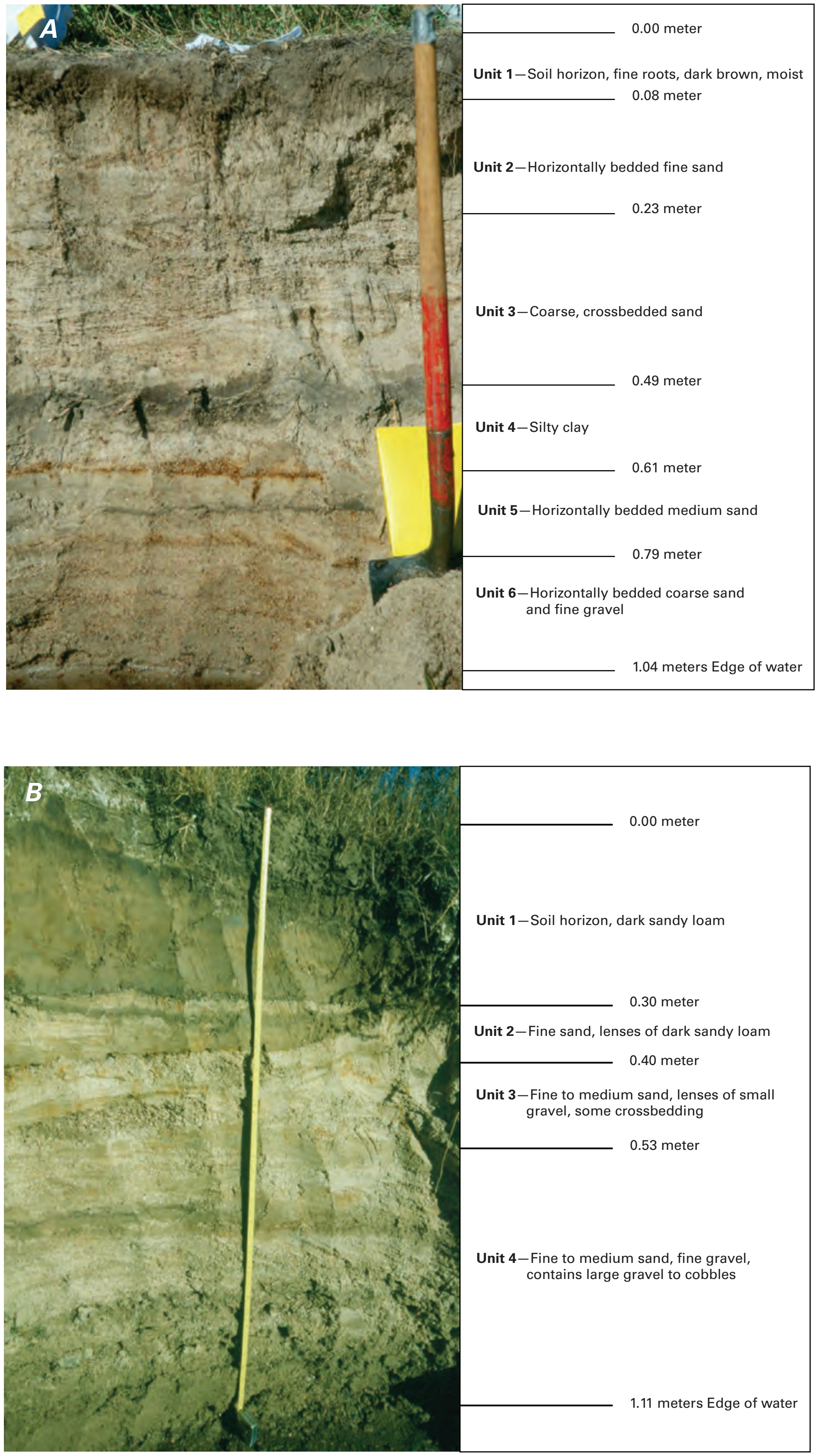

Figure 6. Bank stratigraphy near (*A*) Input Reach transect 9, September 9, 2000; (*B*) Output Reach transect 9, November 1, 2001; and (*C*) Output Reach transect 25, November 1, 2001.

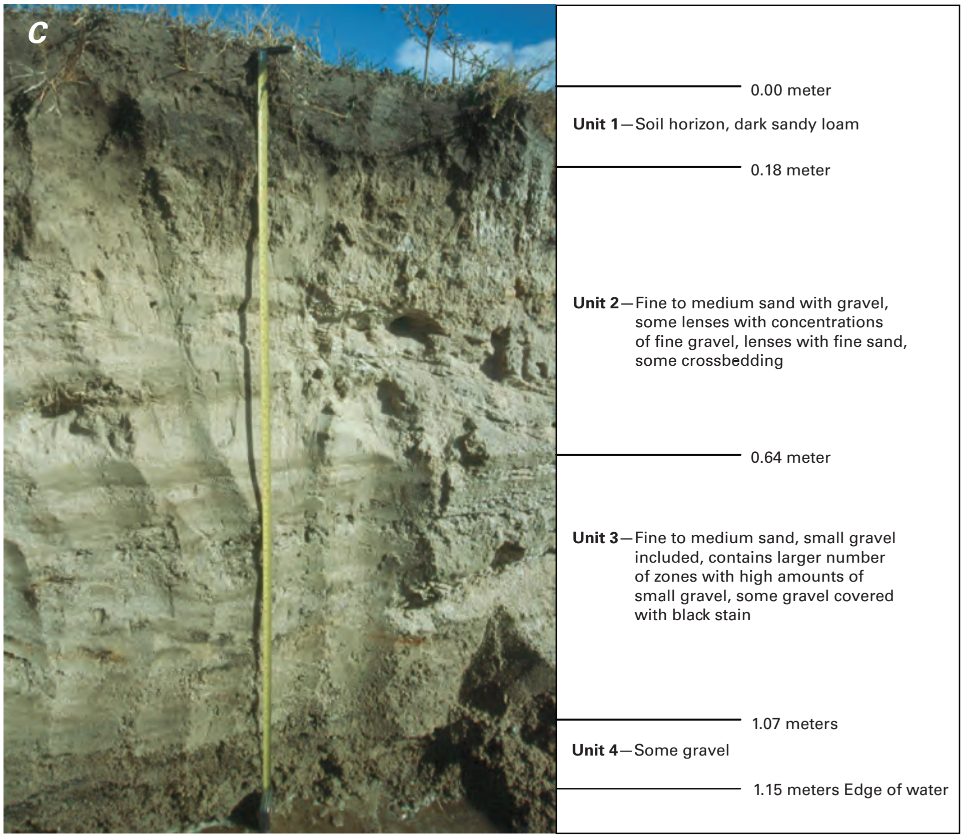

Figure 6. Bank stratigraphy near (*A*) Input Reach transect 9, September 9, 2000; (*B*) Output Reach transect 9, November 1, 2001; and (*C*) Output Reach transect 25, November 1, 2001. —Continued

Since the streamflow-gaging station in the Cottonwood Ranch Property was only recently installed, the period of record was not sufficient for stage-trend analysis. The closest gage to the Cottonwood Ranch study site with a suitable period of record was the upstream gage at Overton. This gage was not analyzed as part of Chen and others (1999), but an analysis at this site was conducted for the time period between 1931 through 2004 for the stage associated with a streamflow of 8.2 m^3/s (David Rus, U.S. Geological Survey, Lincoln, Nebr., unpub. data). The gage at Overton has not been at the same location over its period of operation. The Platte River at Overton had a water-stage recorder on its south channel from October 1, 1930, until measurement was discontinued on September 30, 1976. On October 1, 1968, a water-stage recorder was installed on the north channel and was maintained through June 1, 1976. From June 2, 1976, to present, the gage has measured the total flow (Hitch and others, 2005). For a median discharge of 8.2 m^3/s, the south channel showed a water-surface elevation trend slope of –0.005 m/yr and the north channel showed a water-surface elevation trend slope of –0.08 m/yr in the time periods listed above. The total flow channel showed a trend slope of –0.01 m/yr in the period between June 2, 1976, and September 30, 2004. It can be inferred from the negative water-surface elevation trend slopes at the Cozad, Overton, and Odessa streamflow-gaging stations at these median discharges that the riverbed has degraded at these locations.

Trends in Mean Bed Elevation from Channel Surveys

In 1989 the Bureau of Reclamation (BOR) surveyed transects along the central Platte River (Bureau of Reclamation, unpublished data). Two of those monitoring transects were examined for this report because of their proximity to the Cottonwood Ranch Property. One of these transects is upstream and west of the Cottonwood Ranch Property at U.S. Army Corps of Engineers (USACE) river mile 237.5, and the other is downstream and east at river mile 233.8 (fig. 1). These transects were resurveyed in 1998 and 2002 (Druyvestein, Johnson & Anderson, 1998, 2002). The BOR monitoring transect data were analyzed with the same methodology as that used for the Input, Managed, and Output Reach transects. Comparison of the surveys showed that the mean bed elevation along the middle channel of the Platte River at river mile 237.5 decreased from

697.61 to 696.97 m between 1989 and 2002 (fig. 7). At river mile 233.8, the mean bed elevation along the middle channel decreased from 690.43 to 690.14 m (fig. 7). Murphy and Randle (2001) believed the degradation measured at these transects, and more substantial incision measured upstream, was caused by the clear-water return flows from the Johnson 2 Hydropower plant.

NPPD surveyed river transects at river mile 237.5 and 233.7 (fig. 1) annually from 2002 to 2004 as part of their monitoring program for the USACE Section 404 permit (James Jenniges, unpub. data). Between 2002 and 2004 at river mile 237.5, the mean bed elevation of the middle channel remained measurably constant, only changing from 696.97 to 696.96 m. In the same time period at river mile 233.7, the mean bed elevation of the middle channel decreased from 690.10 to 690.03 m.

Linear-regression lines were fit to the survey data to compute general trends of mean bed elevation at surveyed transects. The transects surveyed by the BOR showed a linear trend slope of –0.05 m/yr in the middle channel upstream from the Cottonwood Ranch Property, at river mile 237.5, and –0.02 m/yr in the middle channel downstream from the Cottonwood Ranch Property, at river mile 233.8, in the time period between 1989 and 2002 (fig. 7). The NPPD transects showed a linear trend slope of –0.005 m/yr at the upstream end of the Cottonwood Ranch Property, at river mile 237.5, and –0.03 m/yr at the downstream end, at river mile 233.7, between 2002 and 2004 (fig. 7).

Transects surveyed by USGS showed a slope in the mean bed elevation from 2000 to 2004 of +0.007 m/yr in the middle channel at the upstream end of the Input Reach (transect 3) (fig. 7), +0.01 m/yr at the downstream end of the Managed Reach (transect 20), and –0.009 m/yr at the downstream end of the Output Reach (transect 24) (fig. 7). Taken together, these trends suggest that some degree of degradation might have occured since 1989, at least at the downstream end of the Cottonwood Ranch Property, because surveys by all three organizations have measured some degradation in their surveys at this location. However, in the period between 2000 though 2004 the riverbed elevation through the Cottonwood Ranch remained relatively constant. This might be explained by a local increase in the supply of sand from flood-plain sediment due to bank failure. Johnson (1997) believed that vertical riverbanks with older, mature vegetation were erodible even at low flows. Bank erosion was measured in all of the monitoring reaches (tables 1–3).

It is noteworthy to point out that the rates of change measured above were extremely small over short periods of time; as such, any trends should be cautiously interpreted. Williams and Wolman (1984) estimated that for a cross section downstream from the Fort Peck Dam on the Missouri River, 30 years of record would be required to show reliably a degradation rate of 0.01 m/yr. However, aggradation was not measured at transect 233.7 surveyed by NPPD in 2004 or in a greater percentage of the Output Reach transects than the Input Reach transects surveyed by USGS. For this reason, we

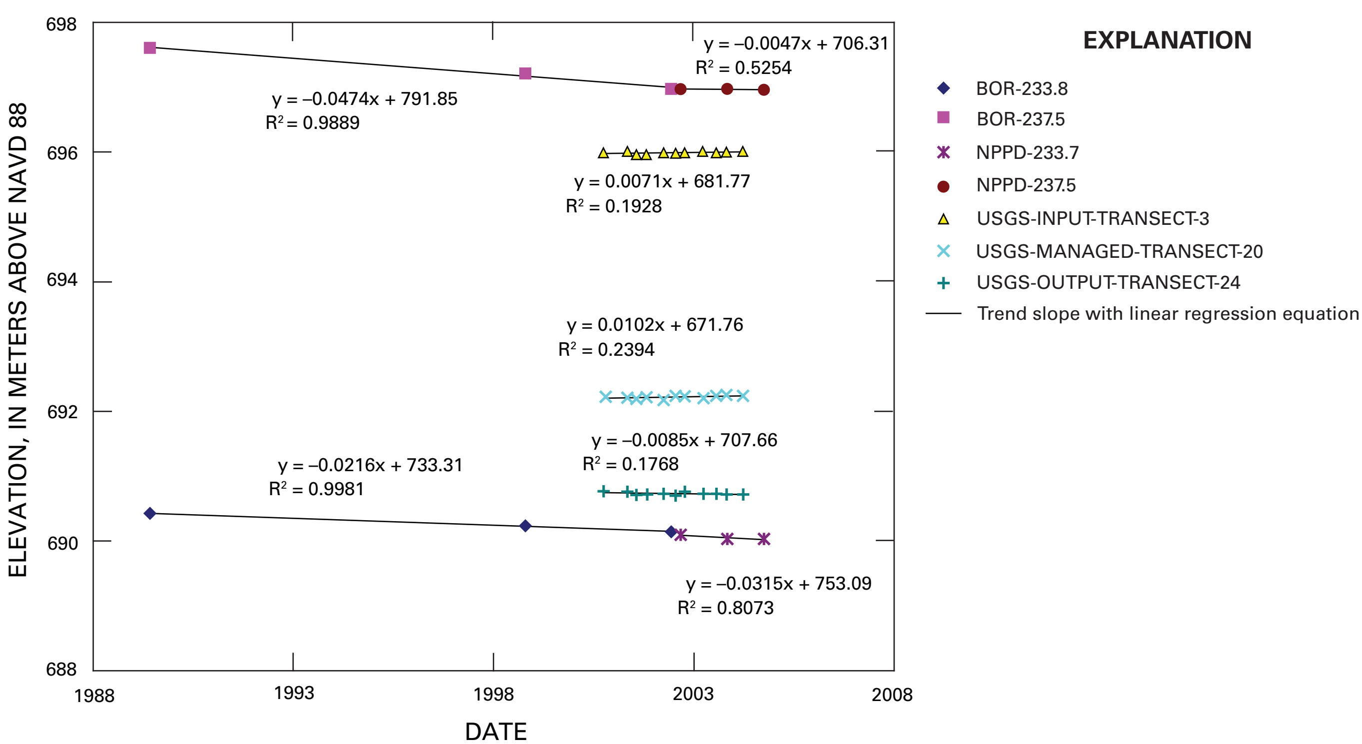

Figure 7. Graph showing the linear trend slopes of mean bed elevation along the middle channel of the Platte River near the Cottonwood Ranch for U.S. Geological Survey, Bureau of Reclamation, and Nebraska Public Power District transect surveys.

conclude from these channel surveys that there is no evidence to support the hypothesis that the contribution of upstream sediment from the management activities substantially exceeded the transport capacity immediately downstream during 2002 to 2004.

Streamflow

The Overton streamflow gage has been operated near its present site since 1918. The discharge measured at the Overton gage prior to increased flow regulation in 1941 ranged from no-flow periods in 1919, 1922, 1925, 1927–28, and 1930–1941 to a peak flow of 1,065 m^3/s on July 5, 1935 (Hitch and others, 2005). Between 1942 and 2004 there were no periods of zero flow, and the maximum peak flow was 648 m^3/s on June 28, 1983. The lowest annual mean flow in water years 1942 through 2004 was 9.1 m^3/s in 2004 and the highest was 165 m^3/s in 1983. Daily mean flows at the Overton streamflow gage have been computed since October 1, 1930. The average daily mean flow for 73 water years, 1931 through 2004, and the recorded discharges at the Overton and Cottonwood Ranch gages during the study period are shown in figure 8. Soenksen and others (1999) computed peak-flow frequencies for the Overton gage for the period since 1941. The 2-, 5-, 10-, 25-, 50-, 100-, 200-, and 500-year peak discharges for the Platte River at Overton were computed to be 148, 262, 362, 530, 682, 869, 1,093 and 1,455 m^3/s. The peak discharges during the study (water years 2001 through 2004) were 127, 89, 57, and 61 m^3/s, respectively. Thus, no flows equal to or greater than the 2-year peak discharge occurred during the study period. Hydropower generation at the Johnson Hydropower plant by Central Nebraska Public Power and Irrigation District typically results in a peak flow of 48 m^3/s lasting 2 to 4 hours each day at the Overton gage. This wave requires approximately 3 hours to travel from the Overton gage to the Cottonwood Ranch gage, and the peak discharge of this wave by then is attenuated between 10 to 20 percent.

The mean of the annual flows measured at the Overton gage from 1931 to 2004 was compared to the annual flow measured at the Overton gage in water years 2001–2004. The annual flows for water years 2001–2004, expressed as a percentage of this mean, are shown figure 9. In water year 2001, the annual flow at the Overton gage was 67 percent of the mean of the 1931–2004 annual flows. The Overton annual

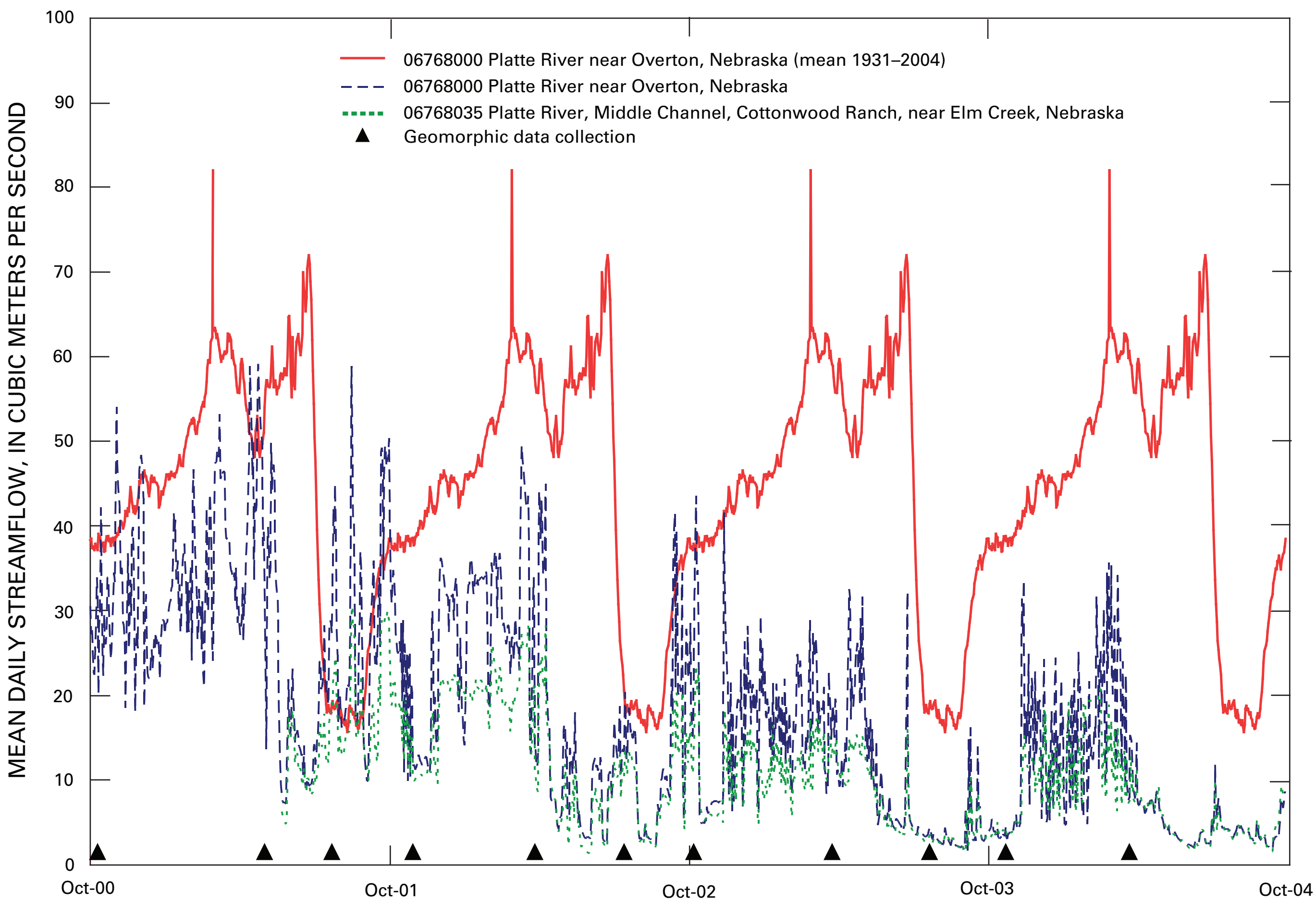

Figure 8. Average mean daily discharge measured at USGS streamflow-gaging station 06768000, Platte River near Overton, 1931–2004, compared with discharges measured during this study, water years 2001 through 2004, at the Overton and Cottonwood Ranch gages.

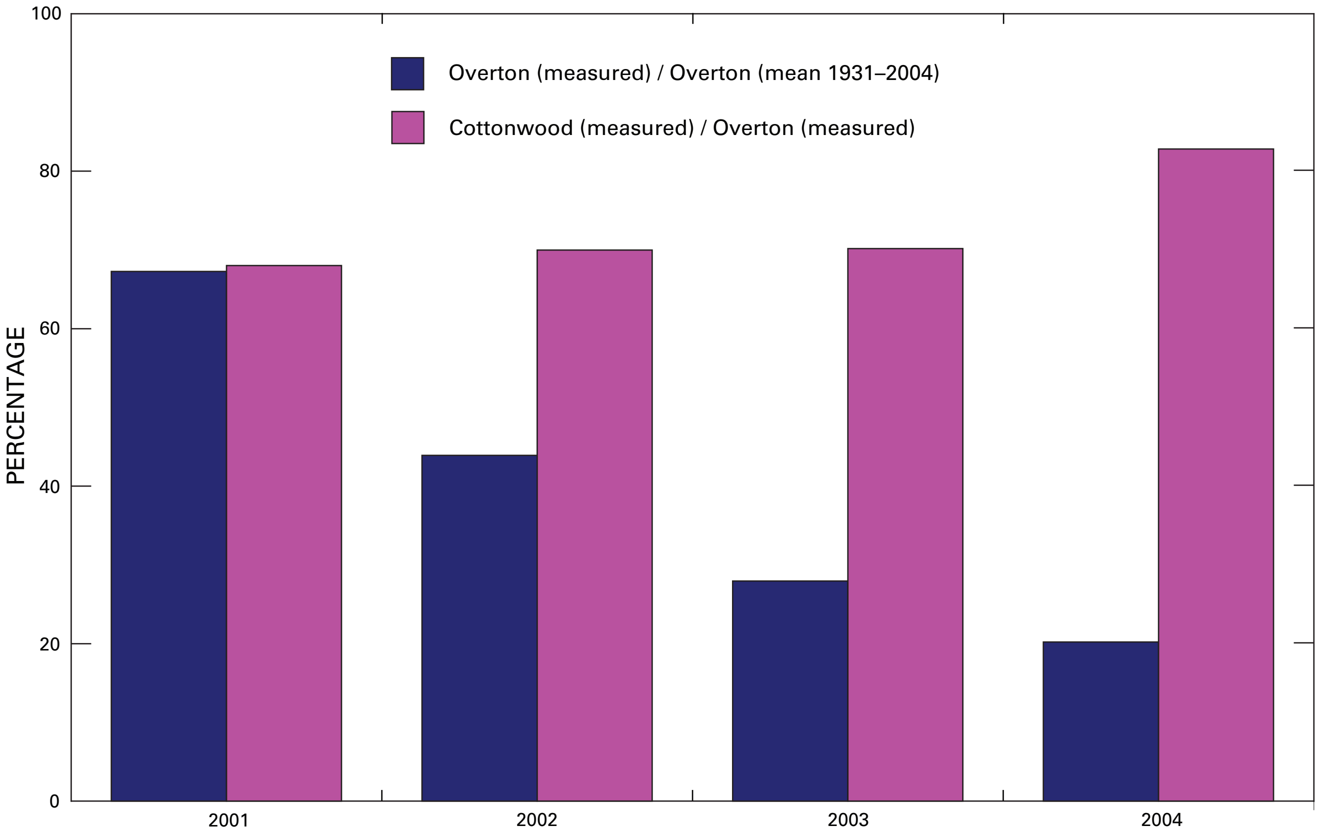

Figure 9. Percentage of the mean of the annual flows, 1931–2004, measured at the Overton gage, water years 2001 through 2004 and percentage of the annual flow measured at the Overton gage that was measured at the Cottonwood Ranch gage for water years 2001–2004.

flow decreased each subsequent year of the study, and in water year 2004 the annual flow was only 20 percent of the mean. The flows measured at the Overton gage during the study also were compared with those at the Cottonwood Ranch gage to determine the percentage of the flow conveyed in the middle channel. The annual flow in the middle channel measured at the Cottonwood Ranch gage was 68 percent of the total annual flow of the river measured at the Overton gage in water year 2001. This proportion was based only on data from May through September of 2001 because the streamflow-gaging station was not installed until May of 2001. As the annual flow decreased annually at Overton over the study period, the proportion of that flow carried in the middle channel increased annually and reached 82 percent of the total flow of the river for water year 2004 (fig. 9). At higher discharges, when other channels convey an increasingly larger portion of the riverflow, the proportion of the flow carried in the middle channel is expected to be less than 68 percent. It is suspected that interactions with ground water are occurring in the area between the two streamflow-gaging sites on the basis of occasional discrepancies between the discharges recorded at Overton and Cottonwood Ranch; however, the magnitude of this influence has not been quantified and would require further study.

Summary and Conclusions

Riparian areas along a reach of Platte River passing through Nebraska Public Power District's Cottonwood Ranch Property were modified during 2002 to 2004 to enhance in-channel habitats for endangered and threatened avian species. The U.S. Geological Survey in cooperation with the Platte River Endangered Species Partnership conducted a study to investigate and detect potential downstream effects of the management activities performed by NPPD on the Cottonwood Ranch Property. This study monitored the effects of the management activities on the channel morphology and sediment transport by measuring transect elevation profiles and bed-sediment-size gradations upstream, within, and downstream from the managed area before and after the development activities. An analysis of variance (ANOVA) was performed to determine if the geomorphic variables measured before and after the development activities were significantly different.

From 2002 to 2004 the combination of the volume of sediment supplied to the middle channel of the Platte River from the management treatments and the volume of water supplied was not sufficient to cause more prevalent statistically significant increases in the mean bed elevation downstream as compared with upstream from the management. Significant changes in riverbed sediment gradation were not observed in any of the individual temporal-intensive transects in the Input Reach, Managed Reach or downstream in the Output Reach. Analysis of temporal stage trend conducted for a median discharge at streamflow-gaging stations both upstream and downstream from the Cottonwood Ranch Property over the last 70 years suggested a downward trend, or degrading condition, in this reach of the central Platte River. This trend also is reflected in surveys conducted by the Bureau of Reclamation from 1989 to 2002. Recent surveys of the middle channel of the Platte River in the Cottonwood Ranch from 2000 to 2004 by the U.S. Geological Survey indicate the riverbed has been relatively stable and that if degradation has occurred, it has been at a slower rate during this relatively short period as compared to 1989–2002. The rate could be the result of historical low streamflows during this period, but also could be influenced by erosion of the upstream riverbanks. However, a longer period of monitoring is needed in the Cottonwood Ranch to elucidate any trends in mean bed elevation. The absence of extensive statistically significant increases in mean bed elevation in the transects measured downstream from the management indicates that if sediment were mobilized as a result of the management treatments, it was not deposited in substantial volume immediately downstream. However, it is important to place these short-term and site-specific results in the context that riverflows after the management activities were at historical low rates, and therefore the potential to affect and the opportunity to detect possible geomorphic change within and downstream from the managed reach were limited.

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