APPENDIX A

SEDIMENTATION STUDY REPORT

THE ORIGINAL SEDIMENTATION STUDY REPORT WAS INCLUDED IN THE DISTRICT'S AUGUST 26, 2010, INITIAL STUDY REPORT FILING, AND A SEDIMENTATION ADDENDUM WAS INCLUDED IN THE DISTRICT'S FEBRUARY 11, 2011, SECOND INITIAL STUDY REPORT FILING.

THIS UPDATED SEDIMENTATION STUDY REPORT COMBINES BOTH OF THE PREVIOUSLY FILED DOCUMENTS AND INCLUDES MODIFICATIONS REQUESTED BY FERC IN ITS DETERMINATION ON REQUESTS FOR MODIFICATIONS TO THE STUDY PLAN FOR THE INITIAL STUDY REPORT ON DECEMBER 20, 2010, AND FOR THE SECOND INITIAL STUDY REPORT ON JUNE 10, 2011.

LOUP RIVER HYDROELECTRIC PROJECT
FERC PROJECT NO. 1256

SEDIMENTATION

Loup Power District
Hydro Project

STUDY 1.0 - SEDIMENTATION

AUGUST 26, 2011

Serving You Electrically
LOUP POWER DISTRICT

Loup Power District
Hydro Project

Loup River Hydroelectric Project
FERC Project No. 1256

Study 1.0
Sedimentation

August 26, 2011

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Revised 09/06/11

STUDY 1.0 SEDIMENTATION

This sedimentation study was conducted by the Loup River Public Power District (Loup Power District or the District) in accordance with its Revised Study Plan and the Federal Energy Regulatory Commission's (FERC's) Study Plan Determination, dated August 26, 2009. The results of this study were published as Appendix A of the District's Initial Study Report (ISR) on August 26, 2010.

An addendum to the Sedimentation Study Report was published as Appendix A of the District's Second Initial Study Report (Second ISR) on February 11, 2011. The addendum described additional sedimentation studies completed subsequent to submittal of the ISR. Specifically, the addendum described data collection and analysis related to channel cross-section data from ungaged sites on the Loup and Platte rivers. Due to early summer flood flows and high winds, the cross-section surveys were not completed until June and July 2010. As a result, there was insufficient time to complete the sedimentation analysis for the ungaged sites prior to submittal of the ISR.

Following publication of the ISR and the Second ISR, resource agencies were provided opportunities to submit comments to FERC. FERC evaluated the agency comments and then provided the District with a "Determination on Requests for Modifications to the Loup River Hydroelectric Project Study Plan" for the ISR on December 20, 2010, and for the Second ISR on June 10, 2011. The modifications requested by FERC in these determination letters are presented in the table on the following page. References to the sections in this Updated Study Report where the District has addressed these items are also provided in the table.

FERC requested that the Updated Study Report "be prepared as a stand-alone comprehensive document that consolidates the new and previously filed information to clearly address the stated objectives for the Sedimentation Study" (April 8, 2011). Therefore, in this Updated Study Report, the original Sedimentation Study Report and the original Sedimentation Addendum have been combined, and the modifications requested by FERC have been addressed as noted below.

Study Modification	Methodology	Results
Include confidence limits on the sediment rating curves used to develop the sediment budgets and effective discharges that are presented in the Sediment Study Report.	NA	Section 5.2.2, Effective Discharge and Other Sediment Transport Calculations
Include aggradation/degradation analyses developed for the Duncan, North Bend, Ashland and Louisville gages that were presented in the Pre-Application Document into the Updated Study Report for the Sedimentation Study.	Section 4.4, Task 4: Stream Channel Morphology	Section 5.3.1, Specific Gage and Kendall Tau Analyses
Conduct an aggradation/degradation analysis using Genoa gage data and provide the results in the Updated Study Report for the Sedimentation Study.	Section 4.4, Task 4: Stream Channel Morphology	Section 5.3.1, Specific Gage and Kendall Tau Analyses
Use the Kendall tau test to assess trends in the aggradation/degradation data.	Section 4.4, Task 4: Stream Channel Morphology	Section 5.3.1, Specific Gage and Kendall Tau Analyses
Perform the more comprehensive statistical analyses recommended by Nebraska Game and Parks to evaluate the relationship between sediment transport parameters and tern and plover nesting.	Section 4.5.3, Statistical Analysis of Interior Least Tern Data by River Mile	Section 5.4.3, Statistical Analysis of Interior Least Tern Data by River Mile
Attach publications by Chen et al. (1999) and Missouri River Basin Commission (1975) to the Updated Study Report.	The District filed electronic versions of these publications with FERC on April 21, 2011; therefore, these publications are not attached to this Updated Study Report.	
Relate effective discharge to channel geomorphologic characteristics (mean velocity, flow width, flow depth and flow area).	Section 4.3.3, Spatial Analysis	Section 5.2.3, Spatial Analysis
Using each of the four channel geomorphologic characteristics developed at each of the seven gaged sites and five ungaged sites, make longitudinal (spatial) comparisons of all of the sites on the Loup and Lower Platte rivers starting at the most upstream site on each river, and progressing downstream.	Section 4.3.3, Spatial Analysis	Section 5.2.3, Spatial Analysis

Note:

NA = Not applicable.

1. INTRODUCTION

The Loup River Hydroelectric Project (Project) is located in Nance and Platte counties, Nebraska, where water is diverted from the Loup River and routed through the 35-mile-long Loup Power Canal, which empties into the Platte River near Columbus. The Project includes various hydraulic structures, two powerhouses, and two regulating reservoirs. The portion of the Loup River from the Diversion Weir to the confluence with the Platte River is referred to as the Loup River bypass reach.

The Loup and Platte rivers both carry a large sediment load. When water is diverted from the Loup River, it enters the 2-mile-long Settling Basin. The Settling Basin is designed for low velocity to allow heavier sediment materials to settle out of the water before it enters the Upper Power Canal. A Sluice Gate Structure adjacent to the Diversion Weir is operated periodically to mobilize and remove accumulated sediment from in front of the Intake Gate Structure. This process conveys sediment into the Loup River bypass reach. As documented in the Pre-Application Document (PAD), a Hydraulic Dredge removes approximately 2 million tons of sediment from the Settling Basin annually (Loup Power District, October 16, 2008).

The U.S. Fish and Wildlife Service (USFWS) has asserted that Project operations, such as the removal of sediment through Project dredging at the Settling Basin, may affect the morphology of both rivers, which may affect sandbar development and, by extension, may affect interior least tern (*Sternula antillarum athalassos*), piping plover (*Charadrius melodus*), and pallid sturgeon (*Scaphirhynchus albus*) habitat. On the other hand, the District has contended that the morphology of both rivers is in a state of dynamic equilibrium and that any speculated effects on the diverse biological resources of either river are not a result of Project operations. To address this issue, the District conducted this sedimentation study. This study focused on four principal questions:

- How do Project operations affect sediment transport in the Loup River bypass reach and the lower Platte River, defined as the reach between the confluence of the Loup and Platte rivers and the confluence of the Platte and Missouri rivers?
- What is the stream morphology of the Loup River bypass reach and the lower Platte River, and how does that morphology vary over time?
- Is there a discernible relationship between any of the sediment transport parameters and nest counts of the interior least tern and piping plover?
- Is sediment transport a limiting factor for pallid sturgeon habitat in the lower Platte River?

These questions were used to form the goals and objectives of this study, which are described in Section 2. These goals and objectives and the proposed methodology were reviewed and approved by FERC in its Study Plan Determination on August 26, 2009.

2. GOALS AND OBJECTIVES OF STUDY

The goal of the sedimentation study is to determine the effect, if any, that Project operations have on stream morphology and sediment transport in the Loup River bypass reach and in the lower Platte River because stream morphology relates directly to habitat, and habitat may determine species abundance and success. In addition, the study will compare the availability of sandbar nesting habitat for interior least terns and piping plovers to their respective populations and will compare the general habitat characteristics of the pallid sturgeon in multiple locations.

The objectives of the sedimentation study are as follows:

1. To characterize sediment transport in the Loup River bypass reach and in the lower Platte River through effective discharge and other sediment transport calculations.
2. To characterize stream morphology in the Loup River bypass reach and in the lower Platte River by reviewing existing data and literature on channel aggradation/degradation and cross sectional changes over time.
3. To determine if a relationship can be detected between sediment transport parameters and interior least tern and piping plover nest counts (as provided by the Nebraska Game and Parks Commission [NGPC]) and productivity measures.[1]
4. To determine if sediment transport is a limiting factor for pallid sturgeon habitat in the lower Platte River below the Elkhorn River.

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[1] It was determined at the May 27-28, 2009, Study Plan Meeting that productivity measures (fledge ratios) are also an important indicator of the reproductive success of interior least terns and piping plovers. These data were provided to the District by NGPC for use in this study; however, limited data exist for interior least terns and piping plovers on the Loup and lower Platte rivers. Fledge ratios only exist for a few select sandpit sites adjacent to the Loup and Platte rivers between 2000 and 2008. 2005 is the only year of productivity data provided for sandbars in the Loup River. 2008 is the only year of productivity data provided for sandbars in the lower Platte River.

3. STUDY AREA

The study area includes the Loup River from approximately 5 miles upstream of the Diversion Weir, the Loup River bypass reach, and the lower Platte River. Specific study sites were selected based on the availability of gaged flow data from the U.S. Geological Survey (USGS) and Nebraska Department of Natural Resources (NDNR) and are listed in Table 3-1. The records at each gage station include daily and sub-daily flow data as well as the associated rating curves and velocity and cross-sectional data used to create the rating curves.

In addition to these gaged sites, three "ungaged" sites were to be evaluated. However, because data from two additional ungaged sites were required for other studies (that is, the hydrocycling and the flow depletion and flow diversion studies), the following five ungaged sites were evaluated in this sedimentation study:

- Loup River upstream of the Diversion Weir (Site 1)
- Loup River immediately downstream of the Diversion Weir (Site 2)
- Lower Platte River downstream of the Loup River confluence and upstream of the Tailrace Return confluence (Site 3)
- Lower Platte River within 5 miles downstream of the Tailrace Return confluence (Site 4)
- Lower Platte River near the USGS North Bend gage (Site 5)

Sites 1, 3, and 4 are those required for this sedimentation study. Site 1, on the Loup River, was identified in the Revised Study Plan, and Sites 3 and 4, on the lower Platte River, were added by FERC in its Study Plan Determination dated August 26, 2009. Figure 3-1 shows the extent of the study area and the study sites, including the seven gaged sites and five ungaged sites. Two gaged sites on the Loup Power Canal are also shown.

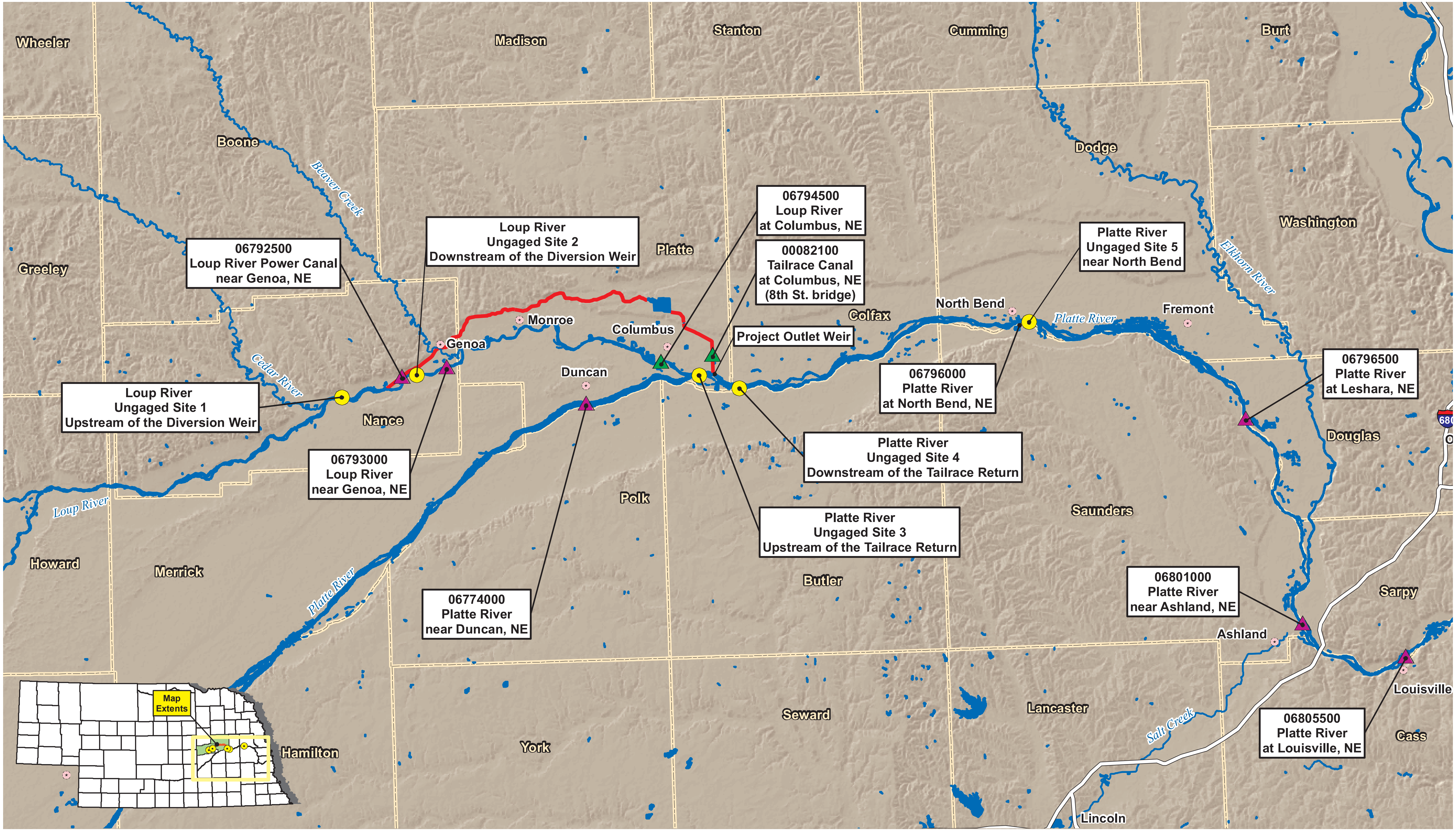
Table 3-1. Gaged Study Sites

USGS Gage Number	Gage Name and Location	Drainage Area (sq. mi.)	Mean Daily Discharge (cfs)	Period of Record	Comments
06793000	Loup River near Genoa, NE	14,320	989	1929 - 2009	Available discharge and gage height data from April 1, 1929, to 2009 include daily and sub-daily data.
06794500[1]	Loup River at Columbus, NE	15,200	1,197	1934 - 1978	Available daily discharge and gage height data from April 1, 1934, to October 10, 1978. This gage was restarted by NDNR on September 23, 2008.
06774000	Platte River near Duncan, NE	59,300	2,078	1929 - 2009	Available discharge and gage height data from May 3, 1895, to 2009 include daily and sub-daily data. Data between 1895 and 1928 are incomplete. The period of record for continuous approved data is 1929 to 2009.
06796000	Platte River at North Bend, NE	70,400	4,938	1949 - 2009	Available discharge and gage height data from April 1, 1949, to 2009 include daily and sub-daily data.
06796500	Platte River at Leshara, NE	NA	4,834	1994 - 2009	Available discharge and gage height data from June 29, 1994, to 2009 include daily and sub-daily data.
06801000	Platte River near Ashland, NE	84,200	6,543	1988 - 2009	Available discharge and gage height data from September 1, 1988, to 2009 include daily and sub-daily data.
06805500	Platte River at Louisville, NE	85,370	8,273	1953 - 2009	Available discharge and gage height data from June 1, 1953, to 2009 include daily and sub-daily data.

Note:

NA = Not available.

[1] Formerly a USGS gage, but currently maintained by NDNR.



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8 4 0 8
Miles

Source: Stream Gage, Nebraska Department of
Natural Resources; Streams/Waterbodies, 2000 Tiger Files

Legend

⊙	City	—	Stream/River
▲	NDNR Gaging Station	—	Loup Power Canal
▲	USGS Gaging Station	■	Waterbody
●	Ungaged Study Sites	☐	County
═	Interstate		

Loup Power District Hydro Project

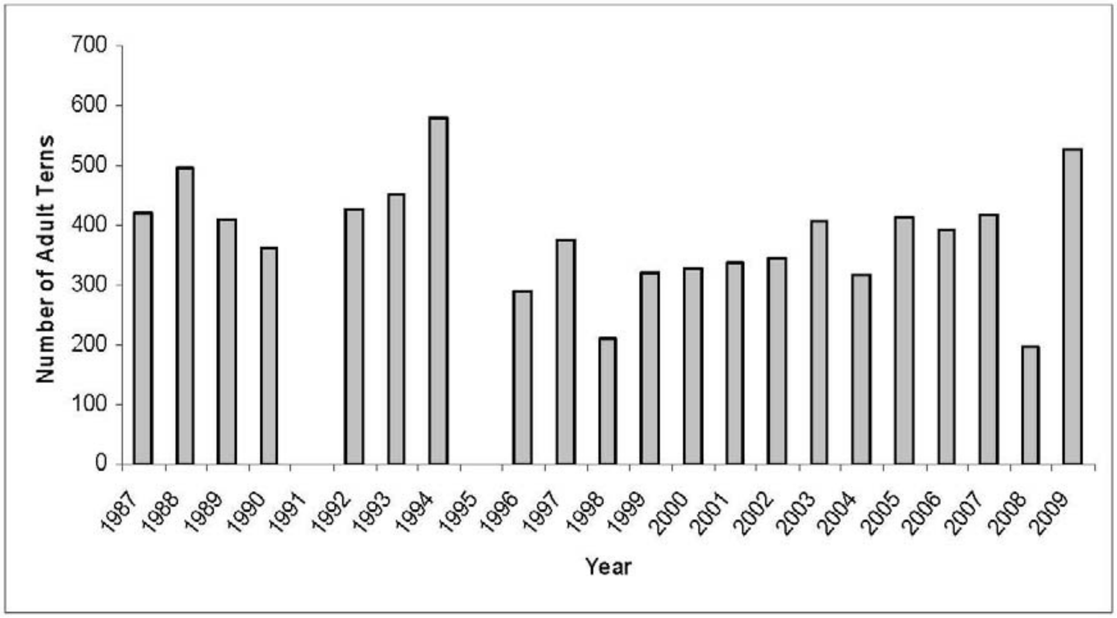
Sedimentation Study Sites

Loup River Hydroelectric Project
FERC Project No. 1256
Study 1.0 - Sedimentation

DATE
August 26, 2011

FIGURE
3-1

Within the study area and directly downstream, interior least terns and piping plovers use mainly the lower Platte River and adjacent sandpit lakes for nesting, breeding, and feeding. Interior least terns arrive in Nebraska in early May to mid-June and nest in colonies on open sandbars in rivers and on gravel and sand beaches on lakes. Their nests are shallow depressions with small stones, twigs, or other debris nearby. Egg-laying begins in late May with an incubation period of 17 to 28 days (USFWS, September 1990; Thompson et al., 1997). Fledging occurs 3 weeks after hatching, and departure from the colonies is usually complete by early September. The home range during breeding is limited to a reach of the river near the nest; however, this species has been known to fly up to 3.2 kilometers (Smith and Renken, 1990) and possibly farther (USGS, February 23, 2009) from the nest site to forage. Interior least terns are routinely seen on the lower Platte River. A review of adult count survey information from 1987 to 2009 indicates that interior least tern numbers have remained relatively stable along the lower Platte River during this period, as shown in Figure 3-2 (Brown and Jorgensen, 2009). These numbers include both on-river and off-river sites along the lower Platte River.

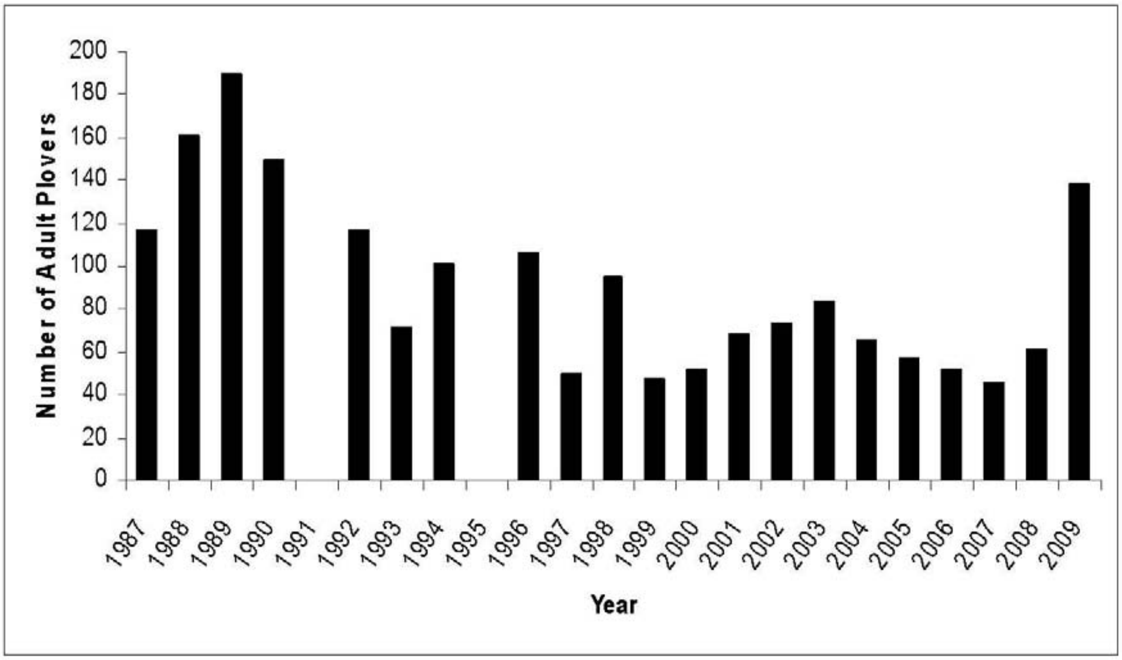


Note: No data are included for 1991 and 1995 because those surveys were not conducted during the standardized June summer survey window.

Figure 3-2. Total Number of Adult Interior Least Terns Recorded During the Lower Platte River Mid-Summer Survey, 1987–2009

Piping plovers arrive in Nebraska in mid-April and breed in open, sparsely vegetated habitats; on sandbars in large, open rivers; along sand and gravel shores of rivers and lakes; and in alkaline wetlands and sand flats. These migratory birds spend approximately 3 to 4 months at their breeding sites, with nesting and egg-laying commencing in mid-May and an incubation period of approximately 28 days.

Hatching occurs in late May to mid-June (USFWS, 1988; Haig, 1992; USFWS, November 30, 2000). During this time, the home range of the piping plover is limited to the wetland, lakeshore, sandbar, or section of beach on which its nest is located. The shallow nests, frequently lined with small pebbles or shell fragments, are located on dry salt flats, barren sandbars, or sand and gravel beaches with less than 5 to 20 percent vegetation (National Research Council, 2005). Piping plovers frequently nest in interior least tern colonies and are therefore considered nesting associates with the interior least tern. Piping plovers are routinely seen in the lower Platte River. A review of adult count survey information from 1987 to 2009 indicates a slight decline in piping plover numbers along the lower Platte River during this period; however, after 2009 monitoring efforts, the numbers spiked in 2009, as shown in Figure 3-3 (Brown and Jorgensen, 2009). These numbers include both on-river and off-river sites along the lower Platte River.



Note: No data are included for 1991 and 1995 because those surveys were not conducted during the standardized June summer survey window.

Figure 3-3. Total Number of Adult Piping Plovers Recorded During the Lower Platte River Mid-Summer Survey, 1987–2009

Prior to 2009, there were no known occurrences of pallid sturgeon in the vicinity of the Project. The most recent survey at that time was performed by Peters and Parham (2008) and documented the nearest pallid sturgeon occurrence in the lower Platte River at the confluence of the Elkhorn and Platte rivers, approximately 69 miles downstream of the Project. On March 31, 2009, in association with the University of Nebraska-Lincoln's (UNL's) Shovelnose Sturgeon Population Dynamics Study within the Platte River, a juvenile pallid sturgeon was captured upstream of the

Elkhorn River confluence, near Leshara, Nebraska (approximately 55 miles downstream of Columbus) (Associated Press, April 10, 2009). Since the initial capture upstream of the Elkhorn River confluence, UNL researchers have captured an additional 9 to 11 juvenile pallid sturgeon in this reach of the Platte River; the farthest upstream capture occurred approximately 0.5 mile below the Tailrace Return confluence with the Platte River (UNL, July 14, 2010). In total, and along the entire reach of the UNL study (the Platte River confluence with the Missouri River to an upstream location approximately 30 miles west of Columbus), researchers captured 69 pallid sturgeon in 2009 and 20 to 25 additional pallid sturgeon through mid-summer 2010 (UNL, July 14, 2010). There are no documented occurrences of pallid sturgeon in the Loup River.

4. METHODOLOGY

The methodology used to complete the sedimentation analysis is described below. The results of the sedimentation study are discussed in Section 5, and supporting graphs and tables are included in Attachments A through G. The methodology for the sedimentation study includes six tasks designed to meet the four objectives presented in Section 2, Goals and Objectives of Study. These objectives and the tasks that were conducted to meet each objective are as follows:

- All four objectives
    - Task 1: Literature Review and Data Collection
- Objective 1: To characterize sediment transport in the Loup River bypass reach and in the lower Platte River through effective discharge and other sediment transport calculations.
    - Task 2: Sediment Budget
    - Task 3: Effective Discharge and Other Sediment Transport Calculations
- Objective 2: To characterize stream morphology in the Loup River bypass reach and in the lower Platte River by reviewing existing data and literature on channel aggradation/degradation and cross sectional changes over time.
    - Task 4: Stream Channel Morphology
- Objective 3: To determine if a relationship can be detected between sediment transport parameters and interior least tern and piping plover nest counts (as provided by NGPC) and productivity measures.
    - Task 5: Interior Least Tern and Piping Plover Nesting and Sediment Transport Parameters

- Objective 4: To determine if sediment transport is a limiting factor for pallid sturgeon habitat in the lower Platte River below the Elkhorn River.
    - Task 6: Pallid Sturgeon Habitat

4.1 Task 1: Literature Review and Data Collection

4.1.1 Literature Review

Numerous reports were available from USGS and others regarding the Loup and Platte rivers. All relevant reports were obtained and reviewed and are referenced throughout this sedimentation study report.

Both the Loup and Platte rivers are considered braided rivers; therefore, sediment transport is an important factor in retaining their natural characteristics (Donofrio, 1982). A braided river is defined as a river channel in which water flows around deposited bars and islands. It has been shown that for a given discharge, braided channels slope more steeply than meandering channels, which exist on relatively flat ground and tend to form relatively broad channels that wander back and forth like a snake. Braiding occurs when the steep slopes create high energy for sediment transport, when discharge fluctuates frequently, when the river cannot carry its full sediment load, where the river is wide and shallow, where banks may be easily eroded, and where there is abundant bed material available for transport. The position of the bars is changeable; sediment may be entrained by scour at channel junctions and then be re-deposited down-channel as flows diverge again and new channels are cut by overbank flooding (Mayhew, 2004).

Studies of morphology are important because morphology defines habitat. Ginting, Zelt, and Linard (2008) concluded that "[p]hysical processes that control the streamflow regime and channel characteristics govern the distribution of habitat availability and quality for fish…, and similarly may affect nesting habitat for shore birds…." In addition, Elliott, Huhmann, and Jacobson (2009) state that "geomorphic mediation of flow regime…provides an indirect assessment of sandbar habitat potential for least terns and piping plovers."

The shape and width of a river channel is an ever-changing function of the watershed supply of sediment (yield), flow, the quantity and size of the sediment load, and the character and composition of the materials, including vegetation, composing the bed and banks of the channel (Leopold, Wolman, and Miller, 1964). Streams that experience changes that deviate about average long-term morphologic characteristics are commonly said to be in dynamic equilibrium, quasi-equilibrium, or "in regime."

Watson, Biedenharn, and Scott (July 1999) state that a stable river, "from a geomorphic perspective, is one that has adjusted its width, depth, and slope such that there is no significant aggradation or degradation of the stream bed or significant plan form changes (meandering to braided, etc) within the engineering time frame (generally less than about 50 years). By this definition, a stable river is not in a static condition, but rather is in a state of dynamic equilibrium where it is free to adjust laterally through bank erosion and bar building."

Reviews of the literature on available tools for characterizing flow and sediment processes; utility of sediment budget analyses; validity of effective discharge methods, including the roles of peak flows in shaping channels; and applicability of regime theory are described below.

Tools for Characterizing Flow and Sediment Processes

Among others, the following qualitative and quantitative methods are considered by the scientific community to be state-of-the-art practices used in characterizing a river's morphology and assessing impacts of alternative operations on morphology:

- Sediment Budgets (applying the continuity equation to sediment yield, sediment transport, and changes in sediment storage)
- Hydraulic Geometry Relationships
- Effective Discharge Calculations combined with Regime Analysis
- Chang's Regime Channel Geometry for Sand-bed Rivers
- Leopold and Wolman's Regime Threshold Analysis
- Lane's Regime Method
- Lane's Law of River Adjustment
- Specific Gage Analysis

Standard texts on rivers, such as Richards (1982), provide state-of-the-art discussions of these tools in addition to numerous general observations regarding processes and characteristics of braided and anabranched[2] streams.

Experts not only agree that the above tools are state-of-the-art, but also conclude that computer models are not the preferred method for assessing river channel geometry adjustments due to alternative operations and should not be used for regulatory or management purposes (American Society of Civil Engineers [ASCE], September 1998a and September 1998b; Jacobson, Johnson, and Dietsch, 2009). Instead, sediment budgets and channel regime methods, especially when supplemented with effective and dominant discharge calculations, are recommended.

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[2] An "anabranched stream" is a stream that contains one or more secondary branches that rejoin further downstream.

Sediment Budget Analyses

Detailed estimates of sediment yields in the Platte River Basin were developed by the Missouri River Basin Commission (MRBC) in September 1975. Although estimates of yield are useful for determining whether a river is flow or supply limited, the literature cautions users of indirect estimates of yield like those used by MRBC in performing aggradation/degradation analyses, noting that they have limited value in making aggradation/degradation conclusions. For example, the U.S. Army Corps of Engineers (USACE) (July 1990) describes the indirect methods of determining yields as "indicators at best." Because direct measurements consist predominantly of suspended load values, USACE reports that suspended load measurements on average are the most relevant estimates of yields of this material. True yields in the lower Platte River, at least of material matching the river's bed material, are probably much closer to the measured transport rates than estimates by indirect methods.

Although useful for supply- versus flow-limited analyses, the sediment yields estimated by indirect methods by MRBC should not be used to assess whether the Loup and lower Platte rivers are aggrading or degrading. Better indicators of aggradation and degradation are available from long-term cross-section and channel flowline measurements over time as well as from assessments of trends in effective discharge (see Section 5.3.2, Analysis of Existing Data and Literature on Channel Aggradation/Degradation and Cross Sectional Changes Over Time, for the discussion of this analysis). Without variation, several independent investigations of long-term trends (see Section 5.3.2) conclude that the Loup and lower Platte rivers within the study area are neither aggrading nor degrading and have remained "in regime" (in a state of dynamic equilibrium) since the early 1950s (USACE, July 1990) or even longer (U.S. Department of the Interior, Bureau of Reclamation [USBR], April 2004).

Effective Discharge Methods

State-of-the-art tools to quantify and characterize flow and sediment transport in any river include effective and dominant discharge and regime methods. Generally, a small range of daily flows transports the largest fraction of total sediment load. These flows are widely accepted in geomorphologic literature as the flows that result in the average morphologic characteristics of the channel. These are called "effective" or "dominant" discharges. Specific literature addressing previous applications of these methods in the Platte River includes Kircher and Karlinger (1981); USGS (1983); HDR (1983); Parsons (May 2003); Hydrology Work Group (December 1989); USACE (July 1990); and Nelson, Dwyer, and Greenberg (1988).

A standard definition of how best to calculate the effective and/or dominant discharge has not emerged in the literature. However, the majority of references assign the same significance to both of these terms even though the method of calculating them varies.

The various definitions of both terms communicate their significance (that is, their role in shaping and maintaining river morphology), which has virtually universal agreement, as well as how they are calculated, which varies but does not impact the universally adopted significance. Whenever a single value is cited by an investigator for either term, the author is simply providing a single-value measure of the central tendency of channel forming/maintaining flows, all the while recognizing that a range of flows transport the sediment. At least some of the bed sediment in the Platte River is readily moved by all flows (Karlinger et al., 1983).

Calculation of either measure involves the mathematical convolution of day-by-day discharge rates with a sediment transport rating curve so that the entire history of daily discharges is incorporated in assessing what flows are shaping the river. The mechanisms of sediment transport in any river, and of the associated morphologies, are best defined by the entire hydrograph and sediment transport capacity of each day's flows. Effective or dominant discharge rates are simply standard statistical measures (mean, median, or mode) of the central tendency of the distribution of sediment amounts being transported by all the daily flows within the hydrograph. The analyses involve all the daily flow records.

Most investigators define the effective discharge as the modal (peak) value of a histogram developed from a class analysis of a number of equal increments of discharge (or logs of discharge) versus total long-term sediment transported by each class of flows. Kircher and Karlinger (1981) and USGS (1983) adopted this definition.

As often happens, the peaks of these histograms are broad-crested, and some analysts prefer to represent this by reporting a range of flows that transport the majority of the sediment, while others select a mid-point of this range, which may not occur at the overall mode. Uses of the centroid or median values of the histogram are also acceptable measures of central tendency of the discharges that transport the majority of the sediment.

The modal value is only a single-value measure of the central tendency of flows having the greatest impact on channel morphology. The range of flows transporting the majority of sediment generally covers two to four class intervals in the histogram distributed near the mode. USACE (July 1990) defined the effective discharges for Platte River locations as the mid-point of the highest bars in the broad-crested histogram. A similar approach was used by the District.

Some literature contains references to a different method of analyzing what flow rate is responsible for shaping the river. The dominant discharge is defined as the flow rate that, if continued constantly for the long term, would transport the same total load as the actual hydrograph. Dividing the total sediment transported over any time period by the length of the study and finding the corresponding discharge rate that carries that load from the discharge-transport rating curve produces this value. This definition and methodology has the advantage that it does not require separating the flows into discrete class intervals. Because the modal value of an effective discharge transport histogram varies with the number of discrete classes selected (USGS, 1983), the dominant discharge is an alternative method of assessing the channel-forming rate, requiring less qualitative judgment.

Parker (1978), for example, used this definition of dominant discharge for both the Middle Loup and Niobrara rivers. Although the result of this type of calculation is generally different from the effective discharge, his discussion makes it clear that he interprets its significance as being the channel-forming discharge. The terms "effective discharge" and "dominant discharge" always have the same significance even though methods of determining the values may vary. The dominant discharges discussed in Section 5.2.2, Effective Discharge and Other Sediment Transport Calculations, were determined using Parker's definition.

As an illustration of the industry-wide concurrence regarding the significance of these terms, Kircher and Karlinger (1981) and USGS (1983) determined Platte River effective discharges from North Platte to Ashland. They reasoned that the discharge that is "effective" in transporting sediment and shaping the river is "the mean value of a narrow range of water discharge that, by virtue of its frequency of occurrence and transporting capacity, transports on the average more sediment during the period of record than any other comparable water discharge" (Kircher and Karlinger, 1981). Karlinger et al. (1983) defined the effective discharge as "the water discharge that maintains the present channel cross section."

Thus, the terms "effective discharge" and "dominant discharge" are used interchangeably, and although they sometimes differ in calculation method or value, they have the same significance (that is, a measure of the central tendency of flows that shape and maintain a stream's morphology and riverine habitat).

The studies cited above, as well as the results of this sedimentation study, reveal that the flows that are effective in shaping the river channel are moderately small in comparison to the large variability of daily flows, and even smaller in comparison with the high magnitudes of instantaneous floods. Among other investigators, Richards (1982) provides helpful insight into the often-challenged notion that instantaneous peak flows define a river's equilibrium morphology, although it is accepted that floods do have temporary influences. For braided rivers in particular, use of a frequency-based (1.5-year) flood flows or even "bankfull" estimate for the channel-forming discharge is sometimes attempted but never necessary because simple spreadsheet methods are available to determine the physical-process-based, effective (or dominant) discharge values.

Richards' experience with a large number of rivers led him to conclude that "most effective discharge classes in several streams … are well below bankfull stage." He notes that "in humid environments with more consistent flow and lower sediment yield from slopes during extreme events because of the protective effects of vegetation, more than 90% of sediment transport is by frequent events" (Neff, 1967, as cited in Richards, 1982). In summarizing his discussion of effective discharges, Richards concludes that the results "confirm that relatively frequent discharges dominate the transport of sediment."

Regime Theory

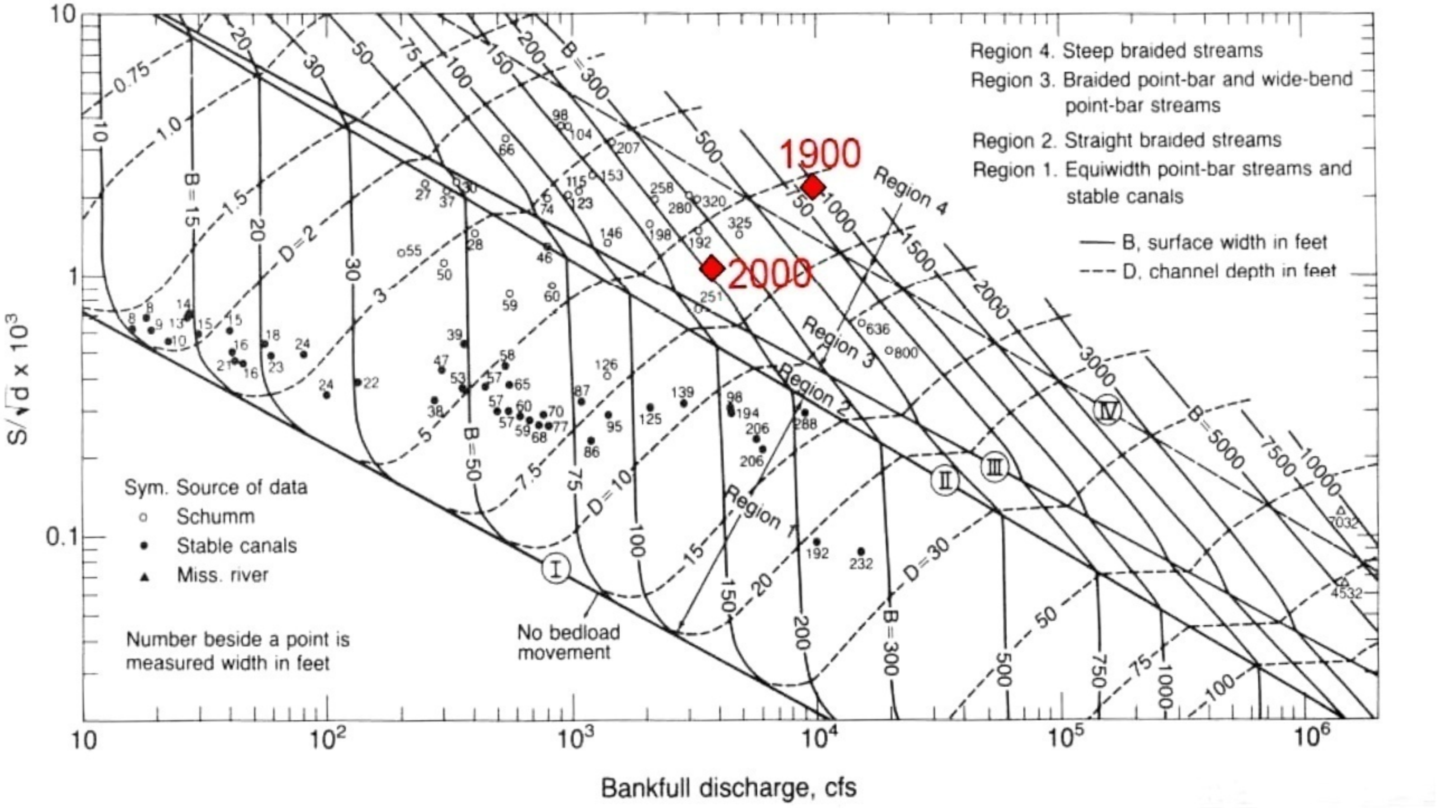
When combined with effective discharge calculations, a methodology known as "regime analysis" provides a potent method of assessing stability of, and impacts of alternative operations on, river morphology (and habitat). As a precedent for use of regime theory in the Platte River Basin, the USBR report titled "The Platte River Channel: History and Restoration" (April 2004) applied regime theory to assess historical changes in plan form of the Platte River and to demonstrate the validity of using regime theory for assessing morphological aspects of the Platte River, as well as impacts of alternative operations.

USBR (April 2004) notes that:

> The association of the quasi-equilibrium channel geometry of natural channels with flow rate, channel slope and sediment properties is called regime theory (ASCE 1998a). The braided pattern typical of the [Platte] river prior to the 1900s, requires a steeply sloped channel or an over supply of sediment. The average channel slope of the Platte River (0.00126) is considered steep for a sandbed river of this size. The slope has not changed during the1900s because a large change in river bed elevation is needed to change the average slope over the length of the river, and because the alignment of the river channel is still relatively straight.

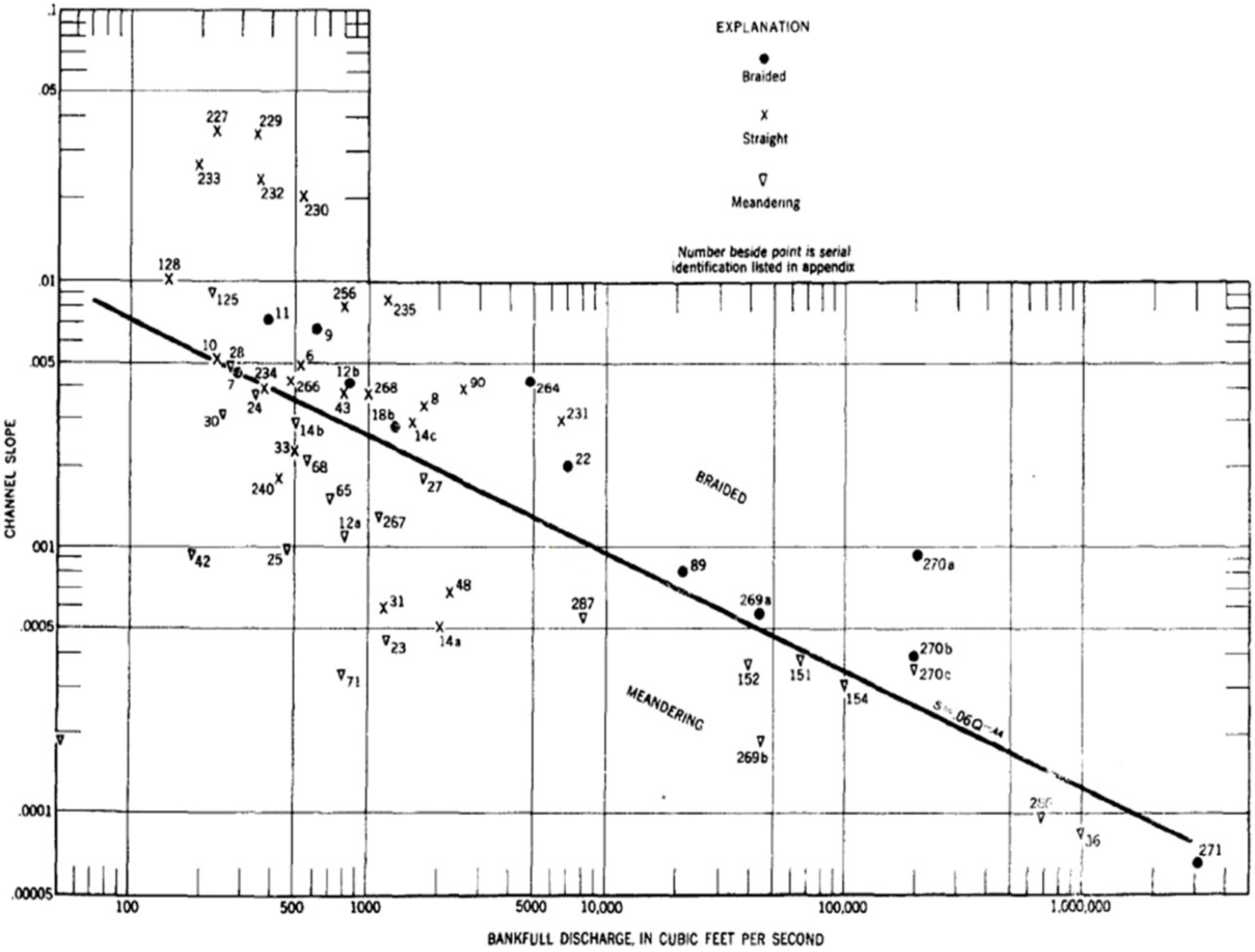
The year 2000 channel bed profile developed by USBR in its April 2004 report is nearly identical to the turn-of-the-century profile developed by Gannett (1901). USBR notes that because the Platte River is relatively straight, extraordinary amounts of sediment would need to be moved in order to affect its profile.

USBR tested three widely adopted regime diagrams (Chang, March 1985; Leopold and Wolman, 1957; Lane, 1957), showing that all three are applicable to assessing the stability of the braided Platte River morphology as well as to assessing impacts of alternative conditions in the Platte River. These graphs are reproduced below as Figures 4-1, 4-2, and 4-3. Even though the horizontal axes of the graphs are either "bankfull" or "mean" discharge, it is clear from the original source documents that the intent was that the user would input the channel-forming discharge.



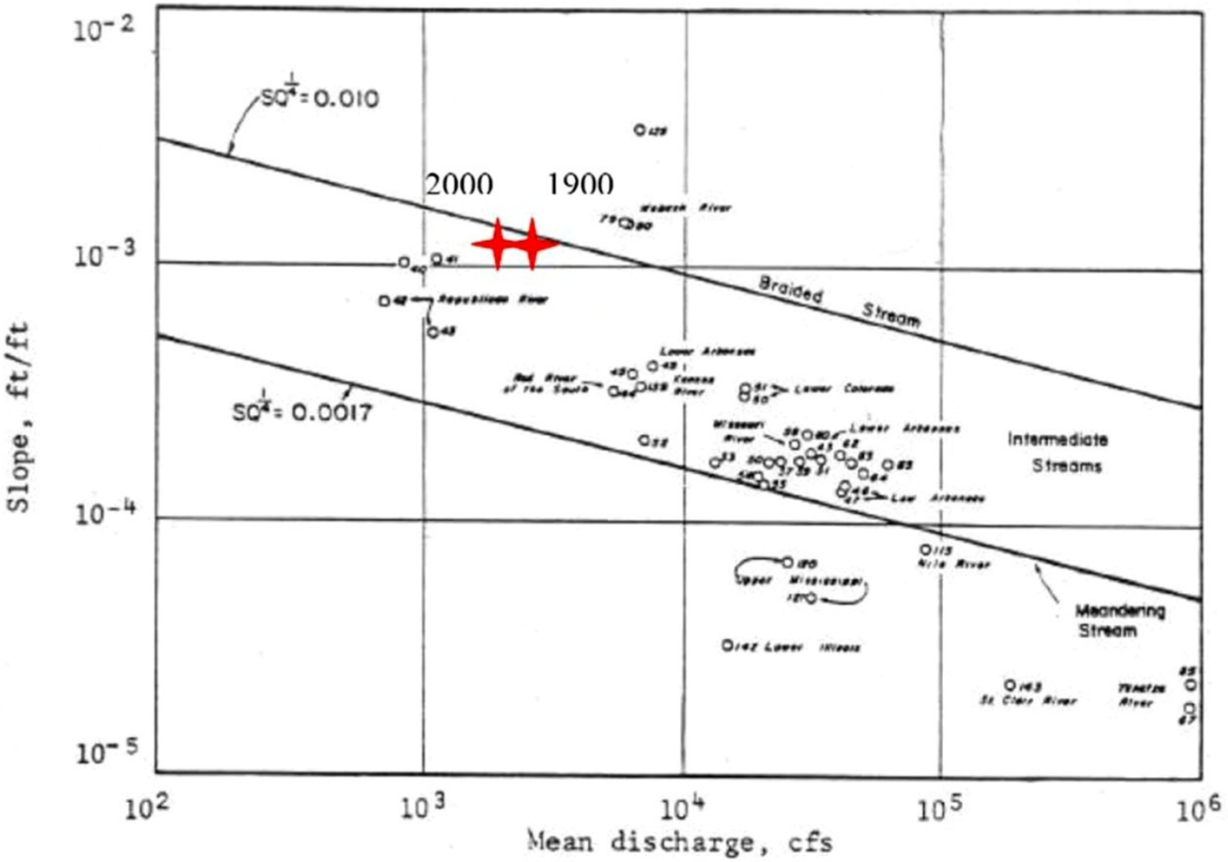
Regime channel bed geometry for sand bed rivers, from Chang (1985). For the historic Platte River channel (1900), the bankfull discharge was about 10,000 cfs, the median grain size was about 0.4 mm, and the slope was 0.00126. Therefore, the term $[(S/d^{0.5})1000]$ was equal to 2.0. For the present Platte River channel (2000), the bankfull discharge is about 4,000 cfs, the median grain size near Overton, Nebraska is about 1.5 mm, and the slope is still 0.00126. Therefore, the term $[(S/d^{0.5})1000]$ is now equal to 1.0. Based on the classification by Chang (1985), the Platte River evolved from a steep braided channel (Region 4) to a braided point-bar and wide bend point-bar channel (Region 3).

Figure 4-1. Chang's (March 1985) Regime Morphology Chart for Sand Bed Rivers



Values of slope and bankfull discharge for various natural channels and a line defining critical values which distinguish braided from meandering channels.

Figure 4-2. Leopold and Wolman's (1957) Threshold Chart for Meandering and Braided Rivers



Lane's (1957) regime diagram for sandbed streams based on slope and mean discharge, taken from Richardson, et al. (1990). Red points shown are for the central Platte River with a slope of 0.0026 ft/ft and a mean discharge of 3,700 cfs for the year 1900, and a mean discharge of 2,100 cfs for the year 2000.

Figure 4-3. Lane's (1957) Regime Morphology Chart for Sand Bed Rivers

USBR (April 2004) concludes that "[r]egime theory does…provide a guide to the changes in channel geometry that can be expected with changes in the channel-forming discharge, bed slope, and…bed material grain size." Aerial photos from 1939 to 1998 were evaluated and shown to support USBR's conclusions about the validity of regime theory.

In its assessment of Platte River channel morphology, USACE (July 1990) adopted a definition of "in regime" that is typical of standards of the industry. The definition adopted by USACE was that a river is in regime "when a balance exists between all of the variables that affect it, and there is no net change in the river conditions." However, USACE adds that regime is "a state of quasi-equilibrium in which there are fluctuations about a mean value for each of the variables, but there are no long-term changes in mean values." Finally, USACE adds, "It is a good indication that a river reach is in regime when there is no aggradation, degradation, or change in channel pattern" (USACE, July 1990). Conclusions by USACE, USGS, and other investigators regarding the current morphological status of the study reaches are provided in Section 5, Results and Discussion.

USBR's (April 2004) regime theory assessment of changes in plan form in the Platte River since 1900 show that parts of the river have changed but are still well within the regime zones for stable, braided rivers. Although the Leopold and Wolman graph (Figure 4-2) suggests that the Platte River has shifted from a braided stream to the threshold divide between braided and meandering, it does not incorporate grain size and does not include data from streams similar to the Platte River. Henderson (November 1961) incorporated particle size and obtained an equation that incorporated median material size.

USBR (April 2004) also assumed in applying Figures 4-1 and 4-3 that the bankfull discharge (which was USBR's interpretation of the channel-forming discharge) reduced from 10,000 cfs in 1900 to 4,000 cfs in 2000 but did not document that either are the effective discharges, especially in the lower Platte River. Meandering rivers are geomorphologically "old" streams. Given enough time, most braided rivers transition to meandering forms with age. Early literature on braided rivers described them as "an incipient form of meandering rivers," but braided rivers are no longer considered necessarily representative of disequilibrium in aggrading systems (Richards, 1982).

4.1.2 Data Collection at Gaged Sites

Numerous data sets regarding the Loup and Platte rivers were available from USGS and others. All relevant data were obtained and reviewed and are referenced throughout this sedimentation study report. Specific information acquired included streamflow measurement data, daily and sub-daily discharges, stages, stage discharge rating curves, and sediment gradation and transport measurement data. Finally, District sediment (dredging and stockpiling) records were also acquired and analyzed.

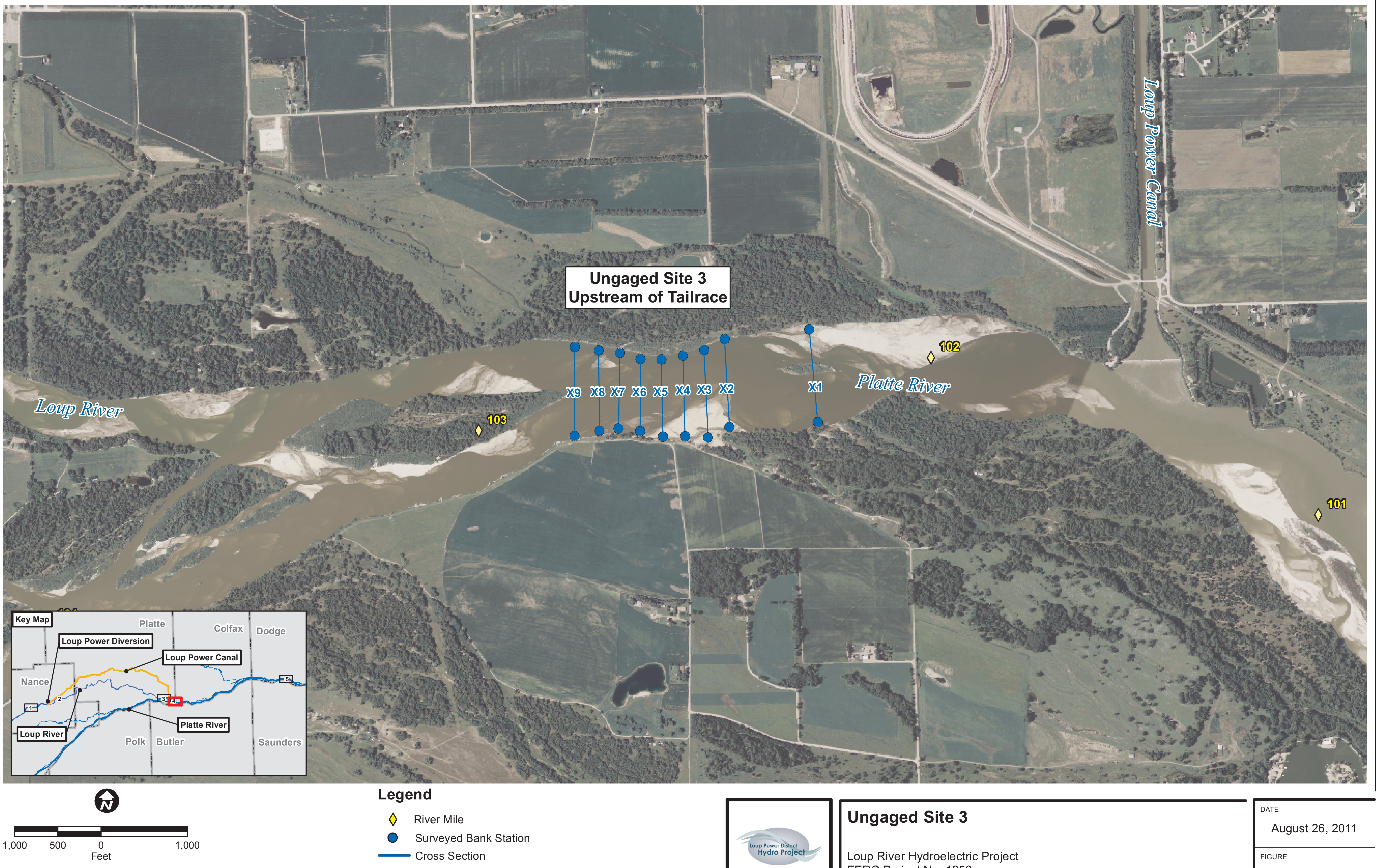
Hydrologic analyses were performed for each of the gaged sites listed in Table 3-1 in support of this and other relicensing studies. A full description of the hydrologic analyses is presented in the Second ISR, Appendix D, Flow Depletion and Flow Diversion Study Report. Annual and seasonal flood flow frequencies were calculated, and volume and flow duration curves were developed. The USACE computer program HEC-SSP was used for the analysis.

4.1.3 Data Collection at Ungaged Sites

Cross-section surveys were conducted at the ungaged sites listed in Section 3, Study Area. The District, in coordination with USFWS and NGPC, selected the final cross-section locations for each ungaged site by examining aerial photographs. The District surveyed nine or ten cross sections at each of the ungaged sites on at least two occasions: May to July 2010 and September to October 2010. The survey methodology is discussed further in the Second ISR, Appendix B, Hydrocycling Study Report. Cross-section locations for each ungaged site are shown in Attachment A. A representative figure showing the cross-section locations for Site 3 is provided below as Figure 4-4.

Streamflow measurements were not possible at the ungaged sites due to high flow, as discussed below under Hydraulic Geometry Relationships among Discharge and Channel Width, Depth, and Velocity for Ungaged Sites. However, water surface elevations during each day’s measurements were recorded for use in calibrating the HEC-RAS models.

The dates when data collection occurred at each cross section are provided in Table 4-1. The times when data collection occurred are not included; multiple survey team rovers and site conditions caused many cross sections to be surveyed in portions at varying times of day. Graphs of the cross sections comparing the spring and fall measurements at each location are included in Attachment A.



Source: Stream Gage, Nebraska Department of
Natural Resources; Streams/Waterbodies, 2000 Tiger Files

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Loup Power District
Hydro Project

Ungaged Site 3

Loup River Hydroelectric Project
FERC Project No. 1256
Study 1.0 - Sedimentation

DATE
August 26, 2011

FIGURE
4-4

Table 4-1. Cross-Section Data Collection

Location	Data Collection Effort	Cross Section 1	Cross Section 2	Cross Section 3	Cross Section 4	Cross Section 5	Cross Section 6	Cross Section 7	Cross Section 8	Cross Section 9	Cross Section 10
Site 1 – Upstream of the Diversion Weir	Spring	6/3/2010	6/3/2010	6/3/2010	6/3/2010	6/3/2010	6/3/2010	6/2/2010	6/2/2010	6/2/2010	
	Fall	10/5/2010	10/5/2010	10/5/2010	10/5/2010	10/5/2010	10/5/2010	10/5/2010	10/5/2010	10/5/2010	
Site 2 – Downstream of the Diversion Weir	Spring	4/15/2010	4/15/2010	4/15/2010	4/15/2010	4/15/2010	4/15/2010	4/15/2010	4/15/2010	4/15/2010	
	Summer	8/5/2010	8/5/2010	8/5/2010	8/5/2010	8/5/2010	8/5/2010	8/5/2010	8/5/2010	8/5/2010	
	Fall	9/28/2010	9/28/2010	9/28/2010	9/28/2010	9/28/2010	9/28/2010	9/28/2010	9/28/2010	9/28/2010	
Site 3 – Upstream of the Tailrace Return	Spring[1]	5/2/2010 or 5/3/2010	5/2/2010 or 5/3/2010	5/2/2010 or 5/3/2010	5/2/2010 or 5/3/2010	5/2/2010 or 5/3/2010	5/2/2010 or 5/3/2010	5/2/2010 or 5/3/2010	5/2/2010 or 5/3/2010	5/2/2010 or 5/3/2010	
	Summer	8/11/2010	8/11/2010	8/11/2010	8/11/2010	8/11/2010	8/11/2010	8/11/2010	8/11/2010	8/11/2010	
	Fall	9/29/2010	9/29/2010	9/29/2010	9/29/2010	9/29/2010	9/29/2010	9/29/2010	9/29/2010	9/29/2010	
Site 4 – Downstream of the Tailrace Return	Spring[2]	6/30/2010	6/30/2010	7/1/2010	6/30/2010	6/29/2010	6/29/2010	6/29/2010	6/29/2010	6/30/2010	7/1/2010
	Fall	9/7/2010	9/7/2010	9/7/2010	9/7/2010	9/7/2010	9/8/2010	9/8/2010	9/8/2010	9/8/2010	9/8/2010
Site 5 – Near North Bend	Spring	7/8/2010	7/8/2010	7/8/2010	7/8/2010	7/8/2010	7/9/2010	7/9/2010	7/9/2010	7/9/2010	
	Fall	9/21/2010	9/21/2010	9/21/2010	9/22/2010	9/22/2010	9/22/2010	9/22/2010	9/22/2010	9/22/2010	
Headworks	Spring	6/3/2010	6/3/2010	6/3/2010							
	Summer	8/5/2010		8/5/2010							

Notes:

[1] Data were collected on May 2 and May 3, but the exact date when data was collected at each cross-section location is unknown.

[2] The following cross sections were surveyed on multiple days: Cross section 3 (6/30 and 7/1); Cross section 4 (6/30 and 7/1); Cross section 7 (6/29 and 6/30); Cross section 8 (6/29 and 6/30); Cross section 9 (6/29 and 7/1).

4.1.4 Data Collection for Threatened and Endangered Species

Interior least tern and piping plover population, nesting, and habitat information for the lower Platte River were obtained from the NGPC Nongame Bird Program. For additional information on this data, see Section 4.5.1, Interior Least Tern and Piping Plover Data.

Objective 1: To characterize sediment transport in the Loup River bypass reach and in the lower Platte River through effective discharge and other sediment transport calculations.

4.2 Task 2: Sediment Budget

The first task in characterizing sediment transport was to develop an updated sediment budget. An updated sediment budget was determined based on the sediment budget and sediment yield analysis completed by MRBC in September 1975. In the MRBC report, the Platte River Basin was divided into subwatersheds, one of which was the Loup River Basin. MRBC calculated annual sediment yields for each subwatershed by determining the sediment production from all erosion processes (sheet and rill, gully, and streambank). The MRBC sediment yield analysis was then used to calculate an annual sediment supply available to the river system.

Since approximately 1975, the amount of material (primarily sand) dredged from the Settling Basin has been reduced by nearly half (Loup Power District, October 16, 2008). FERC stated in its Study Plan Determination (FERC, August 26, 2009) that a system-wide reduction in sediment yield may be evidenced by the reduction in material dredged, reaching a fairly constant, but significantly lower, value around 1975. Therefore, the calculated sediment yield for the Loup River and its tributaries downstream of the Diversion Weir as well as downstream of the Tailrace Return was adjusted based on documented reductions from the Settling Basin.

Figure 4-5 shows the amount of sediment dredged from the Settling Basin by the District each year from 1937 through 2009. A table containing the amount of sediment dredged each year is included in Attachment B. This table provides dredged values in cubic yards as well as amounts in equivalent tons assuming the dredged material weighs 120 pounds per cubic foot. The amounts were converted to equivalent tons for comparison with calculated amounts of sediment transport capacities described in Section 5.2.1, Sediment Budget.

As shown in Figure 4-5, the amount of sediment dredged began to level off in approximately 1975. To adjust the MRBC estimates of yield, the average total dredged amount from 1940 to 1974 was calculated, as was the average total dredged amount from 1975 to 2009. The sediment yield reduction factor was found by dividing the post-1974 average dredged amount by the pre-1974 average dredged amount. Adjustments made to the MRBC yields are described in Section 5.2.1, Sediment Budget.

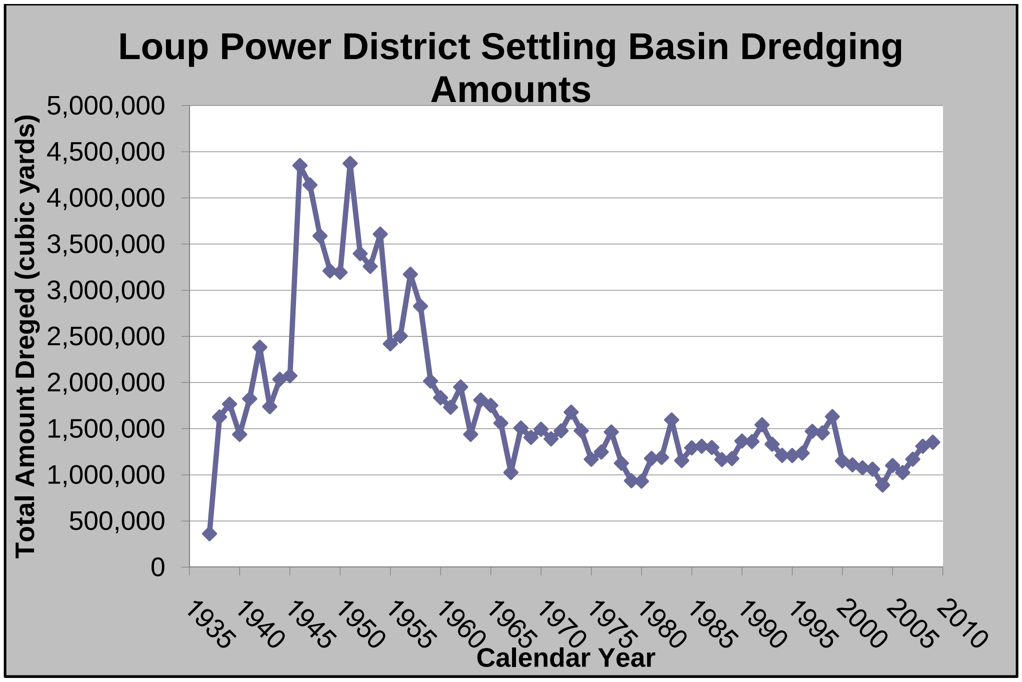

Figure 4-5. Loup Power District Settling Basin Dredging History

The sediment yield accounting presented in the MRBC report was reproduced and then recalculated to include the reduction factor in the Loup River watershed from the Diversion Weir to the Tailrace Return. The current sediment yield at each gaged study site was then re-calculated using the reduction factor. The results at the gaged and ungaged sites as well as at other points of interest are presented in Section 5.2.1, Sediment Budget, in Table 5-1.

The results of the revised sediment yield analysis from Task 2 were compared to the annual sediment transport capacity calculations developed in Task 3, described in Section 5.2.2, Effective Discharge and Other Sediment Transport Calculations, to assist in determining whether the gaged and ungaged sites are currently flow or supply limited. In addition, the results from Task 2 were compared spatially to other sediment transport calculations developed in Task 3.

4.3 Task 3: Effective Discharge and Other Sediment Transport Calculations

The second task in characterizing sediment transport was to determine the daily, seasonal, annual, and long-term sediment transport parameters at each of the gaged sites as well as daily sediment transport parameters at each of the ungaged sites. The sediment transport calculations and associated analysis included the following:

- Determining sediment transport parameters, including daily calculations of the capacity of discharges to transport bed material sediment
- Grouping daily transport values to determine which discharges are "effective" or "dominant" in shaping the morphologies (and habitat) of the

Loup River bypass reach and the lower Platte River by transporting the greatest amount of sediment

- Comparing cumulative sediment transport capacities with adjusted MRBC annual sediment yield estimates
- Applying regime theory to the effective discharges to assess whether the morphologies of the Loup River bypass reach and the lower Platte River are in dynamic equilibrium

A relationship was developed between flow and sediment transport, resulting in sediment discharge rating curves. Then, from this relationship, several sediment transport indicators were calculated: total sediment transport capacity, effective discharge, and dominant discharge. These two subtasks are described below.

4.3.1 Sediment Discharge Rating Curves

A sediment discharge rating curve is a relationship between flow in a channel and the capacity that flow has to carry sediment. The rating curve shows the capacity for total sediment transport rate (both bed load and suspended load) in units of weight per unit of time versus discharge on a log-log scale. In analysis, flow is then used to predict sediment carrying capacity. This is useful because there is a more comprehensive record of flow than sediment carrying capacity. Analyses performed by Leopold and Maddock (1953), Yang and Stall (July 1974), Hey (1997), and many others show a relationship between sediment discharge and water discharge through the use of known values such as channel slope, hydraulic geometry, and shear stress. The sediment discharge rating curves that were generated at each of the gaged sites and the resulting graphs and best-fit equations are presented in Attachment C. The sediment discharge rating curves for the ungaged sites are presented in Attachment D.

Several well-established methods allow development of a relationship between sediment discharge and water discharge. Yang and Stall (July 1974) showed that for the Middle Loup River, Yang’s (1972) Unit Stream Power method and the modified Einstein method both adequately predicted sediment discharge capacity as well as adequately predicted USGS measurements of transport. The Unit Stream Power method provides a rating of total bed material transport capacity versus discharge, which is required for sediment transport capacity calculations. The modified Einstein method provides a rating of the total sediment transport rate, including wash load. Wash load, however, does not contribute to the geomorphology of the channel; therefore, the modified Einstein method was not chosen for use in this analysis.

For this sedimentation study, Yang’s (1972) Unit Stream Power method was implemented to generate sediment discharge rating curves. These were then used to determine the capacities for each day’s discharge to transport bed material at each study site.

Stream power is the product of slope and discharge. Slope directly affects flow velocity; consequently, a shallow, meandering stream with low slope generates less stream power, and has lower erosion and sediment transport capacity, than a deep, straight stream. The unit stream power is defined as the rate of potential energy expenditure per unit weight of water.

The following variables are used in Yang's Unit Stream Power method:

- Velocity/discharge and depth/discharge relationships
- Energy slope
- Particle size
- Kinematic viscosity
- Fall velocity

These variables and the data to support these variables for the gaged and ungaged sites are discussed in detail below.

In developing sediment transport indicators for the gaged sites, sediment gradation and transport data were available only for USGS gages at the Loup River near Genoa, Platte River near Duncan, Platte River at North Bend, and Platte River at Louisville. For the gaged sites with no corresponding USGS sediment data, the closest USGS site with sediment data was used as a surrogate.

The flow data used for the Loup River at Columbus for the study period (1985 to 2009)[3] were developed based on a relationship between the Loup River near Genoa and the Loup River at Columbus. Flow regression equations obtained from USFWS (May 15, 2002) were used to obtain a flow estimate at the Loup River at Columbus from the flow data at the Loup River near Genoa. This regression takes into account all gains and losses within the reach, including the addition of flow from Beaver Creek.

To develop sediment transport indicators for the ungaged sites, daily discharges for the study period were synthesized using data from the gaged sites on the Loup and Platte rivers. The methodology for the synthetic hydrograph development is detailed in the Second ISR, Appendix B, Hydrocycling Study Report, Section 4.2. Because cross-section data were measured only in 2010 and discharge measurements at gaged sites were available only through 2009, the assessment of sediment transport parameters at the ungaged sites was restricted to using synthesized discharges during 2009. The year 2009 has be classified as a normal year, as discussed in Second ISR, Appendix B, Hydrocycling Study Report, Section 4.2.3.

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[3] The study period of 1985 through 2009 is a 25-year period that was selected to correspond to those years for which adequate interior least tern and piping plover population information exists, namely 1986 to 2009.

The resulting 2009 synthetic hydrographs are presented in the Second ISR, Appendix B, Hydrocycling Study Report, Section 4.2. As discussed below under Hydraulic Geometry Relationships among Discharge and Channel Width, Depth, and Velocity for Ungaged Sites, the assumption was made that the cross sections taken in 2010 were the same as the geometries that existed throughout 2009. The implications of this assumption are addressed in detail in Section 4.3.2, Sediment Transport Indicators.

The discussion below describes the District's development of variables for use in Yang's Unit Stream Power method.

Yang's Unit Stream Power Method

Yang and Stall's (July 1974) equation 19 describes Yang's Dimensionless Unit Stream Power Equation and is as follows:

$$\begin{aligned}\log C_t = 5.435 - 0.286\, log(\omega\, d/\upsilon) - 0.457\, log(U_*/\omega) \\ + [1.799 - 0.409 \log(\omega\, \mathrm{d}/\upsilon) - 0.314\, log(U_*/\omega)] \\ \times\ log(V\, S/\omega - V_{cr}\, S/\omega)\end{aligned}$$

Where:

C_t = Total Sediment Concentration (parts per million)
ω = Fall Velocity of Sediment Particle (ft/sec)
U_* = Sheer velocity
d = particle size – diameter (mm)
υ = kinematic viscosity (ft^2/sec)
S = energy slope (ft/ft)
$V_{cr}S$ = Critical unit stream power required at incipient motion
V = Average water velocity (ft/s)
V_{cr} = Critical Velocity (ft/s)
$\omega\, d/\upsilon$ = Fall Velocity Reynolds number

The sheer velocity (U_*) is calculated by:

$U_* = \sqrt{\frac{\tau_b}{\rho}}$ or rewritten as: $U_* = \sqrt{gravity \times depth \times slope}$

When the critical velocity is divided by the fall velocity, the result is called the Dimensionless Critical Velocity and is defined as:

$$\frac{V_{cr}}{\omega} = \frac{2.5}{log\left(\frac{U_* d}{v}\right) - 0.06} + 0.66, \qquad 0 < \left(\frac{U_* d}{v}\right) < 70$$

And

$$\frac{V_{cr}}{\omega} = 2.05, \qquad 70 \leq \left(\frac{U_* d}{v}\right)$$

The results of the equation yield bed material concentration in parts per million by weight. For this sedimentation study, a water density at 15°C was used, which is 1 ppm and is equivalent to 0.00006243 pounds of sediment per cubic foot of water. The results of the equation were converted to tons of sediment per day by multiplying by the flow rate.

Velocity/Discharge and Depth/Discharge Relationships for Gaged Sites

USGS collects cross-sectional data approximately monthly to aid in the continual adjustment of the rating curves used at each gage station. The cross-sectional data is then combined so that a single width, area, velocity, and discharge are obtained for each cross sectional measurement event. For this sedimentation study, the water depth was found by dividing the area by the width. The cross-sectional measurements used in this analysis were from 1984 through 2008, with 1984 being the earliest year the data were available electronically. All data from 1984 through 2008 were used to develop the velocity/discharge and depth/discharge relationships in order to provide enough data points at both lower flows and higher flows to allow development of the relationships through a large range of flow rates.

To use the surveyed USGS data as input for Yang’s equation, the measured velocity and calculated depth were graphed versus measured discharge at each study site. A power equation trend line was fitted for each variable using Microsoft Excel. The trend lines for the velocity/discharge and depth/discharge rating curves did not adequately describe the data for all flow rates. Therefore, the rating curves were split into lower and higher flow curves, which fit the data much better. Figures 4-6 through 4-9 show an example of the velocity versus discharge and depth versus discharge at North Bend. Curves for each study site are shown in Attachment C. Width, depth, and velocity data for the Loup River at Columbus were collected starting in 2007 in preparation for reestablishing this gage in 2008; therefore, the velocity, discharge, and width graphs are not separated into low and high flows.

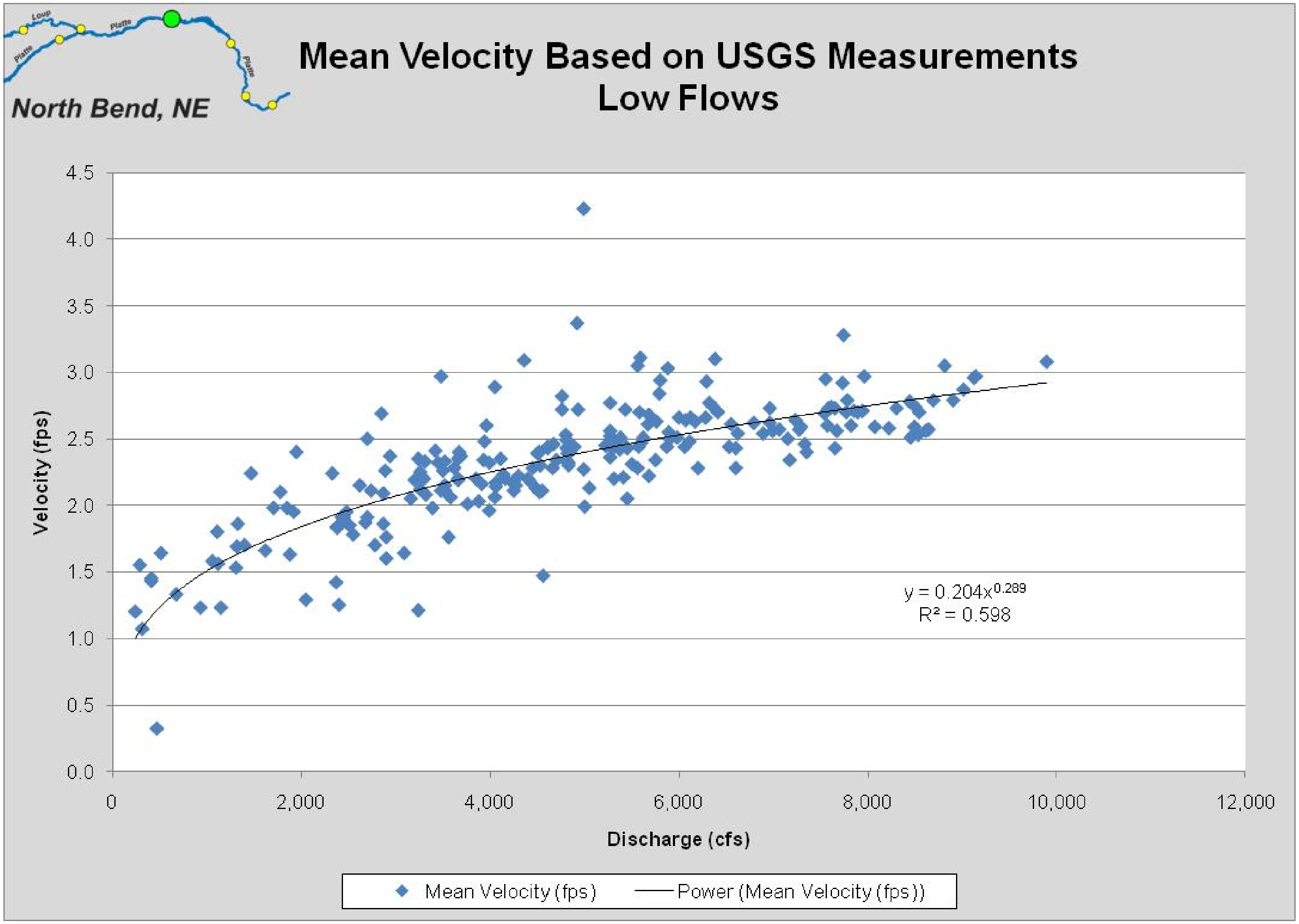


Figure 4-6. Mean Velocity Based on USGS Measurements, Low Flows, at the Platte River at North Bend (USGS Gage 06796000)

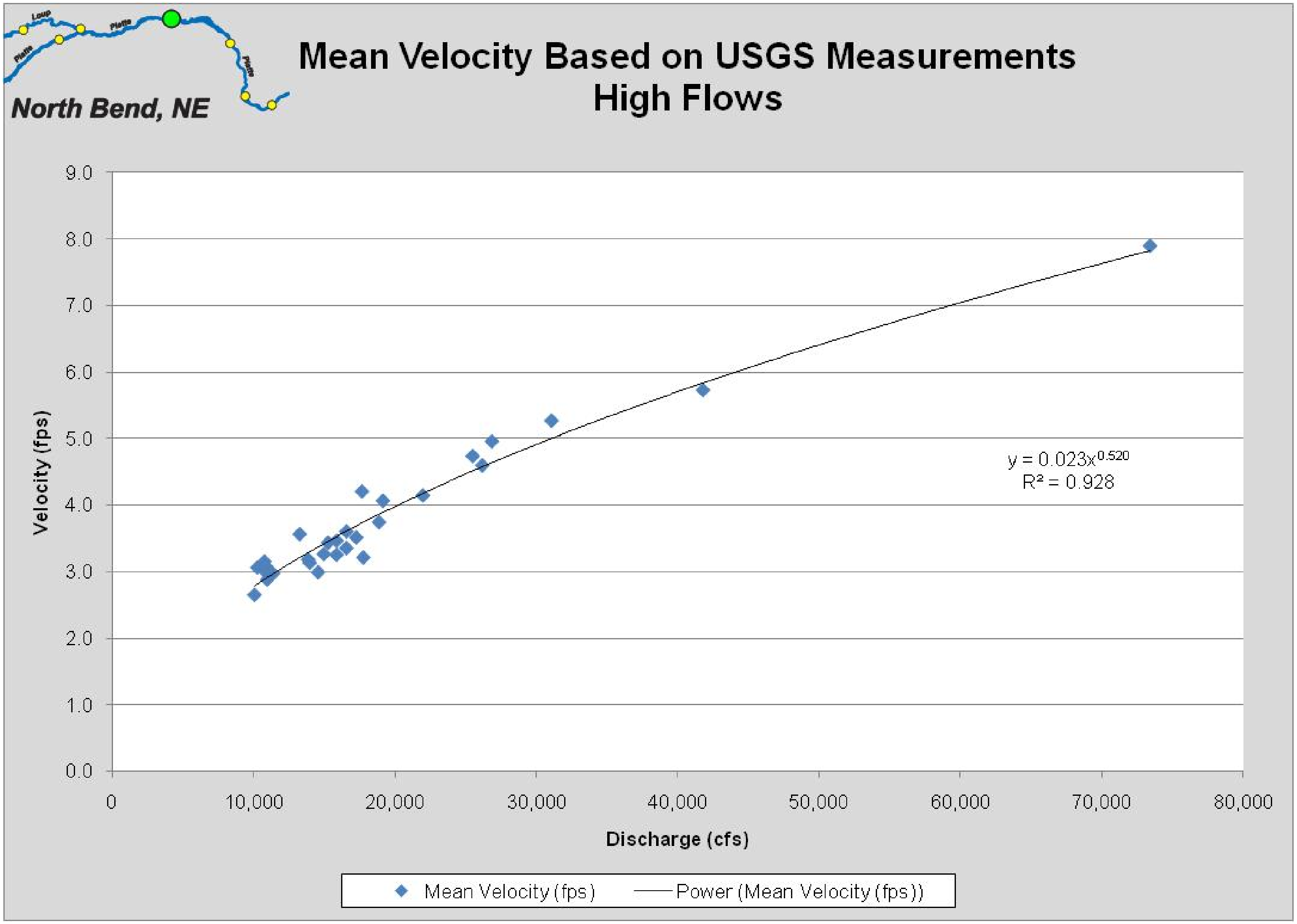


Figure 4-7. Mean Velocity Based on USGS Measurements, High Flows, at the Platte River at North Bend (USGS Gage 06796000)

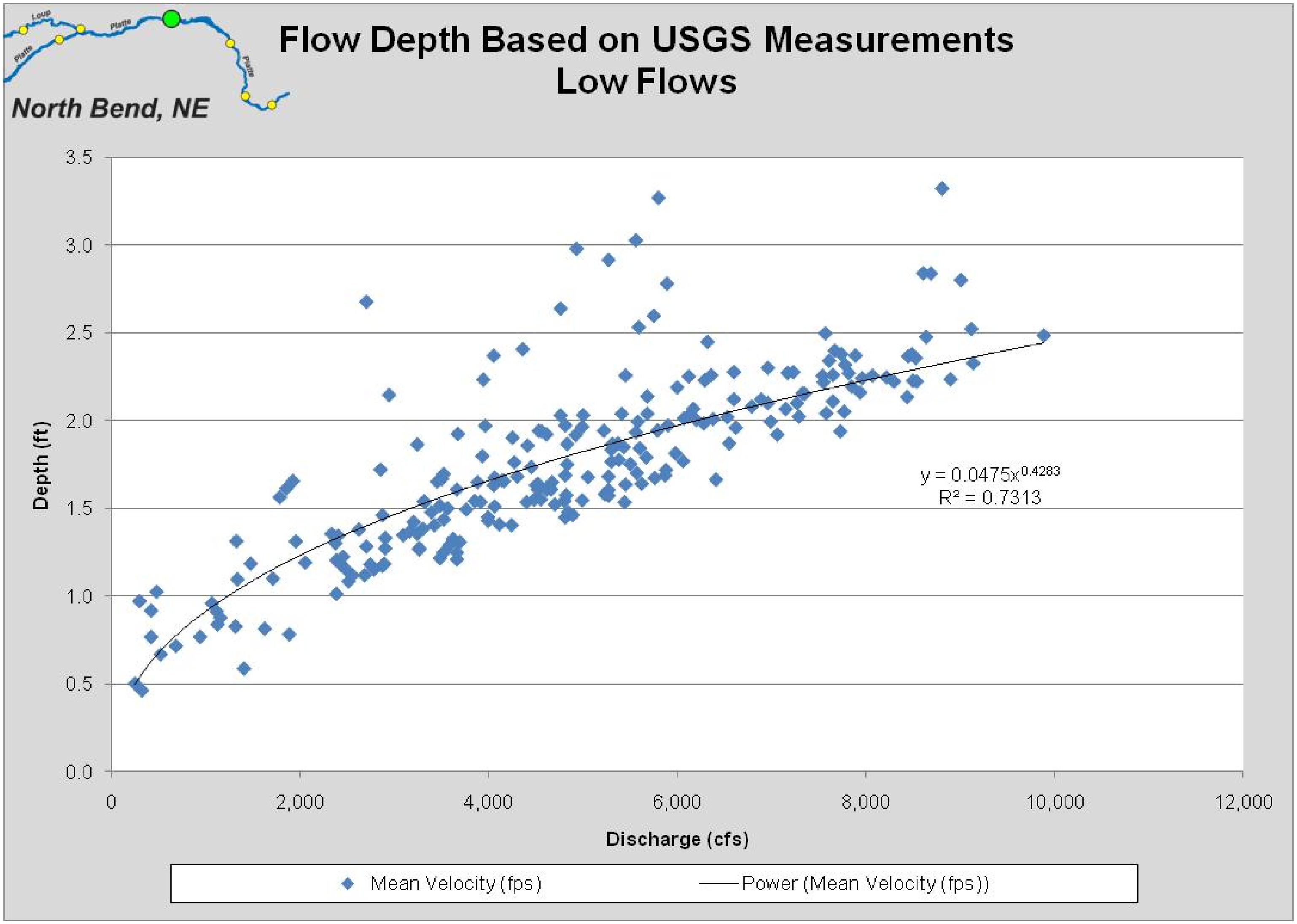


Figure 4-8. Flow Depth Based on USGS Measurements, Low Flows, at the Platte River at North Bend (USGS Gage 06796000)

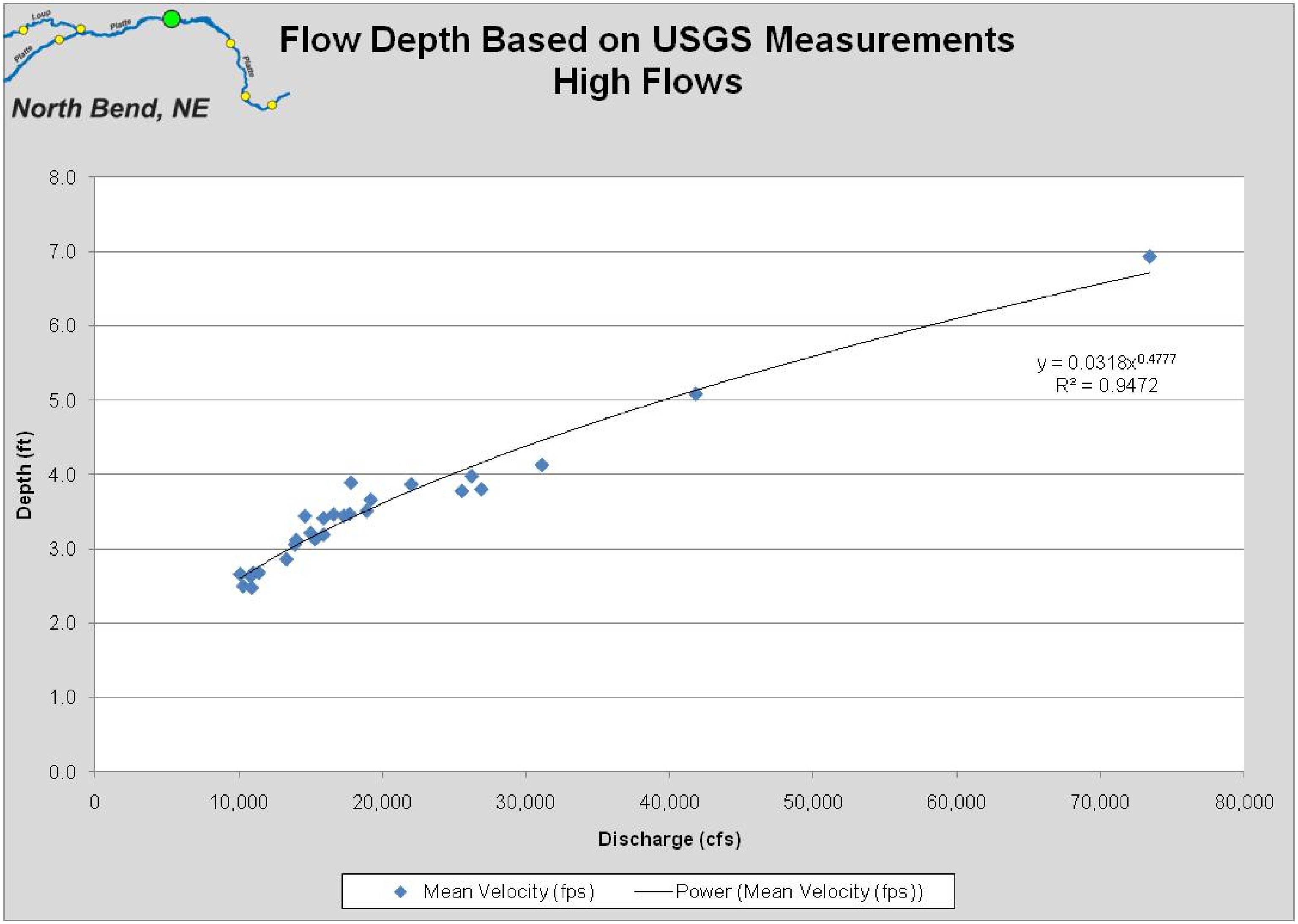


Figure 4-9. Flow Depth Based on USGS Measurements, High Flows, at the Platte River at North Bend (USGS Gage 06796000)

Hydraulic Geometry Relationships among Discharge and Channel Width, Depth, and Velocity for Ungaged Sites

Although FERC's Study Plan Determination directed that streamflow measurements be taken at the ungaged sites, this was not possible due to high flow and inaccessibility for wading the entire stream. Because hydraulic geometry relationships among channel width (W), depth (D), and velocity (V) for a range of discharges are needed for Yang's sediment transport equation, synthetic relationships for each variable were developed using HEC-RAS. The cross-section measurements from high bank to high bank were input to develop HEC-RAS models at each ungaged site, and runs were made using the synthesized ungaged-site discharges, measured water surface levels, and synthesized flow rates for the dates of the surveys. For a more detailed description of the model development, see the Second ISR, Appendix B, Hydrocycling Study Report, Section 4.6.5.

In addition to inputting synthesized flow rates on the dates of the cross-section surveys, testing ranges of input parameters to HEC-RAS was conducted, followed by comparing the modeled water surface profiles with observed water surface elevations. Parameters providing the best fit to the measurements were adopted. These calibration values were also compared with previous studies in the area by USACE and others and agreed well within standard limits of calibration.

Once the HEC-RAS models were calibrated to match measured water levels, runs were made over a wider range of discharge values to derive discharge (Q) versus width, depth, and velocity curves. This approach assumed a fixed bed geometry (using measured cross sections) over the full range of discharges tested. It further assumed that the cross sections in 2010 adequately represent geometries during the 2009 study period. Either or both of these assumptions can introduce bias into any sediment transport calculations. As shown by the comparisons of the spring and fall cross sections in Figure 4-10, Figure 4-11, and Attachment A, the channel cross sections are not fixed and instead experience significant variations over short periods of time and over short distances at the same time.

Graphs of discharge versus width, depth, and velocity from the USGS measurements at gaged sites are presented in Attachment C. Similar graphs for the ungaged sites are included in Attachment D. Both sets show that even for the same discharge value, the width, depth, and velocity values can vary by two to three orders of magnitude.

It is important to reiterate that cross-section geometry on any day is not a function of the flow that day, but instead is the result of the history of flows and other factors occurring for days, weeks, months, or even years leading up to that date. It is very likely that on any two days with the same discharge, the channel geometry and hydraulic properties could vary at least by as much as is demonstrated in Figures 4-6 through 4-9, and by the raw USGS data at the gaged sites. However, using the best-fit curves for the historical data statistically provides the best estimate for prediction of any of the parameters. The average is a measure of the central tendency of the long-term trends in the channel geometry parameters.

Figures 4-10 through 4-13 are samples of the cross-section measurements and hydraulic properties for one of the ungaged sites (Site 4). They clearly illustrate the non-uniform nature of the channel geometry over a 3-month time span and over short distances at the same time, as well as the resulting diversity of hydraulic geometry results that HEC-RAS gives (discharge versus width, depth, and velocity) for the variable cross-section geometries. Figure 4-10 shows that from June to September 2010, the bed geometry experienced dramatic changes. This example is among, but not the most dramatic of, the most extreme cases. To further illustrate the variability of channel geometry within a short distance at the same time, Figure 4-11 shows three of the nine cross sections taken at Site 4 in June 2010. This particular comparison is typical of what was found at all the ungaged sites. All other cross sections are included in Attachment A.

Although best-fit curves are included in Figures 4-12 and 4-13, they demonstrate the uncertainty introduced in using a rigid-bed assumption and steady-flow routines over a wide range of discharges in HEC-RAS to estimate width, depth, or velocity for a braided river. For each discharge rate across the graphs, the wide range of depths plotted illustrates that the natural changes in shape of the cross sections in June versus September can result in dramatically different depths (and other hydraulic parameters). More importantly, the at-the-same-time variability in shape of cross sections within a few hundred feet of each other (shown in Figure 4-11) has a similar impact on predictability of depth for any discharge. Examination of the width, depth, and velocity graphs in Attachment D for all five ungaged sites shows that the examples included here are typical.

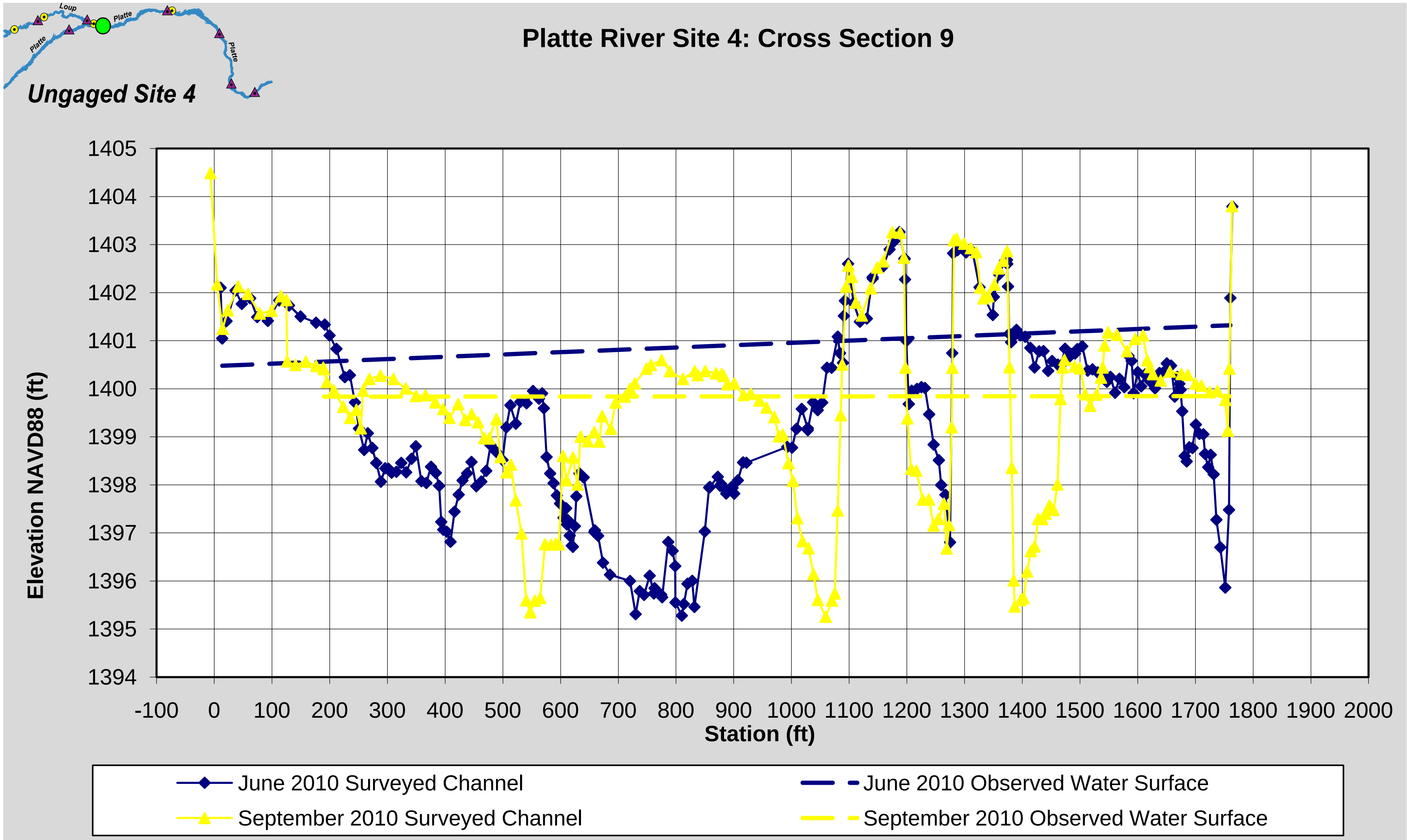


Figure 4-10. June and September Cross Sections at Site 4, Platte River Downstream of the Tailrace Return, Location 9

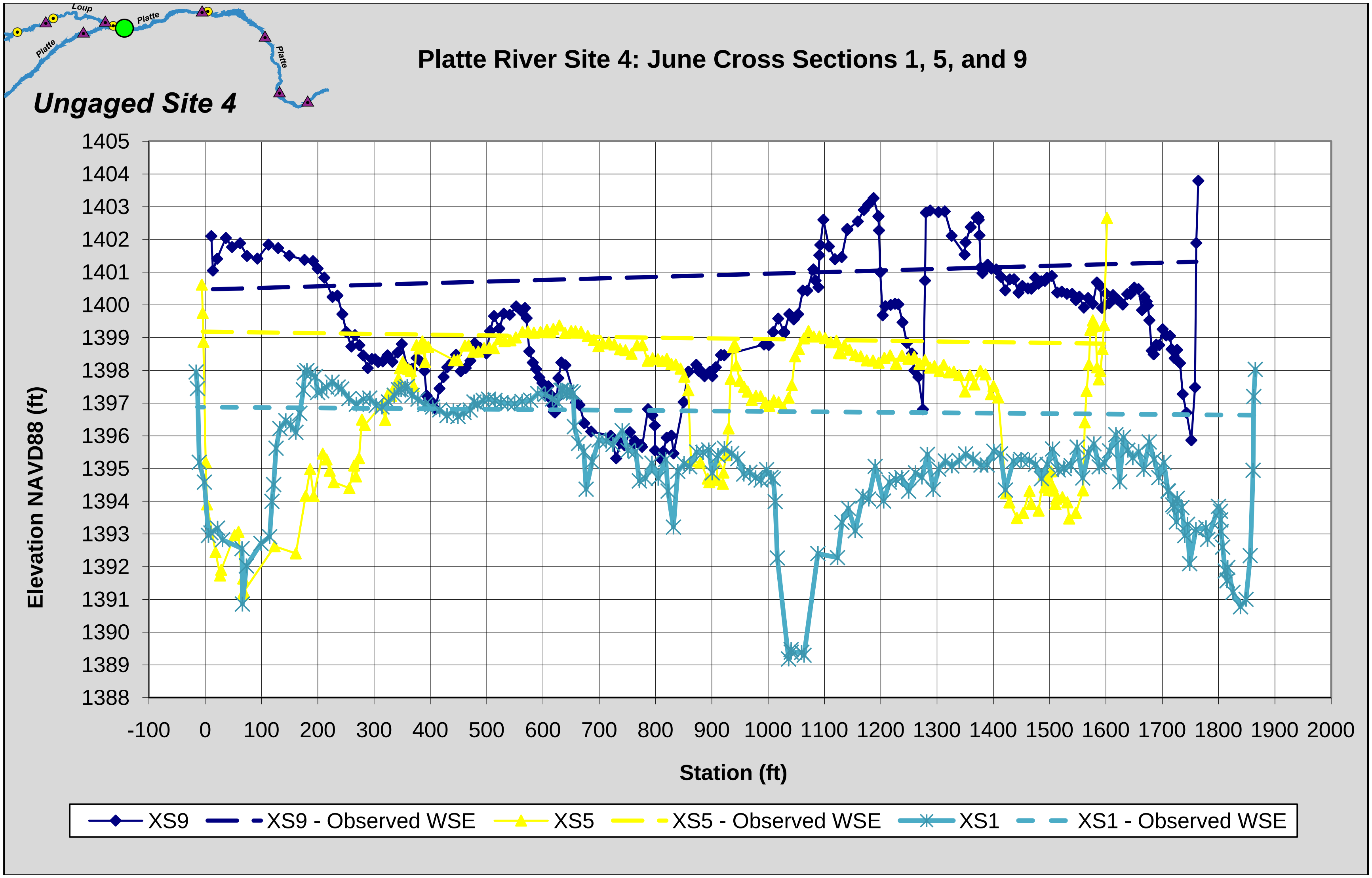


Figure 4-11. June Cross Sections at Site 4, Platte River Downstream of the Tailrace Return, Locations 1, 5, and 9

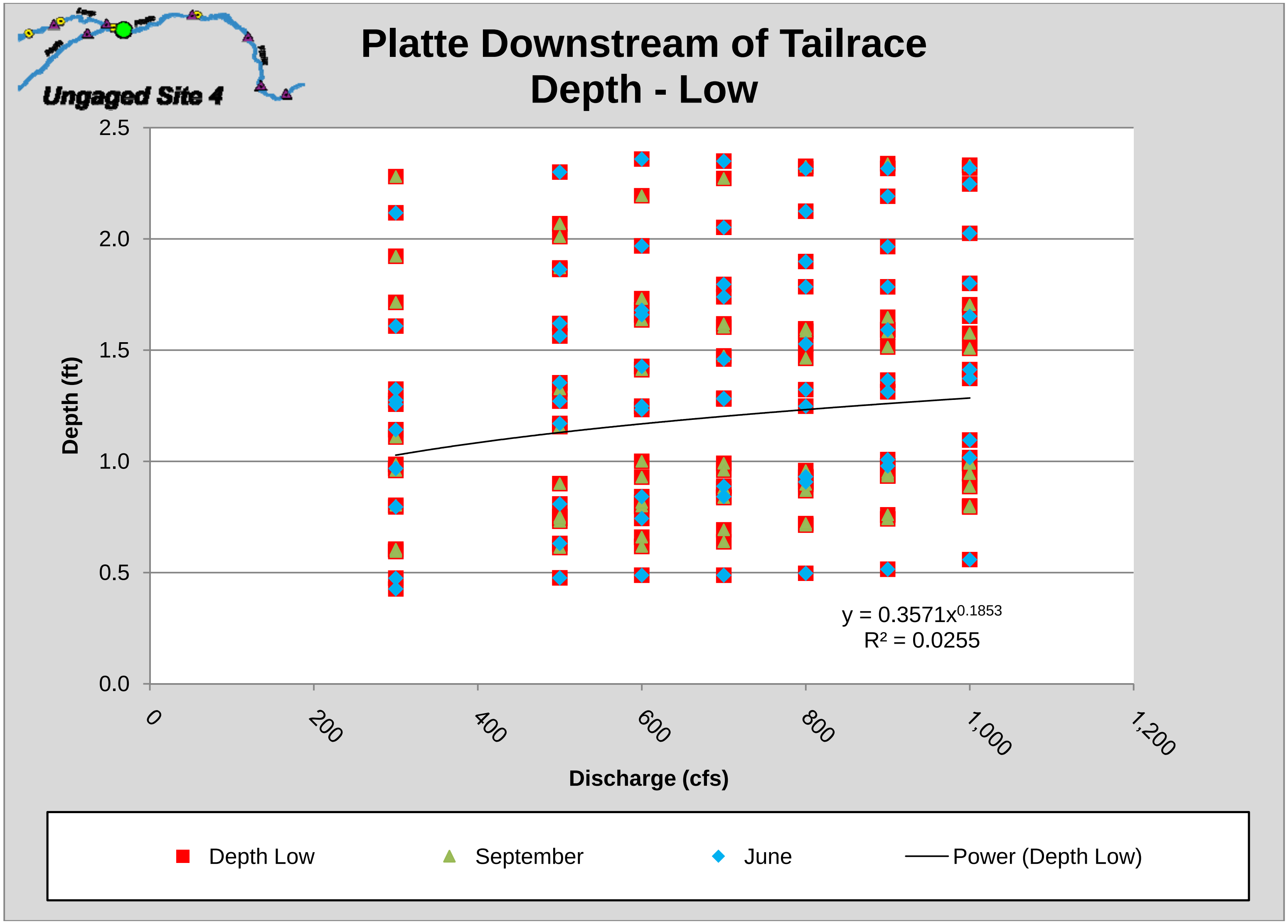


Figure 4-12. HEC-RAS Depth-Discharge Graph at Site 4 using June and September Cross-section Geometries at Locations 1 through 9, Flows up to 1,000 cfs

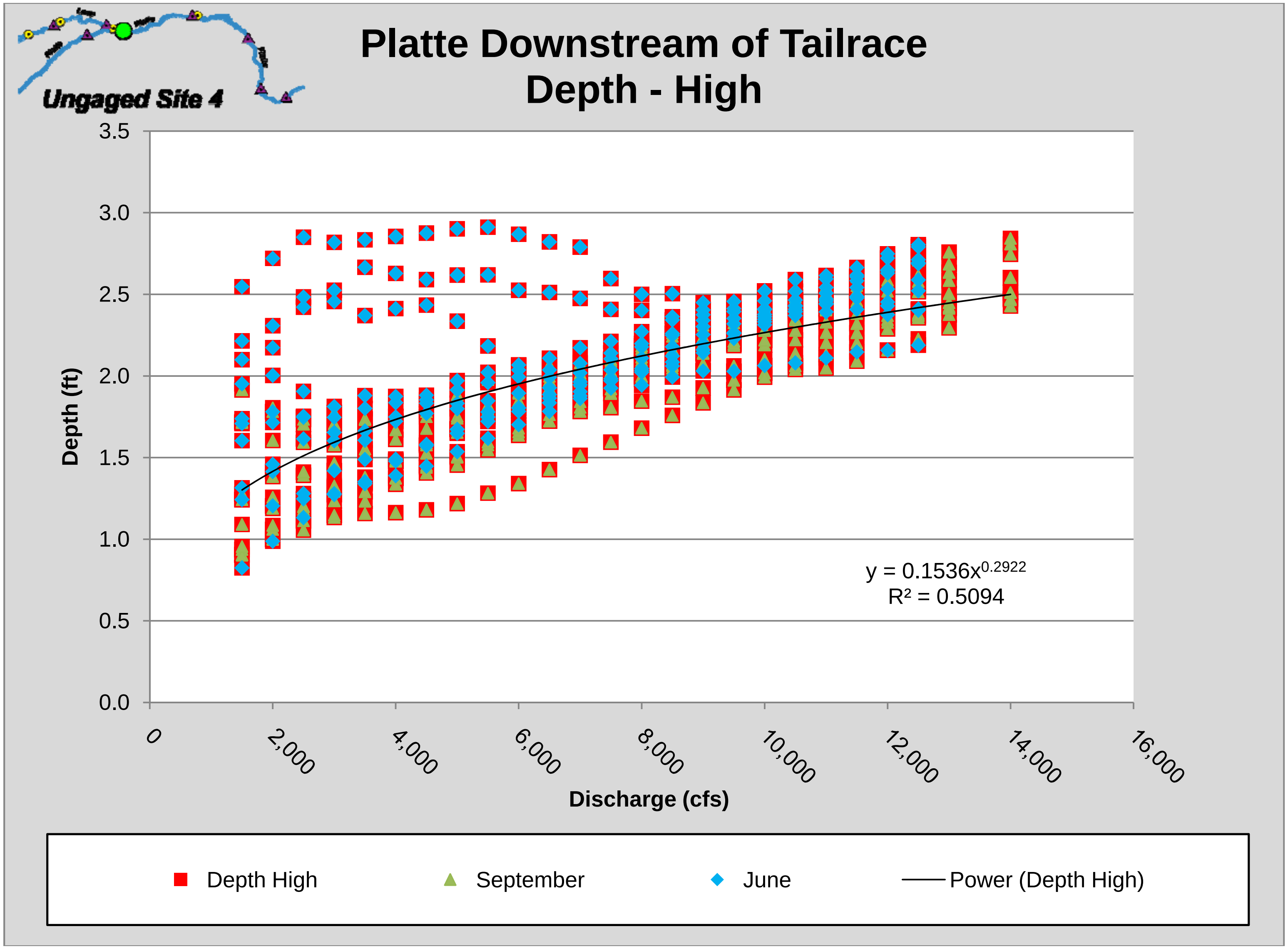


Figure 4-13. HEC-RAS Depth-Discharge Graph at Site 4 using June and September Cross-section Geometries from Locations 1 through 9, Flows Greater than 1,000 cfs

Because each daily calculation of sediment transport capacity requires a depth and velocity, and because the estimates were obtained from best-fit curves through widely scattered values illustrated above, the variability in the raw data of Figures 4-10 and 4-11 and the impacts of this variability on hydraulic geometry relationships (Figures 4-12 and 4-13) suggest that all single values of any of these variables contain uncertainties. This uncertainty is compounded when the sediment transport rates are calculated.

The ranges of width, depth, and velocity for the gaged and ungaged sites were similar, exhibiting a wide range of parameters for any given flow rate. This illustrates the indeterminate nature of a braided river. In addition to variability in width, depth, and velocity at the gaged sites, the variability in cross-section geometry within a few hundred feet discovered at the ungaged sites probably also exists at the gaged sites.

The variability of important parameters discovered here is not necessarily a reflection of error or even bias introduced by assuming rigid-bed geometries in HEC-RAS over a wide range of flows. A significant amount of the variability from section to section, date to date, and discharge to discharge demonstrated here is a reflection of the dynamics of a braided river and its ability to defy sub-daily micro-level replication of its geometry with numerical models. The indeterminate nature of a braided river's geometry, much less morphology, has been analyzed in the literature (Maddock, November 1970; ASCE, 1998a and 1998b).

Sediment transport indicators and regime methods are far more reliable because they use physical process algorithms that average these variabilities over the long term in a way that provides reliable tools for assessing braided river morphologies and allowing reliable interpretations of variabilities in the morphology indicators.

Energy Slope

Energy slope is an important part of the Unit Stream Power equation. Either channel slopes or energy grade line slopes (if available) were obtained from Bentall (1991), USACE Flood Insurance Studies (June 2002, March 2003, and August 2003), and USGS topographic maps. Channel slope was used as an estimation of energy slope, which is an acceptable estimation assuming normal flow. In some instances, the slope was averaged between two sources, which provided the best approximation between measured and predicted sediment transport. Slope data are summarized in Table 4-2.

Table 4-2. Summary of Slopes and Sources[1]

Site or USGS Gage Number	Site Description or Gage Name and Location	Slope (feet/mile)	Source	Secondary Source
Site 1	Loup River Upstream of the Diversion Weir	8.0	Same as the Genoa gage	
Site 2	Loup River Downstream of the Diversion Weir	8.0	Same as the Genoa gage	
06793000	Loup River near Genoa, NE	8.0 (average)	Bentall (1991)	USGS topographic maps
06794500	Loup River at Columbus, NE	5.3	USGS topographic maps	Bentall (1991)
06774000	Platte River near Duncan, NE	6.2	Bentall (1991)	USGS topographic maps
Site 3	Platte River Upstream of the Tailrace Return	5.9	2nd Order Polynomial regression from slopes from all Platte River study sites	
Site 4	Platte River Downstream of the Tailrace Return	5.8	2nd Order Polynomial regression from slopes from all Platte River study sites	
06796000	Platte River at North Bend, NE	4.9 (average)	Bentall (1991)	USACE Flood Insurance HEC-RAS model
Site 5	Platte River near North Bend	4.9	Same as the North Bend gage	
06796500	Platte River at Leshara, NE	4.8	Bentall (1991)	USACE Flood Insurance HEC-RAS model
06801000	Platte River near Ashland, NE	4.0	Bentall (1991)	USACE Flood Insurance HEC-RAS model
06805500	Platte River at Louisville, NE	4.0	Bentall (1991)	USACE Flood Insurance HEC-RAS model

Sources: Bentall, R, 1991, Facts and Figures about Nebraska Rivers, Water Supply Paper No. 73, University of Nebraska, Conservation and Survey Division, Lincoln, NE.

USACE, June 2002, “Hydraulic Analyses Lower Platte River, Nebraska, Flood Insurance Study, Missouri River to Sarpy-Douglas County Line.”

USACE, March 2003, “Hydraulic Analysis Lower Platte River, Nebraska, Lower Platte River Flood Insurance Study, Reach from Sarpy/Douglas County Boundary through Fremont.”

USACE, August 2003, “Hydraulic Analysis Lower Platte River, Nebraska, Lower Platte River Flood Insurance Study Revision, Reach from Fremont to Columbus.”

Note:

[1] Energy grade slopes were available from the USACE HEC-RAS model. All other slopes are channel grades.

Particle Size

Yang's equation results in an approximation of the total transport capacity of bed material. The input for particle size is the median particle diameter (d_{50}) of the bed material. For this sedimentation study, it was assumed that the material dredged from the Project was a reasonable representation of the total bed material. The gradations from 12 test hole sites in the North Sand Management Area were compared to the sediment (suspended and bed material) data at the Loup River near Genoa. The d_{50} of the dredged material for the 12 test hole sites ranged from approximately 0.17 to 0.32 mm, with a median of 0.24 mm. The d_{50} from the suspended measurements was approximately 0.12 mm and ranged in size from 0.009 to 0.357 mm. The d_{50} of the bed material measurements was 0.335 mm and ranged in size from 0.205 to 1.33 mm.

Combining the suspended and bed material measurements results in a composite d_{50}. This was performed by taking the "percent finer than" data for both the suspended and bed sediment data, adding them together, then dividing by 200 percent. This resulted in a new "percent finer than" data set from which a new composite d_{50} was obtained. The composite d_{50} was 0.21 mm and ranged in size from 0.11 to 0.42 mm. The composite d_{50} provided the best approximation of the measured dredged material and was assumed a reasonable surrogate to the total bed material d_{50}. Therefore, a composite d_{50} for all of the remaining gaged sites based on suspended and bed material gradations was used as input in Yang's equation, as presented in Table 4-3.

The sediment sizes used in Yang's Unit Stream Power equation were cross checked with several different sources. Marlette and Walker (1968) found the d_{50} of the bed sediment in the Platte River at Louisville to be 0.4 mm. The composite d_{50} for this sedimentation study in the Platte River at Louisville was 0.22 mm. USACE (July 1990) reports a median bed size of 0.45 mm in the Platte River at North Bend. In addition, USACE (1990) reports a suspended median particle size of 0.06 mm in the Platte River at North Bend and of 0.02 mm in the Plate River near Duncan and the Platte River at Louisville.

At the ungaged sites, median particle sizes for sediment being transported were determined by either the nearest gage location or through an average of the nearest gaged sites or through a regression analysis, as follows:

- Site 1 – Mean d_{50} from the dredged material
- Site 2 – Same as the Genoa gage
- Site 3 – Average between the d_{50} for Duncan and Genoa
- Site 4 – Linear regression from d_{50}s from Platte River sites
- Site 5 – Same as the North Bend gage

This approach was considered to result in comparable and commensurate estimates of the composite particle size adopted for use at the gaged sites. The particle sizes used for the ungaged sites are presented in Table 4-3.

Kinematic Viscosity

Kinematic viscosity, a property of all fluids, is temperature dependent. For both the gaged and ungaged sites in this analysis, a constant water temperature of 15 degrees Celsius (°C) was used, resulting in a kinematic viscosity of 1.23E-5 (ft^2/s). As discussed in the sensitivity analysis, this method is insensitive to temperature. USACE (July 1990) used a different transport equation and different constant temperature (21°C) and concluded that results were indistinguishable for temperatures between 10 and 27°C. After reviewing temperature data available at the Platte River at Louisville and taking into account that there are no temperature data available during the winter, 15°C was chosen as a balanced value.

Fall Velocity

The particle fall velocity was calculated from Van Rijn's (1993) equation, which is written as:

$$\omega = \frac{10\upsilon}{d}\left[\left(1 + \frac{0.01(s-1)gd^3}{\upsilon^2}\right)^{0.5} - 1\right], \qquad 0.1 < d < 1mm$$

Where:

$\omega \equiv$ fall velocity of sediment particle (ft/sec)
$\upsilon =$ kinematic viscosity (ft^2/sec)
$d \equiv$ particle size – diameter (mm)
$s =$ specific gravity
$g =$ gravity (ft/sec/sec)

For silicon-quartz-based sediment (sand), the assumed specific gravity value used was 2.65. The fall velocities used for the gaged and ungaged sites are presented in Table 4-3.

Summary of Data Developed for Yang's Unit Stream Power Method

The data used for computation of Yang's Unit Stream Power equation are summarized in Table 4-3.

Table 4-3. Data for Computation of Yang's Unit Stream Power Equation[1]

Site or USGS Gage Number	Site Description or Gage Name and Location	Velocity/ Discharge Graph	Depth/ Discharge Graph	Energy Slope (ft/mile)	Particle Size (d_{50}) (mm)	Fall Velocity (ft/sec)
Site 1	Loup River Upstream of the Diversion Weir	Attachment D-1	Attachment D-1	8.0	0.24	0.10
Site 2	Loup River Downstream of the Diversion Weir	Attachment D-2	Attachment D-2	8.0	0.20	0.08
06793000	Loup River near Genoa, NE	Attachment C-1	Attachment C-1	8.0	0.20	0.08
06794500	Loup River at Columbus, NE	Attachment C-2	Attachment C-2	5.3	0.20	0.04
06774000	Platte River near Duncan, NE	Attachment C-3	Attachment C-3	6.2	0.38	0.18
Site 3	Platte River Upstream of the Tailrace Return	Attachment D-3	Attachment D-3	5.9	0.29	0.13
Site 4	Platte River Downstream of the Tailrace Return	Attachment D-4	Attachment D-4	5.8	0.23	0.10
06796000	Platte River at North Bend, NE	Attachment C-4	Attachment C-4	4.9	0.23	0.10
Site 5	Platte River near North Bend	Attachment D-5	Attachment D-5	4.9	0.23	0.10
06796500	Platte River at Leshara, NE	Attachment C-5	Attachment C-5	4.8	0.23	0.10
06801000	Platte River near Ashland, NE	Attachment C-6	Attachment C-6	4.0	0.22	0.09
06805500	Platte River at Louisville, NE	Attachment C-7	Attachment C-7	4.0	0.22	0.08

Note:

[1] Kinematic viscosity was held constant at 1.23E-5 ft^2/sec.

Comparison of Sediment Supply and Transport Capacity at UGSG Gage 06793000, Loup River near Genoa, NE

Additional calculations were used to estimate the total sediment supplied to the study site at the Loup River near Genoa, as shown in Table 4-4. Assumptions made include the following:

- The dredged amounts plus amounts carried by the Loup Power Canal and Loup River bypass reach were assumed to equal the entire supply of bed material supplied to the Diversion Weir.
- The split in sediment arriving at the Diversion Weir between the Loup River bypass reach and the Loup Power Canal was assumed to match the split in flow based on data from USGS and NDNR gages on the Loup Power Canal, listed in Table 4-5.
- Sediment amounts in the Loup River bypass reach plus the sediment amounts from the South Sand Management Area were compared with estimates of the capacity at the Loup River near Genoa.

Table 4-4. Additional Analysis of Sediment Capacity at the Loup River near Genoa using Dredging Data from 1975 through 2009

Parameter	Value[1]
Average Annual Sediment Dredged[2]	2,005,000 tons/year
Flow Split Between Loup Power Canal and Loup River Bypass Reach[3]	67%
Average Annual Sediment Carried by the Loup River just upstream of the Diversion Weir	3,000,000 tons/year
Average Annual Sediment Carried by the Loup River Bypass Reach	995,000 tons/year
Average Annual Sediment Dredged to South Sand Management Area	560,000 tons/year
Average Annual Sediment in Loup River Bypass Reach + Dredged Material at South Sand Management Area	1,554,000 tons/year
Average Annual Cumulative Sediment Discharged as Calculated by Yang's Equation	1,758,000 tons/year

Notes:

[1] Values in this table have been rounded.

[2] Assuming the hydraulic dredge captures the vast majority of sediment.

[3] Assuming flow split equals sediment split.

The conclusion from the last two rows is that from 1975 through 2009, a total of 1.55 million tons per year is potentially supplied to the Loup River bypass reach, and Loup River flows are capable of transporting 1.76 million tons. These values are very close to the sediment carrying capacity at the Loup River near Genoa, calculated using Yang's Unit Stream Power Method, giving confidence to the methodology.

Additionally, the assumptions relative to the sediment transport being proportionate to the flow split made in this analysis were conservative. For example, a 67 percent flow split does not necessarily represent a 67 percent sediment flow split. The Diversion Weir holds back water, which causes sediment to fall out, resulting in less sediment being transported into the canal. The District sluices sediment down the Loup River bypass reach several times a month to mitigate this sediment buildup. It is likely that a greater percentage of sediment is transported down the Loup River bypass reach than what is represented by the assumed flow split. Therefore, it is reasonable to conclude that based on this analysis to evaluate the applicability of using Yang's equation, the calculated capacity very nearly matches the potential supply.

Table 4-5. USGS and NDNR Gages on the Loup Power Canal

Gage Number	Gage Name and Location	Drainage Area (sq. mi.)	Mean Daily Discharge (cfs)	Period of Record	Comments
USGS Gage 06792500	Loup River Power Canal near Genoa, NE	NA	1,610	1937 - 2009	Available discharge data from January 1, 1937, to 2009 include daily and sub-daily data.
NDNR Gage 00082100	Loup River Power Canal Return [Tailrace Canal] at Columbus, NE (8th Street bridge)	NA	1,610	2002 - 2009	Available discharge data from October 1, 2002, to 2009 include daily and sub-daily data.

4.3.2 Sediment Transport Indicators

Three sediment transport indicators were computed for each of the gaged and ungaged sites to assist in characterizing the sediment transport. The indicators are total sediment transport capacity, effective discharge, and dominant discharge.

The total sediment transport capacity is found by combining the sediment discharge rating curve and a flow hydrograph. The flow hydrograph is based on the period of interest, such as annually, seasonally, monthly, daily, or sub-daily. The total sediment transport capacity was determined for each study site on an annual and seasonal basis. For purposes of this sedimentation study, the season from May 1 to August 15 was used to coincide with the interior least tern and piping plover nesting season. Tables and graphs for each gaged site are located in Attachments B and C, respectively. Graphs for each ungaged site are located in Attachment D.

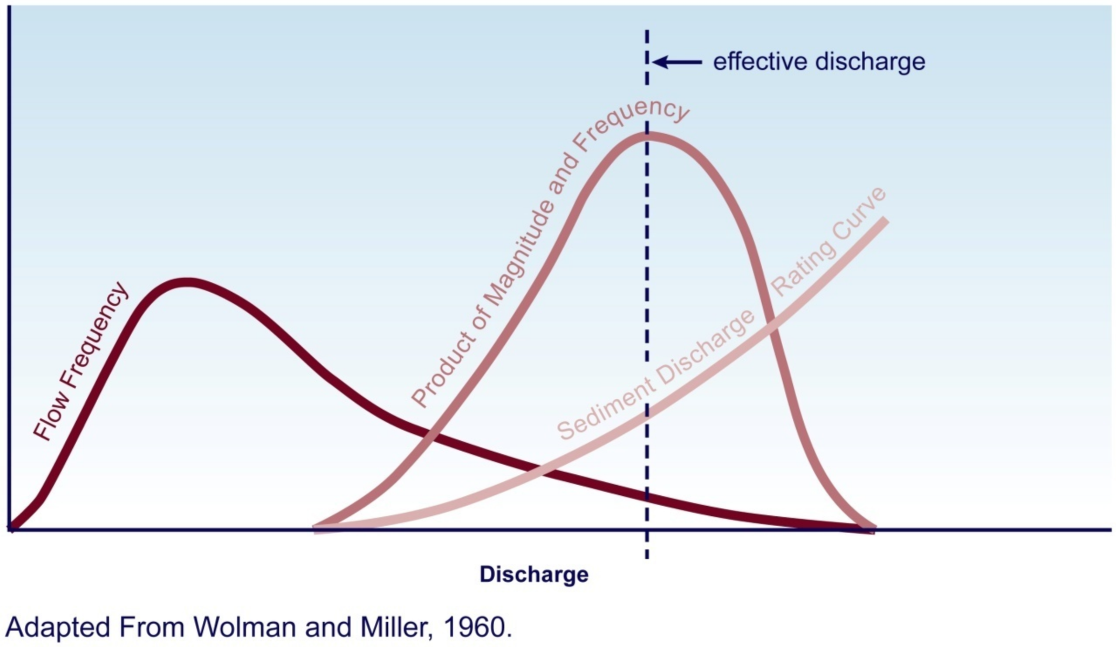
The effective discharge, defined as the mid-value of the narrow range of flows that transports the most sediment (and therefore shapes the channel), is found by developing a collective sediment discharge curve. A collective sediment discharge curve is developed by combining the flow frequency and sediment discharge rating curves. The flow frequency curves that were used in this analysis are graphs of the daily discharge on the x-axis and flow frequency (number or percent of days a particular daily discharge was exceeded) on the y-axis. For each of the gaged sites, study period (1985 to 2009), annual, and seasonal daily flow frequency curves were generated using the discharge records. For each of the ungaged sites, study period (2003 to 2009) flow frequency curves were developed based on the availability of data at the NDNR gage on the Tailrace Canal at Columbus (8th Street bridge).

The collective sediment discharge curve was developed by combining the daily discharge rates and the sediment discharge rating curve to arrive at daily estimates of transport capacity. Then, by grouping the amount of sediment transported into equal increments, a histogram of the sediment capacity was created. The flow corresponding to the peak of the collective sediment discharge histogram is the effective discharge.

As often happens, the peaks of these histograms are broad-crested, and some prefer to represent this by reporting a range of flows that transports the majority of the sediment, while others select the mid-point of this range, which may not occur at the overall mode. Uses of the centroid or median values of the histogram are also acceptable measures of central tendency of the discharge that transports the majority of the sediment.

Previous USGS sedimentation studies (Kircher and Karlinger, 1981; USGS, 1983) and this study adopted the modal definition, but the modal value is only a single-value measure of the central tendency of flows having the greatest impact on channel morphology. The range of flows having the “majority” effect generally covers two to four class intervals in the histogram. USACE (July 1990) defined the effective discharges for its Platte River locations as the mid-point of the highest bars in the broad-crested histogram.

The collective discharge curve can be developed on a daily, monthly, seasonal, or annual basis or for the entire study period (1985 to 2009), if needed. Figure 4-14 illustrates the concept of using the flow and sediment rating curves to create the collective sediment discharge curve.



Adapted From Wolman and Miller, 1960.

Figure 4-14. Effective Discharge Determination from Typical Sediment Rating and Flow Duration Curves

The effective discharge was determined for each gaged study site for Project operations for the study period (1985 to 2009) as well as on an annual and seasonal basis for each year of the study period. These graphs are located in Attachment C and are discussed in Section 5, Results and Discussion. Karlinger et al. (1983), Richards (1982), and others support the calculation of effective discharge for long periods and caution that use of shorter periods may not establish equilibrium conditions because of climatic and other factors.

The dominant discharge is defined as the flow rate that, if continued constantly for the long term, would transport the same total load as the actual hydrograph. It is a geomorphic characteristic of the river, without the subjectivity involved in calculating the effective discharge. The dominant discharge is found by first dividing the total sediment transported over time by the number of days in that time period to obtain the tons of sediment transported per day. Then, by taking that sediment discharge rate and using the calculated sediment discharge rating curve, the flow rate associated with that sediment discharge, defined as the dominant discharge, can be found. The dominant discharge was calculated for each of the gaged sites for the study period, annually, and seasonally. The graphs are shown in Attachment C and are discussed in Section 5, Results and Discussion. In addition, values for the 2009 dominant discharge at each ungaged site were determined.

The terms “effective discharge” and “dominant discharge” are used interchangeably and have the same definition when addressing significance (shaping and maintaining morphology), but vary in methods used to calculate them. The literature contains references to a different method of calculating the “dominant” discharge. This method does not require separating flows into discrete class intervals because transport is determined for every day’s flow and may be superior because it has been shown that the modal value of an effective discharge transport histogram varies with the number of classes (USGS, 1983). Parker (1978), for example, used this method of calculating the dominant discharge for both the Middle Loup and Niobrara rivers, but his discussion makes it clear that he interprets its significance as being the channel-forming discharge. As noted previously, others determine the dominant discharge as the modal value of the transport histogram, so the terms “dominant” and “effective” discharge always have the same significance but methods of determining the values vary.

The study period (1985 to 2009) included years with wet, dry, and normal flows, as defined by USFWS (Anderson and Rodney, October 2006). The three calculated sediment transport indicators—total sediment transported, effective discharge, and dominant discharge—were calculated for current conditions. Using regime analysis, the three sediment transport indicators were compared both spatially and temporally, as discussed in Section 4.3.3, Spatial Analysis, and Section 4.3.4, Regime Analysis.

Using the USGS-based depth/velocity/width versus discharge rating curves, the channel characteristics were calculated for each of the following:

- Study period effective discharge
- Annual effective discharge
- Study period dominant discharge
- Annual dominant discharge
- Seasonal effective discharge
- Seasonal dominant discharge

The graphs for each gaged site are located in Attachment C and are discussed in Section 5, Results and Discussion.

Yang’s equation was applied to the daily synthesized flows at each ungaged site for calendar year 2009. As shown in the Second ISR, Appendix B, Hydrocycling Study Report, Section 4.2.3, the Platte River flows in 2009 classified it as a “normal” year using the wet, dry, and normal year criteria approved in the Revised Study Plan. Using the same class analysis described in Section 4.1.1, Literature Review, the sediment transport capacities for each flow rate were developed for the ungaged sites. These are shown in Attachment D.

Calculations of the capacity of the flows to transport total bed material sediment were compared to adjusted, indirect estimates of the sediment supply (yield). If the capacity for total bed material sediment transport for a given time period were equal to or less than the sediment yield, it would be concluded that the braided river is not supply limited and is currently in dynamic equilibrium. The term "dynamic equilibrium" means that there can be fluctuations about a mean value for variables but no long-term changes in the mean values (USACE, July 1990). If the capacity for total bed material sediment transport for a given time period were to exceed the sediment yield, it would be concluded that the braided river may be supply limited and possibly degrading. In the latter event, Project operations relative to sediment removal could be impacting morphology. The resolution of the severity of any impacts is dependent on proximity of the current morphology (braided river) to thresholds of morphologic change, which can be established by regime methods.

USBR (April 2004) tested three widely adopted regime diagrams (Chang, March 1985; Leopold and Wolman, 1957; Lane, 1957), showing that all three are applicable to assessing impacts of alternative conditions in the Platte River. These are discussed in greater detail in Section 5, Results and Discussion. USBR concludes that "Regime theory does provide a guide to the changes in channel geometry that can be expected with changes in the channel-forming discharge, bed slope, and bed material grain size." USBR evaluated aerial photos from 1939 to 1998, which supported its conclusions developed using regime theory. USBR's assessment of changes in plan form since 1900 show that the river has changed but is still well-seated within the regime zones for stable, braided rivers (USBR, April 2004).

4.3.3 Spatial Analysis

The methodology for assessing the morphologies of the Loup River bypass reach and the lower Platte River included a spatial analysis. The spatial analysis was conducted to assess whether the sediment transport indicators and the regime analysis suggest that the morphological indicators from upstream to downstream at the gaged and ungaged sites was consistent with natural river processes. For the gaged sites, transport capacities were determined over the entire 25-year study period (1985 to 2009), allowing average values to be determined and compared with the revised MRBC average annual sediment yields. Then the results for the gaged sites for 2009 were compared to the ungaged sites for 2009.

Following publication of the Sedimentation Addendum in the Second ISR on February 11, 2011, FERC issued its "Determination on Requests for Modifications to the Loup River Hydropower Project Study Plan" on June 10, 2011. In that document, FERC requested that the District supplement the spatial analysis previously presented by doing the following:

> …for each of the seven USGS sites and five ungaged sites, we recommend that Loup Power District relate effective discharge to mean velocity, flow width, flow depth, and flow area. Using each of the four

> channel geomorphologic characteristics (mean velocity, flow width, flow depth and flow area) developed at each of the seven gaged sites and five ungaged sites, Loup Power District should make longitudinal (spatial) comparisons of all sites on the Loup and Lower Platte rivers starting at the most upstream site on each river, and progressing downstream. The Loup River analysis should include comparisons of ungaged site 1, ungaged site 2, USGS gage no. 06793000 (Genoa gage), and USGS gage no. 06794500 (Columbus gage). [In other words, ungaged site 1 should be compared to ungaged site 2, ungaged site 2 should be compared to the Genoa gage, and so on and so forth progressing downstream.] Similarly, the Lower Platte river analysis should include comparisons of USGS gage no. 06774000 (Duncan gage), ungaged site 3, ungaged site 4, USGS gage no. 06796000 (North Bend gage), ungaged site 5, USGS gage no. 06796500 (Leshara gage), USGS gage no. 06801000 (Ashland gage) and USGS gage no. 06805500 (Louisville gage) progressing upstream to downstream. To facilitate the spatial analysis, we recommend that Loup Power District present the information graphically similar to figure 5-2 of the Sedimentation Addendum, dated February 11, 2011 (filed on February 14, 2011).

The spatial analysis was conducted for the geomorphologic characteristics of mean velocity, flow width, flow depth, and flow area, as directed by FERC in its June 10, 2011, determination. The 2003 to 2009 mean velocity, flow width, flow depth, and flow area associated with the effective and dominant discharges were compared for all sites from upstream to downstream. The comparisons were made for both the Loup River bypass reach and the Platte River. The results of the original and supplemental spatial analyses are presented in Section 5.2.3.

4.3.4 Regime Analysis

The final test of whether either the Loup or Platte River or any location within either river is transitioning to another form can best be accomplished through regime analysis. The 2009 data for the ungaged sites were plotted on Chang's and Lane's regime morphology graphs (see Figures 5-15 and 5-17). Because of the subjectivity of determining effective discharges from the sediment transport histograms, especially for seasonal or single-year data, the 2009 dominant discharges at the ungaged sites were input along the abscissa of each graph.

Objective 2: To characterize stream morphology in the Loup River bypass reach and in the lower Platte River by reviewing existing data and literature on channel aggradation/degradation and cross sectional changes over time.

4.4 Task 4: Stream Channel Morphology

Stream morphology is a function of a number of physical water- and sediment-related processes and environmental conditions, including the following:

- Stream habit (for example, meandering or braided)
- Daily flows and instantaneous peak flow rates
- Watershed sediment yields
- Composition and erodibility of bed and banks (for example, sand, clay, and bedrock)
- Vegetation and rate of plant growth
- Availability of sediment to be transported
- Size and composition of bed material sediment
- Composition of wash load
- Rate of removal and re-deposition of sediment on floodplain, banks, bars, and bed
- Regional aggradation or degradation due to subsidence or uplift

Stream morphology is the result of water flowing through erodible material. The resulting channel geometry is three-dimensional, where the cross section, planform, and longitudinal profile properties are interrelated and make up the "morphology" (Richards, 1982). In a braided sand-bed stream like the Platte River with an unchanging longitudinal profile (USBR, April 2004), the topological aspects (for example, braids, bars, islands, areas of sand above the water level, and number or locations of bars) of the braided cross section and planform comprise the morphology, which is used as habitat. Maintenance of a braided river's morphology is equivalent to maintenance of its habitat.

The methodology for evaluating the current stream channel morphology at the gaged and ungaged sites included the following:

- Specific gage analysis and associated Kendall tau analysis
- Conclusions from studies by others
- Supplemental studies of changes over time
- Annual trends in flows and effective and dominant discharge
- Seasonal trends in flows and effective and dominant discharge

- Annual trends in channel hydraulic geometry
- Seasonal trends in channel hydraulic geometry
- Regime implications of trends

If the literature review, sediment transport calculations, specific gage analysis, and regime analysis indicate that short-term fluctuations in the morphology of the Loup River bypass reach and lower Platte River are not transitioning to another form, it would be further affirmed that the rivers are currently in dynamic equilibrium. If the literature review and calculations indicate that the Loup River bypass reach and lower Platte River are transitioning to another form and either aggrading or degrading, it would be concluded that the rivers are currently not in dynamic equilibrium.

A specific gage analysis was conducted for the USGS gages on the Platte River near Duncan, at North Bend, near Ashland, and at Louisville, and the results were presented in the PAD (Loup Power District, October 16, 2008). FERC, in its December 20, 2010, "Determination on Requests for Modifications to the Loup River Hydropower Project Study Plan," requested that the specific gage analysis be updated with current data (flows through 2010) and that the USGS gage on the Loup River near Genoa be added to the analysis.

Therefore, a specific gage analysis was conducted using the Loup River gage near Genoa and the Platte River gages near Duncan, at North Bend, near Ashland, and at Louisville. Mean daily discharge and corresponding stage records for each gage were obtained from the USGS website at http://waterdata.usgs.gov/nwis/. The period of available discharge and stage data for each gage is listed in Table 4-6. The mean daily discharge versus the stage was graphed for each year for each gage. A trend line was established by determining a best fit using a power equation ($\text{Stage} = a^*\text{Flow}^b$). In a similar manner to the depth-discharge graphs used for the sediment discharge rating curves, as discussed in Section 4.3.1, some of the stage-discharge graphs were broken into two parts; for a single year, there is one trend line for low flows and one for high flows. Specific rating curves were generated for each gage based on the stage versus discharge curves. Specific rating curves for all gages for a given discharge were also graphed.

Table 4-6. Period of Available Discharge and Stage Data

USGS Gage Number	Gage Name and Location	Period of Available Data
06793000	Loup River near Genoa, NE	1997 - 2010
06774000	Platte River near Duncan, NE	1997 - 2010
06796000	Platte River at North Bend, NE	1989 - 2010
06801000	Platte River near Ashland, NE	1995 - 2010
06805500	Platte River at Louisville, NE	1985 - 2010

FERC also requested that a Kendall tau test be applied to the specific gage analysis to assess trends in aggradation and degradation (FERC, December 20, 2010). Kendall's tau can be used to test for the presence of trends. As defined in Chen, Rus, and Stanton (1999), the trend is a monotonic change over time occurring as either an abrupt or gradual change in time-series data. Because the test is nonparametric, the test variables need not be normally distributed, and outliers or missing values present no computational or theoretical problem in application of the test.

For the application of Kendall tau on this specific gage analysis, if all gage height values increased with time, the tau coefficient would equal 1, and if all gage height values decreased with time, the tau coefficient would equal -1. If the number of increasing gage heights and decreasing gage heights are equal, the tau coefficient will equal 0. By this definition, the Kendall tau is a measure of the correlation between the direction of change in the gage height values and time, while the sign of tau indicates whether the gage height data are increasing or decreasing with time.

A p-value is the probability of observing a tau value for the data at least as extreme as a critical value from a normal distribution of the computed tau; the smaller the p-value, the greater confidence in that trend. Similar to the methodology used in Chen, Rus, and Stanton (1999), a 99 percent confidence level (level of significance, $p = 0.01$) was used to identify the specific gage trends, at different flow rates, as being either statistically significant or not significant. For each test, at each site, the probability (p-value) representing the attained significance level also is presented. A trend was considered to be significant when tau differed from zero at the 99 percent confidence level (p is equal to or less than 0.01). SPSS Statistics, an IBM software product that is a comprehensive system for analyzing data, was used to calculate both the Kendall tau and the p statistic.

The characteristic channel morphology associated with the effective discharges was assessed according to the methodology described by Leopold and Maddock (1953) for the Loup and Platte rivers and by Karlinger et al. (1983) for the Platte River. Channel characteristics include channel cross-sectional area changes, width changes, channel aggradation/degradation changes, and the rate at which these changes, if any, occur over time. Leopold and Maddock (1953) developed general stream morphology relationships between effective discharge and channel characteristics, and Karlinger et al. (1983) calibrated and applied Parker's (1978) regime equations (similar to Leopold and Maddock's) to the central Platte River.

By definition, a braided river has a surplus of sediment supplies that exceeds its ability to transport the sediment and, as a result, could be (and generally is) gradually aggrading; however, the river would be in dynamic equilibrium even for a relatively wide range of effective discharges, slopes, and bed material sizes if the flows are maintaining its braided morphology. A conclusion that a river is not in dynamic equilibrium would occur only if the river's sedimentation processes have arrived at a threshold of change to a different morphology, such as meandering. Proximity to these thresholds can be assessed using qualitative and quantitative geomorphologic relationships, known as "regime" methods.

Finally, if the analysis of the current condition morphology indicates that the Loup River bypass reach and lower Platte River either are in dynamic equilibrium or are not supply limited based on the adjusted yields and sediment transport capacity calculations, then no alternatives relative to sediment augmentation would be evaluated. However, if it is determined that either the Loup River bypass reach or the lower Platte River is not in dynamic equilibrium or is sediment supply limited, then alternatives would be evaluated to determine if a change in Project operations would beneficially affect the braided river dynamic equilibrium.

Objective 3: To determine if a relationship can be detected between sediment transport parameters and interior least tern and piping plover nest counts (as provided by NGPC) and productivity measures.

4.5 Task 5: Interior Least Tern and Piping Plover Nesting and Sediment Transport Parameters

The District's Revised Study Plan included conducting a statistical analysis to test for a relationship between sediment transport parameters and interior least tern and piping plover nest counts. An initial statistical analysis was conducted at a course spatial scale based on rivers segments associated with the sediment transport and other hydrologic parameters.

In response to comments received on the ISR, the District conducted a supplemental statistical analysis at a finer spatial scale (by river mile), reduced the number of hydrologic variables for analysis, and used additional statistical methods.

4.5.1 Interior Least Tern and Piping Plover Data

The NGPC Nongame Bird Program's Nebraska Least Tern and Piping Plover database was used[4] to obtain the most current and comprehensive data available on the occurrences of these species in the state of Nebraska. The data was provided to the District in a raw database format that would allow the District to conduct statistical analyses without restriction. Data collection for the database was not based on a formal research design specific to this sedimentation study but occurred over a period of years to provide general information regarding interior least tern and piping plover populations. The database includes information on data location (for example, river segment and river mile), dates and year collected, number of adults observed, number of nests observed, number of eggs, and fate of the nest/chicks. Prior to the

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[4] The Nebraska Least Tern and Piping Plover database was used under a data use agreement signed on June 24, 2009.

use of these data, pertinent literature covering the species' biology and avian survey methods was reviewed to better understand the limitations of the data (Kirsch, 1996; Thompson et al., 1997; Haig, 1992; Bart, 2005; Bart and Earnst, 2002; Gregory et al., 2004).

The appropriate use of the species data was also discussed with the NGPC Nongame Bird Program Manager (NGPC, June 9, 2009). Based on the amount of available data for analysis, the adult population counts were determined to be the largest data set. However, because of the mobility of these species and because they also breed on non-riverine habitat adjacent to the Platte River, this number may not accurately reflect the value of the riverine habitat for nesting and breeding. Reproductive success, in the form of fledge ratio,[5] is a standard metric used to quantify interior least tern and piping plover reproduction and to estimate the success of a particular habitat for sustaining and/or growing a population. However, there is a limited amount of data from only a few years, and there are several problems with using these data as most of the data are based on observations and not on more rigorous methods, such as mark-recapture statistical analysis.

Due to the limitations of adult counts to reflect actual nesting on the Platte River and the scarcity of fledge ratio data, the sedimentation study incorporated the recommendations from NGPC, USFWS, and the Tern and Plover Conservation Partnership (TPCP). Interior least tern and piping plover nest count numbers were recommended as the best available data to use for a trend analysis to determine if there is a relationship between sediment transport indicators and interior least tern and piping plover nesting response. The measurement of nest presence is an effective gage of the relative population size and whether the habitat is actually being used by interior least terns and piping plovers (Parham, 2007). Nest count data do not provide information on successful breeding but rather provide an index of habitat availability.

For the initial statistical analysis, only nesting locations and nest counts for both interior least terns and piping plovers found within the confines of the lower Platte River from the confluence with the Loup River to the confluence with the Missouri River (River Mile [RM] 106 to RM 0) from 1983 through 2009 were used.[6] The initial analysis did not include interior least tern and piping plover data for off-river nesting locations, such as sand and gravel mine sandpits and lakeshore housing developments; however, off-river data was used for portions of the supplemental statistical analysis.

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[5] The reproductive success of the birds in a given year is often described in terms of fledge ratio, defined as the number of young that survive to fledging age (the age when they can fly) per adult pair. This is calculated by dividing the total number of fledglings by the total number of adult pairs surveyed for a certain area that year.

[6] Data from 2007 and 2009 were provided by NGPC at a later time under separate documents but were incorporated into the master database for the purposes of this analysis.

For this initial statistical analysis, the lower Platte River was divided into the following five segments to correspond with the gaged study sites listed in Table 3-1; the segment of the lower Platte River from the confluence with the Loup River to the Tailrace Return was not analyzed in this sedimentation study because the gage installed 5 miles downstream has no historical hydrologic data:

- Tailrace Return to North Bend
- North Bend to Leshara
- Leshara to Ashland
- Ashland to Louisville
- Louisville to confluence with Missouri River

Since 1987, NGPC has attempted to conduct an official survey annually in June to record locations of interior least tern and piping plover adults, nests, and/or established colonies and to provide an annual census population count for the lower Platte River from RM 106 to RM 0. Due to unknown constraints, not every river mile was surveyed every year. In addition, dependent on river flows and the presence of sandbars, occasionally, the June survey was postponed until July. For several years, additional surveys were done throughout the nesting season to gather population demography information.

In some instances, multiple nest counts may have been at the same site during a single breeding season. In those instances, nest count data used in this sedimentation study were refined to the highest nest count per colony location[7] during a single survey per year and then summed to provide a "cumulative highest nest count river mile per year." The data were further refined to look at the highest nest count per colony location in a single survey per river segment and then summed to provide a "cumulative highest nest count per river segment per year." This method does not account for all nests but does provide an estimate of the maximum number of nests present at the same time.

The interior least tern and piping plover data are continuing to evolve (NGPC, July 16, 2009). For some years, no data were recorded for particular segments of the river. There can be multiple reasons for data gaps, including lack of data or issues relative to the conversion of hard copy reports to electronic data. For records (a particular year for a particular segment) where no data were entered in the database and no comments associated with that record provide information as to the reason for

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[7] A "colony location," for the purposes of this sedimentation study, is defined as any location, denoted by river mile (for example, RM 12.5), where one or more interior least tern or piping plover nest has been recorded at that locale. Colony locations are not fixed and may change from year to year as river sandbars shift.

no recorded data, the segment was excluded from the analysis. The years that are not included in the analysis for the associated segment are shown in Table 4-7.

Table 4-7. Years Excluded from Analysis by River Segment

Lower Platte River Segment[1]	Years Excluded From Analysis
Tailrace Return to North Bend (RM 101.5 to RM 72.5)	1995, 1999
North Bend to Leshara (RM 72.5 to RM 48.5)	1995, 1996, 1999, 2000, 2004, and 2005
Leshara to Ashland (RM 48.5 to RM 27.7)	1995
Ashland to Louisville (RM 27.7 to RM 16.5)	1986, 1995
Louisville to confluence with Missouri River (RM 16.5 to RM 0)	1995

Note:

[1] The segment of the lower Platte River from the confluence with the Loup River to the Tailrace Return (RM 106 to RM 101.5) was not analyzed because the gage installed 5 miles downstream has no historical hydrologic data.

4.5.2 Statistical Analysis of Interior Least Tern and Piping Plover Data by Hydrologic River Segment

The following sediment transport indicators and hydrologic parameters were compared to the interior least tern and piping plover data using cumulative highest nest counts per river segment per year (in accordance with the approved study plan, the seasonal time frame is from May 1 through August 15):

- Annual effective discharge
- Annual dominant discharge
- Seasonal dominant discharge
- Annual cumulative sediment discharge
- Seasonal cumulative sediment discharge
- Annual cumulative flow
- Seasonal cumulative flow
- Annual peak mean daily flow
- Seasonal peak mean daily flow
- Annual flow width from effective discharge

- Annual flow width from dominant discharge
- Seasonal flow width from dominant discharge
- Annual percent diverted flow
- Seasonal percent diverted flow

In an effort to consider all potential combinations of nesting data upstream and downstream of a USGS gage used to establish sediment transport indicators in the vicinity of that gage, all nesting data for each river segment were compared to sediment transport indicators both upstream and downstream of the gage of each river segment. In addition, nesting data on river segments adjacent to a USGS gage location were combined and analyzed. A summary of the analysis performed for each reach is provided in Table 4-8.

Table 4-8. River Segments for Nest Count Correlation Analysis

USGS Gage Used for Sediment Transport Indicator Analysis	River Segment Nest Counts Used for Upstream of Gage	River Segment Nest Counts Used for Downstream of Gage	Combined River Segment Nest Counts for Upstream and Downstream of Gage
North Bend	Tailrace Return to North Bend	North Bend to Leshara	Tailrace Return to Leshara
Leshara	North Bend to Leshara	Leshara to Ashland	North Bend to Ashland
Ashland	Leshara to Ashland	Ashland to Louisville	Leshara to Louisville
Louisville	Ashland to Louisville	Louisville to Missouri River Confluence	Ashland to Missouri River Confluence

All of the comparisons were performed for no lag as well as for 1- and 2- year lags. The purpose of comparing sediment transport indicators to nest counts on a 1- and 2-year lag was to see if what occurred either annually or seasonally in a given year had a relationship with bird nest counts in 1 or 2 years following. These scenarios are described as follows:

- No lag – Sediment transport indicator in year X compared to nest counts in year X
- 1-year lag – Sediment transport indicator in year X compared to nest counts in year X+1
- 2-year lag – Sediment transport indicator in year X compared to nest counts in year X+2

For each of the data sets defined above, a linear regression analysis was performed. A graph was developed for each analysis, and a coefficient of determination (R^2) was generated.

4.5.3 Statistical Analysis of Interior Least Tern Data by River Mile

The initial statistical analysis comparing interior least tern and piping plover nest counts to sediment transport and hydrologic parameters was conducted at a course spatial scale using basic linear regression. As discussed above, the data were analyzed according to river segments associated with the sediment transport parameters available at four USGS gage sites located along the lower Platte River. Based on this broad-scale spatial analysis, and as discussed in Section 5.4.2, no statistically significant relationships were identified.

Based on comments submitted by NGPC (October 25, 2010) following presentation of the results of the course-spatial-scale statistical analysis in the ISR, a supplemental statistical analysis was conducted to refine the spatial scale and focus the analysis on potential Project effects by eliminating potentially confounding externalities, such as downstream inflows from other major tributaries, agricultural runoff, and recreation influences.

Hydrologic Data Correlation Analysis

The first step of the supplemental statistical analysis was to eliminate collinear hydrologic variables and reduce the number of variables to be evaluated. The District conducted a collinearity analysis, a normality assessment, and a factor analysis on the hydrologic data to simplify the number of variables to be included in the supplemental statistical analysis.

The collinearity analysis resulted in the following variables being retained for additional analysis:

- Wetted width (Width)
- Peak mean daily flow (PMDF)
- Annual percent diverted flow (APDF)
- Annual dominant discharge (ADD)
- Annual effective discharge (AED)

A factor analysis was conducted for these variables and indicated that PMDF, ADD, and AED loaded very closely on the same factor; therefore, only one of these variables (PMDF) was used in the supplemental statistical analysis.

The remaining variables (Width and APDF) would have limited usefulness in the supplemental statistical analysis because data for these variables are limited to three river miles where this data was developed for other studies.

Agency Coordination

A meeting was held between NGPC and District representatives from HDR Engineering on March 24, 2011, with a representative of TPCP also in attendance. The purpose of the meeting was to further discuss NGPC's comments and outline a methodology to analyze the data in a more refined way.

The results of the collinearity analysis, normality assessment, and factor analysis were presented to NGPC and TPCP staff, and there was general agreement in the reduction of the number of hydrologic variables.

The use of the interior least tern and piping plover nesting data was discussed with NGPC and TPCP to identify limitations of the data as well as possible ways to improve the statistical usefulness of the data. The following general limitations of the data were identified:

- Data collection methods have continued to evolve over the 24-year time period in which interior least tern and piping plover occurrence and nesting data have been collected. As a result, there are inconsistencies in the data collection methods, timing, and location of surveys that are recorded in the database.
- The population of interior least terns and piping plovers that visit Nebraska is part of a larger population that makes nesting site selection on a much larger scale than the lower Platte River.
- Interior least terns nest in colonies; therefore, groupings of nests are not necessarily indicative of repeated selection of a site by multiple birds.
- The database information was not collected specifically for this sedimentation study using a a formal research design.

Regardless of the limitations, the Nongame Bird Program's data is the best available.

Through discussion with NGPC and TPCP, it was determined that the following conditions would be used for the supplemental statistical analysis:

- Interior least tern data should be used for any studies carried forward because there is not enough piping plover data to draw meaningful conclusions.
- Presence/absence of interior least tern nests should be used as the categorical dependent variable.
- A log transformation of the nest count data should be used to normalize the data.
- The interior least tern data should be segmented by river mile rather than by USGS gage, and the hydrologic data should be similarly segmented.

- Analysis should be limited to the area immediately downstream of the Project Tailrace Return in order to limit the confounding effects of downstream inflows from major tributaries and other external factors.
- Logistic regression, analysis of variance (ANOVA), and possibly a repeated measures and mixed model approach should be used to determine statistical relationships between interior least tern nest counts and independent hydrologic variables.

Study Area

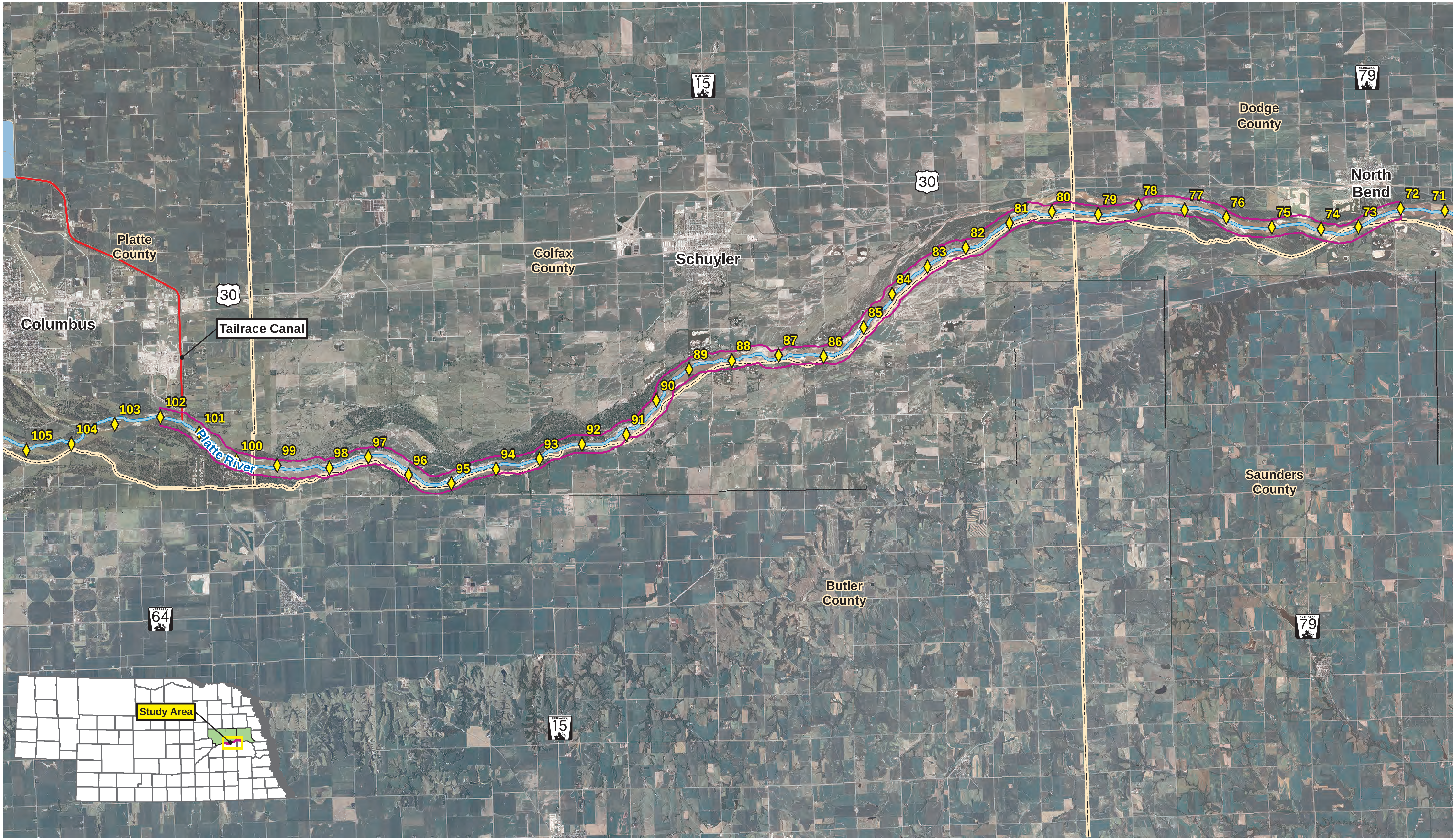
The Tailrace Return is located approximately at RM 101.5 on the lower Platte River. Based on the availability of hydrologic and nest count data, it was determined that the supplemental statistical analysis would be performed for the area from RM 102 (just upstream of the Tailrace Return) to RM 72 (just upstream of the USGS gage at North Bend). Figure 4-15 shows the area identified for supplemental statistical analysis in relation to river miles.

Analysis of Nest Count Data

Nest count data were available from the Nebraska Least Tern and Piping Plover database for the geographic study area from 1987 through 2010. Unless otherwise noted, the data used for this supplemental statistical analysis included only nesting locations and counts found within the confines of the lower Platte River and would be best described as “on-river.” The analysis included data for off-river locations only when specifically noted.

The available nest count data were collected between May and August each year. As noted in Section 4.5.1, Interior Least Tern and Piping Plover Data, the number of data collection visits per river mile and per year was extremely variable, such that a given river mile might have been sampled twice during the 24-year sampling period, while an adjacent river mile might have been sampled 10 or more times, with no relationship between sampling years for the two river miles. The variability in numbers of samples per river mile and the spread of years between samples within and between river miles constrained the data analysis.

The number of data collection visits per year was evaluated in an exploratory manner to assess possible correlations with total nest counts per river mile. A significant correlation in this context would indicate that count data were an artifact of sampling techniques and may not clearly portray a potential association with hydrologic factors.



Aerial Imagery: 2010 National Agricultural Inventory Project (NAIP)
Streams/Lakes: National Hydrography Dataset (NHD)
Platte River Miles: USFWS

Legend

- ◆ Platte River Mile
- Platte River
- Loup Power Canal
- Study Area
- County Line

Loup Power District Hydro Project

Supplemental Statistics Study Area

Loup River Hydroelectric Project
FERC Project No. 1256
Study 1.0 Sedimentation

August 26, 2011

FIGURE
4-15

Z:\Projects\Loup_Power_District\37104_LPD_FERC_Relicensing\map_docs\mxd\Supplemental_Statistics_Study_Area.mxd

Data used for analysis consisted of interior least tern nest counts, PMDF, APDF to the Loup Power Canal, and Width on the lower Platte River. These variables were grouped by calendar year and river mile, which were also in some cases treated as fixed factors. Nest count data were analyzed in three ways:

- As a binomial response variable
- As a normal response variable
- As a loglinear response variable

In the normal model, distributions are assumed to be normally distributed, and the independent and dependent variables are linked by the sample means. The normal linear probability model with independent variable x takes the general form:

$$Y' = \alpha + \beta x$$

where Y' is a predicted value of the dependent variable, α is the regression intercept and β is the ordinary least squares regression coefficient.

The logistic model assumes a binomial distribution (in this case presence or absence of nests) and links the independent and dependent variable via the exponent of the log mean, or logit. The logistic linear probability model with independent variable x takes the general form (Agresti, 2002):

$$\Pi (x) = \alpha + \beta x$$

where Π is the expected population probability of a specified value of x, α is the regression intercept, and β is the logistic regression coefficient. The logistic model is flexible, but because it assumes a binomial distribution, it expresses a limited range of values for Π (0-1) and truncates the sample variance.

The loglinear model assumes a Poisson distribution, which is suited to skewed count data, and links the independent and dependent variables via the log mean. The loglinear probability model with independent variable x takes the general form (Agresti, 2002):

$$\mathrm{Log}\ \mu = \alpha + \beta x$$

where Log μ is the expected population log mean of a particular sample, α is the regression intercept, and β is the loglinear regression coefficient. Because the loglinear model relies on the log means of positive counts rather than presence or absence scores, it preserves the range of information available in the original data. However, the model carries the assumption that sample means and variances are equal, which is rarely the case. This is a serious problem only if sample variances significantly exceed sample means.

In the logistic model, summed nest counts per river mile were coded for nest presence or absence, such that if the number of nests is one or greater, then the nest code is set to one, otherwise the nest code is set to zero. The binomial condition conformed to a logistic model in which coded nest counts were a random component, the hydrologic data were a systemic component, and the link function between the random and system components was the logit or log odds of a response of 1 in a logistic regression equation (Agresti, 2002). In the normal condition, summed nest counts, which were extremely right-skewed in raw form, were converted to natural logarithms to produce a more symmetric distribution (Helsel and Hirsch, 2002). The same operation was applied to PMDF data. In this condition, log-converted nest counts were the random component; hydrologic data, converted as necessary to ensure normality, were the systemic component; and the means and variances of the two components were the link function. Calendar year and river mile were ranked 1 through n. Results were equivalent whether using raw scores or ranked scores; however, the ranked scores were more easily interpreted.

All analyses were conducted using SPSS Statistics, an IBM software product that is a comprehensive system for analyzing data. Predictor variables, including ranked calendar year, were entered singly and in various combinations. The relationship between the independent variables and response variable in the logistic model was assessed by:

- Regression coefficient associated with each predictor
- Significance level of the associated Wald Chi-square score
- Associated logits, including the 95 percent confidence intervals
- Each model's overall correct classification rate in relation to a priori frequency of positive responses

Ordinary least squares multiple regression was conducted using SPSS Statistics. Log-converted nest counts per river mile was the dependent variable. As with the logistic model, various combinations of predictor variables were entered, stepwise or simultaneously, into regression models to determine the most powerful and parsimonious combination of predictors. Compliance with various assumptions underlying the use of a normal model was checked via observed versus expected residuals quantile plots (Q-Q plots), tests of standardized regression residuals distribution against the standard normal distribution, collinearity diagnostics, and assessment of the variance inflation factor. Relationships between nest counts and predictor variables were assessed by:

- Standardized and non-standardized regression coefficients including 95 percent confidence intervals
- Standard errors of the regression coefficients
- The significance levels of t scores associated with each predictor
- The proportion of variance in nest counts that was captured by the independent variable or variables

Loglinear analysis was also applied to a broader set of data that included sandpit nest counts and nest counts for RM 71 to RM 0. These analyses focused primarily on nest count data partitioned by general location and sampling. Because of the variability and confounding effectsof downstream inflows from major tributaries and other external factors, analysis of hydrologic factors was not attempted for off-river nesting locations or for river miles below 72.

Although repeated measures and mixed model analysis was suggested by NGPC, the consistency of the data was not sufficient to conduct these tests. Due to the temporal and spatial fragmentation of count data and the concomitant variability in sample sizes, both repeated measures and mixed analytic designs were unworkable.

Objective 4: To determine if sediment transport is a limiting factor for pallid sturgeon habitat in the lower Platte River below the Elkhorn River.

4.6 Task 6: Pallid Sturgeon Habitat

The sediment transport data were reviewed to determine if the Project is affecting morphology in the lower Platte River. In accordance with the District's Revised Study Plan and FERC's Study Plan Determination, if it is determined that the Project does not affect morphology in this reach, or that the system is in dynamic equilibrium, it would be inferred that the Project does not affect pallid sturgeon habitat parameters related to sediment transport and that no further analysis is warranted. Furthermore, findings from an ongoing 5-year Shovelnose Sturgeon Population Dynamics Study within the Platte River would be assessed to determine if existing conditions in the lower Platte River provide appropriate pallid sturgeon habitat that supports the growth and development of these fish.

If the analysis shows that the Project is affecting morphology, the magnitude of Project effects would be determined using effective discharge and other sediment transport calculations, as detailed in Sections 4.2 through 4.4. Additionally, the existing condition with regard to sediment transport and braided river morphology in the lower Platte River would be compared to habitat characteristics of other rivers used by the pallid sturgeon to determine if changes in Project operations relative to sediment transport could affect pallid sturgeon use of the lower Platte River.

Specifically, information on pallid sturgeon use and corresponding habitat characteristics (flow, sediment transport, and morphology) exists for the upper Missouri River and the Yellowstone River. This information was used to perform a qualitative assessment of habitat characteristics. These habitat characteristics were compared to those of the lower Platte River to determine if there is a differentiating factor between the upper Missouri River and the Yellowstone River habitats and the characteristics of the lower Platte River. If a differentiating factor is determined to be a braided river morphology, then Project effects on this morphology would be reviewed in context with the results of Task 3, Effective Discharge and Other Sediment Transport Calculations, and Task 4, Stream Channel Morphology, to determine if a change in Project operations could materially affect braided river morphology in the lower Platte River.

5. RESULTS AND DISCUSSION

The results of the sedimentation study are summarized below, and a full discussion of the analyses related to each study objective follows. The discussion provides representative tabular and graphical data that support this study's conclusions. A complete presentation of these data is included in Attachments A through G.

5.1 Summary of Results

The body of literature cited and the supplemental analyses at the gaged and ungaged sites demonstrate that the Loup River bypass reach and the lower Platte River are in regime and are seated well within regime zones considered as braided streams. Further, the analyses and other supporting literature cited clearly indicate that both the Loup River bypass reach and the lower Platte River at all locations studied are clearly in regime, not supply limited, and not aggrading or degrading, with no indications of channel geometry characteristic (width and depth) changes over time.

Objective 1: To characterize sediment transport in the Loup River bypass reach and in the lower Platte River through effective discharge and other sediment transport calculations.

This sedimentation study, including the collection and analysis of data at both gaged and ungaged sites, supports the conclusion that the sediment availability and yield throughout the study area by far exceed the capacity of the flow to transport sediment as well as greatly exceed the actual measured amounts of suspended sediment being transported.

USACE came to the same conclusion. The supply of sediment throughout the Platte River Basin, including the Loup River Basin, is "virtually unlimited" (USACE, July 1990) and is significantly greater than both the Loup and Platte rivers' capacities to move the sediment. This means that the Loup River bypass reach and the lower Platte River can be considered to be in an equilibrium condition, with supplies in excess of transport capacity with no evidence of degradation in the channel. USACE noted that an excess of supply over transport capacity exists, as manifested by sand and gravel deposits along banks and in the stream as sand bars (USACE, July 1990).

As noted in the methodology described in Section 4.3.2, Sediment Transport Indicators, if the capacity for total bed material sediment transport for a given time period were equal to or less than the sediment yield, it would be concluded that the braided river is not supply limited and is currently in dynamic equilibrium. The results of the collection and analysis of data at both gaged and ungaged sites show that both the Loup River bypass reach and the lower Platte River at all locations studied are clearly not supply limited.

Effective discharge and other sediment transport and hydraulic geometry calculations, combined with river regime theory, show that the channel geometries are “in regime” with the long-term flows shaping them. The current channel hydraulic geometries match the width, depth, and velocity calculations for flow rates matching the effective and dominant discharge rates. Nothing appears to be constraining either the Loup or the Platte River from maintaining the braided river hydraulic geometry associated with the effective discharges.

The cross-section data at the ungaged sites, described in Section 4.1.3, reveal that the braided channel geometry of both rivers is not only widely diverse over a few hundred feet of length, but highly subject to dramatic changes over a few months’ time. The cross sections both upstream and downstream of the Tailrace Return exhibited similar cross-section changes. Any measured or calculated adjustment in geometry cannot be readily attributed to any other cause than the natural dynamics of a braided river.

The spatial analysis shows that the morphologies and subsequent habitat, as measured by comparing the channel geomorphologic characteristics with effective and dominant discharge, is consistent with natural river processes. No identifiable Project impacts on the morphology occur at any individual study sites or between any sets of two or more adjacent sites.

The methodology described in Section 4.4, Task 4: Stream Channel Morphology, established that if the literature review, sediment transport calculations, specific gage analysis, and regime analysis indicate that short-term fluctuations in the morphology of the Loup River bypass reach and lower Platte River are not transitioning to another form, it would be further affirmed that the rivers are currently in dynamic equilibrium. The combinations of slopes, sediment sizes, and effective discharges at all of the gaged and ungaged sites result in all locations being well within braided river morphologies, with none being near any thresholds of transitioning to another morphology.

Finally, the methodology established that if the analysis of the current condition morphology indicates that the Loup River bypass reach and lower Platte River are in dynamic equilibrium or are not supply limited based on the adjusted yields and sediment transport capacity calculations, then no alternatives relative to sediment augmentation would be evaluated.

Objective 2: To characterize stream morphology in the Loup River bypass reach and in the lower Platte River by reviewing existing data and literature on channel aggradation/degradation and cross sectional changes over time.

Existing literature, including Platte River studies by USACE, USBR, and USGS; calculations of effective discharges; regime analysis; literature on the channels' profiles; and physical observations indicate that the Loup River bypass reach and the lower Platte River are not experiencing aggradation or degradation. Instead, these analyses, particularly the bed gradation studies by others and the effective discharge and regime analysis, clearly indicate that both the Loup and lower Platte rivers are well within parameters establishing them as dynamically stable, non-aggrading and non-degrading, braided rivers.

Objective 3: To determine if a relationship can be detected between sediment transport parameters and interior least tern and piping plover nest counts (as provided by the Nebraska Game and Parks Commission [NGPC]) and productivity measures.

Revised 09/06/11

The initial statistical analysis of interior least tern and piping plover data by hydrologic river segment yielded results of no significant relationship between interior least tern and piping plover nest counts and sediment transport indicators. No evidence from this analysis was discovered that would suggest that a relationship exists between nest counts and sediment transport indicators or hydrologic parameters.

Revised 09/06/11

Supplemental statistical analysis of interior least tern data by river mile for RM 102 to RM 72 used binary logistic regression, multiple linear regression, nonparametric methods, and one-way ANOVA to evaluate if the hydrologic variables could explain nest count numbers and may be an influencing factor in nesting of interior least terns on the lower Platte River. The results of these analyses are as follows:

- Nest counts were weakly associated with number of data collection visits per year, but strongly associated with interior least tern adult counts, which were also weakly associated with number of data collection visits.
- No association was detected between summed nest counts and river mile, which indicates that variability in nest counts is not associated with proximity to the Tailrace Return.
- A period of relatively high nest counts from 1987 to 1995 was followed by a period of lower but also static nest counts from 1995 to 2008 between RM 102 and RM 72; this dichotomy is not associated with Project operations.
- Binary logistic regression analysis failed to detect a measurable relationship between presence or absence of interior least tern nests and ranked calendar year, river mile, peak mean daily flow, percent diverted flow, or any combination of these variables.

- Nonparametric correlation studies suggested annual percent diverted flow as a weak but statistically significant predictor of nest counts summed by river mile. This relationship was demonstrated to be spurious following more thorough examination of results of multiple linear regression analyses.
- One-way ANOVA determined that changes in peak mean daily flow between years in relation to nest counts is statistically significant, providing evidence in support of the theory that high flows followed by low flows may be beneficial for interior least tern nesting. However, effect of flow on nest frequency is difficult to gauge from the current data because of extreme variability in the frequency and locations of annual nest counts.
- One-way ANOVA also determined that changes in flow between river miles is not statistically significant in relation to nest counts.

Objective 4: To determine if sediment transport is a limiting factor for pallid sturgeon habitat in the lower Platte River below the Elkhorn River.

The findings of this sedimentation study determined that the lower Platte River geomorphology and corresponding riverine habitat are in dynamic equilibrium. When these findings are compared to the numbers of shovelnose and pallid sturgeon collected during ongoing capture efforts, it can be inferred that current Project operations relative to sediment removal from Loup River inflows at the Headworks are not acting to limit sturgeon habitat or the success of these species in the lower Platte River.

5.2 Objective 1 – To characterize sediment transport in the Loup River bypass reach and in the lower Platte River through effective discharge and other sediment transport calculations.

The quantity and character of flow and sediment transported along the Platte River have significantly changed during the 20th Century in response to water resource development, droughts, and floods. These changes in flow and sediment transport have a dynamic effect on the river channel width and depth, and on the amount of riparian vegetation present (Lyons and Randle, 1988; Karlinger et al., 1983).

USACE (July 1990) concluded that “the [Platte] river within [all] study reaches is in a state of quasi-equilibrium.” The definition adopted by USACE was that a river is in regime “when a balance exists between all of the variables that affect it, and there is no net change in the river conditions,” but adds that “regime [is] a state of quasi-equilibrium in which there are fluctuations about a mean value for each of the variables, but there are no long-term changes in mean values.” USACE adds, “It is a good indication that a river reach is in regime when there is no aggradation, degradation, or change in channel pattern” (July 1990).

5.2.1 Sediment Budget

Various sources provided the means to update sediment yield estimates completed by MRBC (September 1975). Information from these sources was used to revise the yield portion of the sediment budget as appropriate.

Next, the results of the updated MRBC yield estimates in the sediment budget were compared to the total sediment transport capacity calculations to assist in determining whether the reach is flow limited or supply limited for each flow period or alternative analyzed.

Yang's method (Yang and Stall, May 1976) was used to determine daily estimates of the total sediment transport capacity at each of the gaged and ungaged sites, the results of which are presented in Section 5.2.2, Effective Discharge and Other Sediment Transport Calculations. Yang had previously applied his equations to the Middle Loup River and concluded that "[o]nly the unit stream power equation and the modified Einstein equation can provide good estimates of the total sediment discharge in the Middle Loup River" (Yang and Stall, May 1976). With this and other endorsements of this method's applicability, and using USGS velocity and depth data to create best-fit hydraulic geometry equations, Yang's equation for total transport capacity was applied to the daily flows in this sedimentation study to produce estimates of daily and total bed material transport.

Although it is not recommended that indirect estimates of yield like those employed by MRBC be used to assess whether the river is aggrading or degrading, the estimates are useful but not fully definitive in assessing the question of whether the river is flow versus supply limited.

In order to use the yields for this purpose (flow versus supply limited), adjusted estimates of sediment yields for the post-MRBC report period were needed. Rather than repeating the process used by MRBC of determining present-day net yields by evaluating sheet, rill, gully, and stream bank erosion, adjusted sediment yields were calculated for the Loup River and its tributaries downstream of the Project's Diversion Weir based on documented reductions in dredged material from the Settling Basin in accordance with FERC's Study Plan Determination.

Dredging Records

The District began collecting data on dredged materials from the Project in 1937. Incoming sediment is dredged from the Loup Power Canal on a daily basis. Materials removed from the canal are stockpiled on both banks and differences in repeated bathymetric surveys are used to estimate the amounts dredged.

Figure 5-1 shows the amount of sediment dredged from the Settling Basin annually from 1937 to 2009. This graph is the same as shown in Figure 4-5, with the exception that the vertical scale is in tons per year instead of cubic yards. The assumption was made that the dredged sediment would have a unit weight of 120 pounds per cubic foot.

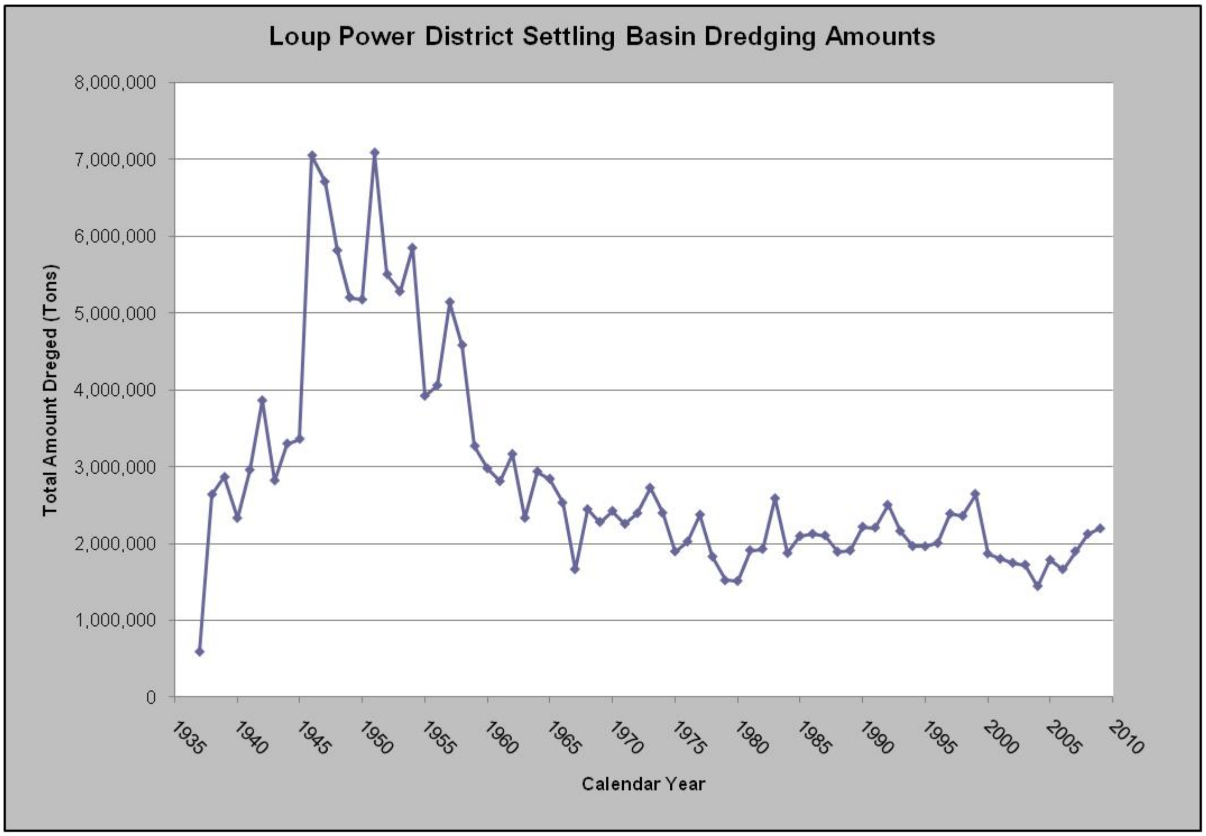


Figure 5-1. Loup Power District Annual Settling Basin Dredging Amounts

The graph reveals that there was a substantial reduction in dredging after about 1974. The earlier record from 1937 to around 1968 shows a steep increase followed by a similarly steep reduction in dredging, with relatively constant dredging between 1968 and 1974, followed by another drop to the horizontal trend line around 1.3 million tons per year since 1975. If these are considered representative of sediment supplies (yields), the river may not have been in equilibrium until around 1975, unless the large pre-1974 fluctuations can be explained by climatic or other influences.

To adjust the MRBC yields (described under Yield Adjustments, below), the ratio of reduction in dredged amounts at the Settling Basin was considered to be representative of the reductions in yield elsewhere in the Loup River Basin. The average dredged amount for 1975 to 2009 was 2.00 million tons per year. The average dredged amount for 1940 to 1974 was 3.75 million tons per year. This gives a ratio of yield reduction of 0.534, which was the basis for adjusting the MRBC yields, as shown in Table 5-1.

The annual range from 1940 to 1974 was from 1.66 to 7.09 million tons per year. An unknown physical process had to be involved during those years because the dredged amounts quickly rose and then fell over several years, reaching an apparent “equilibrium” level around 1975.

Even though the average of fluctuations between 1940 and 1974 were used in determining the ratio for making yield adjustments, the variability is not well represented by an average value. The adjustments in MRBC yields were based on using the 0.534 ratio of average dredging values from 1940 to 1974 in comparison to 1975 to 2009, so it should be recognized that the ratio has a moderate degree of uncertainty due to the high variability in dredged amounts before 1975. However, the conclusion regarding the hypothesis being tested—that is, whether the system is flow or supply limited—would not be likely to change under any alternative assessments of the earlier, highly fluctuating dredging records.

Yield Adjustments

The MRBC estimates from the Diversion Weir downstream to Louisville were intended to be adjusted based on the ratio of pre- and post 1970 dredging. Rather than dividing the data at 1970 as suggested, 1974 was chosen for the reasons provided earlier.

Once the dredging records were used to adjust MRBC estimates of yield from the Loup River basin, and by accepting MRBC’s assumptions of how much of the sediment passing down the Loup Power Canal reaches the Platte River, an adjustment could be made of all MRBC yields by “parlaying” the 0.534 adjustment downstream throughout the lower Platte River. The calculations for this are shown in Table 5-1.

To estimate the average annual yields at the ungaged sites, the adjusted MRBC average annual yields at the gaged sites, shown in Table 5-1, were “parlayed” to the ungaged sites as described above for the gaged sites.

Table 5-1. MRBC Yields with Adjustments Based on District Dredging Records

Watershed or Reach Name	Sediment Yield	
	MRBC Accumulative Total (tons/yr)	New Study Total (tons/yr)
Subbasin total above Diversion Weir (Site 1)	7,825,100	4,180,000
Sediment removed from Settling Basin	1,900,000	2,004,800
Sediment passing down Loup Power Canal	700,000	700,000
South Sand Management Area	NA	560,000
Subbasin total below Diversion Weir near Genoa (Site 2)	5,225,100	2,030,000
Loup Watershed below Genoa	1,860,300	993,500
Sediment yield at Columbus	6,970,000	2,960,000
Tailrace Return + Loup bottom	2,210,300	1,343,500
Loup Subbasin yield to Platte River at Columbus	7,435,400	3,373,500
Upper Platte Subbasin total to Platte River at Columbus	1,865,400	1,870,000
Platte River Upstream of the Tailrace Return (Site 3)	NA	4,900,000
Yield of Upper Platte and Loup Subbasins to lower Platte	9,300,800	5,243,500
Platte River Downstream of the Tailrace Return (Site 4)	NA	5,250,000
Subbasins at Columbus		
Yield to Platte (North Bend and Site 5)	9,885,900	5,770,000
Platte Tributaries (Leshara)	9,956,900	5,850,000
Platte Basin yield including Elkhorn (Ashland)	14,666,600	10,610,000
Yield from Platte Basin at Louisville	16,840,000	12,780,000

5.2.2 Effective Discharge and Other Sediment Transport Calculations

Gaged Sites

The effective and dominant discharges calculated for each of the gaged sites are provided in Table 5-2. In addition, hydrologic parameters, mean daily discharge, 1.5-year return flow flood rates, and percent chance exceedance from flow duration are listed in Table 5-2 for comparison purposes. As discussed in Section 4.1.2, Data Collection at Gaged Sites, hydrologic analyses were performed in support of this and other relicensing studies. A full description of the hydrologic analyses is presented in the Second ISR, Appendix D, Flow Depletion and Flow Diversion Study Report.

Effective discharges are always more reliable indicators of the channel-forming flow rates when determined from daily discharges for prolonged periods of time. None of the studies cited in Section 4.1.1, Literature Review, used shorter periods than 20 years. Using long-term daily flows allows the method to incorporate effects of climate and other factors on morphology because the longer records incorporate the natural flow variability in rivers during wet, normal, and dry periods under a variety of historical operating conditions.

Using shorter increments of daily flow data will provide an estimate of the effective discharge during the interval, but comparison of short-term effective discharges should be made with the long-term effective discharges to incorporate the full range of conditions impacting the river's morphology. Even though the effective discharge for a short period of daily flows might appear to suggest a trend toward a non-equilibrium morphology, a river may not have experienced the short-term flows long enough to adjust its "regime" morphology to the sediment transport mechanisms during the interval. Long-term effective discharge values should always be determined and used as the basis for understanding the river's "preferred" morphology. Regime rivers are dynamic, often experiencing short term variability about their mean morphologies.

Effective discharges reported in Table 5-2, Column 4, were determined by locating the mid-points of the peaks in the cumulative sediment transport histograms. This method was illustrated in Figure 4-14. The histograms for all of the gaged sites are included in Attachment C. When single values are reported for effective discharges, it should be recognized that they are estimates of the central tendency of the flows with the highest transport capacities. Selection of single-value estimates based on the peaks of the transport histograms is somewhat subjective, so ranges are provided in Table 5-2, Columns 5 and 6.

Histograms for some of the stations had relatively broad peaks compared to others. But for most cases, the range of flows transporting the most sediment was relatively narrow, and the modal value of the highest single histogram was adopted to represent the central tendency. For other gages, a wider range of flows was found to transport the majority of the sediment, in which case a weighted mean of two to four histogram peaks were adopted. Daily discharges within the ranges provided in Table 5-2 transport the majority of the sediment.

Table 5-2. Sediment Transport Indicators and Hydrologic Parameters at Gaged Study Sites (1985 to 2009)

USGS Gage Number	Gage Name and Location	Mean Daily Discharge (cfs)	Effective Discharge (cfs)	Effective Discharge Range Low (cfs)	Effective Discharge Range High (cfs)	Dominant Discharge (cfs)	Approx. Return Interval (years)	1.5 Return Interval Flow Rate (cfs)	Flow Duration % Exceeded - Qe	Flow Duration % Exceeded - Dom
06793000	Loup River near Genoa, NE	950	2,400	1,800	3,000	1,350	<1.01	10,740	7	17
06794500	Loup River at Columbus, NE	1,150	2,400	2,110	2,770	1,500	<1.01	9,330	NA	NA
06774000	Platte River near Duncan, NE	1,850	3,000	2,880	3,200	2,240	1.05	5,140	16	27
06796000	Platte River at North Bend, NE	4,670	5,630	3,440	6,730	5,280	<1.01	17,100	28	26
06796500	Platte River at Leshara, NE	4,830	5,750	4,360	6,450	5,260	<1.01	17,100	29	35
06801000	Platte River near Ashland, NE	6,540	7,000	4,770	9,150	7,360	<1.01	27,000	25	21
06805500	Platte River at Louisville, NE	7,930	7,500	5,830	11,340	9,020	<1.01	30,400	30	20

Note:

NA = Not available.

The previous analysis showing that a range of flows transports the most sediment is affirmed by USACE (July 1990). The report of findings for the Platte River does not reveal how USACE defined or calculated effective discharges, but USACE states that "[a] single effective or dominant discharge was found not to accurately describe river regime." Instead, USACE notes that a range of discharges between mean annual and bankfull transports essentially all of the bed material (July 1990). This is consistent with findings here. The effective discharges listed in Table 5-2 are not provided as single-value descriptors of regime flows, but instead as central-value indicators of the range of flows that transports the majority of the sediment.

Ungaged Sites

Comparison of the long-term (1985 to 2009) dominant discharges at the gaged sites from Table 5-2 with the 2009 dominant discharges at the gaged and ungaged sites in Table 5-3 reveals that the 2009 values for both the Loup and Platte rivers are all less than the long-term averages at gaged sites at and upstream of Leshara, and are nearly equal to the long-term values downstream near Ashland and at Louisville. Table 5-3 includes the results at both the gaged and ungaged sites. The mean daily discharges at the ungaged sites were synthesized as described in the Second ISR, Appendix B, Hydrocycling Study Report, Section 4.2.

Table 5-3. Sediment Transport Indicators and Hydrologic Characteristics for 2009 Flows at Gaged and Ungaged Sites

USGS Gage Number	Gage Name and Location	Mean Daily Discharge (cfs)	Effective Discharge (cfs)	Effective Discharge Range Low (cfs)	Effective Discharge Range High (cfs)	Dominant Discharge (cfs)
Site 1	Loup River Upstream of the Diversion Weir	2,910	3,100	2,930	3,250	2,930
Site 2	Loup River Downstream of the Diversion Weir	910	1,900	1,620	2,070	1,070
06793000	Loup River near Genoa, NE	920	1,700	1,620	1,840	1,150
06794500	Loup River at Columbus, NE	1,100	2,500	2,420	2,670	1,290
06774000	Platte River near Duncan, NE	1,400	2,900	2,800	2,990	1,565
Site 3	Platte River Upstream of the Tailrace Return	2,600	3,500	3,130	3,890	2,700
Site 4	Platte River Downstream of the Tailrace Return	4,640	4,900	4,710	5,120	4,760
06796000	Platte River at North Bend, NE	4,240	3,900	3,680	4,140	4,440
Site 5	Platte River near North Bend	4,240	4,200	3,680	4,610	4,000
06796500	Platte River at Leshara, NE	4,610	5,100	4,900	5,380	4,870
06801000	Platte River near Ashland, NE	7,400	8,000	7,650	8,440	7,365
06805500	Platte River at Louisville, NE	8,720	9,900	9,410	10,300	8,995

Sediment Discharge Rating Curve Confidence Limits

Confidence limits for the sediment discharge rating curves were developed using two different approaches. In the first approach, confidence limits were developed using a two-step process:

- Upper and lower confidence limits were computed for the three main variables used to develop the sediment discharge rating curve: velocity, depth, d_{50}.
- Sediment discharge rating curves were developed using various combinations of the upper and lower confidence limits of the three variables, as well as the best fit values adopted for this sedimentation study of the three variables.

In the second approach, confidence limits were developed for the regression line of the USGS-observed sediment discharge data. Both sets of confidence limits were compared to the sediment discharge rating curves developed by the District for this sedimentation study.

Confidence limits were only calculated for the USGS gage on the Loup River near Genoa and the USGS gages on the Platte River near Duncan, at North Bend, and at Louisville because USGS measurements are not available at the Leshara and Ashland gages, Additionally, the Leshara and Ashland gages have shorter periods of record, as shown in Table 3-1, and thus minimal data are available for use in developing confidence limits for the main input variables that were used to develop the sediment discharge rating curve confidence limits.

Confidence Limits for Sediment Discharge Rating Curve Input Variables

SPSS Statistics was used to develop 90 percent confidence limits for the power curve regression lines for the velocity/discharge and depth/discharge relationships that were discussed in Section 4.3.1, Sediment Discharge Rating Curves. The original relationships were developed separately for high and low flows; therefore, upper and lower confidence limits were calculated and graphed for both velocity and depth for both high and low flows. Microsoft Excel was used to develop a power curve regression line from SPSS-calculated confidence interval data. Figures 5-2 through 5-5 are graphs that were developed to show the upper and lower confidence limits for velocity and depth at high and low velocities at the North Bend gage. The green upper confidence line and the red lower confidence line were graphed in Excel using confidence limit data obtained from SPSS. Confidence limit graphs for depth and velocity at the Genoa, Duncan, and Louisville gages are included in Attachment E.

As discussed in Section 4.3.1, Sediment Discharge Rating Curves, the District calculated a combined d_{50} from the suspended sediment data and bed sediment data collected by USGS. Microsoft Excel was used to calculate a 90 percent confidence interval for the combined d_{50} data. The confidence interval value was then added to/subtracted from the median d_{50} value (used to create the original sediment discharge rating curves) to obtain upper/lower d_{50} values, shown in Table 5-4. The upper and lower combined d_{50} values were then used to develop upper and lower settling velocity values.

Table 5-4. Upper and Lower Confidence Limits for D_{50} at Each Gage

USGS Gage Number	Gage Location	Lower d_{50}	District-selected[1] d_{50}	Upper d_{50}
06793000	Loup River near Genoa, NE	0.17	0.20	0.22
06774000	Platte River near Duncan, NE	0.29	0.38	0.46
06796000	Platte River at North Bend, NE	0.20	0.23	0.26
06805500	Platte River at Louisville, NE	0.20	0.22	0.24

Note:

[1] District-selected refers to the value used by the District in calculating the sediment discharge rating curves for the sedimentation analysis contained in the remainder of this report.

Confidence Limits for Sediment Discharge Rating Curves

All combinations (27 total) of the upper, District-selected,[8] and lower values for each variable (depth, velocity, and d_{50}) were used to develop the sediment discharge rating curves using Yang's method. The combination of variables that created the lowest sediment discharge rating curve used the lower confidence limit for both velocity and depth and the upper confidence limit for the combined d_{50}. Similarly, the combination of variables that created the highest sediment discharge rating curve used the upper confidence limits for velocity and depth and lower confidence limit for the combined d_{50}. The upper and lower confidence limits for the sediment discharge rating curve for North Bend are shown in Figure 5-6. The confidence limits for the sediment discharge rating curves for Genoa, Duncan, and Louisville are located in Attachment E.

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[8] District-selected refers to the value used by the District in calculating the sediment discharge rating curves for the sedimentation analysis contained in the remainder of this report.

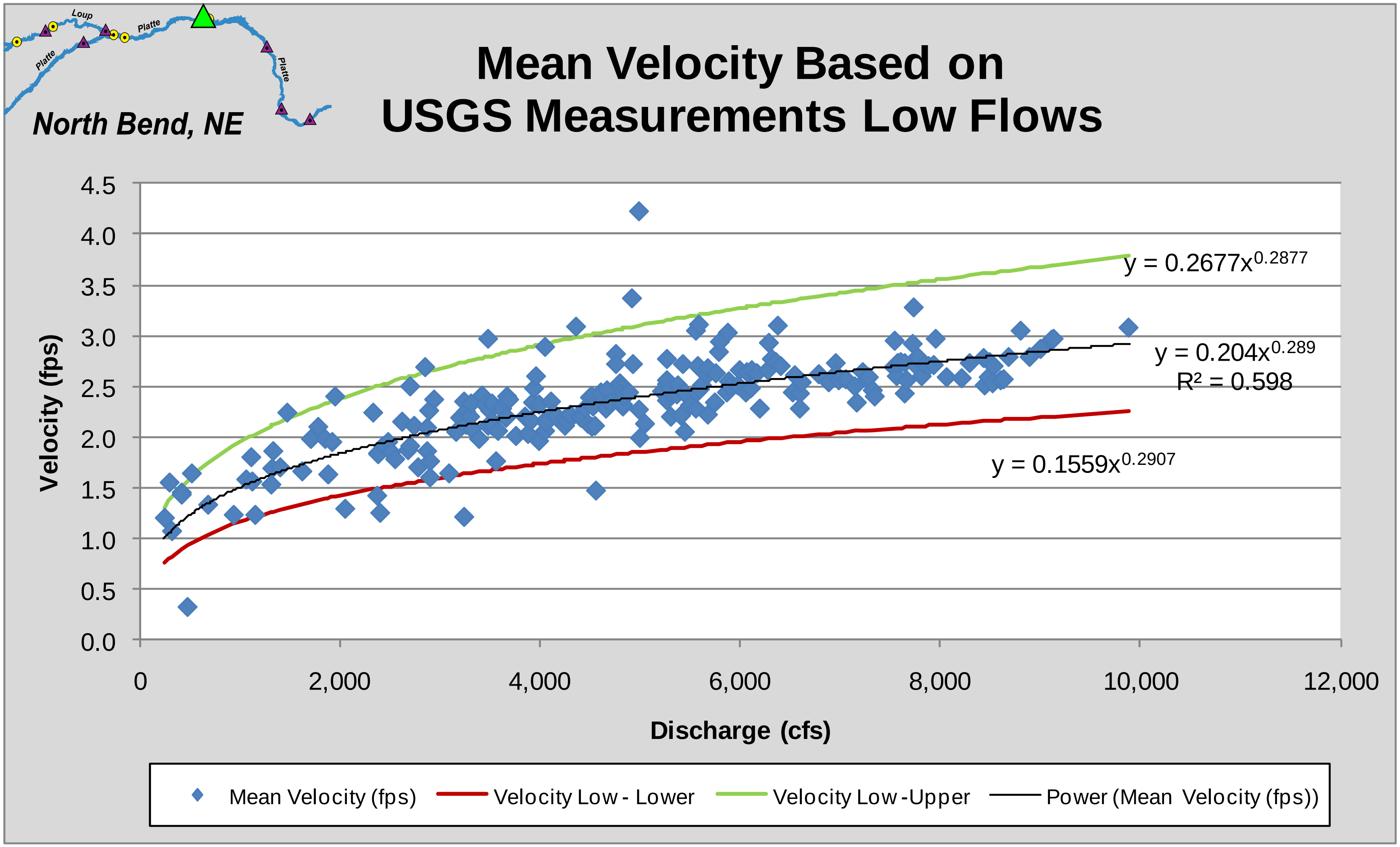


Figure 5-2. Example of 90 Percent Confidence Limits for the Velocity/Discharge Relationship for Low Flows Used in Yang's Unit Stream Power Method of Creating a Sediment Discharge Rating Curve

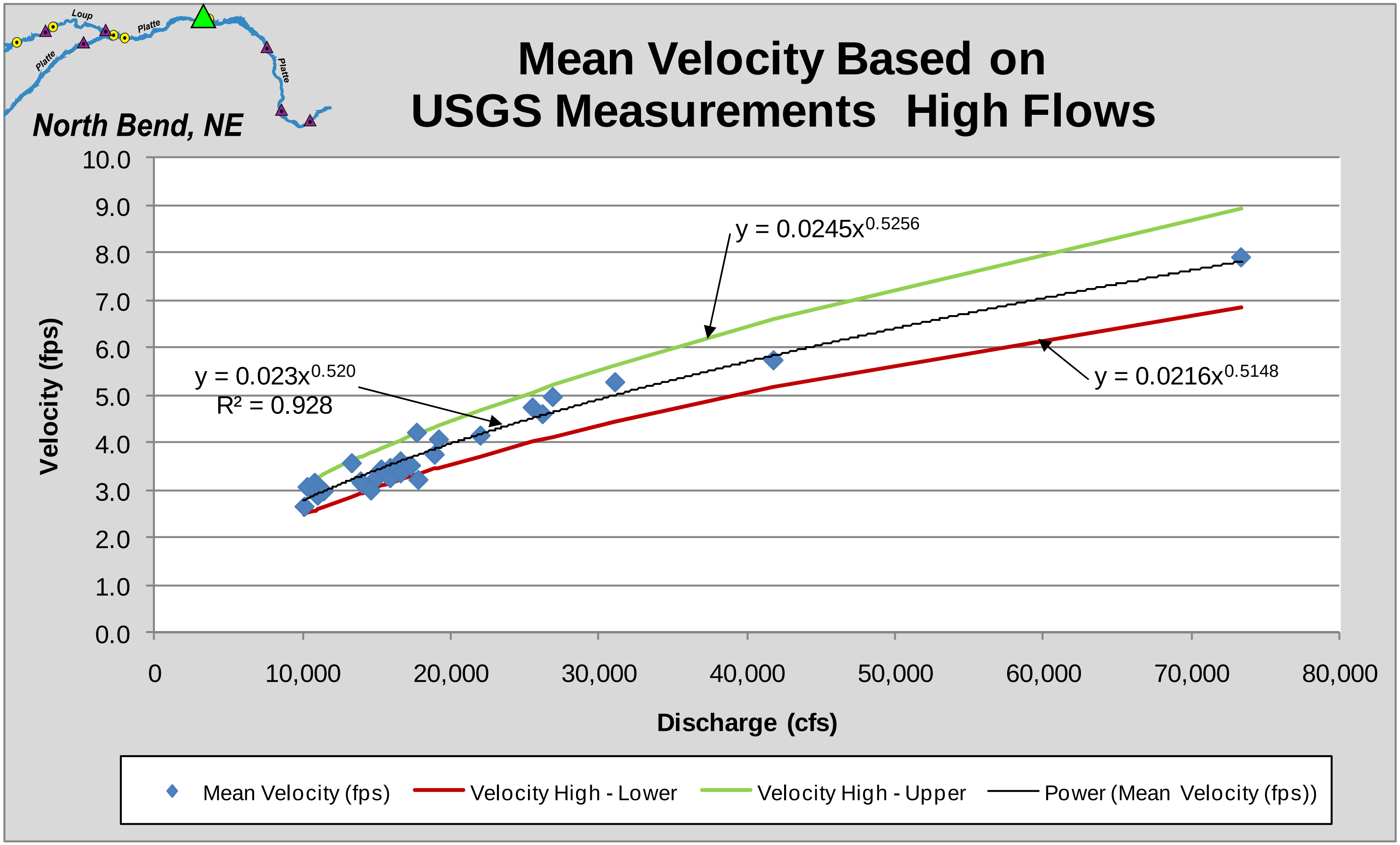


Figure 5-3. Example of 90 Percent Confidence Limits for the Velocity/Discharge Relationship for High Flows Used in Yang's Unit Stream Power Method of Creating a Sediment Discharge Rating Curve

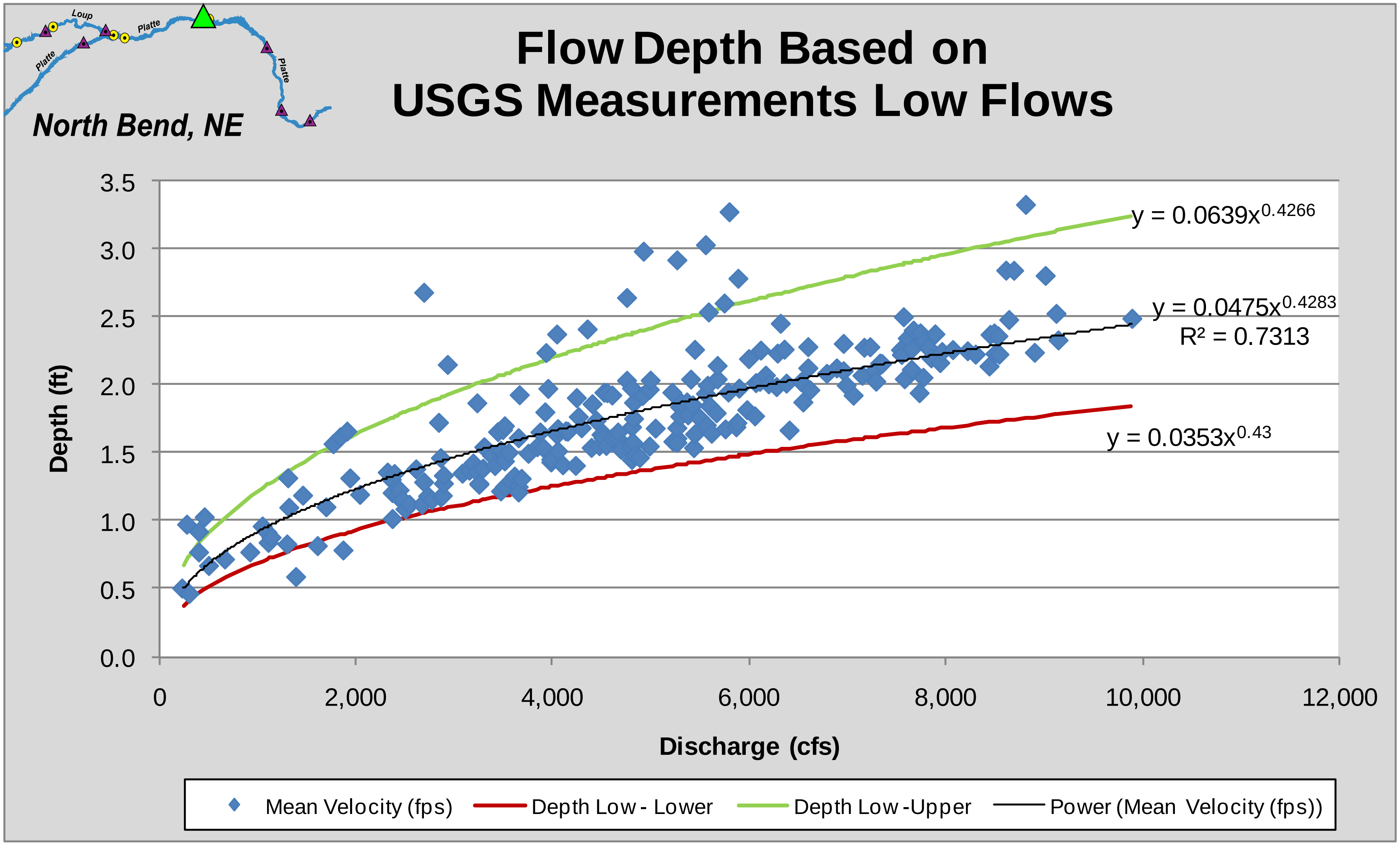


Figure 5-4. Example of 90 Percent Confidence Limits for the Flow Depth/Discharge Relationship for Low Flows Used in Yang's Unit Stream Power Method of Creating a Sediment Discharge Rating Curve

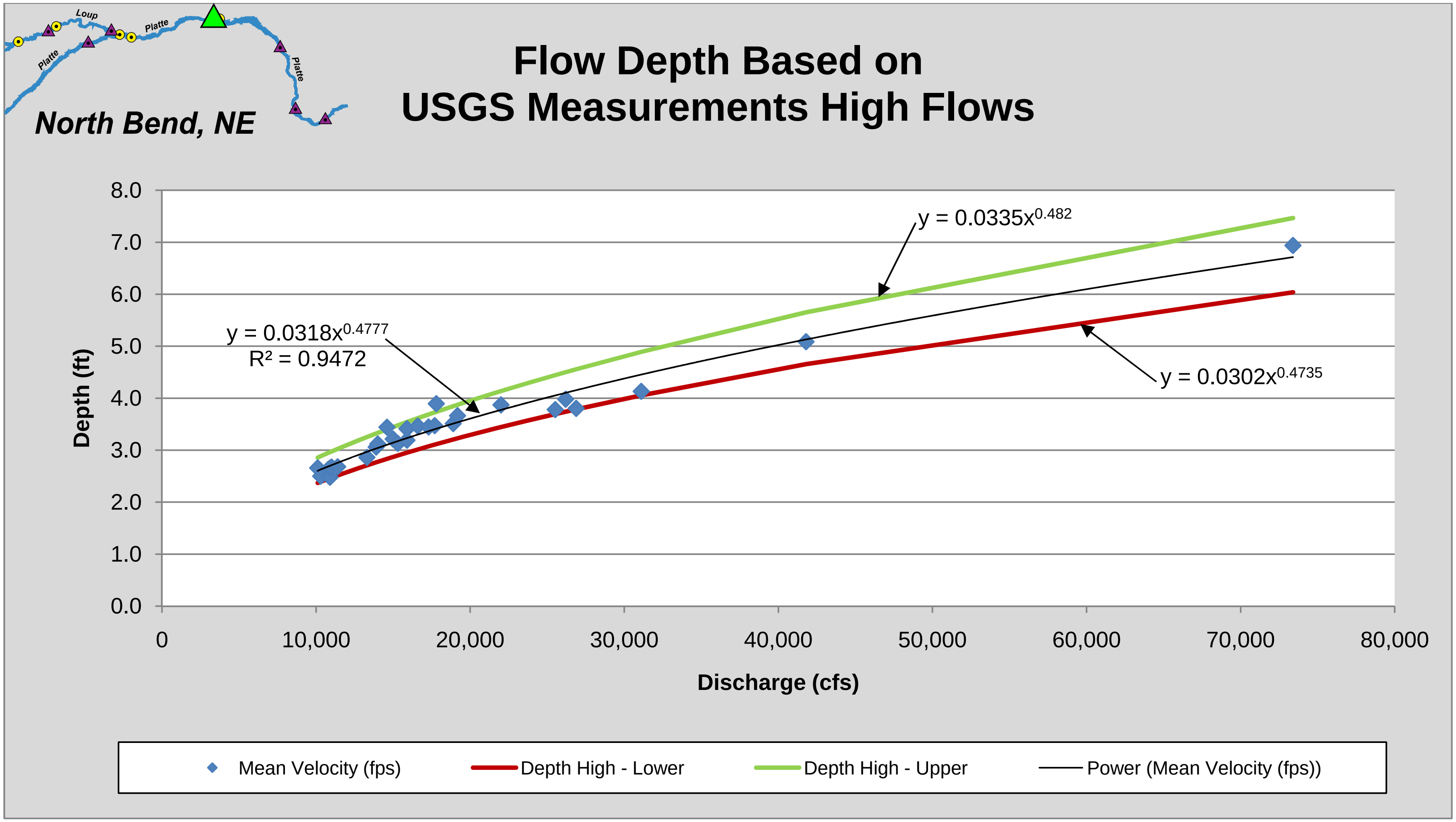


Figure 5-5. Example of 90 Percent Confidence Limits for the Flow Depth/Discharge Relationship for High Flows Used in Yang's Unit Stream Power Method of Creating a Sediment Discharge Rating Curve

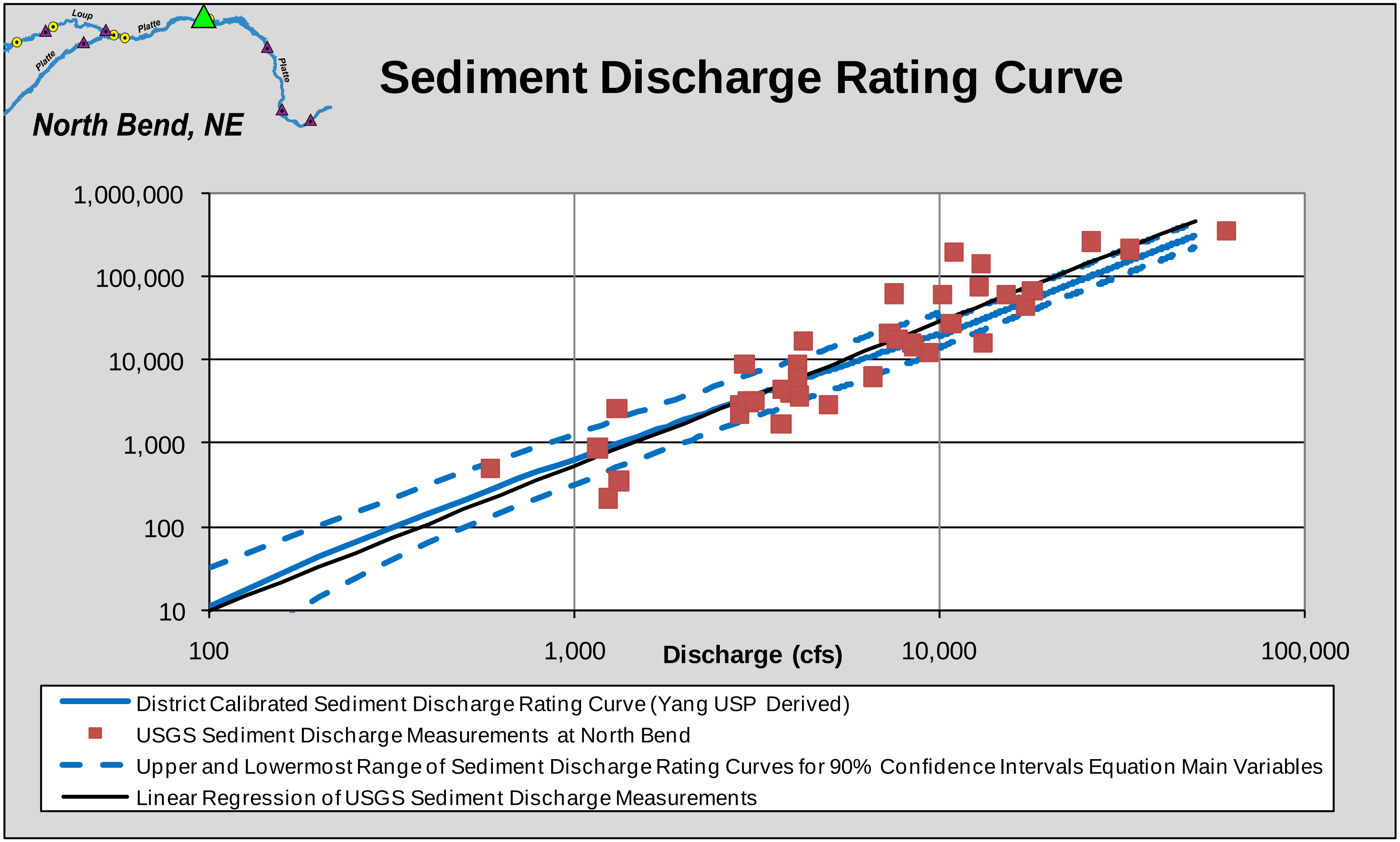


Figure 5-6. North Bend Sediment Discharge Rating Curve with Upper and Lower Variable Combinations

Confidence Limits for the USGS-Observed Sediment Discharge Data

Microsoft Excel was used to plot a regression line, from slope and intercept values calculated by SPSS for the USGS-observed sediment discharge data. Upper and lower 90 percent confidence limits for the regression line were also calculated by SPSS and graphed in Microsoft Excel.

Plots were then developed that show the USGS-observed data, the regression line of those data, the District's calibrated sediment discharge rating curve, and the upper and lower 90 percent confidence limits on the regression line. The graph for North Bend is shown in Figure 5-7. Similar graphs for Genoa, Duncan, and Louisville are located in Attachment E.

Results

Figure 5–7 illustrates that the District's sediment discharge rating curve falls within the 90 percent confidence interval for the regression of the USGS measured data. The confidence limit analysis shows that the District's calibrated sediment discharge rating curve is a reasonable approximation of the USGS suspended sediment discharge data.

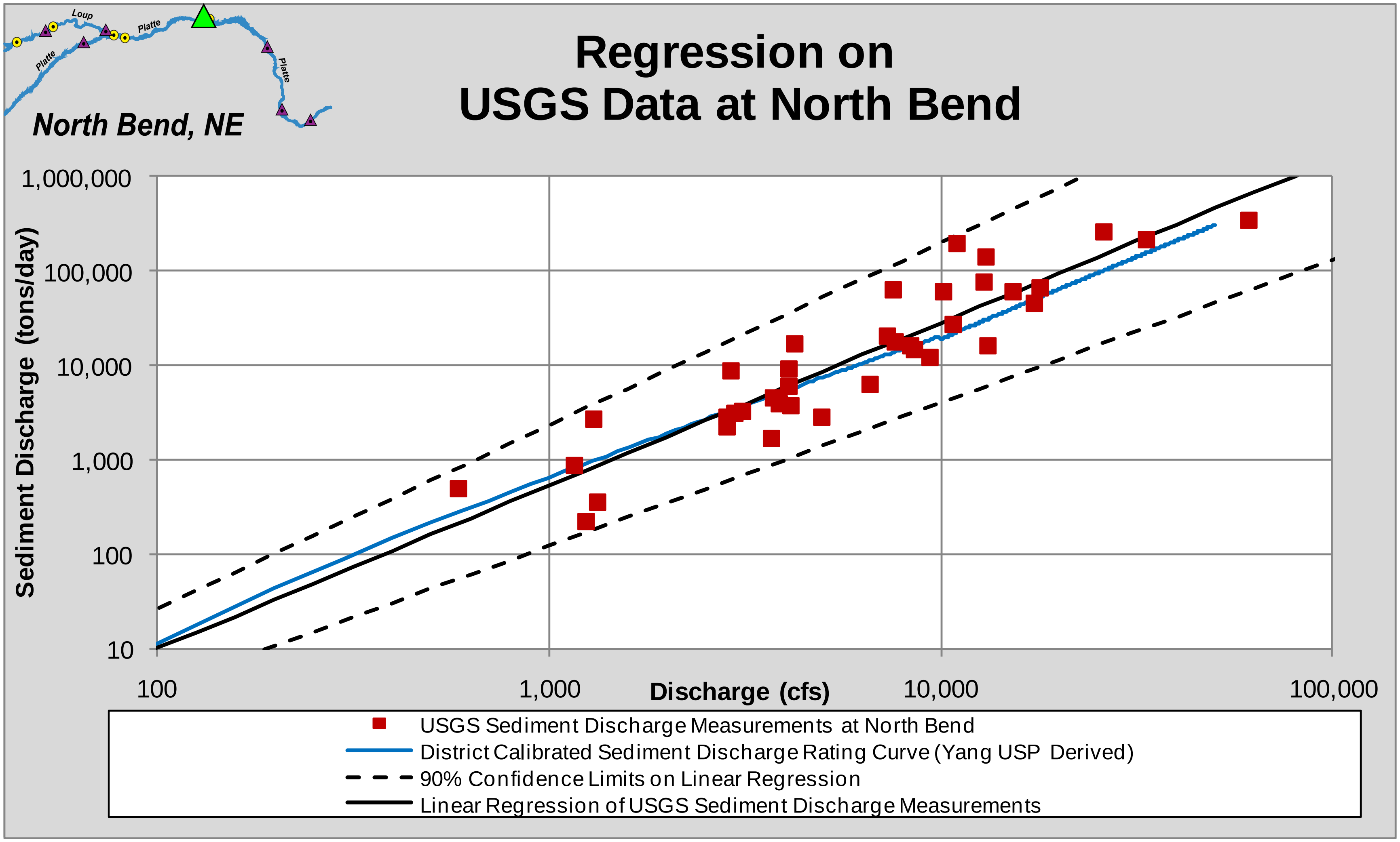


Figure 5-7. North Bend Sediment Discharge Rating Curve with Confidence Intervals

Sediment Discharge Rating Curve Sensitivity Analysis

A sensitivity analysis was performed by changing the variables used in the creation of the sediment discharge rating curves to determine how changes in each variable affect the predictive capability of the sediment discharge rating curve, as shown in Table 5-5.

At each of the four USGS gaged sites where sediment discharge data were available, several different scenarios were run where the variables of energy slope, particle size (diameter), and temperature (which alters kinematic viscosity) were varied. Changing those variables affected the observed versus predicted fit and the annual cumulative discharge and the annual dominate discharge. An example of the results provided by this sensitivity analysis for the Platte River at Louisville is shown in Table 5-5. All of the sensitivity analysis tables are located in Attachment B.

Changing the slope up to 25 percent less than or greater than the original slope value resulted in small changes to the sediment discharge rating curve and relatively small changes to the dominant discharge. Together, those small changes resulted in large changes to the annual cumulative sediment values. Similar changes occurred by decreasing the particle diameter by half a standard deviation (SD) and increasing the diameter by one full standard deviation (SD). However, even with large changes in the results given large changes in the input variables, the outcomes of the flow limited or supply limited question and the regime question reached in this sedimentation study would remain unchanged. Changing the temperature, which alters the kinematic viscosity, yielded only very small changes in the sediment discharge rating curve and associated results.

Table 5-5. Sensitivity Analysis

Scenario Summary	Base Case	Slope -25%	Slope +25%	Diameter -½SD	Diameter +SD	Temperature 20°C	Temperature 10°C
Variables							
Channel Slope	0.0008	0.0006	0.0009	0.0008	0.0008	0.0008	0.0008
Diameter	0.0007	0.0007	0.0007	0.0006	0.0012	0.0007	0.0007
Viscosity	0.000012	0.000012	0.000012	0.000012	0.000012	0.000011	0.000014
Results							
Observed vs. Predicted Regression Slope	0.5972	0.6056	0.5910	0.5947	0.6026	0.5952	0.5993
Observed vs. Predicted Regression Intercept	1.5596	1.3450	1.7209	1.6829	1.3680	1.5595	1.5646
Root Mean Square Error	0.3920	0.4604	0.3909	0.3865	0.4556	0.3946	0.3886
Annual Cumulative Sediment	4,930,000	3,300,000	6,670,000	6,370,000	3,360,000	4,820,000	5,100,000
Dominant Discharge	9,020	9,080	8,970	8,990	9,100	9,010	9,030

5.2.3 Spatial Analysis

Gaged Sites (1985 to 2009)

As discussed in Section 4.3.3, a spatial analysis was conducted to assess whether the sediment transport indicators and regime analysis suggest that the morphological indicators from upstream to downstream at the study sites was consistent with natural river processes. Tables 5-2, 5-3, 5-6, and 5-7 summarize the sediment transport indicators at the gaged and ungaged sites. Table 5-6 compares the average annual MRBC yields with average annual (1985 to 2009) values of total sediment transported at capacity. However, only the 2009 total transport values were derived at the ungaged sites, as described in Section 4.3.1, Sediment Discharge Rating Curves. These were compared with 2009 values at the gaged sites rather than average annual values at the gaged sites. Table 5-7 presents seasonal values for the gaged sites. Values of one of the sediment transport indicators, the average annual capacity of the daily flows to transport bed material, are shown in Figure 5-8, along with each location's value of adjusted MRBC yield.

Table 5-6. Sediment Capacity and Sediment Yield at Gaged and Ungaged Sites

Site or USGS Gage Number	Site Description or Gage Name and Location	Drainage Area (square miles)	Annual Sediment Data (tons/year)		
			Capacity (1985–2009)	Capacity (2009 only)	Updated MRBC Average Annual Yield
Site 1	Loup River Upstream of the Diversion Weir	14,320[1]	NA	2,870,000	4,180,000
Site 2	Loup River Downstream of the Diversion Weir	14,320[1]	NA	890,000	2,030,000
06793000	Loup River near Genoa, NE	14,320	1,760,000	1,280,000	2,030,000
06794500	Loup River at Columbus, NE	15,200	1,260,000[2]	950,000	2,960,000
06774000	Platte River near Duncan, NE	59,300	747,000	410,000	1,870,000
Site 3	Platte River Upstream of the Tailrace Return	74,500	NA	1,160,000	4,900,000
Site 4	Platte River Downstream of the Tailrace Return	74,500	NA	2,960,000	5,250,000
06796000	Platte River at North Bend, NE	70,400	2,890,000	2,050,000	5,770,000
Site 5	Platte River near North Bend	70,400	NA	2,026,000	5,770,000
06796500	Platte River at Leshara, NE	NA	2,800,000[3]	2,240,000	5,850,000
06801000	Platte River near Ashland, NE	84,200	4,080,000[4]	3,720,000	10,610,000
06805500	Platte River at Louisville, NE	85,370	4,930,000	4,590,000	12,780,000

Notes:

NA = Not available.

[1] The drainage area for the Loup River near Genoa was used.

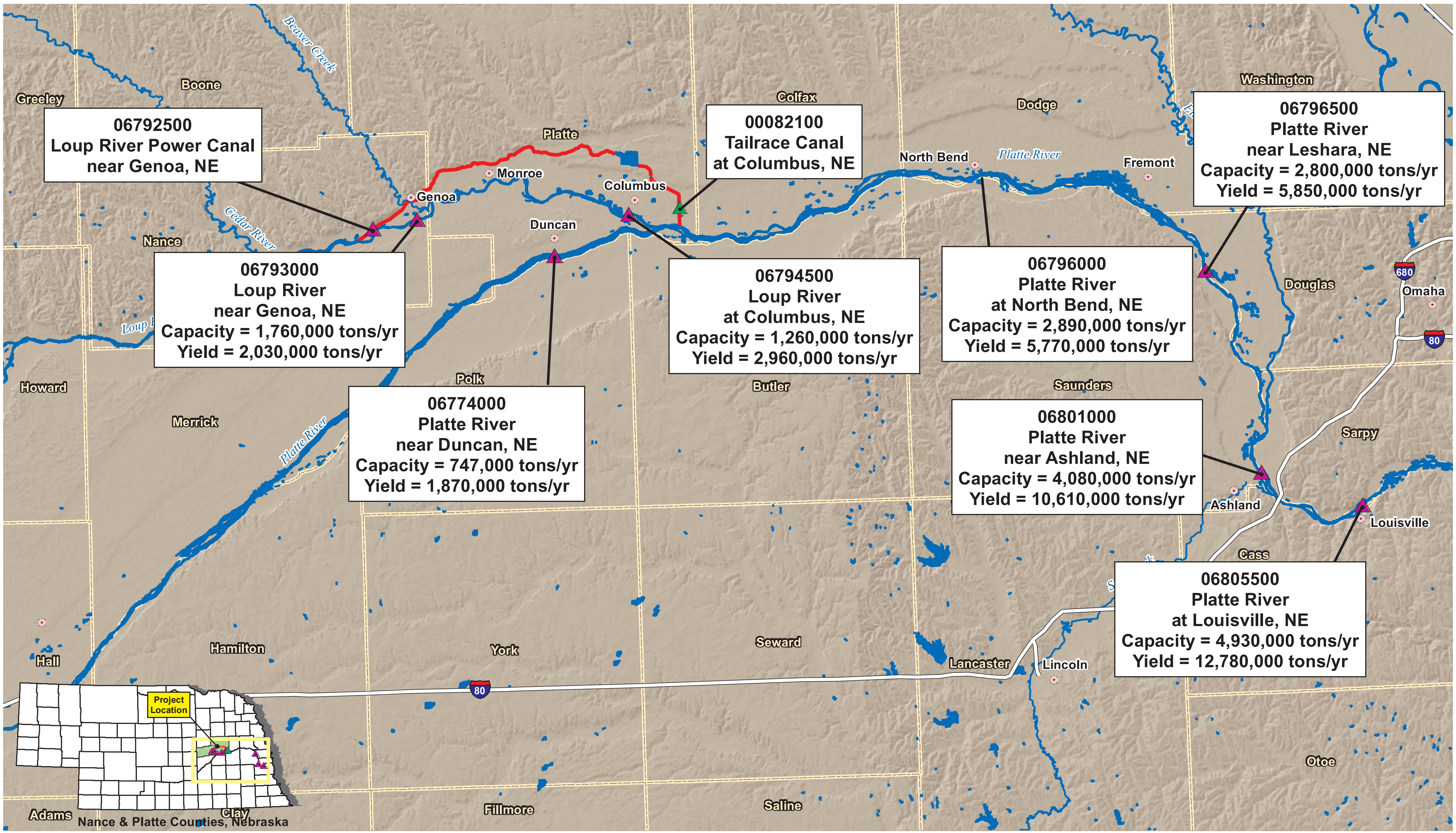
[2] Channel geometry for Columbus was measured only in 2008 and 2009; flows at Columbus from 1985 to 2009 were synthesized as described in Section 4.3.1, Sediment Discharge Rating Curves.

[3] The capacity at Leshara is based on data from 1995 to 2009.

[4] The capacity near Ashland is based on data from 1989 to 2009.

Table 5-7. Seasonal (May 1 through August 15) Values

USGS Gage Number	Gage Name and Location	Mean Daily Discharge (cfs)	Dominant Discharge (cfs)
06793000	Loup River near Genoa, NE	640	1,130
06794500	Loup River at Columbus, NE	910	1,410
06774000	Platte River near Duncan, NE	1,950	2,520
06796000	Platte River at North Bend, NE	4,880	5,770
06796500	Platte River at Leshara, NE	5,350	5,260
06801000	Platte River near Ashland, NE	7,920	9,400
06805500	Platte River at Louisville, NE	9,240	10,910



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Source: Stream Gage, Nebraska Department of Natural Resources; Streams/Waterbodies, 2000 Tiger Files

Legend

- ● City
- ▲ NDNR Gaging Station
- ▲ USGS Gaging Station and Study Site
- ═ Interstate
- ─ Stream/River
- ─ Loup Power Canal
- ■ Waterbody
- ☐ County

Loup Power District Hydro Project

Spatial Analysis at Gaged Sites (1985 to 2009)

Loup River Hydroelectric Project
FERC Project No. 1256
Study 1.0 - Sedimentation

DATE
August 26, 2011

FIGURE
5-8

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Other investigators have conducted spatial assessments in the Middle Platte River region. For example, Kircher (1981) determined that effective discharges were 1,400 cfs at Overton and 1,900 cfs at Grand Island. Effective discharges are determined using daily flows, and different sets of daily flow records will produce different results. Parsons' (May 2003) independently determined values for a different set of daily flows were 1,500 and 2,500 cfs, respectively. Parsons also lists a few other Platte basin investigations showing effective discharges in this same range. The 1985 to 2009 values of effective and dominant discharges in Tables 5-2, 5-3, 5-6 and 5-7 show this overall increase in the downstream direction along the Platte River (from 3,000 cfs at Duncan to 7,500 cfs at Louisville), which is consistent with the USGS trend between Overton (1,500 cfs) and Grand Island (2,500 cfs) as well as with the increasing drainage area and sediment supplies.

Like effective and dominant discharges, the average annual capacities of the daily flows to transport bed material shown in Figure 5-8 increase in the downstream direction consistent with natural river processes. Table 5-6 shows that all capacities fall below the adjusted MRBC yields, revealing that the rivers are not supply limited.

Table 5-6 provides the results of comparisons of adjusted MRBC sediment yields from Table 5-1 with average annual calculations of total sediment transport capacities. It also provides the long-term effective and dominant discharge calculations at each gage location based on daily calculations of sediment transport capacities for the study period.[9]

The results reveal that the original MRBC and adjusted yields greatly exceed the transport capacity of the flows. This readily answers the question of flow versus supply limitations. Because sediment supplies and transport capacities at all locations are not balanced at all times, any conclusions regarding potential aggradation or degradation trends can only be assessed using long-term measurements, effective discharge calculations, and applications of equilibrium (regime) methodologies.

Ungaged Sites (2009)

The long-term (1985 to 2009) annual sediment transport capacities at the gaged sites and 2009 values are compared with updated MRBC estimates of sediment yields in Table 5-6. The addition of ungaged site data reveals that both the long-term average and 2009 transport capacities are all considerably below the estimated average annual yields at both the ungaged sites and at the adjacent upstream and downstream gaged sites.

Because transport capacity at the ungaged sites was only calculated based on 2009 synthesized hydrographs, values of transport capacity for any single year are not necessarily comparable to average annual adjusted MRBC yields. Similarly,

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[9] Fewer years of data were available at Leshara and Ashland.

Table 5-6 shows that 2009 estimates of transport capacity at gaged sites are not necessarily comparable to average annual transport capacities, even though 2009 was a relatively "normal" flow year.

As concluded for long-term average annual values at the gaged sites, the 2009 total transport values at capacity for the ungaged sites all fall considerably below the MRBC yield estimates, confirming that neither the gaged nor the ungaged sites are supply limited. Thus, the inclusion of ungaged site data does not alter the conclusions regarding sediment availability described for the gaged sites.

As with values of dominant discharges in Table 5-3, the 2009 transport totals at the gaged sites in Table 5-6 are lower than long-term average annual values in about the same proportion as the dominant discharges—with the differences decreasing in the downstream direction.

The 2009 dominant discharges at Genoa are 15 percent lower than the 1985 to 2009 long-term values, and the 2009 value at Duncan is 30 percent lower. These percent differences decrease in the downstream direction. The best indicator of equilibrium channel morphology is related to the long-term values of effective and dominant discharges and total sediment transported at capacity.

Although the 2009 values are lower than the long-term values, the spatial analysis for the gaged sites showed that these and the associated fluctuations in hydraulic geometry are normal, and should not be deemed as evidence of either adverse or beneficial morphologic changes, especially if the regime analysis shows all the fluctuations as falling well within braided river morphologies.

At the Columbus gage, a relatively large difference between the effective and dominant discharges occurs for both the long-term averages and 2009. A similarly large difference between effective and dominant discharge occurs on the Platte River at Duncan, which was also observed for the long-term analysis in Table 5-2. Because flows at Duncan are highly variable every year, including evidence of sub-daily fluctuations, the 1985 to 2009 annual fluctuations in both effective and dominant discharge, as well as total sediment transported at capacity, are considered normal. Flows at Columbus are not as variable, but a similar result (moderate annual fluctuations and moderate difference between effective and dominant discharge) is probably due to the limited data for that gage.

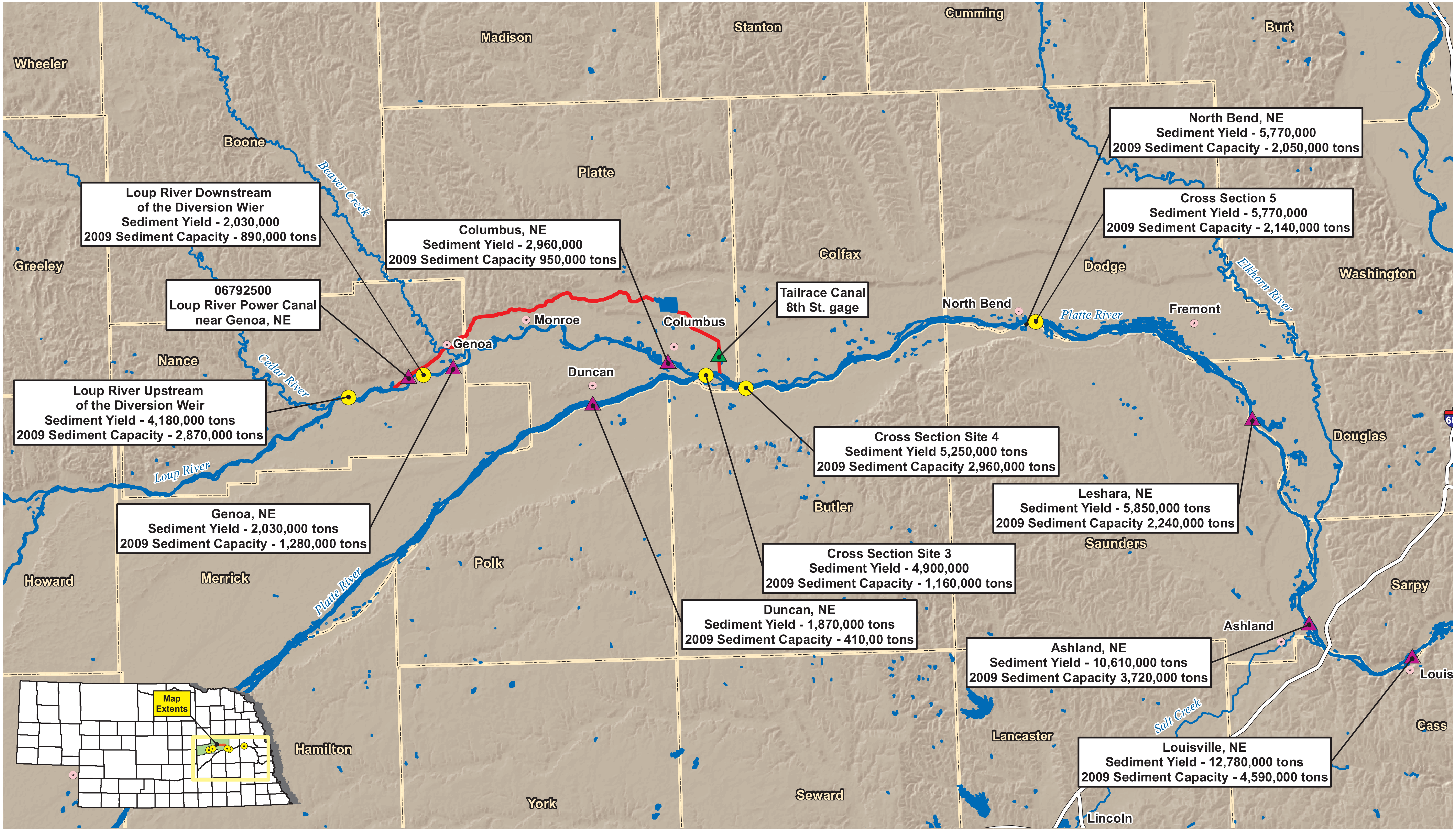
Even if effective discharge is substituted for dominant discharge at Columbus, smaller increases in dominant discharge on a per-mile basis occur on the Loup River than the Platte River. This is probably indicative of relatively small intervening drainage areas and drainages between the Diversion Weir and Columbus compared to drainage area sizes between the Platte River gages. In any case, there is no absence of sediment available for transport at any of the study sites, whether gaged or ungaged.

Tables 5-3 and 5-6 and Figures 5-9 and 5-10 allow the ungaged site results for 2009 to be analyzed spatially. Due to the subjective nature of selecting effective discharges from the sediment transport histograms, the dominant discharges are used in this integration and spatial comparison of results from gaged and ungaged sites. As demonstrated in Table 5-3, effective discharges tend to be proportionately higher than dominant discharges, particularly for the Loup River when compared with the Platte River, but both indicators generally increase in the downstream direction.

For the Loup River, the 2009 dominant discharge of 2,930 cfs upstream of the Diversion Weir drops to 1,030 cfs across the Diversion Weir. This is expected because both annual flow hydrographs and affiliated sediment transport capacities at the two locations are altered by the Diversion Weir and Settling Basin. With the exception of bypassing most of the flow on flood flow days, diversions average 1,600 cfs, which is about equal to the difference in dominant discharge. The impact on sediment transport of the bypasses during flood flows is incorporated because the bypass amounts, and their transport capacities, would be reflected in the synthesized flows.

From just downstream of the Diversion Weir at Site 2 to Genoa and Columbus, the dominant discharges increase in the same increasing pattern described for the Platte River in Kircher (1981) and Parsons (May 2003). For the Platte River, the 2009 effective and dominant discharges shown in Table 5-1 reveal that no discernable discontinuity in either indicator occurs from just upstream to just downstream of the Tailrace Return. Thus, the results of including the ungaged sites in the spatial analysis for the Loup River are consistent with the findings for the gaged sites, and with others' studies of rivers in this region (literature described in Section 5.3.2, Analysis of Existing Data and Literature on Channel Aggradation/Degradation and Cross Sectional Changes Over Time).

The total sediment transport amounts at capacity shown in Table 5-6 reveal that a quantum increase in transport capacity (from 1,160,000 to 2,960,000 tons per year) occurs just below the Tailrace Return, followed by a reduction to 2,060,000 tons per year downstream at North Bend. In the absence of the Project, it would be consistent with river dynamics to expect the total transport at a location just below the Tailrace Return to be slightly less than the 2,060,000 tons per year value at North Bend. The results for 2009 show it to be about 900,000 tons per year higher. This is expected because the flows immediately downstream of the Tailrace Return include the diverted amounts, and an increase in transport capacity across the junction would be expected because of the increase in flow rates.



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Source: Stream Gage, Nebraska Department of Natural Resources; Streams/Waterbodies, 2000 Tiger Files

Legend

- ⊙ City
- ▲ NDNR Gaging Station
- ▲ USGS Gaging Station and Study Site
- ● Ungaged Study Sites
- ═ Interstate
- — Stream/River
- — Loup Power Canal
- ■ Waterbody
- ▭ County

Loup Power District Hydro Project

Spatial Analysis at Gaged and Ungaged Sites (2009) Capacity and Yield

Loup River Hydroelectric Project
FERC Project No. 1256
Study 1.0 - Sedimentation

DATE
August 26, 2011

FIGURE
5-9

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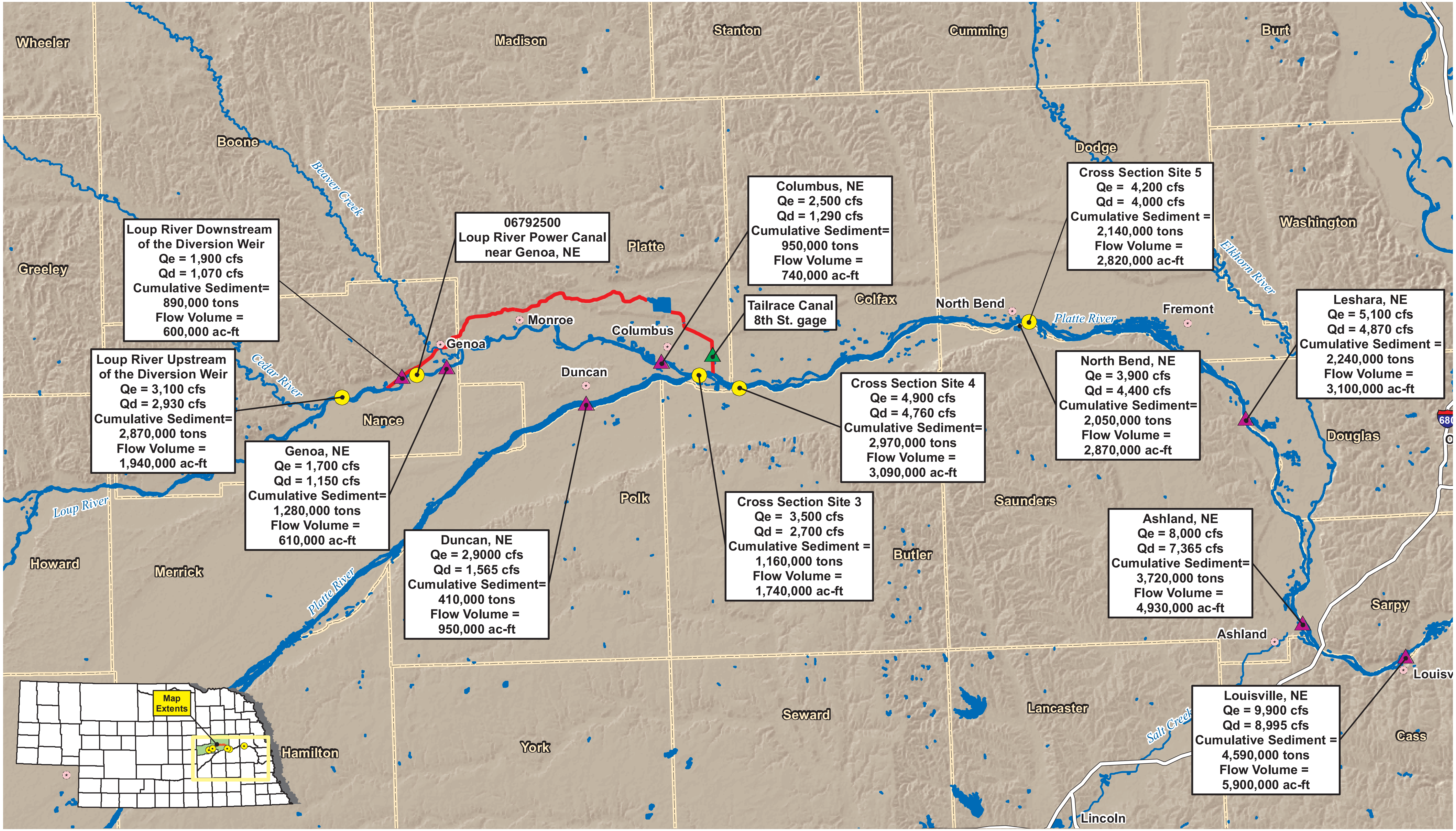

Loup River Downstream of the Diversion Weir
Qe = 1,900 cfs
Qd = 1,070 cfs
Cumulative Sediment=
890,000 tons
Flow Volume =
600,000 ac-ft

06792500
Loup River Power Canal
near Genoa, NE

Columbus, NE
Qe = 2,500 cfs
Qd = 1,290 cfs
Cumulative Sediment=
950,000 tons
Flow Volume =
740,000 ac-ft

Tailrace Canal
8th St. gage

Cross Section Site 5
Qe = 4,200 cfs
Qd = 4,000 cfs
Cumulative Sediment =
2,140,000 tons
Flow Volume =
2,820,000 ac-ft

Leshara, NE
Qe = 5,100 cfs
Qd = 4,870 cfs
Cumulative Sediment =
2,240,000 tons
Flow Volume =
3,100,000 ac-ft

Loup River Upstream of the Diversion Weir
Qe = 3,100 cfs
Qd = 2,930 cfs
Cumulative Sediment=
2,870,000 tons
Flow Volume =
1,940,000 ac-ft

Genoa, NE
Qe = 1,700 cfs
Qd = 1,150 cfs
Cumulative Sediment=
1,280,000 tons
Flow Volume =
610,000 ac-ft

Duncan, NE
Qe = 2,9000 cfs
Qd = 1,565 cfs
Cumulative Sediment=
410,000 tons
Flow Volume =
950,000 ac-ft

Cross Section Site 4
Qe = 4,900 cfs
Qd = 4,760 cfs
Cumulative Sediment=
2,970,000 tons
Flow Volume =
3,090,000 ac-ft

North Bend, NE
Qe = 3,900 cfs
Qd = 4,400 cfs
Cumulative Sediment=
2,050,000 tons
Flow Volume =
2,870,000 ac-ft

Cross Section Site 3
Qe = 3,500 cfs
Qd = 2,700 cfs
Cumulative Sediment =
1,160,000 tons
Flow Volume =
1,740,000 ac-ft

Ashland, NE
Qe = 8,000 cfs
Qd = 7,365 cfs
Cumulative Sediment=
3,720,000 tons
Flow Volume =
4,930,000 ac-ft

Louisville, NE
Qe = 9,900 cfs
Qd = 8,995 cfs
Cumulative Sediment =
4,590,000 tons
Flow Volume =
5,900,000 ac-ft

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Source: Stream Gage, Nebraska Department of Natural Resources; Streams/Waterbodies, 2000 Tiger Files

Legend

- City
- ▲ NDNR Gaging Station
- ▲ USGS Gaging Station and Study Site
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Loup Power District Hydro Project

Spatial Analysis at Gaged and Ungaged Sites (2009)

Loup River Hydroelectric Project
FERC Project No. 1256
Study 1.0 - Sedimentation

DATE
August 26, 2011

FIGURE
5-10

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It should also be noted that the mean daily discharge at Site 4 is higher than the mean daily discharge at North Bend. As demonstrated in the Second Initial Study Report, Appendix B, Hydrocycling Study Report, Section 5.4.1, the dominant and effective discharges at Site 4 for the 7-year period of 2003 to 2009 do not experience this quantum increase. As noted earlier, use of longer-term data is superior to use of data for any individual year.

The amount of sediment that could be transported at capacity is directly linked to the amount of flow passing any point. An increase in the capacity to transport just downstream of the Tailrace Return because of the increase in flow should not be considered evidence of possible degradation. No physical data or studies by others, including the cross-section measurements by the District, reveal a problem with degradation at this location. The appropriate measure of Project impacts is whether the morphology, measured by the effective and dominant discharges, and by the supplemental spatial analysis of flow versus hydraulic geometry parameters (described below) is impacted by the return.

As shown above, the capacity to transport sediment increases just downstream of the Tailrace Return, but the effective and dominant discharges (and analysis by other observers [Kircher, 1981; Parsons 2003]) show that morphology is not being impacted. The fact that the effective and dominant discharges just downstream of the Tailrace Return are not abnormal relative to the overall river pattern indicates that morphology (determined by the effective and dominant discharges) is not being impacted by this localized increase in transport capacity. The flow rates that transport the most sediment (effective or dominant rates) would need to be significantly “out of kilter” with the river’s pattern in order to conclude that aggradation or degradation or possible widening or narrowing of the river is occurring. As shown in the supplemental spatial analysis, below, the flow rates controlling the river’s width, depth, and overall morphology do not appear out of ordinary across this junction.

One other relevant observation regarding Table 5-3 is that the total sediment that would be transported at capacity at Duncan and Columbus add up to being within 17 percent of the value at Site 3, downstream of the confluence of the Loup and Platte rivers. Although this type of arithmetic is not recommended (see discussion below), it is somewhat intuitive that transport below any confluence should be about equal to the sum of capacities upstream. Deviations from this rule (total = sum of the parts) would be either because the actual daily transport by both rivers is frequently above or below capacity (see graphs of USGS suspended load transport data in Figure 5-6 and in Attachments B and C), or because of temporary additions or subtractions from storage of sediment among the three locations, which USACE (1990) documented.

Prior to completing the ungaged site analysis, the sum of Loup and Platte river transport amounts at capacity could be compared with the value at only the North Bend gage, which showed a 2009 difference of 31 percent. By including Site 3, the data reveals that the sum of upstream transport rates differ with the North Bend amount by 17 percent, or about half of the difference arises between Duncan and the Tailrace Return. This is essentially proportionate with the river distances.

Adding transport capacities upstream of river confluences in a spatial analysis in order to estimate capacities in the main stream may seem intuitive, and in this case may even appear reasonable, but it is not recommended. Total sediment transport at any location is determined by adding daily values of transport assuming that actual amounts match Yang's capacity equation. As shown in Figure 5-6 and in Attachments B and C, USGS measurements of suspended sediment loads at the gaged sites reveal that suspended load transport rates for any given discharge vary by several orders of magnitude.

Any differences, even on the order of 17 or 31 percent, in comparing upstream and downstream total transport assuming transport at capacity are not of use in assessing equilibrium conditions through typical sediment "budget" accounting (inflow – outflow = change in storage). Even if the values reported in Table 5-6 were precise, the reach inflows and outflows in any given year, such as 2009, would never be expected to match downstream transport rates in a braided river because of the dynamic physical processes involved with sediment being continually drawn from and deposited to temporary storage in the stream bed. Longer-term analysis would be required, along with (non-existent) records of sediment being contributed by the intervening area between sites. This process of continual (and moderately dramatic) change in channel geometry (and accompanying change in sediment being stored and removed) is readily seen in the graphs showing the June to September cross sections illustrated in Section 5.2.4, Regime Analysis, in Figures 5-19 and 5-20 as well as in the other data at other stations and times included in Attachment A.

Supplemental Spatial Analysis

A supplemental spatial analysis was conducted to compare effective and dominant discharge with four channel geomorphologic characteristics—flow depth (D), mean velocity (V), flow width (W), and flow area (A)—on a paired-site basis, starting upstream and proceeding downstream in both the Loup River bypass reach and the Lower Platte River. The four channel geomorphologic characteristics were defined by FERC in its June 10, 2011, "Determination on Requests for Modifications to the Loup River Hydroelectric Project Study Plan." The results are presented graphically.

Rather than showing only two sites per graph, graphs showing the results at all four sites on the Loup River bypass reach and all eight sites on the lower Platte River are provided in Figures 5-11 and 5-12. The development of the graphs and graphed relationships are discussed below. A pair-by-pair interpretation of site results is provided below under Results of the Supplemental Spatial Analysis.

Loup River Bypass Reach

The four study sites on the Loup River bypass reach are ungaged Sites 1 and 2, the Genoa gage, and the Columbus gage. The channel geomorphologic characteristics at the Genoa gage are based on historical measurement taken by USGS. Those same characteristics for the Columbus gage were based on NDNR measurements taken from 2007 through 2009. However, the characteristics at Sites 1 and 2 were derived from HEC-RAS models developed for this sedimentation study. The development of these characteristics is detailed in Section 4.3.1, Sediment Discharge Rating Curves. Because of the limited data from the Columbus gage, three of the four sites on the Loup River bypass reach were essentially ungaged sites, requiring reliance on synthetic hydrology and HEC-RAS hydraulic geometries using once-in-time cross-section data. In each case involving HEC-RAS analysis, the cross sections were assumed to be rigid, having the same bed geometry for all discharge rates. The ramifications of this are further discussed below.

The effective and dominant discharges for the Genoa and Columbus gages were calculated using hydrology from 1985 to 2009 (Initial Study Report) and 2003 to 2009 (Updated Study Report). The effective and dominant discharges for Sites 1 and 2 were calculated using hydrology from 2003 to 2009. Because the 2003 to 2009 analysis made the same comparisons, but using data for the 2003 to 2009 study period at all four sites to allow “same-flow-sequence” comparisons, the 2003 to 2009 study period was used for the Loup River bypass reach. However, there is still a mixture of methods, including using HEC-RAS for Sites 1 and 2, and using actual long-term hydraulic geometry relationships for the gages at Genoa and Columbus. In addition, as discussed in Section 4.1.1, Literature Review, longer study periods result in more accurate determination of the effective discharge.

Figure 5-11 was developed where effective and dominant discharges for 2003 to 2009 at all four sites were plotted against the channel geomorphologic characteristics. Table 5-8 provides the values of the effective and dominant discharges at the four sites shown in Figure 5-11.

Table 5-8. 2003 to 2009 Effective and Dominant Discharges for the Loup River Bypass Reach Study Sites

Site or USGS Gage Number	Site Description or Gage Name and Location	Qe	Qd
Site 1	Loup River Upstream of the Diversion Weir	2,300	2,500
Site 2	Loup River Downstream of the Diversion Weir	1,700	1,100
06793000	Loup River near Genoa, NE	1,700	1,200
06794500	Loup River at Columbus, NE	1,800	1,300

Note:

Qe = effective discharge; Qd = dominant discharge.

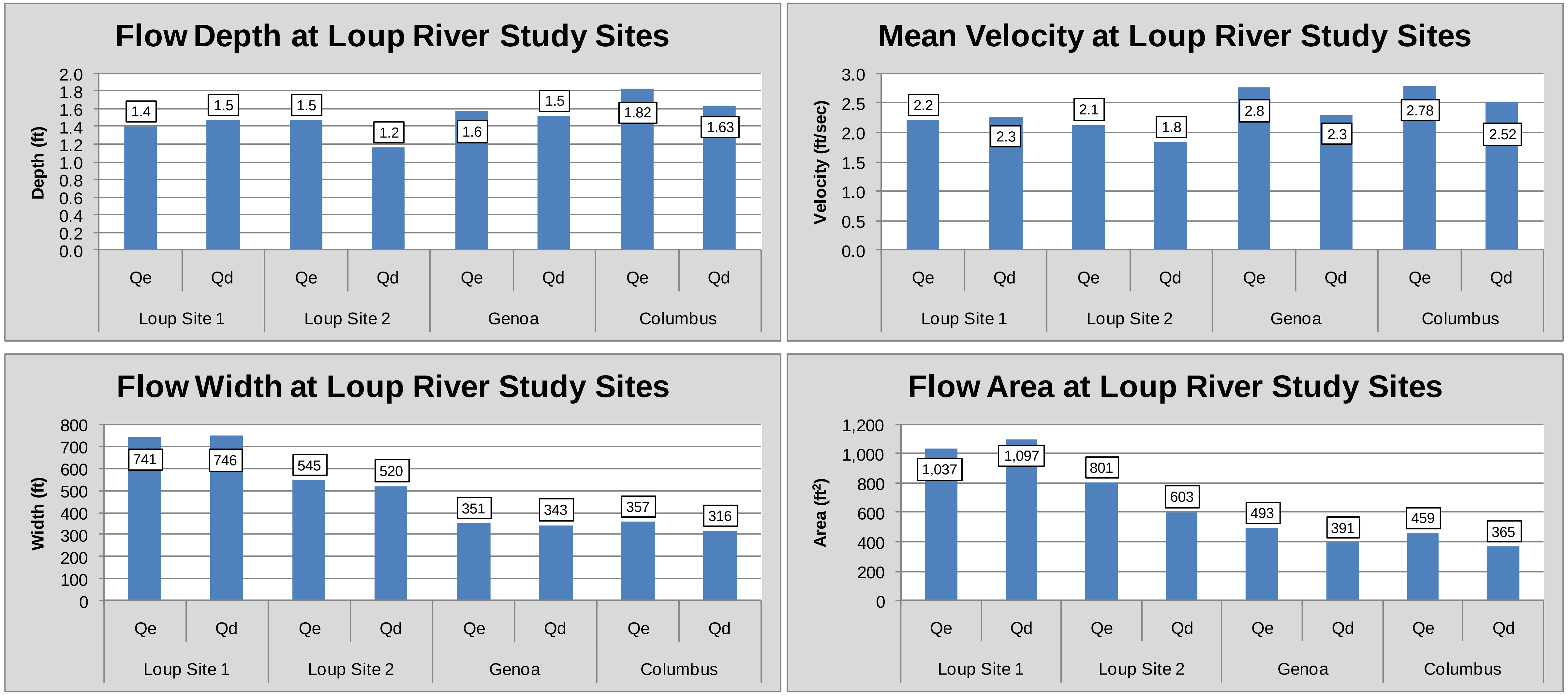


Figure 5-11. Spatial Analysis of Loup River Bypass Reach Sites Showing Estimated Channel Geomorphologic Characteristics at Each Site for Both the Effective and Dominant Discharges

Lower Platte River

The eight study sites on the lower Platte River are the Duncan gage; ungaged Site 3; ungaged Site 4; the North Bend gage; ungaged Site 5; and the Leshara, Ashland, and Louisville gages.

Derivation of the discharge versus flow depth, mean velocity, flow width, and flow area relationships for the lower Platte River followed the same approach described above for the Loup River bypass reach. In the former analysis, it was shown that comparing effective and dominant discharges with the channel geomorphologic characteristics using both the 1985 to 2009 and 2003 to 2009 data provided useful (and in the case of 2003 to 2009, compatible) information. However, interpretations require recognition of the extreme variability in both year-by-year values and even 7-year cumulative values compared to the more-reliable long-term (1985 to 2009) values listed in Section 5.2.2, Effective Discharge and Other Sediment Transport Calculations.

Because the primary interest in the spatial analysis for the lower Platte River sites was to compare the results for the three ungaged sites (Sites 3, 4, and 5) with each other and with gaged locations, a common time frame for the comparisons was selected, namely 2003 to 2009. Figure 5-12 presents the results of the characteristic comparisons with both effective and dominant discharge at all eight study sites, beginning at Duncan and extending downstream to Louisville. Even though all eight sets of results are included in the same graphs, the site results can easily be compared side by side. Having all eight sites on the same graphs has the advantage of viewing overall spatial trends as well as side-by-side results.

Table 5-9 provides the values of the effective and dominant discharges at the eight sites shown in Figure 5-12.

Table 5-9. 2003 to 2009 Cumulative Effective and Dominant Discharges for the Lower Platte River Study Sites

Site or USGS Gage Number	Site Description or Gage Name and Location	Qe	Qd
06774000	Platte River near Duncan, NE	900	1,200
Site 3	Platte River Upstream of the Tailrace Return	2,100	2,400
Site 4	Platte River Downstream of the Tailrace Return	3,600	3,900
06796000	Platte River at North Bend, NE	3,400	4,100
Site 5	Platte River near North Bend	3,500	3,650
06796500	Platte River at Leshara, NE	4,400	4,400
06801000	Platte River near Ashland, NE	7,300	6,400
06805500	Platte River at Louisville, NE	7,000	7,700

Note:

Qe = effective discharge; Qd = dominant discharge.

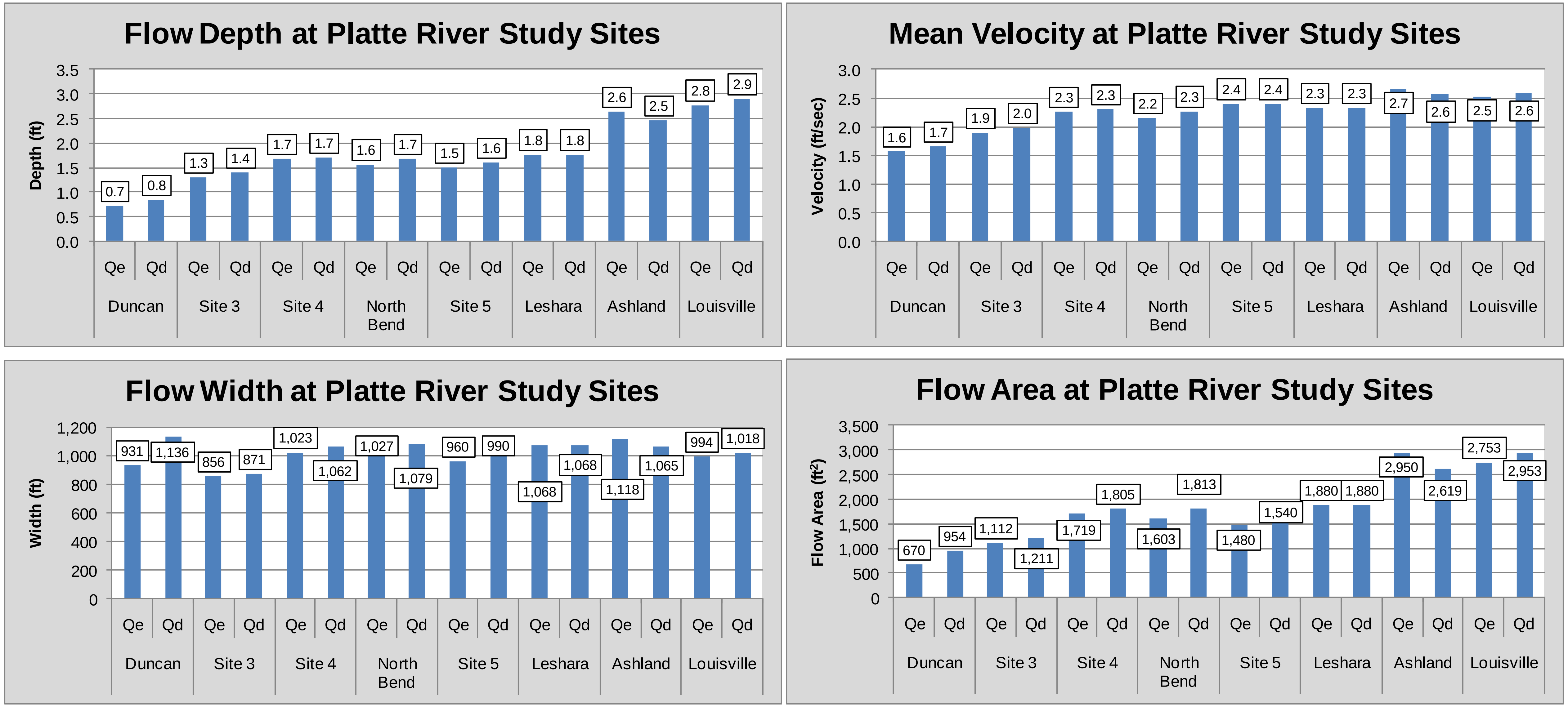


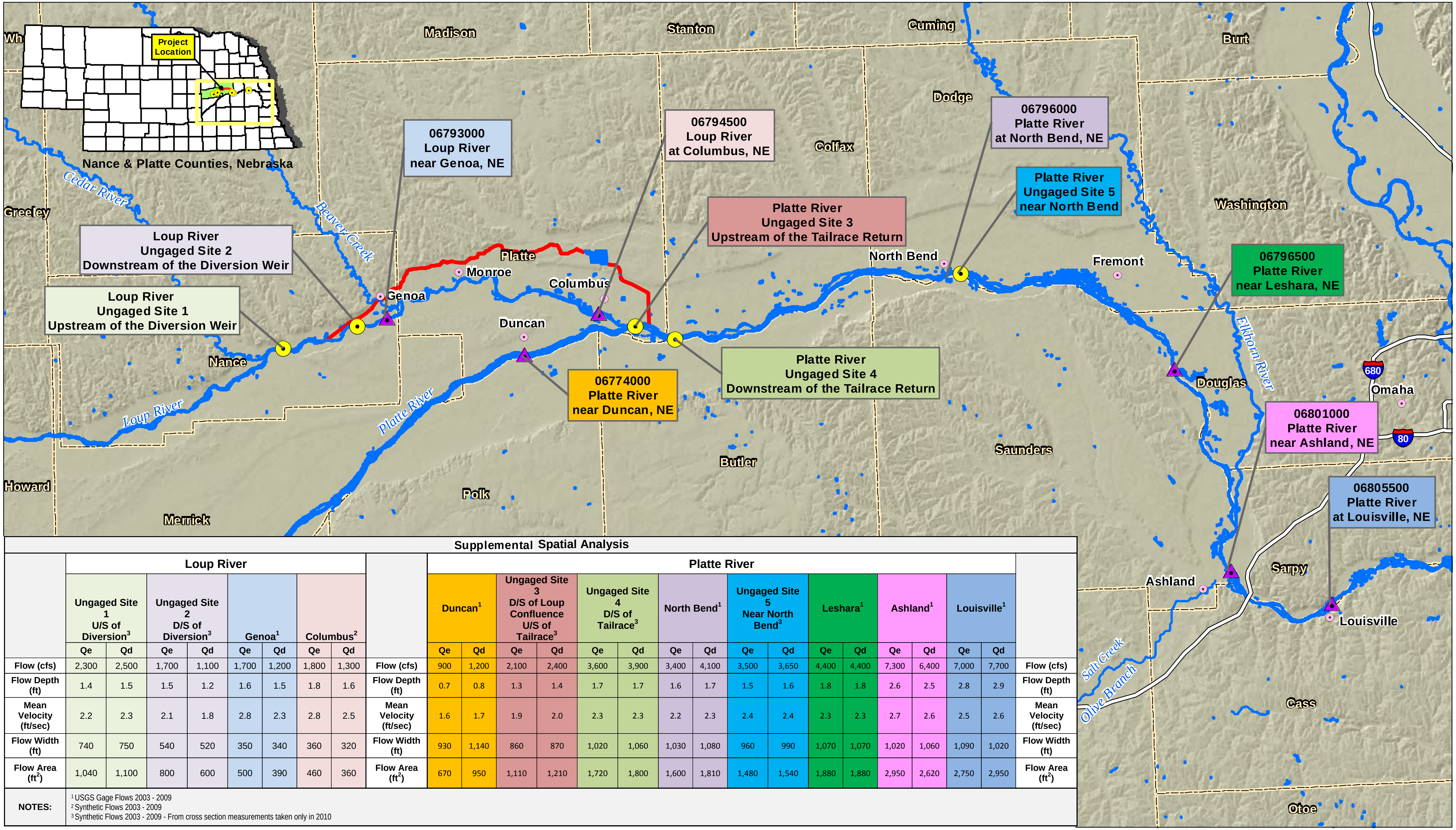
Figure 5-12. Spatial Analysis of Lower Platte River Study Sites Showing Estimated Hydraulic Geometries at Each Site Using Only the 2003 to 2009 Actual or Synthetic Hydrographs for Both the Effective and Dominant Discharges at Each Site

Three of the four graphs have similar trends. Except for the graph showing flow widths, the other three show a gradual increase in the parameters from Duncan to Site 4 associated with increases in effective and dominant discharges, followed by all three graphs "leveling-off" between Site 4 and Leshara, followed by an incrementally larger step upward between Leshara and Ashland, which stay at about the same level downstream to Louisville. Minor fluctuations in these trends are attributable to data and computation uncertainties.

The graph in Figure 5-12 showing flow width versus effective and dominant discharge reveals that flow width, with one exception, is relatively constant everywhere, at an average value around 1,000 feet for all effective and dominant discharges, including flow widths at Duncan. The exception is an apparent 14 percent "narrowing" at Site 3 from the average value. In a river with all degrees of freedom to adjust its channel, locations with equal effective or dominant discharges would be expected to have similar flow widths, and flow widths for different effective discharges would be expected to be proportionate. One possible explanation may be the presence of reventment.

The USFWS Bank Stabilization Survey for the Lower Platte River (Runge and Harms, July 13, 2006) reveals that "linear structures" appear to occur on both sides of the channel around Site 3, while not occurring as heavily on both sides at adjacent sites just upstream and downstream. Channel width throughout the lower Platte River is not as free to vary naturally with effective or dominant discharge because of the bank stabilization that has occurred throughout.

Paired-site and overall interpretations of the relationships in Figures 5-11 and 5-12 are provided below under Results of the Supplemental Spatial Analysis. Figure 5-13 shows a map and a table of flow depth, mean velocity, flow width, and flow area for all study sites.



Supplemental Spatial Analysis

	Loup River									Platte River																
	Ungaged Site 1 U/S of Diversion[3]		Ungaged Site 2 D/S of Diversion[3]		Genoa[1]		Columbus[2]			Duncan[1]		Ungaged Site 3 D/S of Loup Confluence U/S of Tailrace[3]		Ungaged Site 4 D/S of Tailrace[3]		North Bend[1]		Ungaged Site 5 Near North Bend[3]		Leshara[1]		Ashland[1]		Louisville[1]		
	Qe	Qd	Qe	Qd	Qe	Qd	Qe	Qd		Qe	Qd	Qe	Qd	Qe	Qd	Qe	Qd	Qe	Qd	Qe	Qd	Qe	Qd	Qe	Qd	
Flow (cfs)	2,300	2,500	1,700	1,100	1,700	1,200	1,800	1,300	Flow (cfs)	900	1,200	2,100	2,400	3,600	3,900	3,400	4,100	3,500	3,650	4,400	4,400	7,300	6,400	7,000	7,700	Flow (cfs)
Flow Depth (ft)	1.4	1.5	1.5	1.2	1.6	1.5	1.8	1.6	Flow Depth (ft)	0.7	0.8	1.3	1.4	1.7	1.7	1.6	1.7	1.5	1.6	1.8	1.8	2.6	2.5	2.8	2.9	Flow Depth (ft)
Mean Velocity (ft/sec)	2.2	2.3	2.1	1.8	2.8	2.3	2.8	2.5	Mean Velocity (ft/sec)	1.6	1.7	1.9	2.0	2.3	2.3	2.2	2.3	2.4	2.4	2.3	2.3	2.7	2.6	2.5	2.6	Mean Velocity (ft/sec)
Flow Width (ft)	740	750	540	520	350	340	360	320	Flow Width (ft)	930	1,140	860	870	1,020	1,060	1,030	1,080	960	990	1,070	1,070	1,020	1,060	1,090	1,020	Flow Width (ft)
Flow Area (ft^2)	1,040	1,100	800	600	500	390	460	360	Flow Area (ft^2)	670	950	1,110	1,210	1,720	1,800	1,600	1,810	1,480	1,540	1,880	1,880	2,950	2,620	2,750	2,950	Flow Area (ft^2)

NOTES:

[1] USGS Gage Flows 2003 - 2009

[2] Synthetic Flows 2003 - 2009

[3] Synthetic Flows 2003 - 2009 - From cross section measurements taken only in 2010

8 4 0 8
Miles

Legend

●	City
▲	USGS Gaging Station and Study Site
●	Ungaged Study Sites
═	Interstate
─	Stream/River
🟥	Loup Power Canal
🟦	Waterbody
▭	County

Loup Power District Hydro Project

Supplemental Spatial Analysis

Loup River Hydroelectric Project
FERC Project No. 1256
Study 1.0 - Sedimentation

DATE
August 26, 2011

FIGURE
5-13

Z:\Projects\Loup_Power_District\37104_LPD_FERC_Relicensing\map_docs\mxd\Supplemental_Spatial_Analysis.mxd

Results of the Supplemental Spatial Analysis

Because FERC's request for supplemental analysis of spatial changes in the channel geomorphologic characteristics referenced comparisons of flow depth, mean velocity, flow width, and flow area with effective discharge, this discussion primarily addresses effective discharge as the sediment transport and morphological indicator. Where appropriate, interpretations of the results using dominant discharges are included as well.

Loup River Bypass Reach

In reporting results and interpreting geomorphologic trends of the pair-by-pair comparisons of characteristics for channel-forming flows, it is important to repeat cautions. Channel morphologies from short-term sequences of flow data, which is futher caveated when synthetic data on flows and once-in-time, fixed-bed hydraulic geometries are used over a range of flows that would be certain to alter the bed geometry should be interpreted carefully. Implications of the results on habitat require that the spatial analysis of hydraulic characteristics at the four sites be comparable both in terms of the period of record, assumptions made, and methodologies used.

Two study periods were available for this analysis. Long-term effective and dominant discharges and hydraulic geometry relationships were available at the gaged sites from 1985 to 2009 records, while the information for the ungaged sites, and to some extent at Columbus, were only available from 2003 to 2009. The longer period provides better estimates of the cumulative effect of the 25-year sequence of daily flows on equilibrium channel geometry, but comparable values were not available at the ungaged sites, so the analysis was performed using the 2003 to 2009 effective and dominant discharges.

Figure 5-11 (2003 to 2009) provides the spatial analysis results for the Loup River bypass reach, showing flow depth, mean velocity, flow width, and flow area relationships plotted for the effective and dominant discharges. As noted in the above discussion of the development of the relationships, a mixture of methods were used for the four Loup River bypass reach study sites, three of which are essentially ungaged and rely on synthetic hydrology and fixed-bed hydraulics.

Because Figure 5-11 does not show channel dimensions for the same flow "event" (same discharge), they could lead to incorrect spatial analysis conclusions if used to interpret habitat conditions. To make inferences on habitat, comparisons of hydraulic parameters at adjacent or sequential sites should be based on hydraulic parameters for the same flow event (or multitude of events) passing through all locations.

Because the changes in flow depth and mean velocity between Sites 1 and 2 were relatively small, it is apparent from the flow width and flow area graphs in Figure 5-11 that effective and dominant discharges have a greater proportional impact on flow width and flow area. Most literature on these transport indicators associate flow width with discharge, with little or no mention of any apparent relationship with flow depth or mean velocity.

Shown in Table 5-8, the effective discharges from Site 2 through Columbus are within 100 cfs of each other (1,700, 1,700, and 1,800 cfs, respectively). So also are the dominant discharge vaules (1,100, 1,200, and 1,300 cfs). For both indicators, the natural trend of increasing amounts in the downsteam direction occurs.

Figure 5-11 shows that when the effective and dominant flow rates from Site 2 downstream are about equal, flow depth and mean velocity are relatively the same as at Site 2. It also reveals that flow depths and mean velocities at all locations downstream of the Diversion Weir are about the same or slightly greater than at Site 1, even though the effective and dominant discharges downstream average 25 and 52 percent, respectively, less than at Site 1. While flow depth and mean velocity do not appear to be significangly altered by effective or dominant discharge, flow width and flow area decrease from Site 1 to Site 2 and again from Site 2 to Genoa, and then level off. This reinforces the above conclusion that effective discharge has a stronger relationship with flow width and flow area, possibly being linearly proportional on a percentage basis.

This "leveling off" of flow width and flow area at Genoa is based on the data showing that wetted channel widths and flow areas at Genoa and Columbus are about equal. The flow width and flow area parameters at Site 2 are midway between the Site 1 and Genoa sites even though the effective and dominant discharges at Sites 2 and Genoa are nearly the same. Because Site 2 has similar physical characteristics as Site 1, the hydraulic geometry between Site 1 and Genoa appears to have an "intermediate" morphology between Site 1 conditions and the current equilibrium at Genoa and Columbus. This reach is relatively wide and straight when compared in aerial photos with the more sinuous and narrow conditions downstream. The analysis shows that conditions from Genoa to Columbus are in equilibrium, and because they differ from the equilibrium conditions at Site 1, it is concluded that the intermediate hydraulic geometry at Site 2 is also in a state of equilibrium, with flow width and flow area hydraulics that reflect the transitional geometry between Site 1 and Genoa.

As further evidence that all four locations are individually in equilibrium and that a relationship between effective discharge and flow width and flow area exists, the 26 percent decrease in channel width and 23 percent decrease in flow area that occur between Sites 1 and 2, shown in Figure 5-10, are a close match with the 26 percent change in effective discharge from 2,300 cfs at Site 1 to 1,700 cfs at Site 2. The Genoa graphs (see Figure 5-29) show that during the study period from 2003 to 2009, the annual effective discharge reached a low value of 1,500 cfs in 2004, followed in 2005 by a near-record high of 3,000 cfs (the last time this occurred was in 1990, when the effective discharge reached 3,400 cfs). Similar fluctuations in dominant discharge occurred (700 cfs in 2003 and 1,700 cfs in 2008). These fluctuations would definitely result in fluctuations of channel conditions, which are part of the dynamic nature of a braided river. This is further evidenced by the significant changes in channel cross sections noted at Sites 1 and 2 and elsewhere during 2010 (see Attachment A). These variations, plus interpretations based on HEC-RAS hydraulics using assumptions of a fixed boundary from 2010 cross sections are helpful but not adequate for making management decisions.

It is concluded that the hydraulic parameters for the Loup River bypass reach are entirely consistent with the conclusions previously presented in Section 5.2.4, Regime Analysis, because:

- Percent changes in both flow width and flow area between Sites 1 and 2 closely matched the percent change in effective discharge between those sites
- The data at Genoa and Columbus reveal a state of equilibrium
- Conditions at Site 2 can be explained as an intermediate but stable geometry between Site 1 and Genoa; namely, the morphology (and habitat) of the Loup River bypass reach, measured by the effective and dominant discharges, is consistent with natural river processes.

Lower Platte River

USGS (Kircher, 1981) surmised that a relationship between effective (or dominant) discharge and channel width exists in the Platte River. This was postulated and evaluated because it is consistent with the theory of dominant and effective discharges. The shape of a channel is formed by the flows that transport the most sediment and the channel geomorphologic characteristics (flow depth, mean velocity, flow width,and flow area) that exist for flows around the effective discharge rate. This allows for estimates of the equilibrium morphology.

Because the effective discharge represents the central value of the flows that transport the greatest amount of the total sediment, and because the dominant discharge is the value that if held constant would move the same amount of sediment, the geometry associated with these flow rates generally defines the equlibrium morphology. A change in either the effective or dominant discharge, if allowed to occur over sufficient time, would alter the channel geometry according to the best estimate of the relationship between channel-forming discharge and relevant equilibrium geometric parameters.

If adequate data exist for sufficient study sites in any unconstrained braided river to establish the effective and dominant discharges and associated geometries, graphs of the hydraulic parameters can be used to affirm that sites are in regime with the overall relationship and each other, and in some cases, they can be used to predict channel morphology changes for alternative, prolonged operations that would alter the effective or dominant flow rates. Both are potentially the most useful aspects of effective and dominant flow methods.

Because there are five gaged sites and three ungaged sites in the lower Platte River, sufficient numbers of sites on the same river are available to create these "quasi-equilibrium condition" graphs, at least using the 2003 to 2009 flows. As noted in the discussion of the Loup River bypass reach, there appeared to be a strong relationship between effective discharge and flow width and flow area. Similar, but somewhat less evident, relationships were found to exist using dominant discharge. Flow depth and mean velocity do not appear to be linked as readily to channel-shaping flows. No literature surveyed, including Kircher (1981), hypothesized relationships in braided rivers for any variables except flow width. In a braided river, flow is largely made up of width, so a relationship between area and discharge may also exist.

Flow Width Versus Effective and Dominant Discharge

Figure 5-14 shows the relationship between channel width and effective and dominant discharge rates for the eight study sites on the lower Platte River. The data points generally plot from left to right on the graph in geographic order, moving downstream, with minor exceptions at the three data points clustered around 3,500 cfs (Site 4, Site 5, and North Bend). The largest exception in Figure 5-14 occurs at the last two data points. Because Ashland has a higher effective discharge than Louisville, those two points are in reverse geographical order as shown in the graph. Dominant discharge generally increases in the downstream direction from Duncan to Louisville, so the data points in Figure 5-14 are in geographical order from left to right. The only minor exception is that the dominant discharge at Site 5 is slightly lower than the value at Site 4.

Except for Site 3 (the second point from the left in both graphs of Figure 5-14) and Louisville (the second point from the right in the first graph of Figure 5-14) and except for both Site 3 and the last two points in the second graph of Figure 5-14 (Ashland and Louisville), the data follow a reasonably uniform trend. If channel widths were not constrained in the lower Platte River, the trend lines developed by this method would "best" explain the average lower Platte River morphology. Because it is known that lateral constraints exist, the data point at Site 3 showing an apparent "narrowing" below the overall pattern is most easily attributed to bank stabilization. If the revetments throughtout the lower Platte River are far enough laterally to fall outside flow rates corresponding to the effective flow rates, they would not necessarily impact the trend line.

Sites 4 and 5, as well as the North Bend gage, are all relatively close together in Figures 5-14 and 5-15. This is reasonable in that the hydrology between Sites 4 and 5 is similar. There are no significant tributaries between the Tailrace Return and North Bend. The hydraulic characteristics shown in Figure 5-12 and the surveyed cross sections show consistent geometries between study sites. In addition, the synthetic flow hydrograph at Site 4 closely matches the North Bend gage hydrograph, as described in the Updated Study Report, Appendix B, Hydrocycling Study Report, Section 4.2.1.

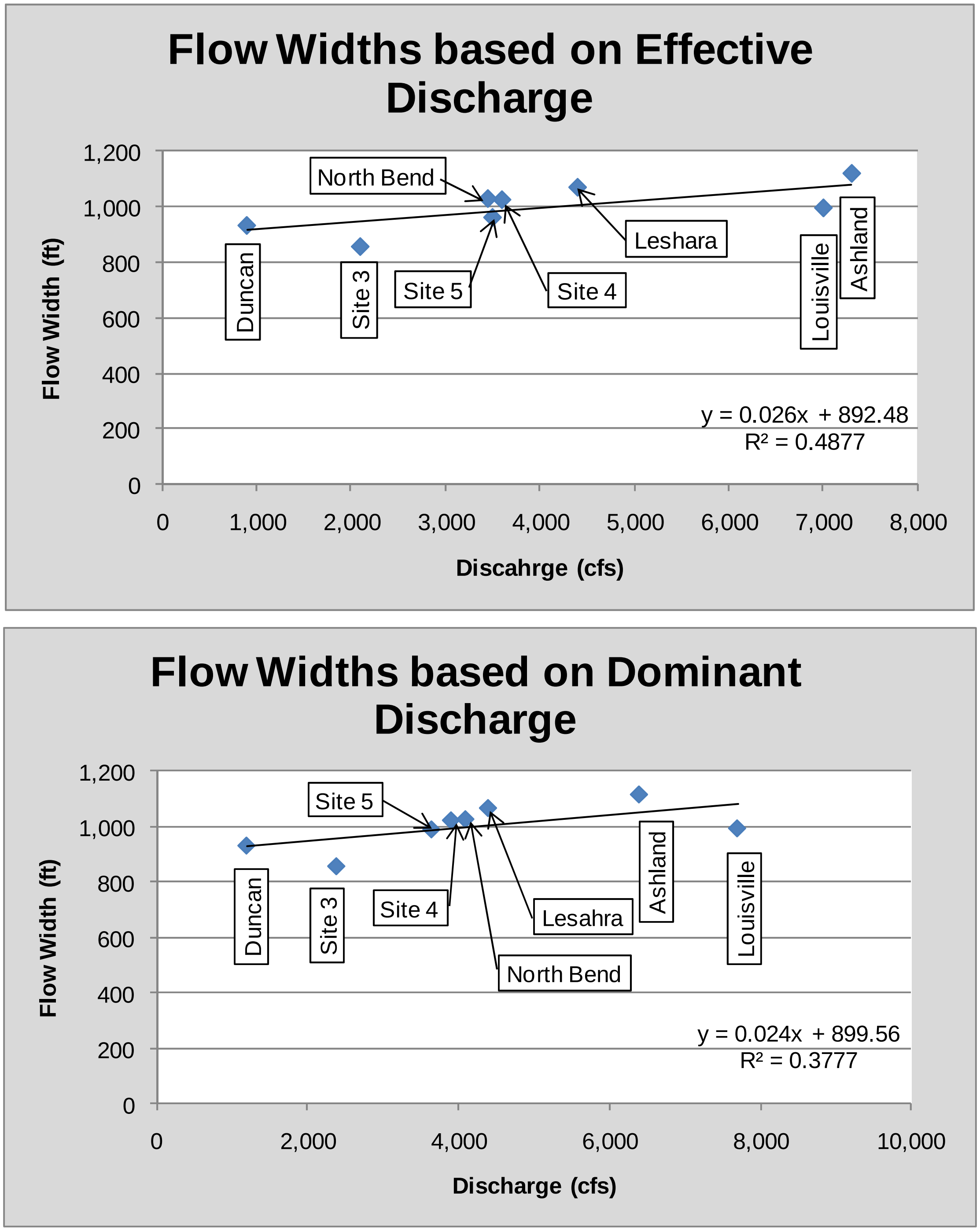
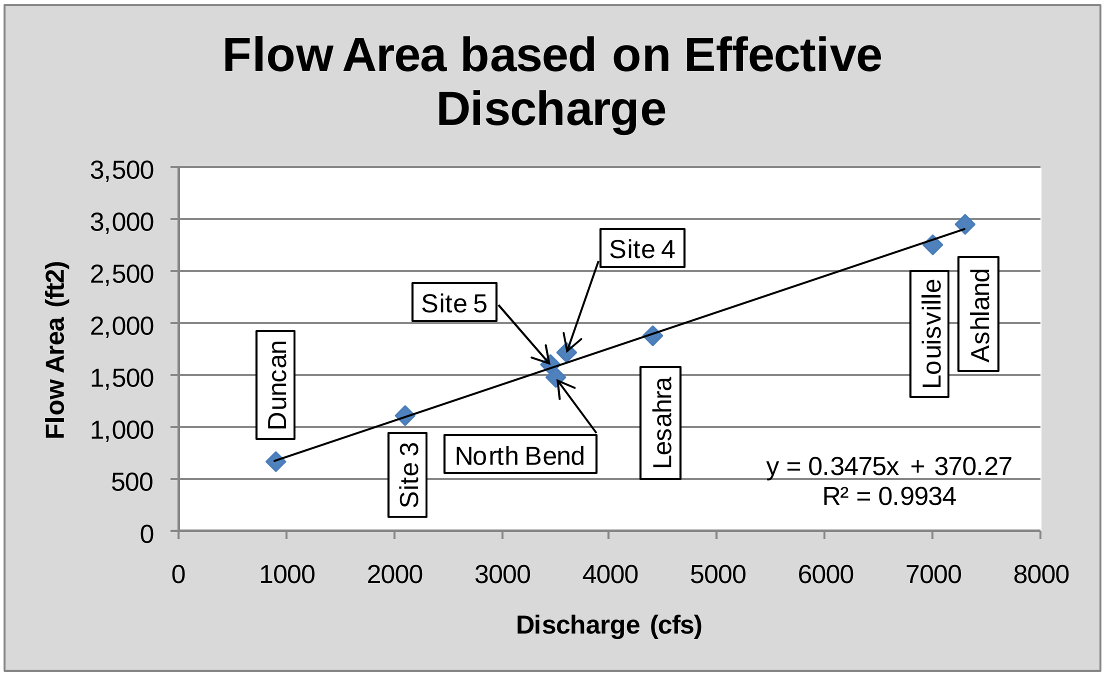


Figure 5-14. Channel Width versus Effective and Dominant Discharges at all Eight Lower Platte River Study Sites based on 2003 to 2009 Actual or Synthetic Hydrographs



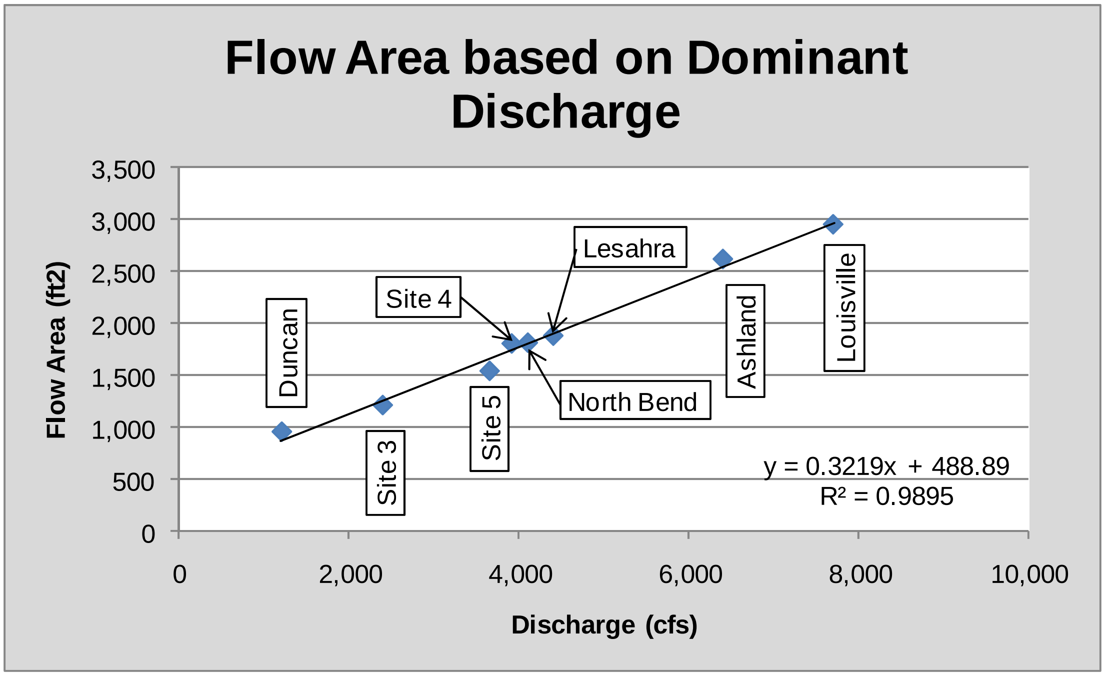


Figure 5-15. Channel Area versus Effective and Dominant Discharges at all Eight Lower Platte River Study Sites based on 2003 to 2009 Actual or Synthetic Hydrographs

In addition to having limited data, the Ashland gage is downstream of the Elkhorn River and upstream of Salt Creek, and the Louisville gage includes all upstream tributaries, which could impact hydrology and sediment transport indicators when comparing the Ashland data with Louisville data. Finally, because all the data points are from the 2003 to 2009 actual or synthetic hydrographs, they are subject to the caveats on using short-term hydrographs to obtain effective and dominant discharges that may not coincide with morhphologies resulting from long-term flows.

Flow Area Versus Effective and Dominant Discharge

As noted previously, a trend line of effective or dominant discharge versus channel width in an unrestrained river would allow credible assessment of consistency of paired-site data as well as overall assurances that the channel geometry is consistent with effective discharge concepts from study site to study site and throughout. Figure 5-15 shows that the relationship between flow area and both effective and dominant discharge are significantly uniform and do not exhibit the anomalies at Site 3 or Ashland to Louisville described for the flow width relationship. Instead, a strong relationship, with significantly strong coefficients of linear regression, exists.

As with Figure 5-14, the second point from the left in the first graph of Figure 5-15 is Site 3, just upstream of the Tailrace Return, showing that the flow area at that site is fully consistent with the overall trend line for the lower Platte River. The data point for North Bend falls on the trend line, with Site 4 falling slightly below the trend line and Site 5 falling equally above the trend line. Both are sufficiently close to the trend line and have sufficient uncertainty in their measurements and calculations to conclude that they are consistent with the “morphology-defining” line.

When flow area is plotted against dominant discharge, as shown in the second graph of Figure 5-15, points for both North Bend and Leshara (the two right-most points in the cluster of four) fall on the trend line, while Site 5 falls slightly below and Site 4 falls slightly above.

If any conclusions about Site 4 (downstream of the Tailrace Return) can be made from this, it would be that the flow area is slightly lower than the defining line for effective discharge, but slightly higher than the defining line for dominant discharge. In other words, the Project has no discernable impact on flow area due to the return flows. Flow area is not significantly impacted by bank revetments while channel width is, so the apparent “narrowing” of channel width at Site 3, indicated by a slightly smaller width there than upstream or downstream, should not be attributed to Project impacts.

Summary of Results of the Supplemental Spatial Analysis

In conclusion, the supplemental spatial analysis for the gaged and ungaged sites reveals that the effective and dominant discharges as well as annual transport capacities, based on use of synthesized flows for 2003 to 2009, do not provide any evidence that the morphology in either the Loup River bypass reach or the lower Platte River downstream of the Tailrace Return or elsewhere is impacted by the Project. Instead, the channel morphologic characteristics, measured by comparing effective and dominant discharges spatially with channel geomorphologic characteristics, are consistent with natural river processes.

Even though the supplemental analysis did not alter the conclusions of the earlier spatial analyses, the use of the 2003 to 2009 data was particularly beneficial in that it produced a set of morphology-defining trend-line graphs for the lower Platte River showing that significantly strong relationships exist between flow width, flow area, and effective and dominant discharges.

Additionally, the river-defining relationships between sediment transport indicators and channel widths (and areas) at the gaged and ungaged sites are consistent with values reported by Kircher (1981), USGS (1983), and Parsons (May 2003) for Middle Platte River gage stations.

Similar trend lines for the Loup River bypass reach may exist, but could not be developed because there is effectively only one gaged location in the bypass reach..

It is concluded that the supplemental spatial analysis shows that the channel geomorphologic characteristics' relationships with effective and dominant discharge for the Loup River bypass reach and lower Platte River are entirely consistent with the original spatial analysis conclusions; namely, the morphology (and habitat) of individual and paired study sites in the Loup River bypass reach and lower Platte River, measured by comparing the parameters with effective and dominant discharges, is consistent with natural river processes. No identifiable Project impacts on the morphology (or habitat defined by the morphology) occur at any individual study sites or between any sets of two or more adjacent sites.

5.2.4 Regime Analysis

Gaged Sites (1985 to 2009)

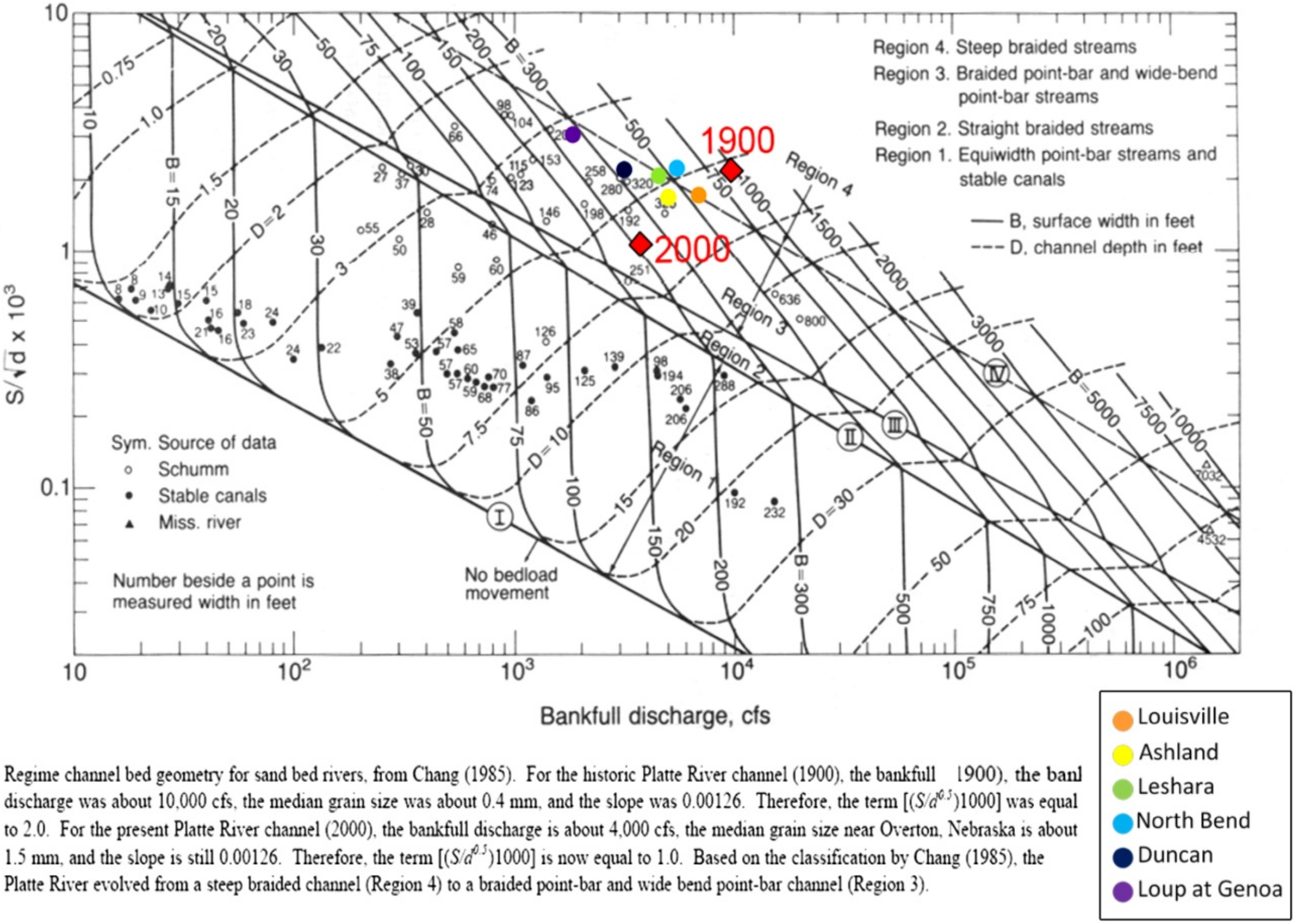
The effective discharges from Table 5-2 were input as bankfull (channel-forming) discharges on copies of all three of the regime methods previously used on the Platte River by USBR (April 2004). The results are shown in Figures 5-16, 5-17, and 5-18. As discussed in Section 4.1.1, Literature Review, all three methods call for "bankfull discharge" on the horizontal axis (abscissa), but it is clear from the literature cited that the intent was that values entered on the abscissa should be the channel-forming discharges. As also discussed in Section 4.1.1, both the 1.5-year flood and "bankfull" flow are crude estimates of the channel-forming discharge and are particularly inappropriate for braided rivers. For the data shown in the graphs at the sedimentation study sites, effective discharge was considered the appropriate estimate of the channel-forming discharge.

The data points on Chang's graph (see Figure 5-16) show that all six stations for this study are along the borderline between Chang's braided river Regions 4 and 3, with all locations being well-distanced from proximity to any threshold to a different morphology. The two dots labeled 1900 and 2000 were graphed by Chang at Overton and should be disregarded because instead of determining the effective discharge, Chang applied crude estimates of "bankfull" rates in each case.

Although the data points for the six stations shown on Leopold and Wolman's graph (see Figure 5-17) suggest that the Loup and Platte rivers have shifted from a braided stream over the threshold to a meandering morphology, their method does not incorporate grain size and does not include data from streams similar to the Platte River. USBR did not use this graph to evaluate its 1900 and 2000 conditions.

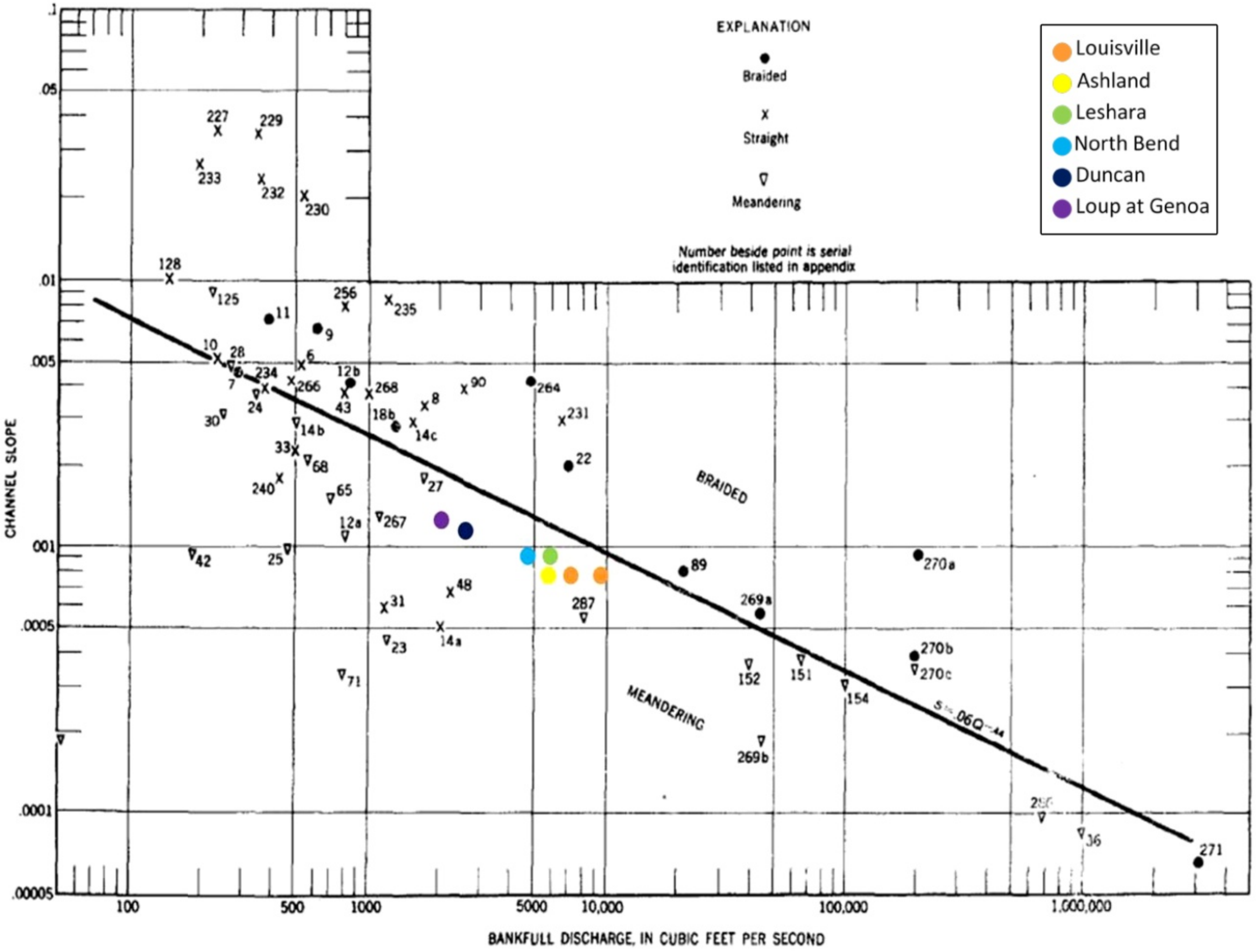
The data points on Lane's graph (see Figure 5-18) lead to the same conclusion indicated by Chang's regime method. All graphed values are well-positioned away from any threshold to a different morphology.

This combined use of effective discharge and regime theory is state of the art and supports the consensus among investigators that the Loup and Platte rivers are in regime. Further, it is the best available technology for determining whether any changes, whether climatic or operational, could impact any river's morphology.



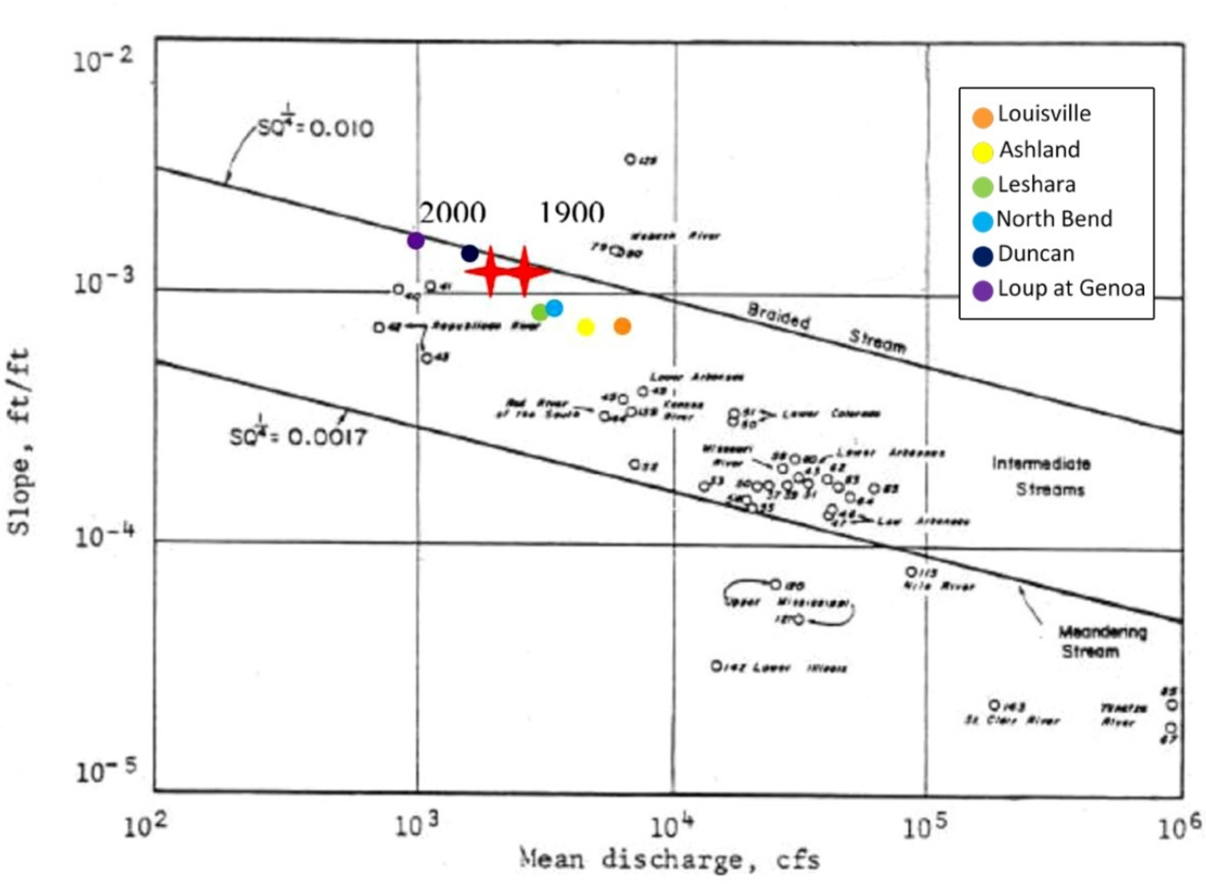
Regime channel bed geometry for sand bed rivers, from Chang (1985). For the historic Platte River channel (1900), the bankfull 1900), the banl discharge was about 10,000 cfs, the median grain size was about 0.4 mm, and the slope was 0.00126. Therefore, the term $[(S/d^{0.5})1000]$ was equal to 2.0. For the present Platte River channel (2000), the bankfull discharge is about 4,000 cfs, the median grain size near Overton, Nebraska is about 1.5 mm, and the slope is still 0.00126. Therefore, the term $[(S/d^{0.5})1000]$ is now equal to 1.0. Based on the classification by Chang (1985), the Platte River evolved from a steep braided channel (Region 4) to a braided point-bar and wide bend point-bar channel (Region 3).

Figure 5-16. Chang's (March 1985) Regime Morphology Chart for Sand Bed Rivers with Sedimentation Study Results



Values of slope and bankfull discharge for various natural channels and a line defining critical values which distinguish braided from meandering channels.

Figure 5-17. Leopold and Wolman's (1957) Threshold Chart for Meandering and Braided Rivers with Sedimentation Study Results



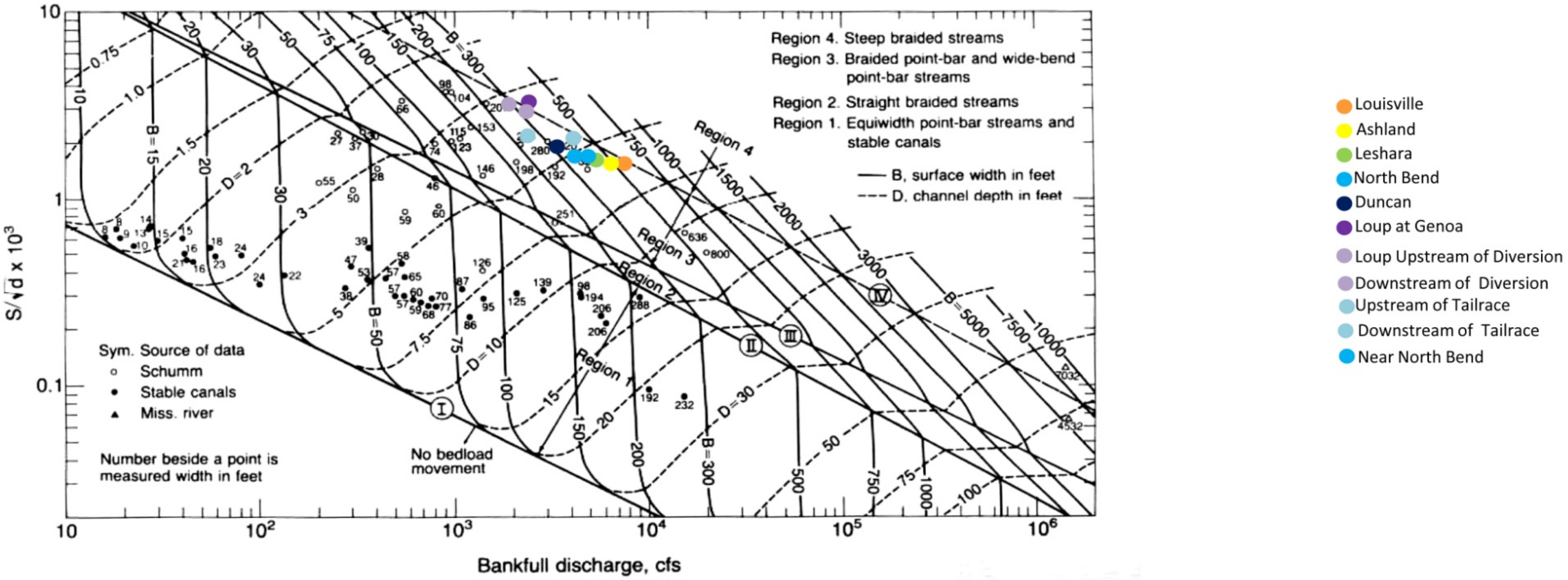
Lane's (1957) regime diagram for sandbed streams based on slope and mean discharge, taken from Richardson, et al. (1990). Red points shown are for the central Platte River with a slope of 0.0026 ft/ft and a mean discharge of 3,700 cfs for the year 1900, and a mean discharge of 2,100 cfs for the year 2000.

Figure 5-18. Lane's (1957) Regime Morphology Chart for Sand Bed Rivers with Sedimentation Study Results

Ungaged Sites (2009)

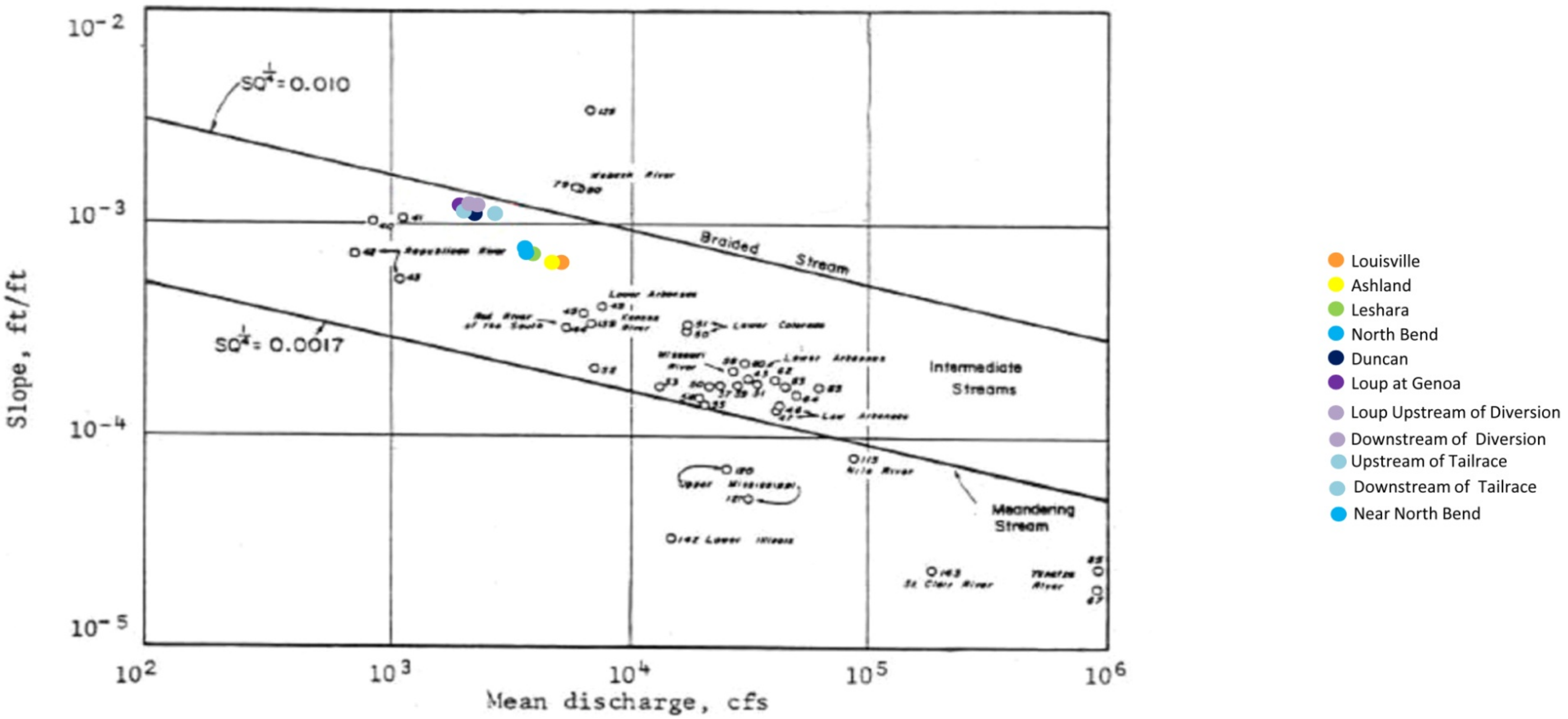
As noted in the methodology for regime analysis in Section 4.3.4, the final test of whether either the Loup or Platte River or any location within either river is transitioning to another form can best be accomplished through regime analysis.

Figures 5-19 and 5-20 were plotted using 2009 data for the ungaged sites. Because of the subjectivity of determining effective discharges from the sediment transport histograms, especially for seasonal or single-year data, the 2009 dominant discharges at the ungaged sites were input along the abscissa of each graph. As shown, all of the points plot in positions well within braided river morphology zones, with none being near any thresholds of transitioning to another morphology.



Regime channel bed geometry for sand bed rivers, from Chang (1985). For the historic Platte River channel (1900), the bankfull discharge was about 10,000 cfs, the median grain size was about 0.4 mm, and the slope was 0.00126. Therefore, the term [$(S/d^{0.5})1000$] was equal to 2.0. For the present Platte River channel (2000), the bankfull discharge is about 4,000 cfs, the median grain size near Overton, Nebraska is about 1.5 mm, and the slope is still 0.00126. Therefore, the term [$(S/d^{0.5})1000$] is now equal to 1.0. Based on the classification by Chang (1985), the Platte River evolved from a steep braided channel (Region 4) to a braided point-bar and wide bend point-bar channel (Region 3).

Figure 5-19. Chang's (March 1985) Regime Morphology Chart for Sand Bed Rivers with Ungaged Site Sedimentation Study Results Plotted



Lane's (1957) regime diagram for sandbed streams based on slope and mean discharge, taken from Richardson, et al. (1990). Red points shown are for the central Platte River with a slope of 0.0026 ft/ft and a mean discharge of 3,700 cfs for the year 1900, and a mean discharge of 2,100 cfs for the year 2000.

Figure 5-20. Lane's (1957) Regime Morphology Chart for Sand Bed Rivers with Ungaged Site Sedimentation Study Results Plotted

5.2.5 Objective 1 Conclusions

If the capacity for total bed material sediment transport for a given time period were equal to or less than the sediment yield, it would be concluded that the braided river is not supply limited and is currently in dynamic equilibrium. If the capacity for total bed material sediment transport for a given time period were to exceed the sediment yield, it would be concluded that the braided river may be supply limited and possibly degrading.

Analysis of the results shown in Tables 5-2, 5-3, 5-6, and 5-7 and Figures 5-16, 5-17, and 5-18 supports the following conclusions regarding the character of sediment transport in the Loup River bypass reach and lower Platte River:

1. Both rivers at all locations studied are clearly not supply limited. Table 5-6 shows that the annual watershed sediment yields above the gages ranges from two to six times the average study period capacity of the daily flows to transport bed material. USACE, after assessing the same question, concluded that "[b]ed material transport for the [Platte] river was found to be capacity limited with a virtually unlimited source" (July 1990). This and literature cited elsewhere in this report supports the fact that the yields in both the Loup and Platte rivers are not lacking in being able to supply more than the transport capacity. This is the nature of a braided river.
2. The spatial analysis of values of effective and dominant discharges and average annual transport capacities shown in Tables 5-2, 5-3, 5-6, and 5-7 and Figure 5-8 reveal that they increase in the downstream direction in a manner consistent with natural river processes, as well as being consistent with the literature and with values determined using similar methods by Kircher and Karlinger (1981), USGS (1983), and Parsons (May 2003) for the Middle Platte River stations.
3. At least at Ashland and Louisville, data exist that confirm that the effective discharge, and associated braided river morphology, has not changed since 1928. The only previous study of effective discharge in the lower Platte River was by Marlette and Walker (1968). Using a different sediment transport capacity equation and a much shorter period of record, Marlette and Walker calculated the dominant discharge using a histogram normally used in effective discharge methods, but instead of selecting the modal (peak) value of the histogram, he chose the median value above which half of the transport under the transport histogram occurs. Marlette and Walker arrived at values of 6,500 cfs at Ashland and 8,000 cfs at the Platte and Missouri River confluence using data from 1928 to 1967. This sedimentation study used a more common definition of effective discharge as the modal (peak) value of the transport histogram. Table 5-2 reveals that the 1985 to 2009 values (using the modal versus median discharges) are

7,000 and 7,500 cfs, respectively. These differences are not considered to be statistically significant.

4. The assumption that the 1.5-year flood is representative of either the channel forming or bankfull discharge is an approximation often used for smaller, single-channel streams. However, this assumption should not be used in non-episodic streams like the Loup and Platte rivers because the peak instantaneous floods are too infrequent and too short in duration to transport enough of the annual sediment transported to do the work of shaping or maintaining the rivers' morphologies. As demonstrated by the fact that the channel forming flows or effective discharges, calculated here for the Loup and Platte rivers, are significantly less than the 1.5-year flow and "bankfull flow," as shown in Table 5-2. Neither the 1.5-year or poorly defined and difficult to estimate "bankfull flows" should be used to approximate the channel-forming discharges in braided rivers. Effective discharges determined from daily flow records are relatively easy to calculate, so there is no need to use either of these approximations.
5. The channel geometries are "in regime," with the long-term flows shaping them. As shown in greater detail in Section 5.3.2, Analysis of Existing Data and Literature on Channel Aggradation/Degradation and Cross Sectional Changes Over Time, the current channel hydraulic geometries match the width, depth, and velocity calculations for flow rates matching the effective discharge rates. Nothing appears to be constraining either the Loup or Platte River from maintaining the hydraulic geometry associated with the effective discharges.
6. The combinations of slopes, sediment sizes, and effective discharges at all of the stations result in all locations being well within braided river morphologies, with none being near any thresholds of transitioning to another morphology.

5.3 Objective 2 – To characterize stream morphology in the Loup River bypass reach and in the lower Platte River by reviewing existing data and literature on channel aggradation/degradation and cross sectional changes over time.

5.3.1 Specific Gage and Kendall Tau Analyses

The results of the specific gage analysis and the subsequent Kendall tau analysis of trends within the specific gage analysis are discussed below.

Specific Gage Analysis

As discussed in the methodology in Section 4.4, a specific gage analysis was conducted using the Loup River gage near Genoa and the Platte River gages near Duncan, at North Bend, near Ashland, and at Louisville. Specific rating curves were generated for each gage using the stage versus discharge curves. Specific rating curves for these gages are shown in Figures 5-21 through 5-25.

Specific rating curves for all gages for a given discharge were also graphed. Figure 5-22 shows the specific rating curves for the gaged sites for a discharge of 1,000 cfs. Graphs for flows of 500 and 5,000 cfs are located in Figures 5-26 through 5-28.

Occasionally, within a year, the stage-discharge relationship had several points plot above the trend line in a similar shape to the trend line, meaning that a higher stage was required for a given discharge. As an example, at North Bend, in July, a discharge of 3,000 cfs has a stage of approximately 4 feet, but in December, that same discharge has a stage of about 6 feet. A review of the records showed that the majority of discharges above the trend line occurred between December and February. Although not designated as ice affected by USGS, these discharges and corresponding stages from December to February appear to represent a systemic shift during this time period and were removed from the data set, thus increasing the accuracy of the predicted trend line.

The following trends and observations are noted at each gage location:

- Genoa gage – The trend is stable at flows between 500 and 10,000 cfs. For flows between 15,000 and 30,000 cfs, the data become insufficient to create meaningful trend lines.
- Duncan gage – The trend is stable for flows ranging between 500 and 5,000 cfs for the 13 years previous to 2009. However, at higher discharges (10,000 to 15,000 cfs), there are fewer available data, and the data are more unstable.
- North Bend and Ashland gages – The stage trend has remained fairly stable, with aggradational and degradational trends less than 0.5 foot for discharges ranging between 500 and 30,000 cfs.
- Louisville gage – There is a slightly degradational trend of less than 0.5 foot for the 20 years previous to 2009.

In a few instances, a temporary decline or increase occurred at a gage site. This is attributed to extrapolating the stage discharge curve for that given year. For example, in 2002, the maximum discharge at North Bend was approximately 8,000 cfs. Extrapolating the best fit line for discharges in excess of 10,000 cfs seemed to under-predict the corresponding stage.

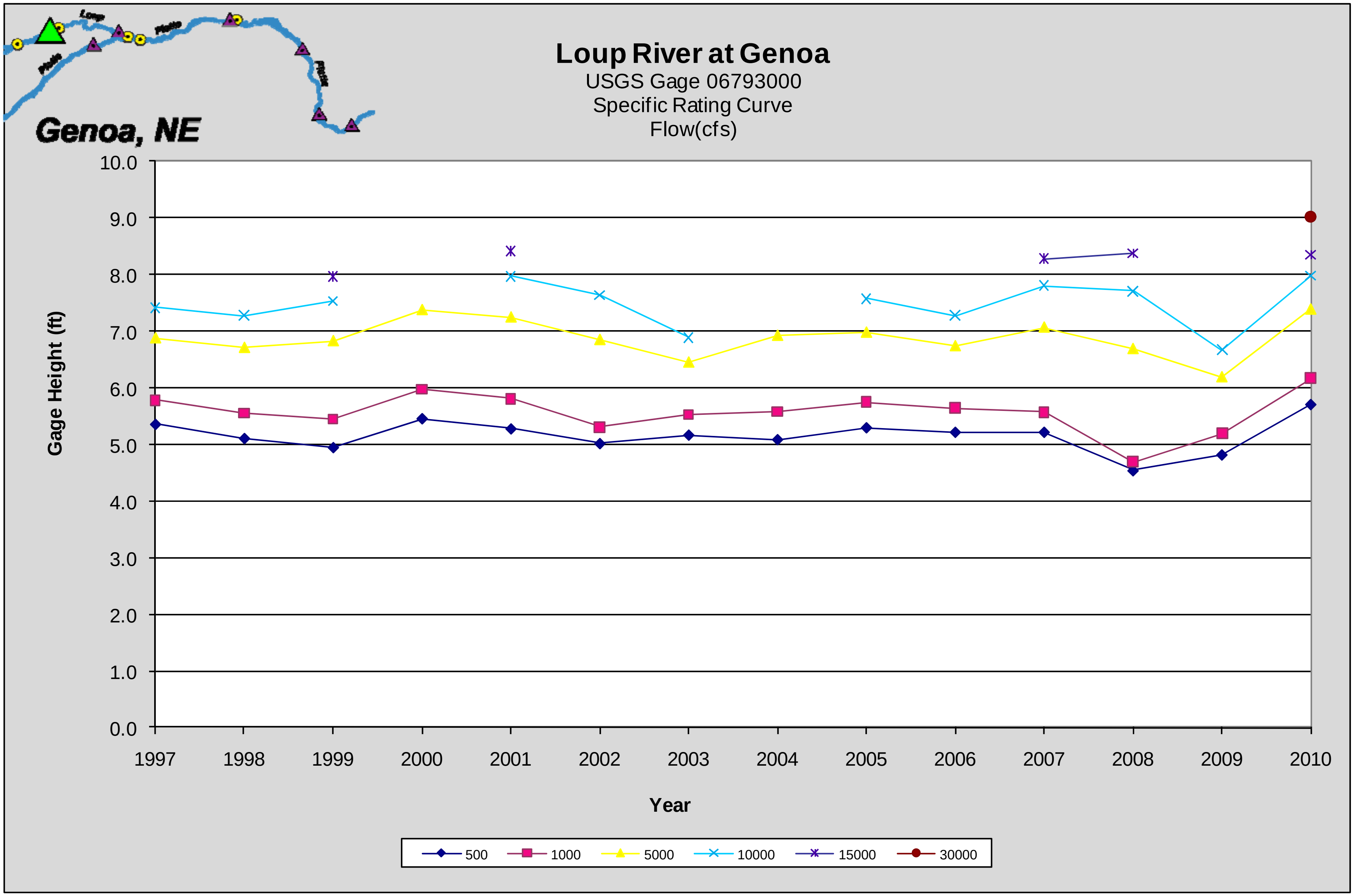


Figure 5-21. Specific Rating Curves for Genoa

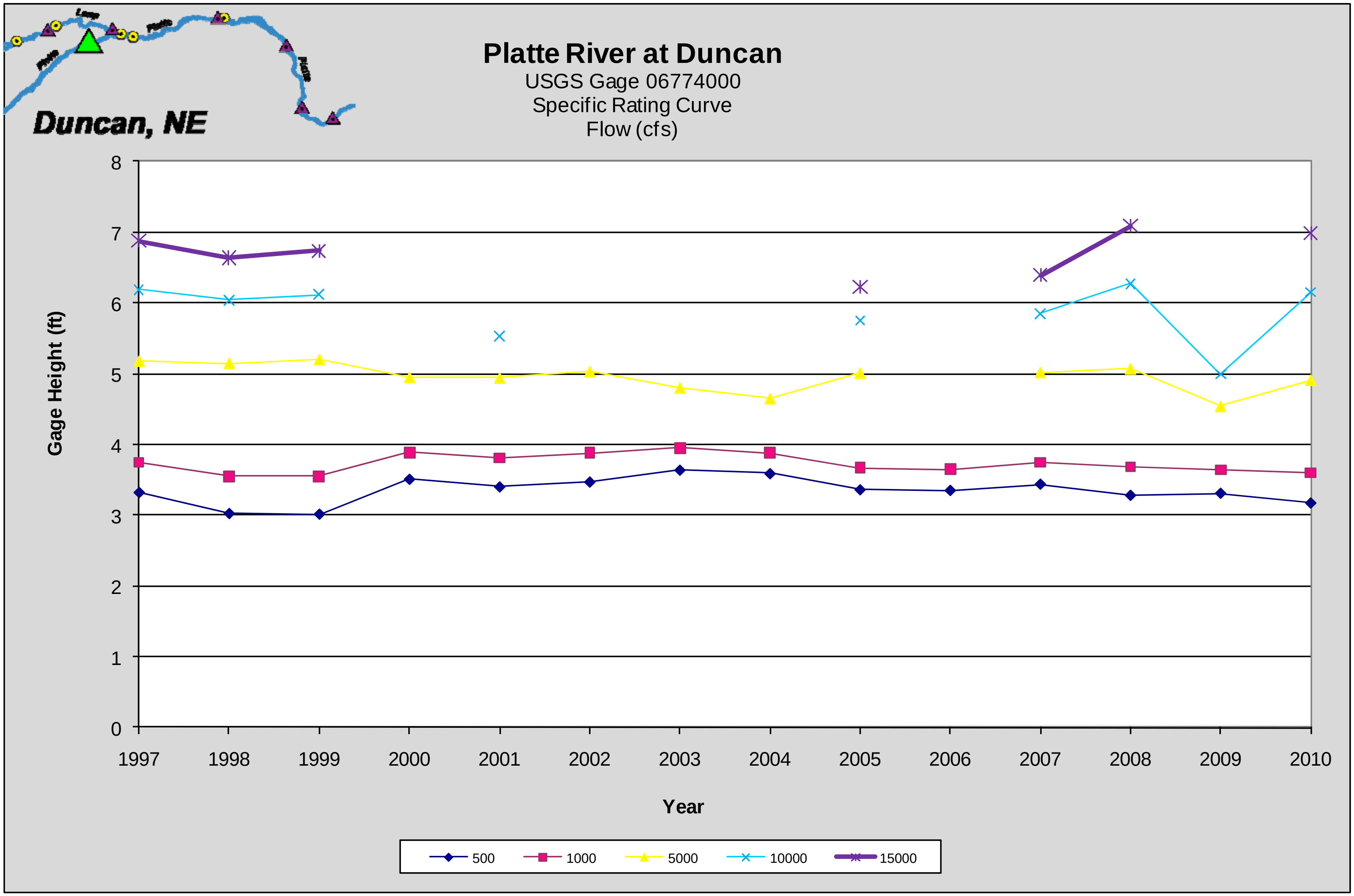


Figure 5-22. Specific Rating Curves for Duncan

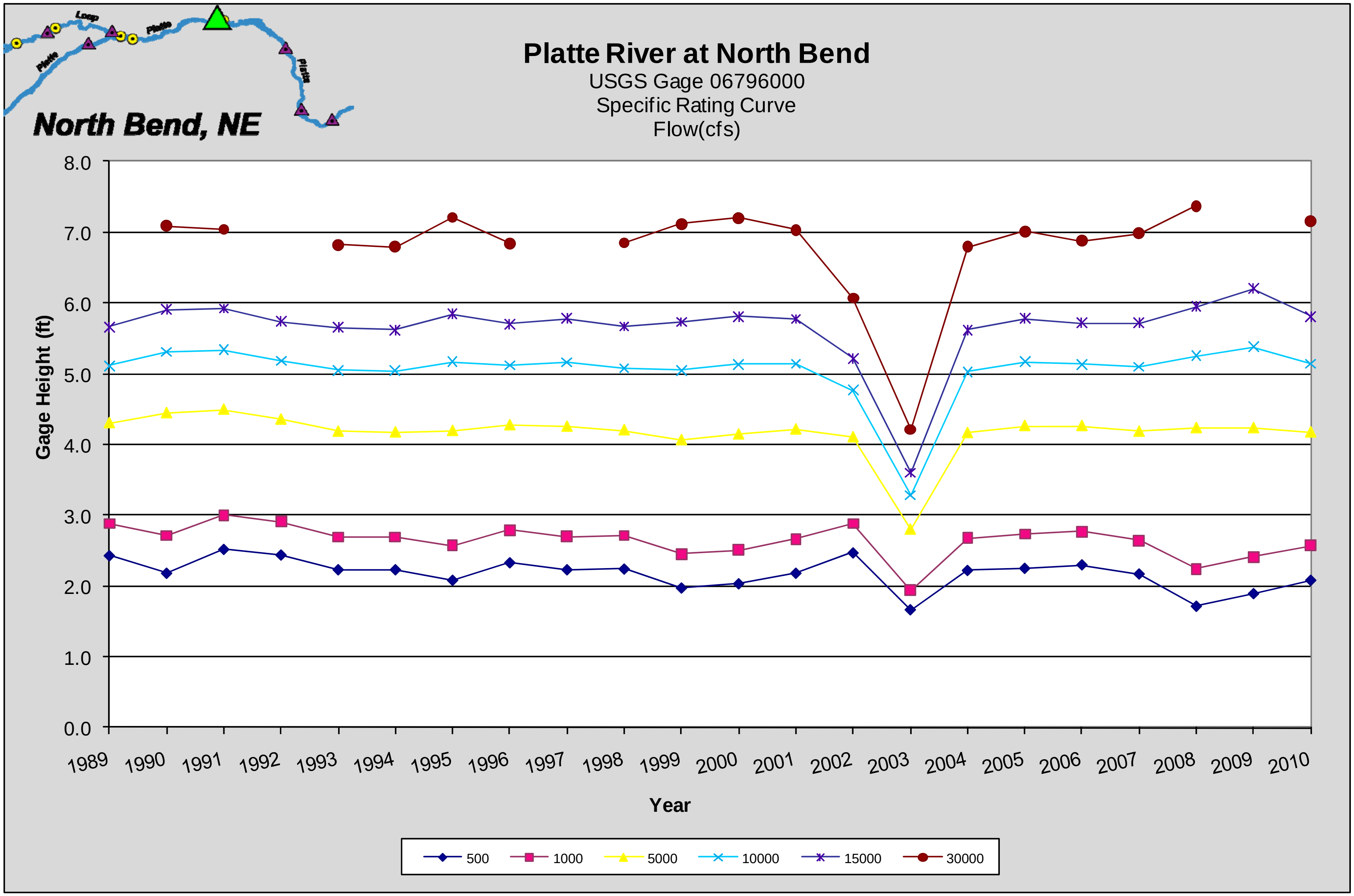


Figure 5-23. Specific Rating Curves for North Bend

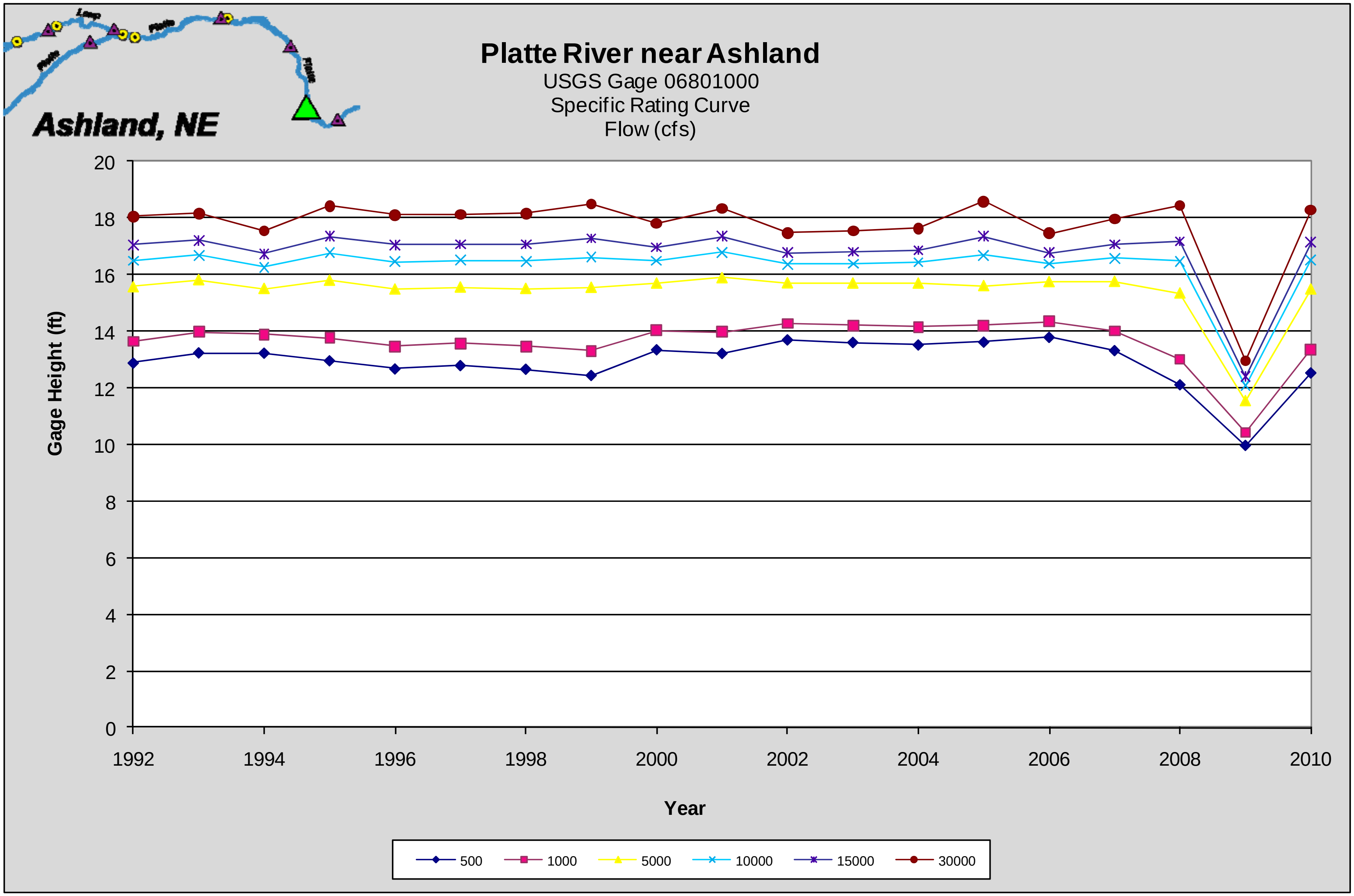


Figure 5-24. Specific Rating Curves for Ashland

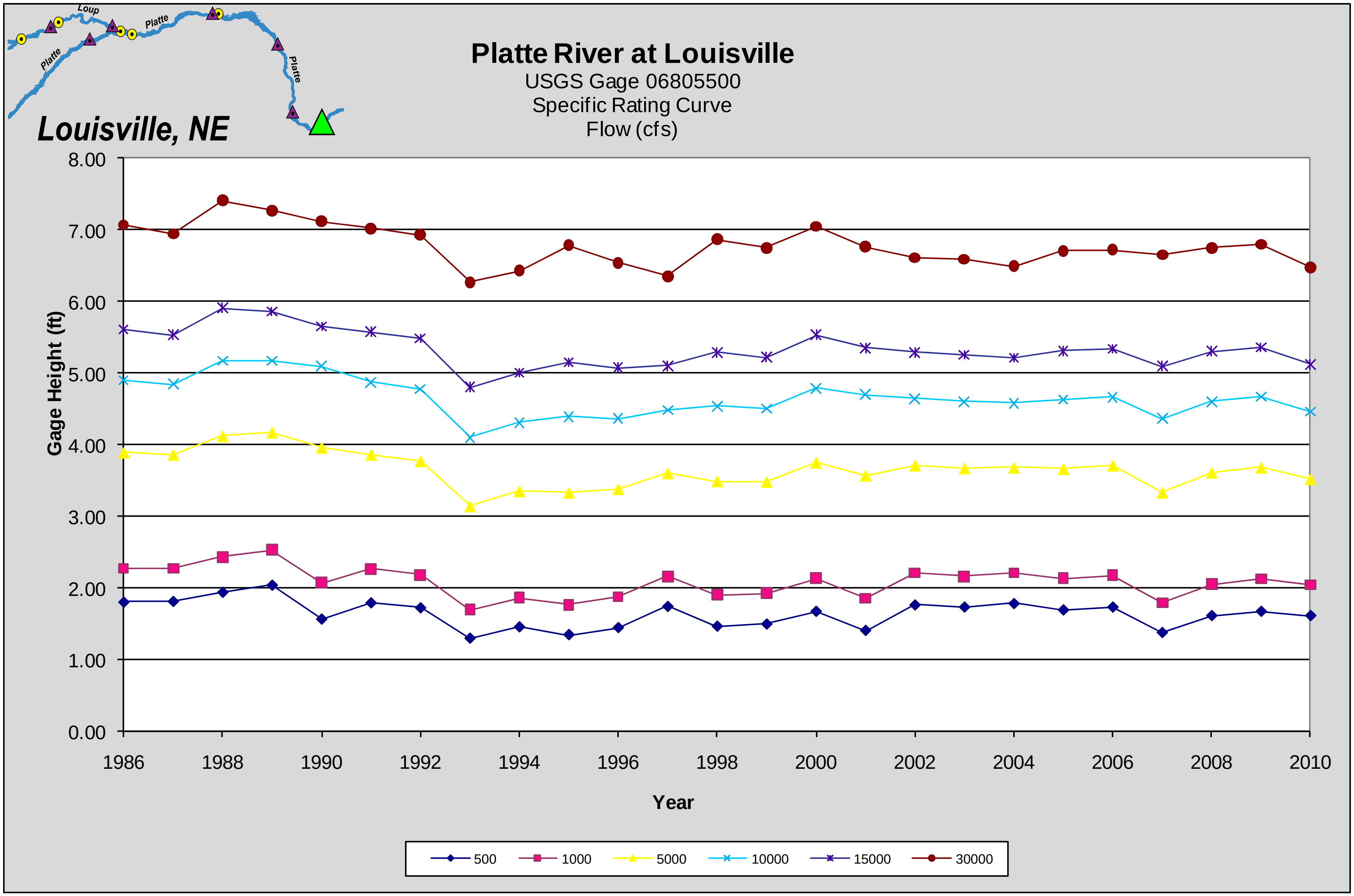


Figure 5-25. Specific Rating Curves for Louisville

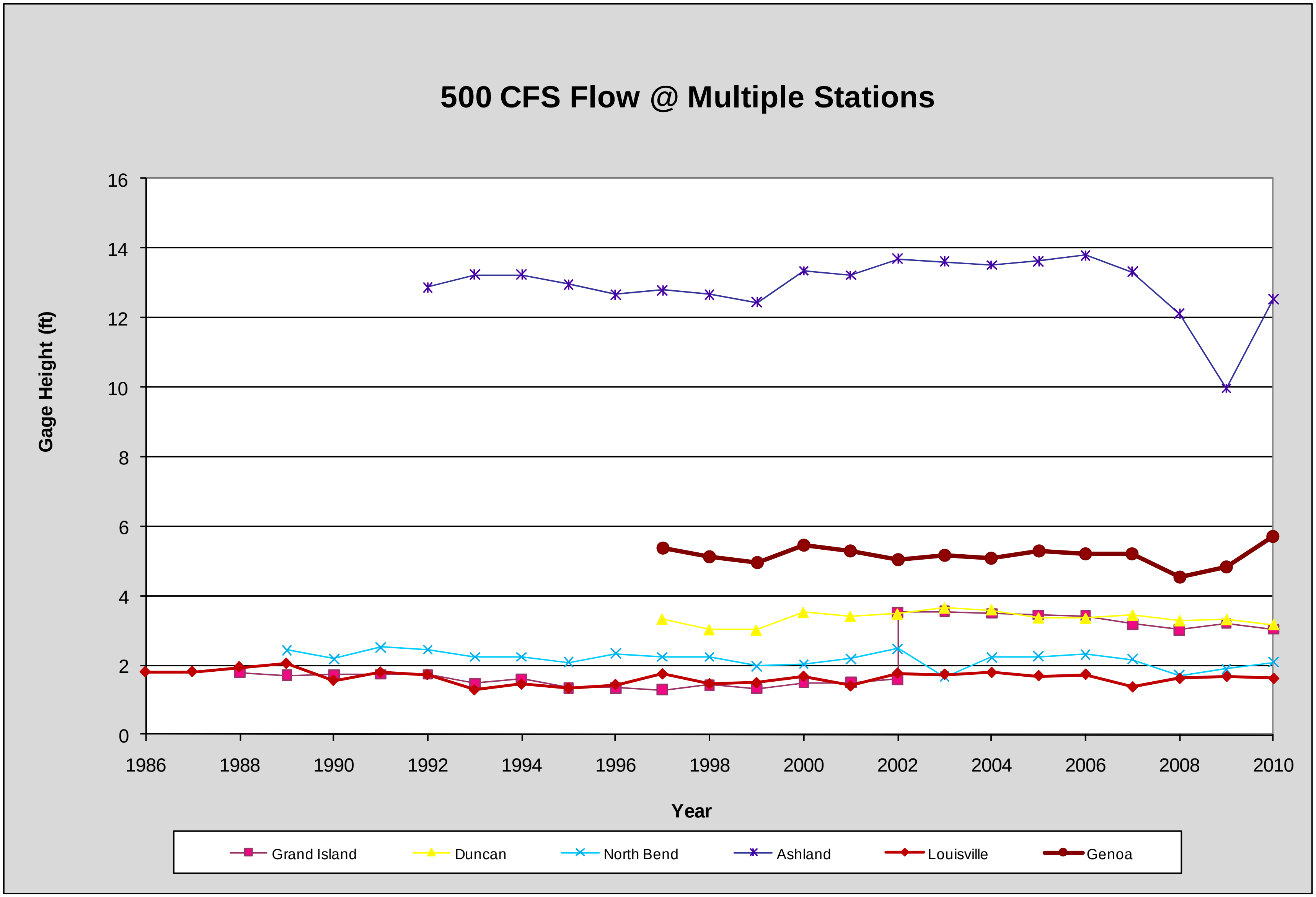


Figure 5-26. Specific Rating Curves at Multiple Sites for a Discharge of 500 cfs

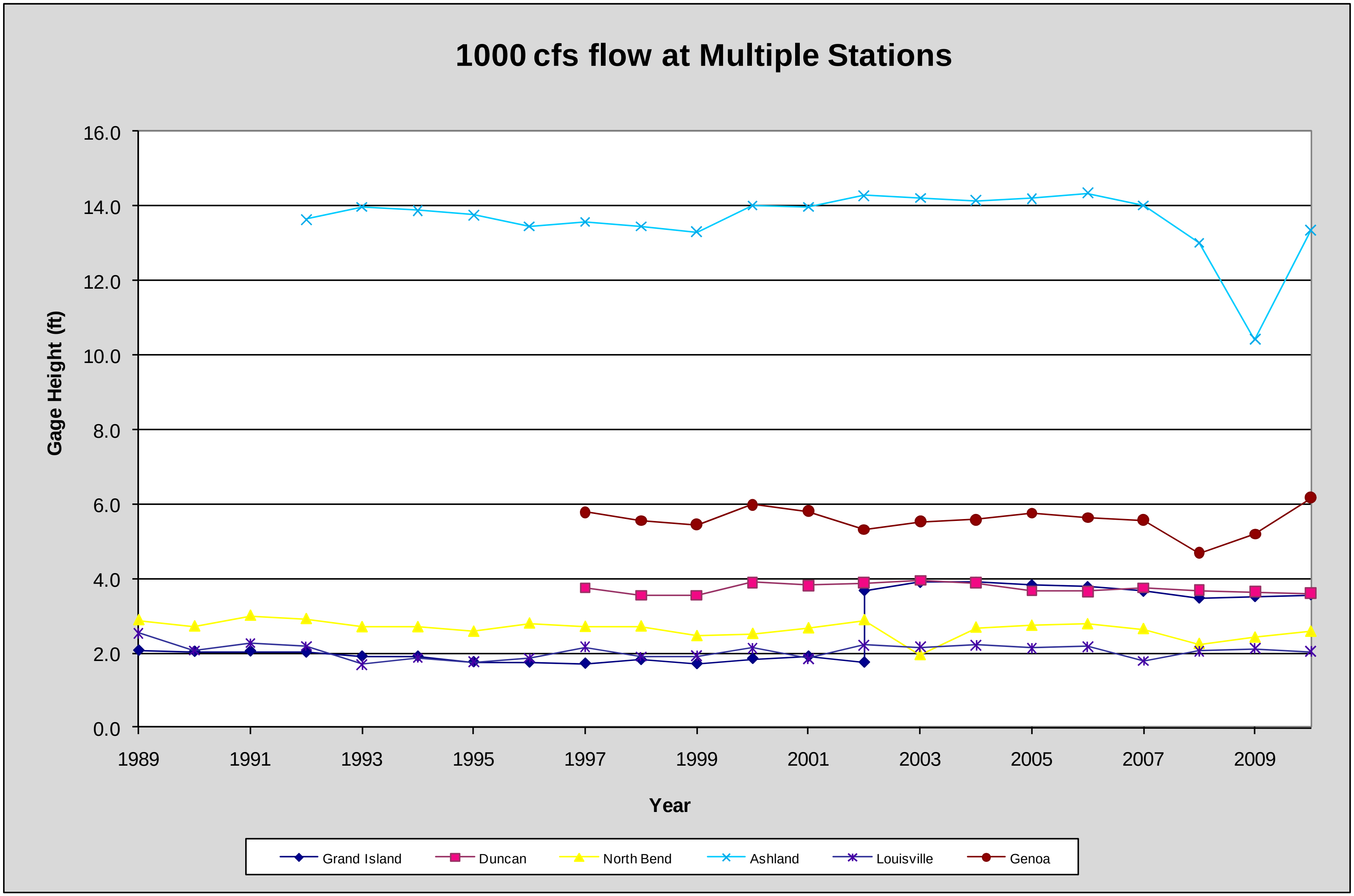


Figure 5-27. Specific Rating Curves at Multiple Sites for a Discharge of 1,000 cfs

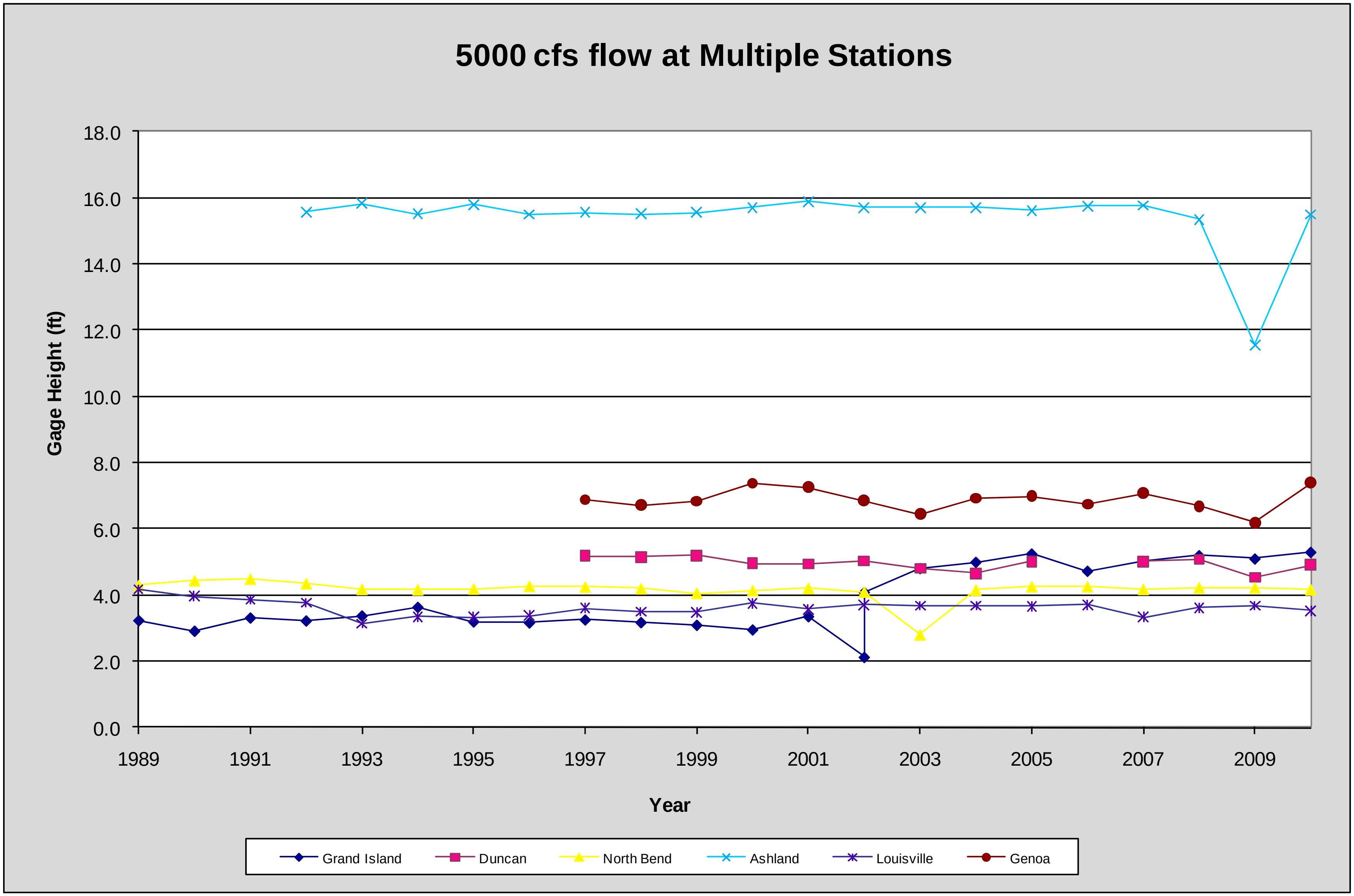


Figure 5-28. Specific Rating Curves at Multiple Sites for a Discharge of 5,000 cfs

Kendall Tau Analysis

While the above discussion of the specific gage analysis includes qualitative descriptions, in accordance with FERC's "Determination on Requests for Modifications to the Loup River Hydroelectric Project Study Plan" (December 20, 2010), a quantitative analysis was performed via a Kendall tau trend analysis. This analysis was conducted for the Loup River gage near Genoa and the Platte River gages near Duncan, at North Bend, near Ashland, and at Louisville, as listed in Table 4-6. For each site and for each flow rate (500 to 30,000 cfs), where more than one data point was available, a Kendall tau trend was calculated. Using a p-value of 0.01 to test for significance, only two significant trends were identified from the Kendall Tau analysis:

- The North Bend gage had a slight negative trend for the 1,000 cfs flow rate but no statistically significant trend for any of the other flow rates.
- The Louisville gage had a slight negative trend for the 30,000 cfs flow rate but no statistically significant trend for any of the other flow rates.

Tables 5-10 through 5-14 show the results of this analysis.

The Kenadall Tau analysis identified statistically significant negative trends for specific flow rates at two gages; however, when reviewing the analysis as a whole, there are no consistent aggradational or degradational trends at any of the analyzed gages. Therefore, it is concluded that at all gages analyzed, there is no overall aggradational or degradational trend.

Table 5-10. Kendall Tau Analysis for Genoa Gage for Various Flow Rates

Flow (cfs)	Kendall's Tau Statistic	P-Value	Significant Trend?
500	-0.09	0.66	No
1,000	-0.12	0.55	No
5,000	-0.03	0.87	No
10,000	0.17	0.43	No
15,000	0.20	0.62	No

Table 5-11. Kendall Tau Analysis for Duncan Gage for Various Flow Rates

Flow (cfs)	Kendall's Tau Statistic	P-Value	Significant Trend?
500	-0.06	0.78	No
1,000	-0.22	0.31	No
5,000	-0.47	0.03	No
10,000	-0.09	0.75	No
15,000	0.14	0.65	No

Table 5-12. Kendall Tau Analysis for North Bend Gage for Various Flow Rates

Flow (cfs)	Kendall's Tau Statistic	P-Value	Significant Trend?
500	-0.34	0.03	No
1,000	-0.42	0.01	**Yes**
5,000	-0.34	0.04	No
10,000	-0.11	0.51	No
15,000	0.58	0.73	No
30,000	0.05	0.76	No

Table 5-13. Kendall Tau Analysis for Ashland Gage for Various Flow Rates

Flow (cfs)	Kendall's Tau Statistic	P-Value	Significant Trend?
500	0.02	0.89	No
1,000	0.02	0.89	No
5,000	-0.07	0.69	No
10,000	-0.19	0.29	No
15,000	-0.14	0.41	No
30,000	-0.09	0.60	No

Table 5-14. Kendall Tau Analysis for Louisville Gage for Various Flow Rates

Flow (cfs)	Kendall's Tau Statistic	P-Value	Significant Trend?
500	-0.19	0.18	No
1,000	-0.22	0.12	No
5,000	-0.26	0.08	No
10,000	-0.25	0.09	No
15,000	-0.25	0.08	No
30,000	-0.35	0.01	**Yes**

5.3.2 Analysis of Existing Data and Literature on Channel Aggradation/Degradation and Cross Sectional Changes Over Time

Several relatively recent studies, described here, were conducted by others to evaluate aggradation/degradation and cross sectional changes in the Loup and Platte rivers. Some studies had a limited focus on middle-Platte locations upstream of Duncan, while others studies focused on the entire basin, evaluating channel profiles all the way to the Missouri River confluence. Some of the more recent investigations focused on conditions in the lower Platte River.

As discussed in Section 4.1.1, Literature Review, sediment yields estimated using indirect methods like those used by MRBC (September 1975) have value in determining whether a reach is flow versus supply limited, but should not be used to assess whether the Loup and lower Platte rivers are aggrading or degrading or whether the channel cross section is changing over time. Better indicators of geometry changes and aggradation or degradation are available from assessments of trends in effective discharge, which are described below.

By examining conditions in 1900 and contrasting them with conditions in 1990, USACE (July 1990) found that all reaches in the basin (including the lower Platte River) had no notable ongoing long-term aggradation or degradation. USACE's primary conclusion was that "the river within the study reaches is in a state of quasi-equilibrium" (July 1990).

As discussed in Section 4.1.1, Literature Review, both sediment availability (yield) and transport capacity in the Platte River were evaluated by USACE (July 1990). USACE affirmed that bed material transport throughout the study area is not supply limited due to a "virtually unlimited source."

To look at impacts of changes such as removal of vegetation from islands and bars on the longitudinal profile of the Platte River, USACE (July 1990) applied both 1- and 2-D modeling of hydraulics and sediment transport, including the use of 108 cross sections in its “Reach 3” (from Duncan to the confluence with the Missouri River). The HEC-6 and TABS-2 sediment transport models were calibrated to known water surface elevations. Among other tests, simulations were made of the effects of clearing vegetation from islands and bars to create habitat. The models (with removal of vegetation) were run up to 20 years in the future and predicted that a general decline in water elevation could be expected at most discharges but that the average bed elevation would remain relatively unchanged. This illustrates the resiliency of the Platte River to maintain its braided morphology.

Elliott, Huhmann, and Jacobson (2009) also concluded that there is unlimited supply of sediment based on the “extent and persistence of emergent sand bars on the lower Platte River.”

For the Platte River, USACE (July 1990) found that all reaches had no notable long-term aggradation or degradation or channel geometry trends. Highly anabranched reaches tended to be less stable than wider, single-channel reaches. The very wide single-channel reaches with no islands exhibited a tendency to aggrade slightly due to lack of transport capacity.

Citing scientific study reports by Peters and Parham (2008) and Parham (2007), NGPC (December 2008) concluded that even though the lower Platte River has been “highly altered” and that centuries-old characteristics have been “tempered” due to development and use of the water resource, the lower Platte River “retains most geomorphic characteristics of the [centuries-old] historic Platte River.”

As discussed in Section 4.1.1, Literature Review, USBR (April 2004) tested three widely-adopted regime diagrams (Chang, March 1985; Leopold and Wolman, 1957; and Lane, 1957), showing that all three are applicable in assessing the stability of the braided river morphology. USBR notes that “The braided pattern typical of the [Platte] river prior to the 1900s, requires a steeply sloped channel or an oversupply of sediment. The average channel slope of the Platte River (0.00126)…has not changed during the1900s because a large change in river bed elevation is needed to change the average slope over the length of the river….” The USBR report shows that the Platte River’s current-day profile is nearly identical to the turn-of-the-century profile published in 1901 by Gannett (USBR, April 2004).

Even though changes in planform occurred since 1900, USBR’s (April 2004) application of regime theory proved that the morphology is still well within the regime zones for stable, braided rivers. USBR concluded that the Platte River is in a greater state of dynamic equilibrium than it was in its pre-development form.

Probably the most relevant publication addressing the question of aggradation or degradation is the USGS report on its study of trends in channel gradation (slopes) in Nebraska streams, including both the lower Platte River and the Loup River at and downstream of the Diversion Weir (Chen, Rus, and Stanton, 1999). By evaluating extensive sets of longitudinal, cross section, and water surface elevation data collected at 145 gaging stations between 1913 and1995, Chen, Rus, and Stanton reported the following conclusions:

- Channel degradation was found at stations downstream of dams.
- No such degradation was found downstream of the Diversion Weir, or "dam."
- A slight aggrading trend was noted at the Loup River at Columbus, but Chen, Rus, and Stanton pointed out that it did not have the same data set as the other gages. Gaging at the site was discontinued in 1978 and not resumed until 2008.
- There was no evidence of any trend in aggradation or degradation in the Loup River at Genoa, Platte River at Duncan, Platte River at North Bend, and Platte River at Ashland.
- A slight degrading trend was noted at Louisville, which was attributed to site-specific circumstances and not considered to be generic.

In a channel stability study, USACE (USACE, October 2009) studies a section of the Platte River near Fremont, Nebraska. Using specific gage analysis on the USGS gages in the area, USGS sediment data, bank line migration information from photographs, and site-specific data, USACE was able to come to three relevant conclusions (USACE, October 2009):

- "No information was discovered to indicate an ongoing change in Platte River dynamic equilibrium within the study reach.
- Specific gage analysis at four gage locations did not indicate a clear increase or decrease in channel stages over time.
- Specific gage plots illustrated stages vary from year to year reflecting natural channel dynamics."

Conclusions from Studies by Others

It is important to note that the channel of a river in regime can and will be "continually changing" (USACE, July 1990), and yet remains in regime as long as there is no long-term change in mean values of the channel geometry indicators. Elliott, Huhmann, and Jacobson (2009) found that the lower Platte River "is an especially dynamic river channel with braid bars and shifting channels that change rapidly at the scale of 10's to 100's of meters…." This is an important aspect in the assessment of impacts of alternative operations on channel morphology (cross section geometry and planform alignment). Before drawing any conclusions, short term morphologic changes predicted in these assessments need to be contrasted with the normal ranges of deviation around the long-term, stable (in-regime) mean values.

Further evidence that yield (sediment entering a reach) in the Platte Basin is best represented by sediment transported is provided by USACE (July 1990), where it is concluded that the quantity of sediment entering each study reach was nearly equal to the sediment leaving when tributaries, diversions, and drains were accounted for.

As shown above, sufficient numbers of scientific studies have been performed regarding the question of aggradation/degradation and cross-sectional changes in the study reaches to thoroughly document that there is no evidence of either process. The number and quality of these studies preclude the need for any new analyses for the purpose of this sedimentation study. The analyses described in Sections 5.2 and 5.3 for Objectives 1 and 2, respectively, are considered to be necessary and sufficient for concluding that the reaches are “in regime” and that the system is in a state of dynamic equilibrium (that is, not aggrading or degrading).

Supplemental Studies of Changes over Time

Even though the literature cited above shows a solid consensus by other professionals that all the study reaches are in regime and that no aggradation or degradation is occurring, none of the studies looked at year-by-year or season-by-season trends in channel geometries in reaching this consensus. Some (Peters and Parham, 2008; NGPC, December 2008) suggest that although they agree that the streams are in regime, any additional impacts through new diversions or storage projects would push the system into disequilibrium.

Because effective discharge methods and regime theory allow assessment of natural or alternative-operation changes over time, the work by others described above was supplemented by the District to allow assessment of trends over time in cross section geometry and longitudinal slope (aggradation/degradation).

The purpose of conducting supplemental analyses, in addition to developing tools to assess alternative operations, was to perform a more in-depth examination of possible channel geometry changes that might indicate a departure from the long-term averages of these parameters. In addition, tests were conducted to determine whether any changing conditions might have shifted, or potentially could shift, either river from its current, stable braided morphology toward the threshold of transitioning to another morphologic class, thereby impacting the habitat.

No technologies exist for quantifying the internal topological aspects (for example, braids, bars, islands, areas of sand above the water level, and number or locations of bars) of a braided river for any given flow rate, but relationships do exist between effective discharge and equilibrium values of average hydraulic geometry (average total wetted width, average depth, and average velocity), as described above.

Ample measurements of the hydraulic geometry (water-top-width, average depth, and average velocity) by USGS are available for a range of discharges, but it should not be assumed that these are fixed. The data on these parameters for the gaged sites are shown in Attachment B, showing that a significantly wide range in each parameter is possible for any discharge.

USGS data on daily discharges, streamflow measurement summaries, and suspended sediment measurements were acquired and evaluated for the calendar years 1985 to 2009. In addition to determining year-by-year effective discharges and their associated channel widths and depths, the District separated daily flows during each year between May 1 and August 15 from the annual records, allowing calculations of effective discharges from year to year during that season along with determinations of the widths and depths associated with the flow rate that shaped the channel in each season evaluated. The dates selected for the seasonal analyses were based on typical times when bird species use river habitat.

Using the best-fit curves through the USGS data on wetted-width, average depth, and average velocity from streamflow measurements, and using Yang's equation for total sediment transport, the day-by-day capacity of the river flow to transport bed material, and the cumulative amounts in transport during each year and each season were calculated. For each calendar year and habitat-use season, the sediment transport histogram was developed and a determination made of the discharge rate that was centered among the flow rates that carried the majority of the sediment for that period. Because this method of determining effective discharge is both subjective and dependent on the number of equal intervals in which the daily flows are grouped, dominant discharges were also determined and tabulated.

Annual Trends in Flows and Effective and Dominant Discharges

Although longer periods of time are normally required to adequately determine which flow rate(s) are shaping the channel, annual and seasonal sequences were used in this part of the investigation. The resulting values of channel geometry during each shorter period are not as reliable as longer-term calculations, but as shown below, the results are helpful in meeting Objective 2 of this sedimentation study.

The 1985 to 2009 year-by-year annual effective and dominant discharges and total sediment transported (in tons) during each period at each study site are tabulated in Attachment B. The results for the May 1 through August 15 seasons are also provided.

Total flow (in acre feet) for each period was also determined and included in the tables. Even though annual or seasonal hydrographs may not have sufficient time to shape a temporarily "stable" geometry, the channel widths, average depths, and mean velocities associated with each effective discharge were calculated and included in all of the tables.

For the annual analyses, the widths, depths, and velocities associated with the dominant discharge are also provided in Attachment B for identification of changes over time. Finally, for reference purposes, the tables also contain the percentage of the flow in the Loup River diverted at the Headworks for each year and each habitat-use season.

The annual effective, dominant, and river discharge data from Tables 5-6 and 5-7 for the seven gaged sites analyzed are graphed in Figures 5-29 through 5-35. Linear trend lines were graphed for each indicator.

Examination of these annual graphs reveals that an apparent (but statistically untested) downward trend in both dominant and effective discharge occurred during 1985 to 2009 at stations from North Bend upstream. The graphs for Ashland and Louisville show slight downward-trending values of both discharge and dominant discharge, but the effective discharge trend-lines are essentially horizontal, matching the long-term (1985 to 2009) effective discharge rates for those two locations.

As discussed in Section 5.2.2, Effective Discharge and Other Sediment Transport Calculations, the 2009 values for both the Loup and Platte rivers are all less than the long-term averages at gaged sites at and upstream of Leshara, and are nearly equal to the long-term values downstream near Ashland and at Louisville. This is attributed to the apparent 2000 to 2009 declining annual flows described below. As shown in Figures 5-29 to 5-35, no permanent or adverse deviations from the long-term morphology have occurred at the gages over the 1985 to 2009 study period. The apparent downward trend in annual flows since around 2000 is not indicative of the actual trend, as shown in Figure 5-36. The apparent downward trend in annual indicators since 1985 has to be attributed to natural climatic cycling of hydrology rather than Project impacts because the Project operation does not impact flows at Duncan, which experienced even steeper reductions in annual flow during the same 25 years.

As expected, years with high annual flows have higher effective and dominant discharges and low-flow years have lower values. Although moderately wide year-by-year fluctuations in flows and effective and dominant discharge values occur, the graphs for Ashland and Louisville show that although some reduction in flow during the period is indicated, the absence of a trend in effective and dominant discharge shows that the reach was in dynamic equilibrium during those years. This corroborates the findings described in Section 4.1.1, Literature Review.

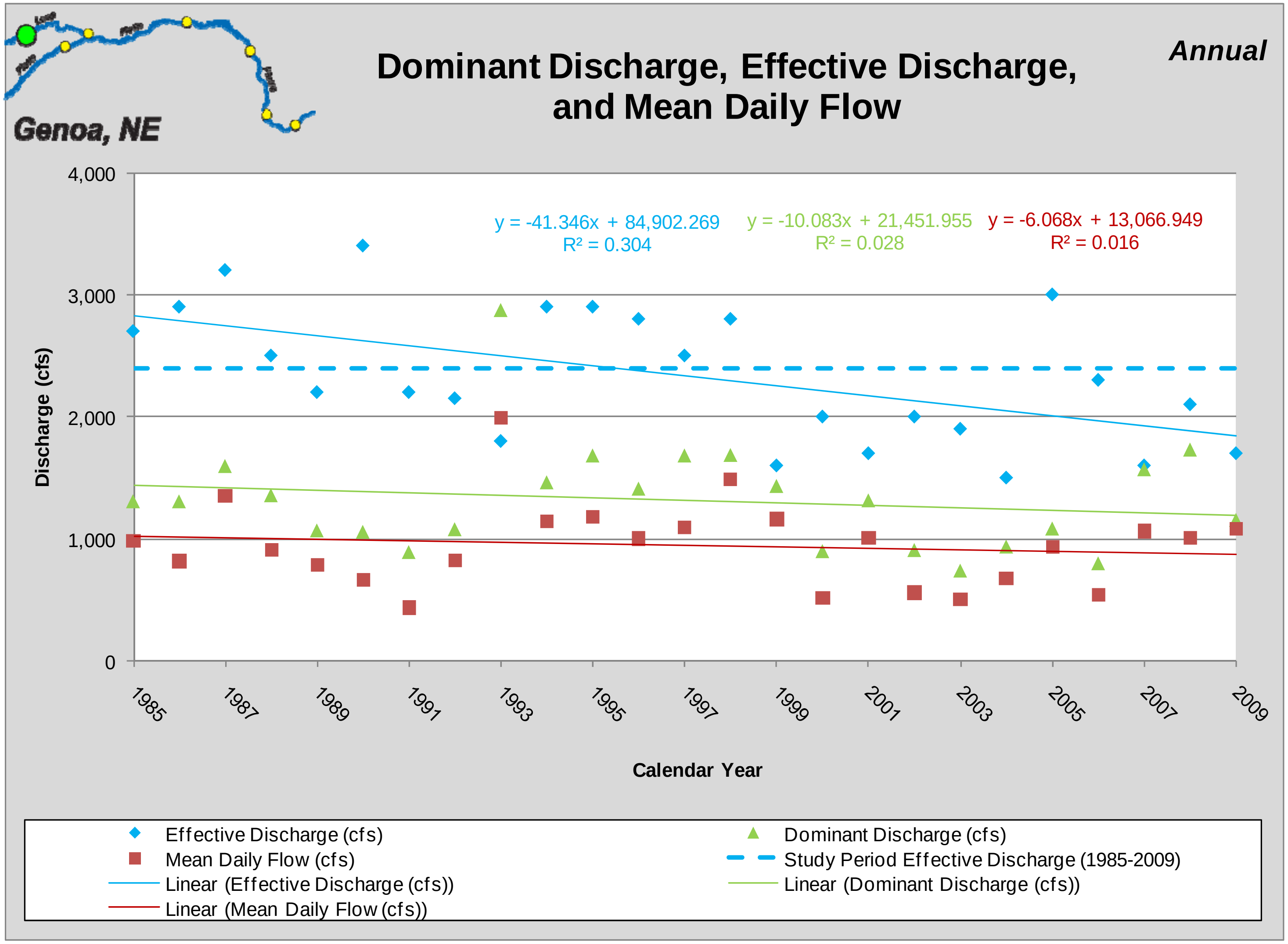


Figure 5-29. Annual Dominant Discharge, Effective Discharge, and Mean Daily Flow at the Loup River near Genoa (USGS Gage 06793000)

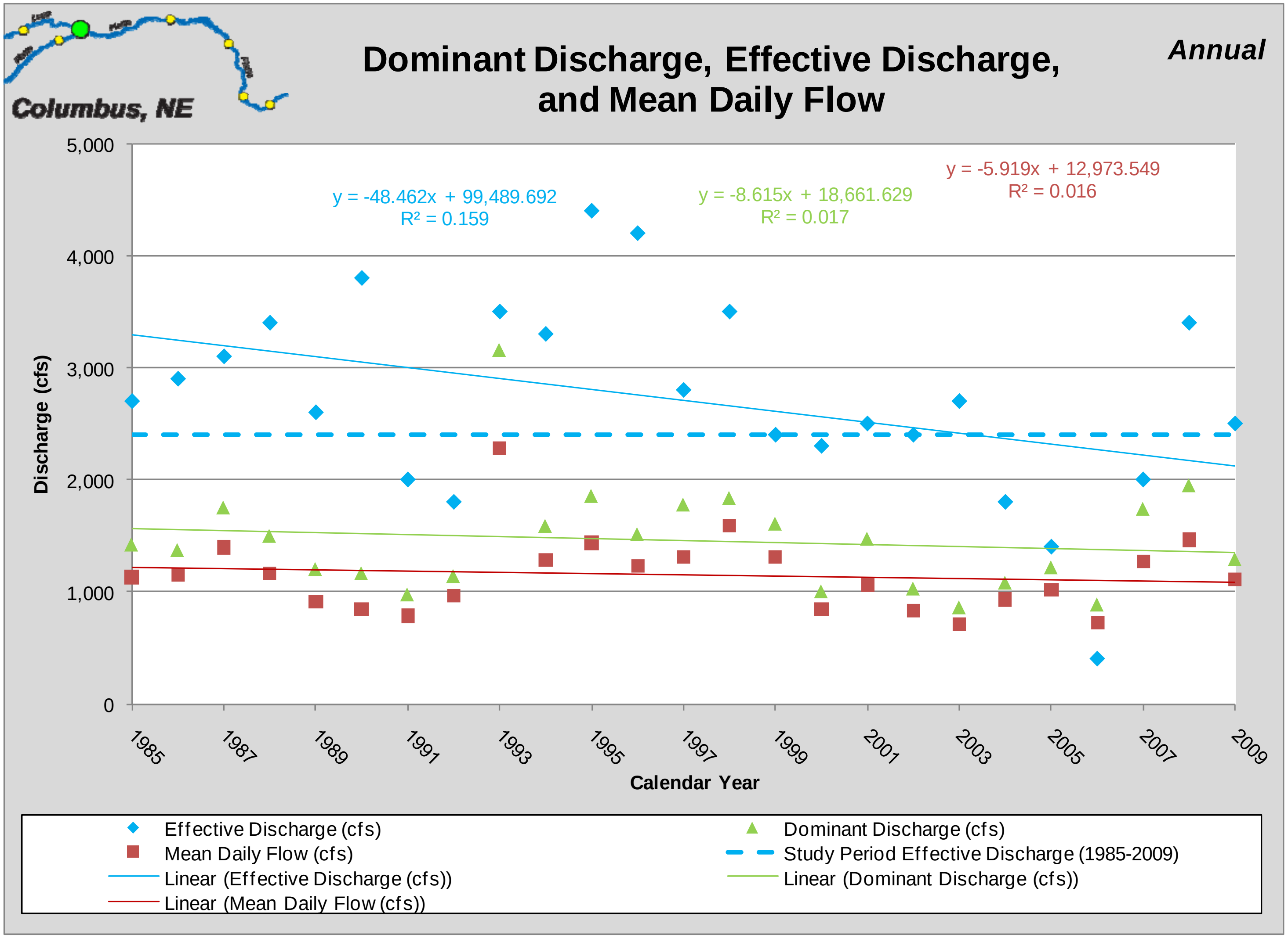


Figure 5-30. Annual Dominant Discharge, Effective Discharge, and Mean Daily Flow at the Loup River at Columbus (USGS Gage 06794500)

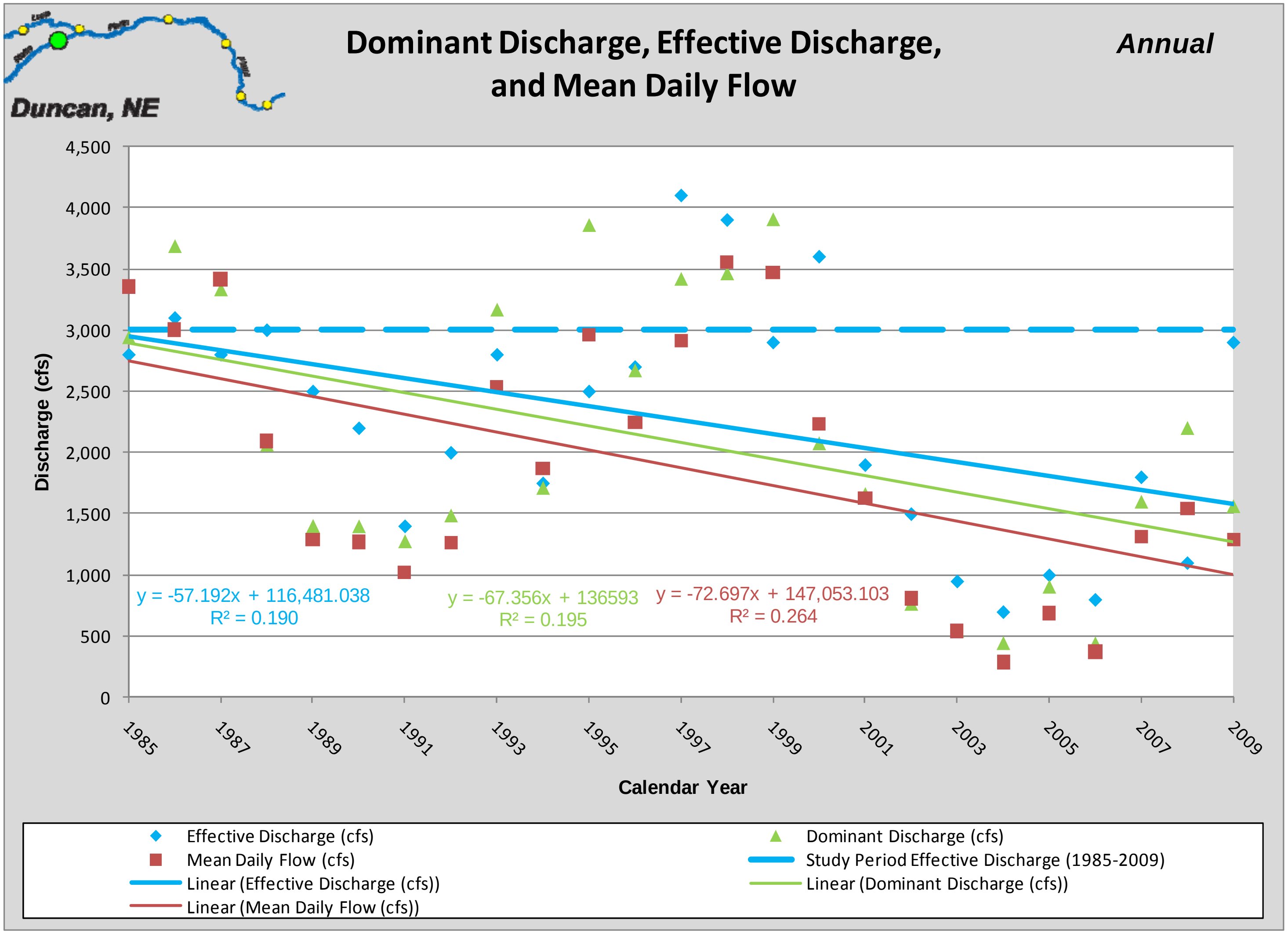


Figure 5-31. Annual Dominant Discharge, Effective Discharge, and Mean Daily Flow at the Platte River near Duncan (USGS Gage 06774000)

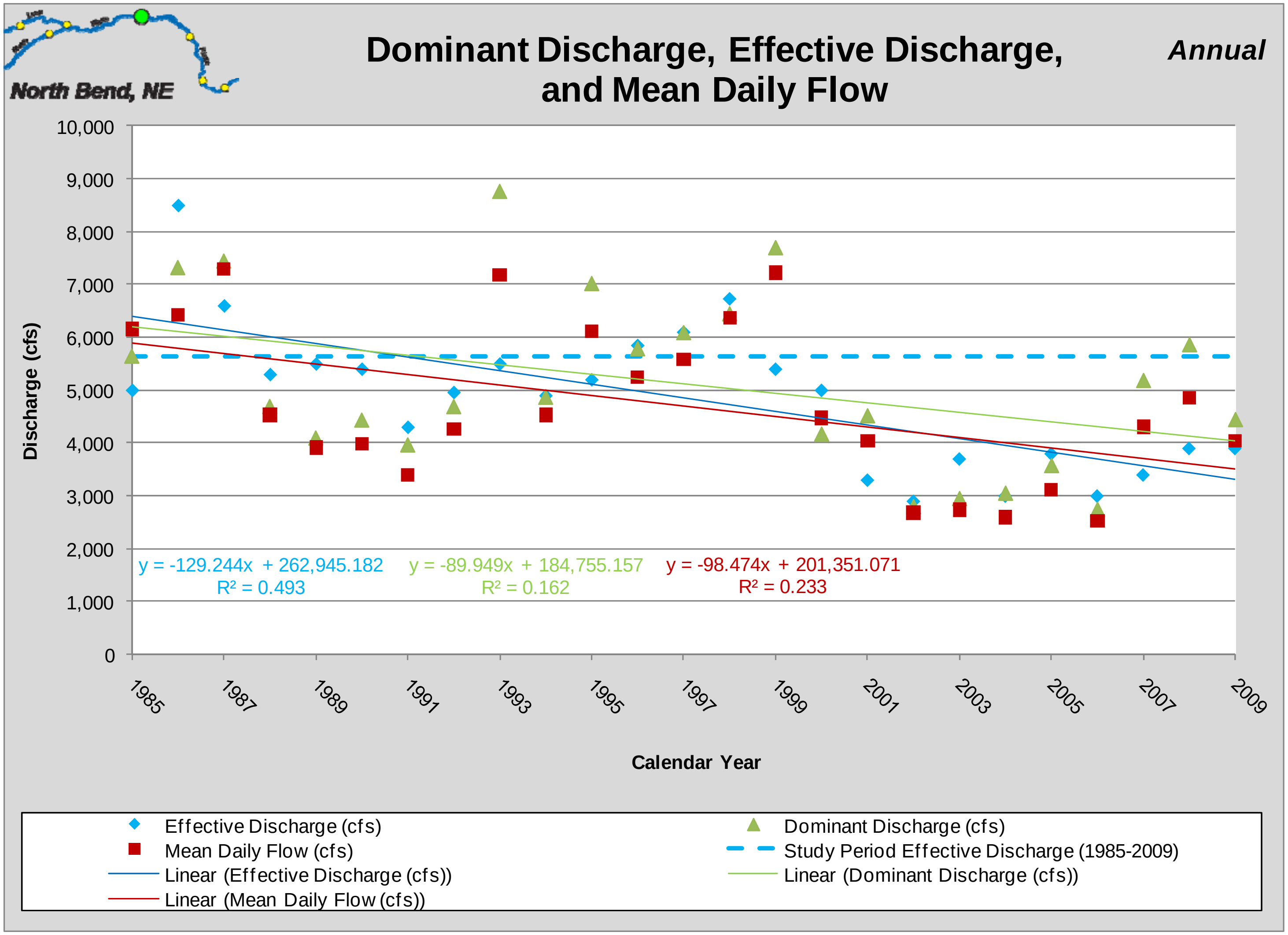


Figure 5-32. Annual Dominant Discharge, Effective Discharge, and Mean Daily Flow at the Platte River at North Bend (USGS Gage 06796000)

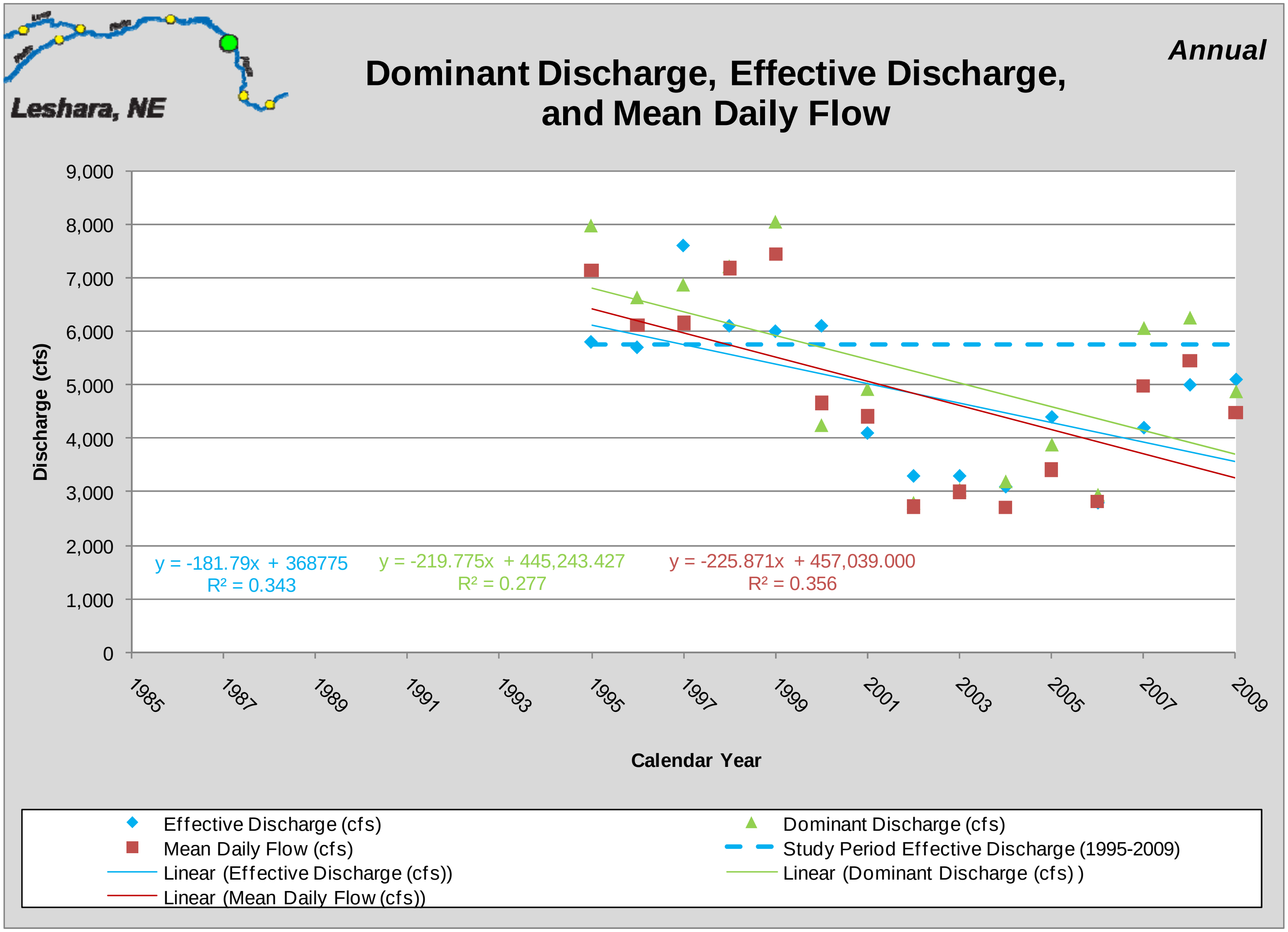


Figure 5-33. Annual Dominant Discharge, Effective Discharge, and Mean Daily Flow at the Platte River at Leshara (USGS Gage 06796500)

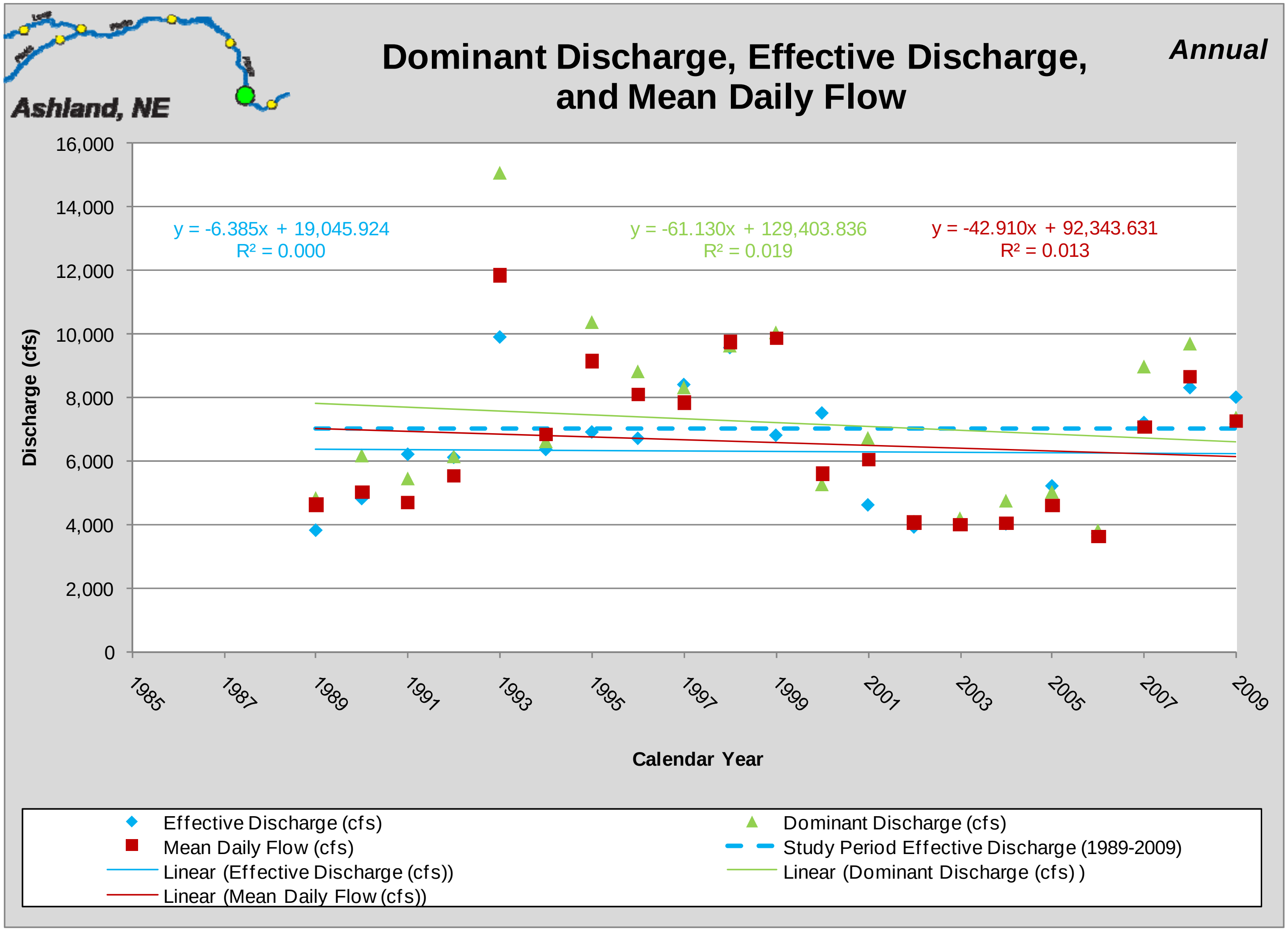


Figure 5-34. Annual Dominant Discharge, Effective Discharge, and Mean Daily Flow at the Platte River near Ashland (USGS Gage 06801000)

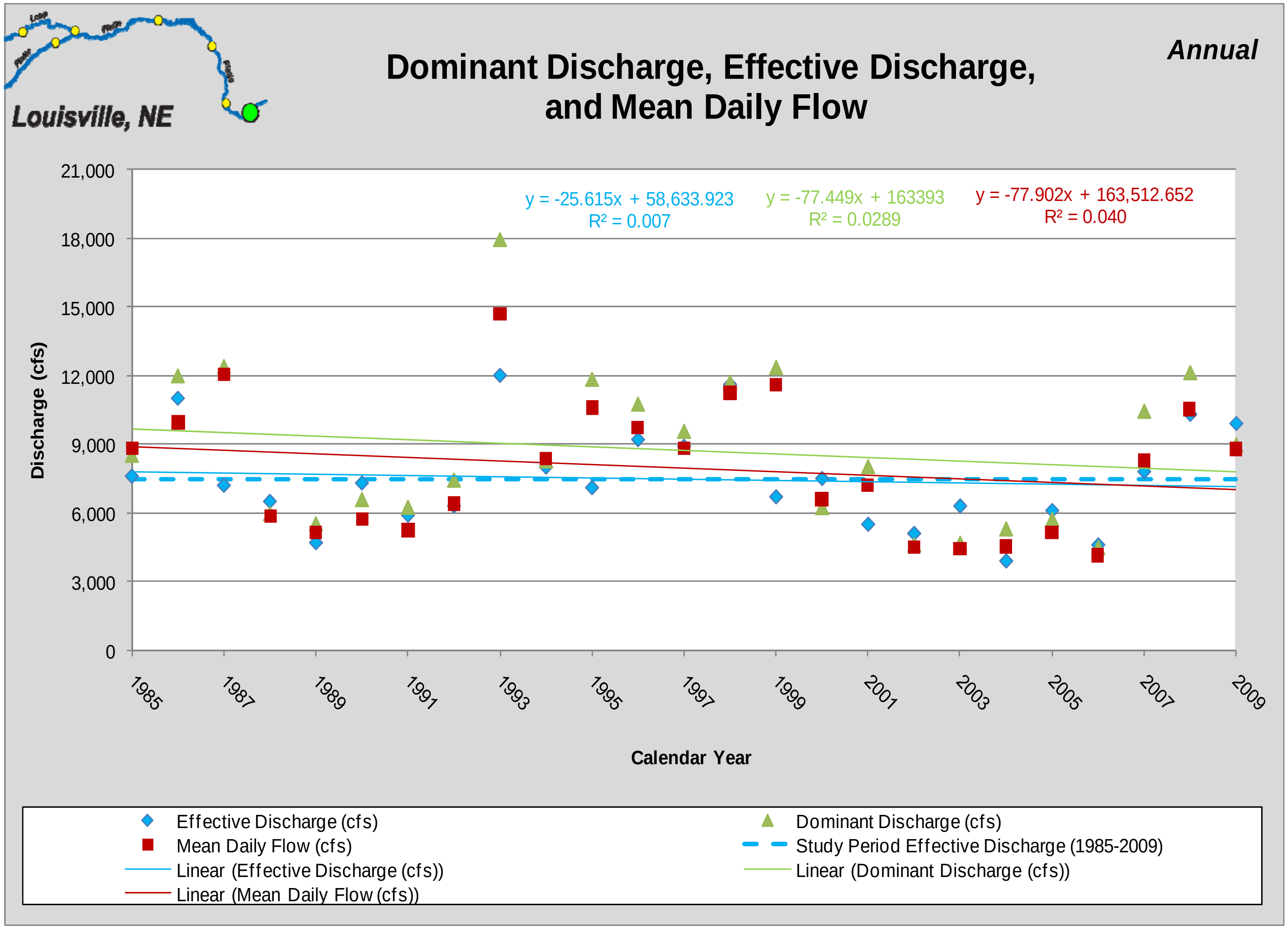
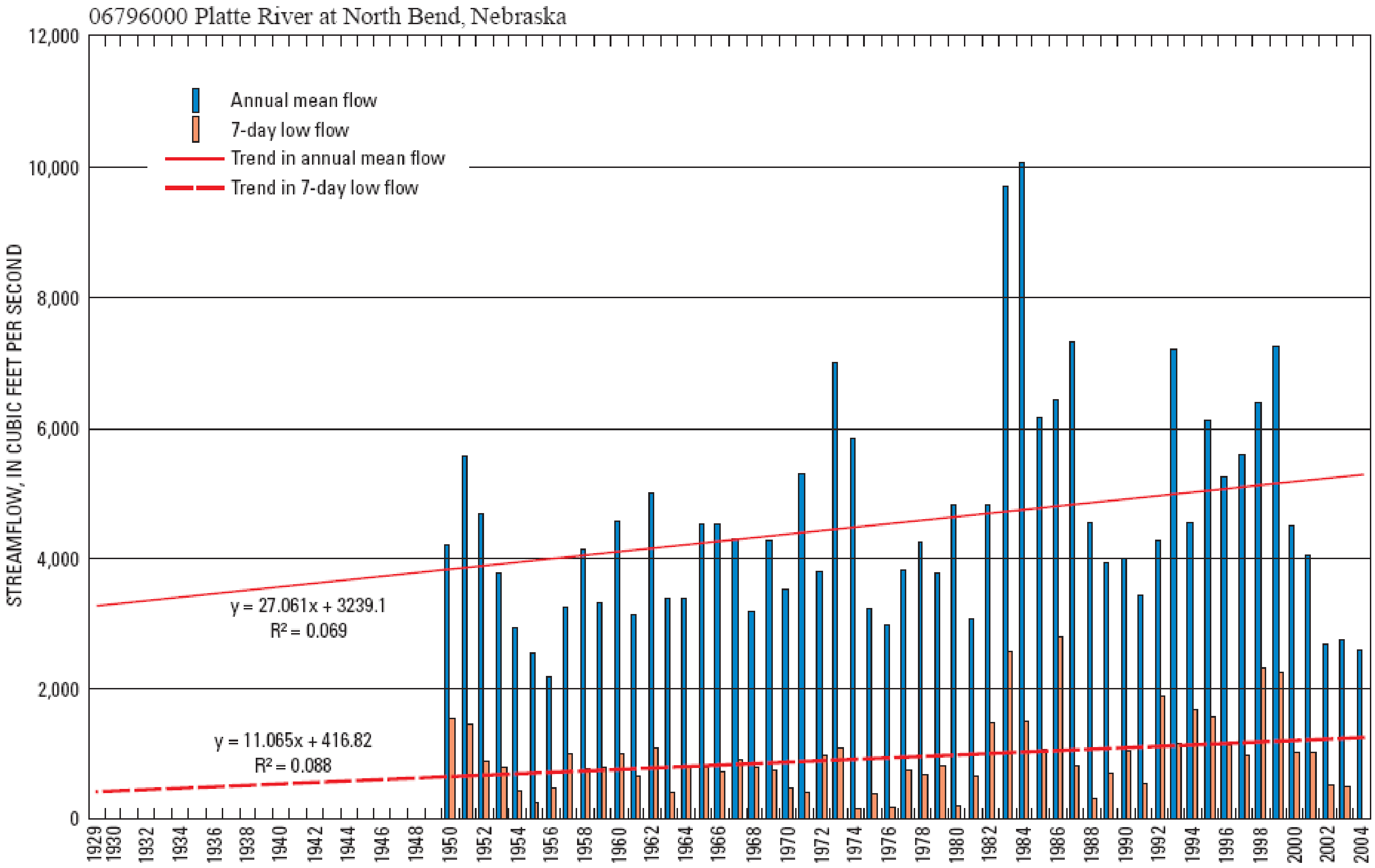


Figure 5-35. Annual Dominant Discharge, Effective Discharge, and Mean Daily Flow at the Platte River at Louisville (USGS Gage 06805500)



Source: Dietsch, Benjamin J., Julie A. Godberson, and Gregory V. Steele, 2009, "Trends in Streamflow Characteristics of Selected Sites in the Elkhorn River, Salt Creek, and Lower Platte River Basins, Eastern Nebraska, 1928–2004, and Evaluation of Streamflows in Relation to Instream-Flow Criteria, 1953–2004," USGS Scientific Investigations Report 2009-5011, available online at http://pubs.usgs.gov/sir/2009/5011/pdf/SIR2009-5011.pdf, Appendix 2, Figure 2-2.

Figure 5-36. Annual Mean Flow, 7-day Low Flow, Trend in Annual Mean Flow, and Trend in 7-day Low Flow of the Platte River at North Bend

The advantage of having the annual mean daily discharge graphed is that it shows that a trend of declining annual flow also occurred, at least during this period, at all gages upstream of North Bend, including Duncan (where the trend lines have the most pronounced slopes). This apparent downward trend in annual flow is an anomaly of having selected the years 1985 to 2009 for this analysis. Dietsch, Godberson, and Steele (2009) evaluated much longer-term trends in streamflow characteristics for the study sites used here as well as several other locations in the Platte River Basin. An example of their results for the North Bend gage are shown in Figure 5-36. Similar, relatively steep upward trends in both the mean annual flows and 7-day low flows were discovered at Duncan and Louisville, as well as at a number of other gages in the Loup, Elkhorn, and other tributary streams.

By looking at the portion of Figure 5-36 from 1985 to 2004, it is readily seen that the two-cycle period of wet and dry years would reflect a downward trend if these years were examined in isolation from the longer-term records. Note that the dry period starting around 2002 is the second lowest in the record at North Bend. Although not duplicated here, the USGS graph at Duncan, upstream of the Project, has even greater upward slopes, and a much-more pronounced reason for caution in making conclusions regarding trends from just the 1985 to 2009 data.

Of additional interest (and of value in interpreting these 1985 to 2009 graphs) is the fact that in all cases, including Ashland and Louisville, the dominant discharge trend line literally matches the slope of the discharge trend line. Any reduction in flows during any year would result in a reduction in total sediment transported, and by virtue of the definition of the dominant discharge, a reduction would be expected in the discharge rate that would transport the same amount of sediment as the annual hydrograph. If this occurred, any conclusions regarding impact on morphology should be conditioned on what the regime methods show as the result of the change.

Downward trending slopes in effective discharge matched the downward slopes in flow in some cases, while others are either steeper or flatter. The less-subjective linear dominant discharge lines more closely match flow trends. As discussed in Section 4.1.1, Literature Review, effective discharges are more subjective than dominant discharge values (although they have the same significance).

To offset the subjectivity of determining a single value of effective discharge, the ranges of effective discharges that transported the greatest amounts of sediment during the entire 1985 to 2009 period were shown in Table 5-2. Ranges of annual and seasonal values of flows doing the most work in forming the channel were broad enough to encompass the dominant discharges in most cases. As discussed in Section 5.2.2, Effective Discharge and Other Sediment Transport Calculations, conclusions about trends are best made from the dominant discharge trend lines on all of these graphs because of the subjectivity in estimating effective discharges, especially for short-term periods.

Examination of the graph in Attachment C for Duncan shows that these apparent downward annual trends in the Platte River were occurring upstream of any Project impact, at least for the years analyzed in this investigation. Data were not available to make the same assessments of Loup River trends upstream of the Diversion Weir, but it is known from the dredging data that a significant drop and leveling off of sediment transport to the Diversion Weir occurred around 1975. Based on this, and the fact that Dietsch, Godberson, and Steele (1999) found no evidence of any trend in aggradation or degradation in the Loup River at Genoa, it is concluded that these trends, if accepted at face value, are more likely the result of climate. In the case of the Loup River at Genoa, it is likely that the trend from 1985 to 2009 does not reflect the longer-term record, as evidenced by the fact that the Dietsch, Godberson, and Steele study did not detect a trend when evaluated over a longer period of time.

As to whether there are enough years to assign significance to the trends, or whether Project operations contributed, the graphs, and tables from which the graphs were generated, reveal several facts that address these questions. First, the actual data points (not the trend lines) in most or all of the seven graphs above (see Figures 5-29 through 5-35) show a definite cycling in the form of a sine-wave, following natural trends in wet, normal, and dry cycles. Both the peak runoff years and lowest runoff years follow an approximately 12-year cycle. Graphs of longer-term data (Dietsch, Godberson, and Steele, 2009) suggest a somewhat longer wave cycling.

Further analysis of both sets of graphs (Attachment C and Dietsch, Godberson, and Steele, 2009) suggests that the apparent annual data trends may be due to the limited number of years used in this investigation and, more importantly, the relatively "wet" cycle from 1985 to 1994 followed by a much drier cycle the rest of the time. All of the graphs in Attachment C show this cycling about every 12 years, and most show that there were two distinct 4- to 5-year-long dry periods occurring from about 1989 through 1992 and about 2002 through 2006.

The graph at Duncan (as well as most others) shows that annual flows in the latter dry period (2002 through 2006) were significantly less than the annual flows in the earlier dry period (1989 through 1992). The longer-term graphs in Dietsch, Godberson, and Steele (2009) show that the second "drought" during this period was second in severity to only one other on record. This is the primary cause of the apparent downward trending lines and should not be considered relevant to the question of flow reductions, changing morphology, or aggradation or degradation. The flow at Duncan in 2004, midway through the second drought, was only 15 percent of the mean annual flow. The flow in 1991, midway through the earlier drought, was 54 percent of the mean annual flow, which is a far less-serious drought.

Graphing any straight line through data containing these two cycles with significantly smaller low flows in the later versus earlier years of the 1985 to 2009 data is the cause of the apparent downward trend. This is more likely caused by two random cycles of wet/normal/dry climatic conditions, with the second cycle being drier than the first.

The long-term study by Dietsch, Godberson, and Steele (2009) places these cycles in proper context; that is, this is an anomaly of the 1985 to 2009 climatic conditions, and the long-term, actual annual flows are increasing at all the study sites.

Whether considered significant or not, the apparent downward trend in annual indicators since 1985 has to be attributed to natural climatic cycling of hydrology rather than Project impacts because the Project does not impact flows at Duncan, which experienced even steeper reductions in annual flow during the same 25 years. The Project did not operate significantly differently during either dry period. Project diversions, as a percent of flow available in 1991 and 2006, were 73 and 72 percent, respectively.

Seasonal Trends in Flows and Effective and Dominant Discharges

The graphs in Attachment B are grouped by study site. The graph for each gage station titled "Effective and Dominant Discharge" contrasts the annual effective (and dominant) discharges already described (see discussion of Figures 5-29 through 5-35) with the year-by-year seasonal dominant discharges. For reasons of subjectivity noted earlier, seasonal values of effective discharges were not compiled or graphed. Because dominant discharge is the continuous flow rate that would have transported all the sediment moved during any period, its value would be expected to be in proportion to the seasonal flows.

The graphs show that the seasonal dominant discharges seldom match the annual values, falling either above or below them by as much as 40 percent. These ratios are nearly equal to the ratios of seasonal versus annual flows. Trend lines for seasonal dominant discharge were not included in the graphs because the seasons are not connected in time, as is the case with the annual values (any year's season does not immediately follow the last years' values).

If it is assumed that the 3.5 month season is long enough to allow changes in channel geometry to occur, the amounts by which the seasonal dominant discharges vary from the annual would be good indicators of the minor fluctuations of channel geometry (width, depth, area) that would be expected within each year, but not maintained over time. In all of these graphs, the long-term (1985 to 2009) values of effective and dominant discharge are shown as horizontal, dashed lines, and it is important to emphasize that any annual or seasonal variance from this line should not be interpreted as an indication of either short- or long-term non-equilibrium.

In order to better visualize the fact that year-by-year fluctuations in annual effective discharge and cumulative sediment transported fluctuate about a long-term, stable median, the graphs titled "Effective Discharge and Cumulative Sediment" for each gaged site are provided in Attachment B. Due to their subjectivity, the data points for annual effective discharge show a wider range of scatter about the long-term median than do the data for annual cumulative sediment transport capacity. Both sets of data, however, follow the sine-wave pattern discussed earlier, and lead to the same conclusions made with regard to Figures 5-29 through 5-35.

Separate annual and seasonal graphs contrasting cumulative flows with total capacity of the flows to transport the sediment are also included for each study site in Attachment B. These are titled "Cumulative Discharge and Sediment Load Capacity." The annual graphs show the same trends and draw the same conclusions as the above analysis of annual trends in effective and dominant discharges.

The seasonal "Cumulative Flow and Sediment Load Capacity" graphs comparing flows with seasonal sediment transport indicators are not as easily analyzed with trend lines nor do they follow the sine-wave pattern described above. Seasonal trends matching annual trends would be expected only if the seasonal flows each year were about the same percentage of the annual flows, which is not the case. In some years, a much greater percentage of the annual flow occurred between May 1 and August 15 than other years, resulting in relatively high corresponding values of cumulative sediment transported and dominant discharges during the season. For those stations having relatively high seasonal flows, accompanied by high dominant discharges, channel geometry adjustments may have been more prevalent during the habitat use period, although as noted earlier, 3.5 months of time with a higher channel-shaping discharge may not be sufficient time for any changes to be noticeable. This could be a consideration in assessing whether any relationships exist between sediment transport indicators and nesting data.

Based on the above analyses and literature, particularly the Dietsch, Godberson, and Steele (2009) study of long-term changes in flows, it is concluded that use of the 1985 to 2009 data to make conclusions about downward trends in any of the annual or seasonal indicators studied needs to be viewed in context of the longer-term records. A downward trend in flow and associated, parallel downward trend in dominant discharge occurred during these years, but the Dietsch, Godberson, and Steele (2009) longer-term studies dating back to the late 1920s reveal that trends in annual mean flow and 7-day low flows are definitely on an upward trend, and have been throughout their entire periods of record. For annual hydrographs typical of this region, any upward trend in annual flows will result in an upward trend in dominant discharge, so it can be reasonably concluded that the dominant discharge, when evaluated over the full periods of record at the study sites, would show an upward trend.

Annual Trends in Channel Hydraulic Geometry

In addition to determining and graphing annual and seasonal values of effective and dominant discharge and assessing any trends, corresponding values of the average channel widths, depths, and velocities were determined for each effective (and dominant, in the case of annual flows) discharge. This use of the best-fit curves through the plethora of USGS measurements of these parameters (see Attachment C) is valid because the calculated values are reasonable estimates of the hydraulic geometries that would exist if the effective discharges were maintained for a long period of time.

As with effective discharges, values of width, depth, and velocity for short sequences of daily flows (calendar years or seasons) are not as reliable as long-term values, but helped in meeting Objective 2 of this sedimentation study.

Graphs showing the year-by-year channel geometry parameters for the full or partial year (seasonal) data are provided in Attachment C. Three graphs are included for each study site showing year-by-year values of effective discharge, dominant discharge, and seasonal dominant discharge. The first two graphs show the variability of the geometry parameters with effective flow and dominant flow, respectively. The third graph shows the seasonal geometry based on the seasonal dominant discharges. Effective discharge hyetographs were graphed for the seasonal data, but selection of a single, representative value of effective discharge from the hyetographs was considered too subjective to be useful in evaluating year-by-year trends.

The color-coded horizontal lines show the long-term 1985 to 2009 values associated with the long-term effective and dominant discharges from Table 5-2. The annual and seasonal data points fluctuate around these lines, with less variability than seen on the earlier effective discharge graphs. As noted earlier, analysis of trends is best accomplished using the graphs for dominant discharge (the bottom two graphs on each page).

Because the annual and seasonal flows cycle through wet and dry periods, the corresponding effective and dominant discharges follow the same cycles. All the best-fit channel geometry equations have increasing values of the parameters with increasing daily discharge, so the widths, depths, and velocities rise and fall with the dominant discharge value used in determining them.

Trend lines were evaluated but are not shown in these graphs for two reasons. First, many had slight or no slopes, and none of those with sloping trend lines were considered relevant for the reasons noted above regarding the two cycles of wet/normal/dry sequences. Downward trends in these values are predictable in any period of time when flows are downward trending from a high low-flow period to a much lower low-flow period, but this does not speak to the stability of a river's long-term morphology. Entering any of the yearly values of either effective or dominant discharge in Figure 5-16, 5-17, or 5-18 would demonstrate that if the channel geometry adjusted to the values, the graphs would all show that the river's morphology is still well within the braided river regime. Second, in most cases, including the trend lines made it difficult to distinguish them from the horizontal, long-term 1985 to 2009 values.

Seasonal Trends in Channel Hydraulic Geometry

It is readily evident that the ranges of fluctuations of the geometry parameters around the long-term average seasonal values (the bottom graphs on each page) is much wider than for the graphs showing results using annual dominant discharges (center graphs). This is in large part due to the high variability of daily flows during the habitat season as well as the relatively short period of time for the dominant discharge to establish the associated geometry. The seasonal graphs are misleading, in part because the points are discontinuous (all intervening flows from August 16 to April 30 are disregarded) and one cannot connect the dots.

In general, high seasonal dominant discharges were associated with high annual dominant discharges, but in some years, a high or low percentage of the annual flow occurred during the habitat season, causing the seasonal and annual dominant discharges to vary, with one being greater than the other.

Regime Implications of Trends

If it is hypothesized that the apparent downward trends from 1985 to 2009 in flows and dominant discharges have long-term significance (this should not be theorized), or that the trends during the past 25 years are relevant to habitat, the logical next question is whether either braided river, the Loup or the Platte, is transitioning from its state of equilibrium to a different morphology.

This is a relatively easy test using regime theory. As an illustration, the annual variation in effective discharge at North Bend is shown in Figure 5-32. The effective discharges from 1985 to 2009 ranged from a low of 2,900 to a high 8,500 cfs, which is about the same as the range of the 1985 to 2009 values in Table 5-2. Graphing either of these end values on either Chang’s regime graph (see Figure 5-16) or Lane’s regime graph (see Figure 5-18) would cause the blue dot (North Bend) to move horizontally only a fraction of an inch either way.

Neither extreme condition, if sustained, would change the conclusion that both rivers are solidly in regime with braided river morphology. In the case of Chang’s graph (see Figure 5-16), the effective discharge would need to decline to about 1,000 cfs before the point would move even halfway to the threshold of his Region 1, which is defined as “equiwidth point-bar streams and stable canals.” Lane’s graph (see Figure 5-18) shows that a much greater decline in effective discharge would be needed to move halfway to a meandering river classification. This not only demonstrates the natural penchant of the Loup and Platte rivers to remain braided, but it also illustrates the magnitudes of changes that would be required to cause any degradation in the braided river morphology or habitat.

The bottom line of the above analysis is best summarized by USBR (April 2004), which concluded that the Platte River is in a greater state of dynamic equilibrium than it was in its pre-development form.

5.3.3 Objective 2 Conclusions

If the literature review, sediment transport calculations, specific gage analysis, and regime analysis indicate that short-term fluctuations in the morphology of the Loup River bypass reach and lower Platte River are not transitioning to another form, it would be further affirmed that the rivers are currently in dynamic equilibrium. If the literature review and calculations indicate that the Loup River bypass reach and lower Platte River are transitioning to another form and either aggrading or degrading, it would be concluded that the rivers are currently not in dynamic equilibrium. Furthermore, if the analysis of the current condition morphology indicates that the Loup River bypass reach and lower Platte River either are in dynamic equilibrium or are not supply limited based on the adjusted yields and sediment transport capacity calculations, then no alternatives relative to sediment augmentation would be evaluated.

The body of literature and the supplemental calculations demonstrate that the Loup River bypass reach and the lower Platte River are in regime and are seated well within regime zones considered as braided streams. None of the sites are supply limited, and the inclusion of sediment transport indicators at the gaged and ungaged sites reveals that the morphology is in dynamic equilibrium. Further, the analyses and other supporting literature cited herein clearly indicate that both the Loup River bypass reach and the lower Platte River at the gaged and ungaged sites are clearly in regime, not supply limited, and not aggrading or degrading, with no indications of channel geometry changes over time.

5.4 Objective 3 – To determine if a relationship can be detected between sediment transport parameters and interior least tern and piping plover nest counts (as provided by the Nebraska Game and Parks Commission [NGPC]) and productivity measures.

5.4.1 Literature Review

In accordance with the Revised Study Plan and Study Plan Determination, if it were determined that the Project did not affect morphology in the lower Platte River, or that the system is in dynamic equilibrium, it would be inferred that the Project does not affect interior least tern and piping plover sandbar nesting habitat parameters related to sediment transport and morphology and that no further analysis would be warranted. As discussed in Sections 5.2 and 5.3 for Objectives 1 and 2, respectively, the investigations of channel morphology in the lower Platte River revealed that the lower Platte River is in a state of dynamic equilibrium, well-seated within regime of a braided river. In addition, the literature review in Sections 4.1.1 and 5.3.1 found that several articles affirmed that the habitat is the morphology and that maintaining a braided river morphology maintains the habitat that it provides. However, the methodology as described in Section 4 was performed because this analysis would further the body of knowledge related to interior least terns and piping plovers on the lower Platte River by determining if there are relationships between sediment transport and/or hydrologic parameters and interior least tern and piping plover nest counts.

Although no other studies comparing nest counts with sediment transport indicators have been conducted to date, one USGS study has drawn conclusions and found relationships regarding interior least tern and piping plover nesting on the lower Platte River and geomorphic classification. The USGS study (Elliott, Huhmann, and Jacobson, 2009) found that valley width is an important variable in the geomorphic process from upstream to downstream on the lower Platte River. The study also found that based on nesting data from 2006 to 2008, interior least terns and piping plovers appear to select those areas of the river with a narrow valley width, as these areas provide a greater potential for emergent sandbar habitat. These conclusions indicate that given the availability of sand in the lower Platte River, the extent and persistence of emergent sandbars is likely limited by discharges that are capable of transporting and destabilizing vegetated sandbars (Elliott, Huhmann, and Jacobson, 2009). This conclusion indicates that, consistent with the analysis performed in this sedimentation study, the lower Platte River is a flow limited system, not a sediment supply limited system. Valley width acts to constrict flow and thereby enhance sediment transport and bar building. In areas with narrow valley width, flood flow constriction could be expected to increase scour and potential re-working of bars, potentially resulting in greater persistence of sandbars for nesting. Conversely, in areas with broad valley widths, containment of flood flows would be minimized, potentially creating persistent vegetated bars and islands.

Confined width was also determined to be a dominant control on channel morphology in the adjacent central Platte River segment (Fotherby, 2009). Fotherby determined that at confined widths of less than 600 meters, fully braided channels were maintained. At widths greater than 600 meters, vegetated islands and an anabranched channel pattern dominated. Fotherby concluded that the success of the interior least tern and piping plover in the central Platte River appears linked to a wide braided main channel.

5.4.2 Statistical Analysis of Interior Least Tern and Piping Plover Data by Hydrologic River Segment

As discussed in Section 4, Methodology, this sedimentation study compared interior least tern and piping plover nest counts with sediment transport indicators. All of the comparisons were performed for three scenarios—no-lag (that is, sediment transport indicators for year X compared to nest data for year X), 1-year lag, and 2-year lag—to see if the occurrence of a given indicator either annually or seasonally in a given year had a relationship with bird nest counts that year or in the following 2 years. For each of these data sets, a linear regression analysis was performed. Each analysis was graphed and the coefficient of determination (R^2) was generated for linear regression for each scenario for each species seasonally and annually. A total of 1008 graphs (504 graphs for each species) were developed, as shown in Table 5-15.

Table 5-15. Summary of Graphs Generated for Correlation Analysis

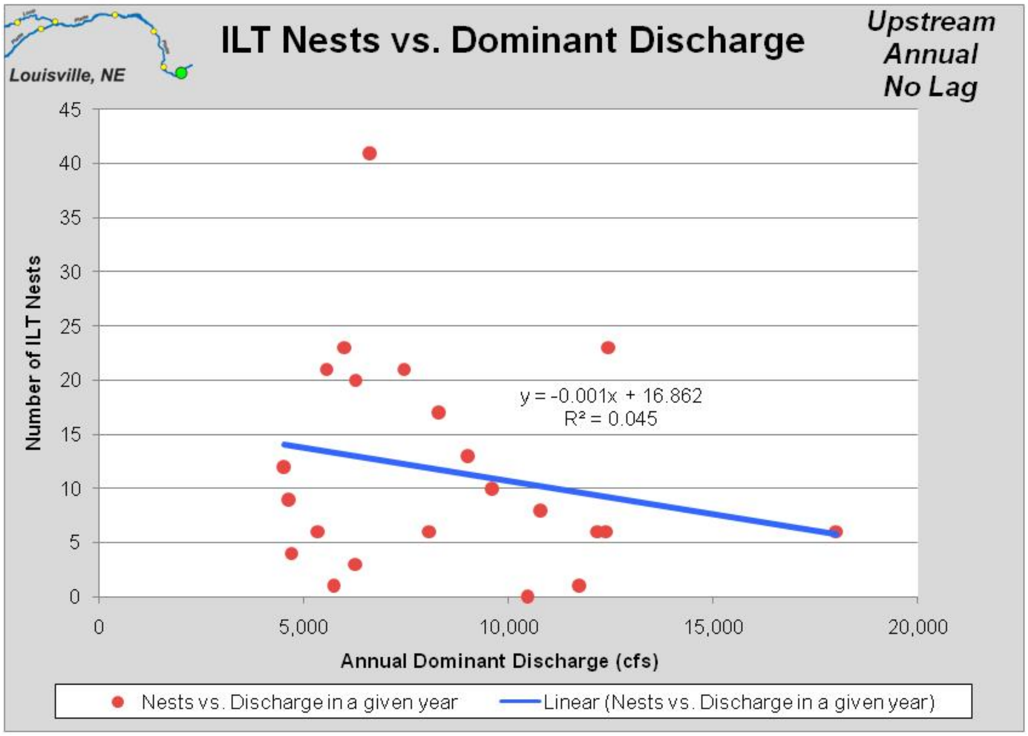
Component of Analysis	Number of Analyses Required
Species Evaluated	2
Sediment Transport Indicators and Hydrologic Parameters	14
River Segments Analyzed	4
Comparisons for Each River Segment (Upstream, Downstream, and Combined Segment)	3
Time Series Evaluation (No lag, 1-year lag, 2-year lag)	3
Total graphs generated	1008

Each graph and corresponding R^2 was reviewed to identify relationships between nest counts and the sediment transport indicators or hydrologic parameters. The R^2 value represents the strength of the linear association between nest counts and a particular sediment transport indicators or hydrologic parameter and describes the proportion of the total variation in nest counts that is explained by linear regression of that indicator or parameter. R^2 values range from 0 to 1, with a higher number indicating a greater correlation. For example, an R^2 value equal to 0.10 indicates that 10 percent of the total variation in nest counts can be explained by a given indicator or parameter. The R^2 tables for all regression analyses are provided in Attachments F and G.

The R^2 values for interior least tern nest counts and sediment transport indicators and hydrologic parameters range between 0.000 and 0.389. A total of 7 of the 504 R^2 values reached 0.300 (representing 30 percent of the total variation in nest counts that can be explained by a sediment transport indicator or hydrologic parameter variable), and no patterns could be discerned for those that did. The R^2 values that exceeded 0.300 could best be described by the random nature of numbers. When working with a large dataset, it is inevitable that there will be a degree of randomness that explains why some of the numbers align in some degree of association. These few higher R^2 values do not change the conclusion that there are no discernable relationships. Those few graphs that show the higher R^2 values may indicate rejecting the null hypothesis for a statistical relationship; however, because of the large variance of the data and because a large range of number of nests can be found in a small range of sediment transport and hydrologic parameters, these were considered spurious.

The R^2 values for piping plover nest counts and sediment transport indicators and hydrologic parameters range between 0.000 and 0.588. A total of 26 of the 504 R^2 values reached 0.300, with 9 of those occurring in the no-lag scenario downstream of Leshara to Ashland. This segment averaged 6.3 nests a year over a 22-year period. A limited sample size increases the probability of false correlation. In addition, higher R^2 values exist in the Leshara to North Bend reach for piping plover nests when analyzing Year X+1. These higher values are likely attributed to the small dataset for piping plover nest counts. For example, years 1995, 1996, 1999, 2000, 2004, and 2005 were excluded from the data set in this river segment due to lack of data (as described in Section 4, Methodology). As the amount of data available to correlate decreases, the possibility of spurious correlation increases. Therefore, for reaches where adequate nest count data exists, no relationships with sediment transport indicators and hydrologic parameters were identified. In segments where the data set is small, the analysis between sediment transport indicators and hydrologic parameters is inconclusive.

Figures 5-37 through 5-40 are example graphs that are typical of the 1008 graphs that were generated. Each graph contains the number of nests on the x-axis and the indicator or parameter analyzed on the y-axis. Each point on the graph represents the intersection of the number of nests at the indicator or parameter analyzed for a given year. Also displayed on the graph is the best fit line from the linear regression analysis (and corresponding slope). Finally, the R^2 value is provided. Consistent with the review of all of the R^2 values, visual observation of the best fit line compared to the points on the graph does not indicate a trend between an increase or decrease in an indicator or parameter and resultant change in number of nests for either species.



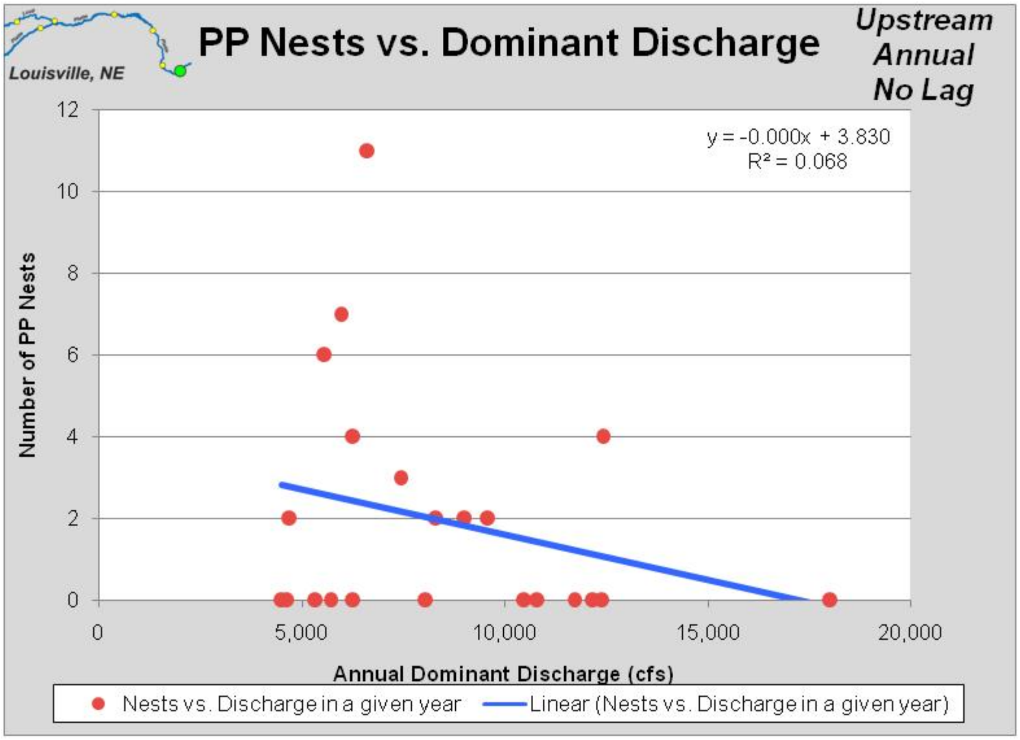
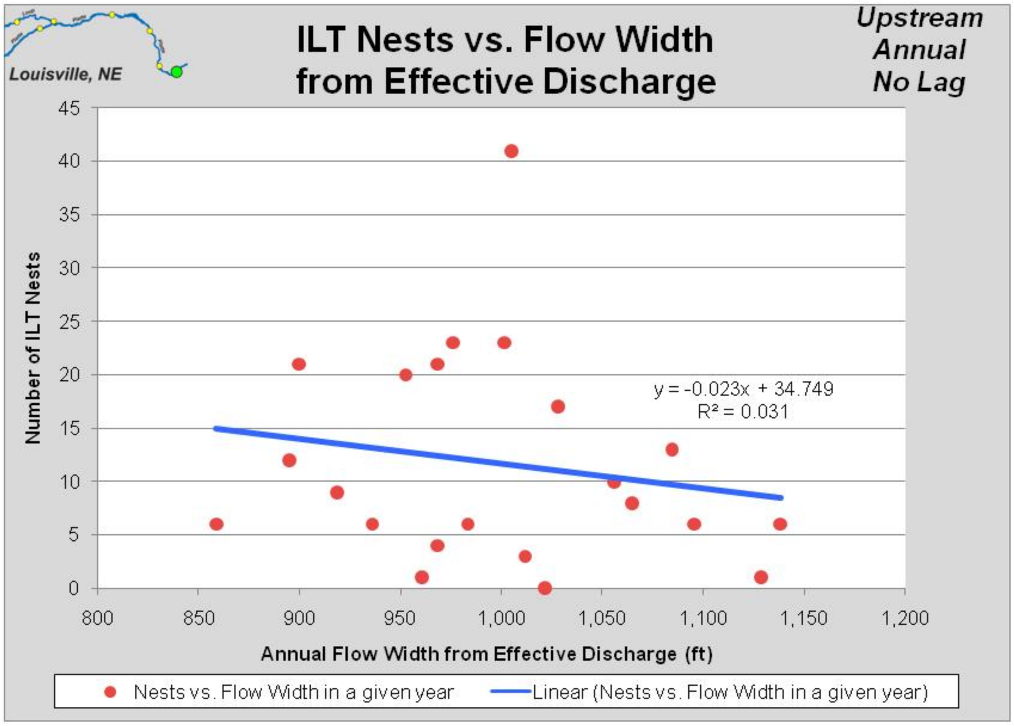


Figure 5-37. No Lag, Upstream of the Platte River at Louisville (USGS Gage 06805500)



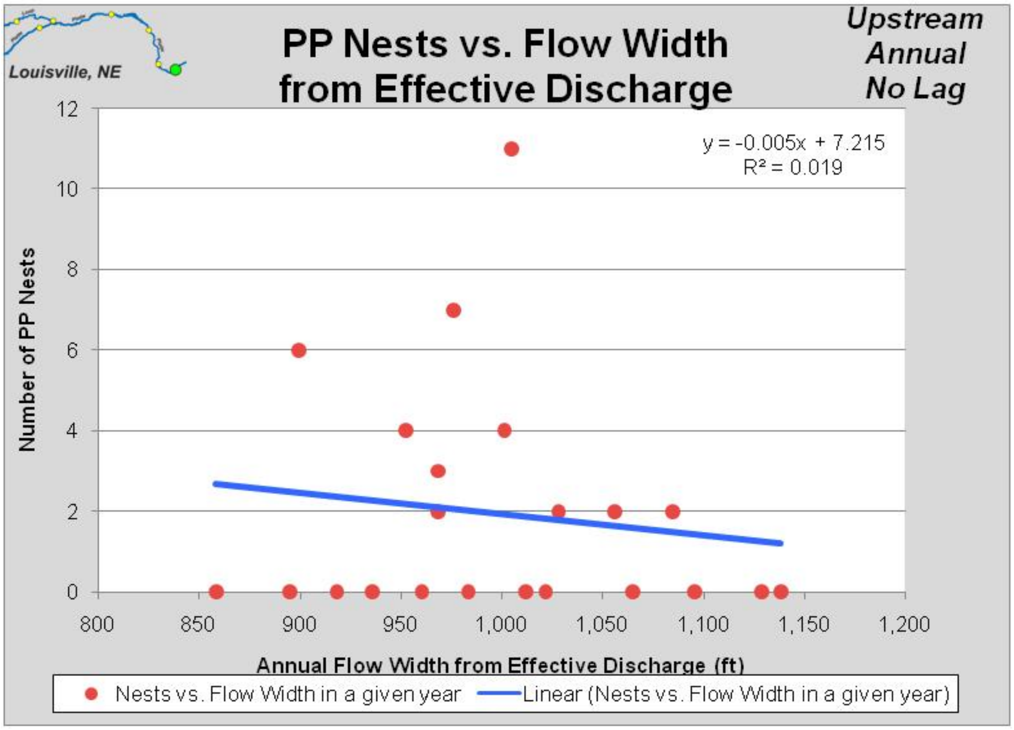
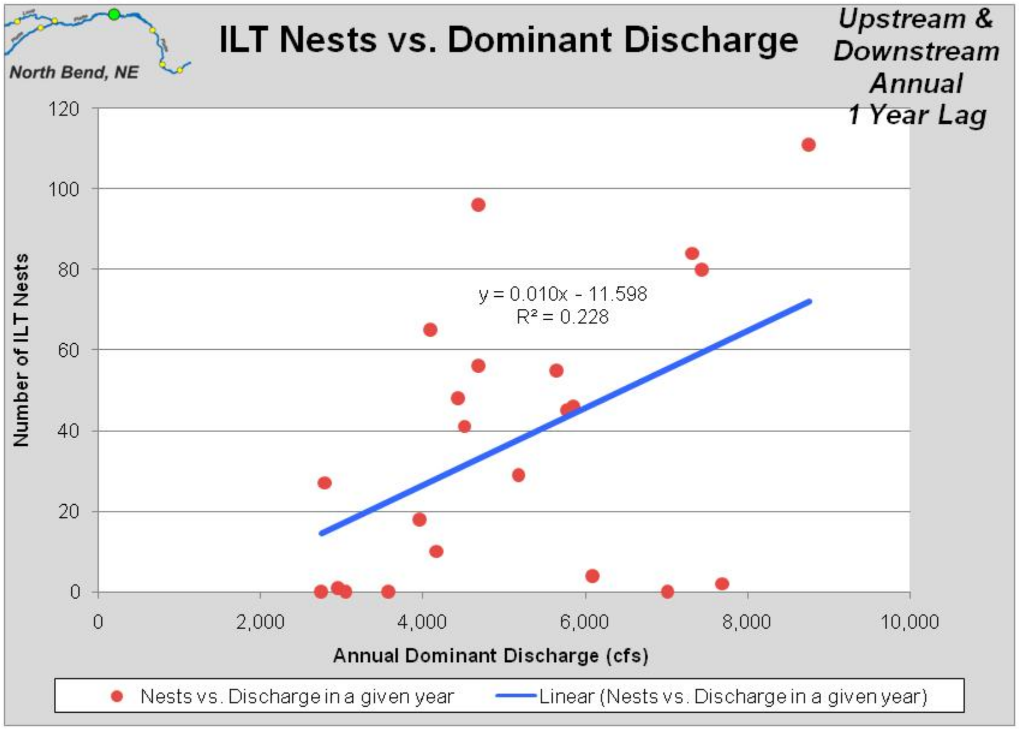


Figure 5-38. No Lag, Upstream of the Platte River at Louisville (USGS Gage 06805500)



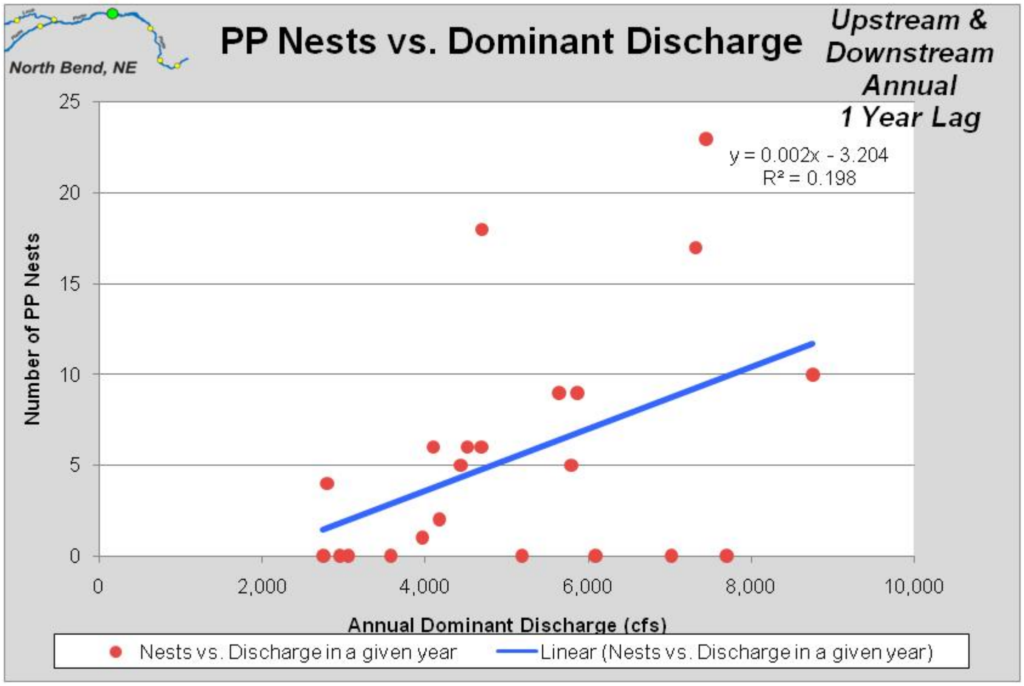
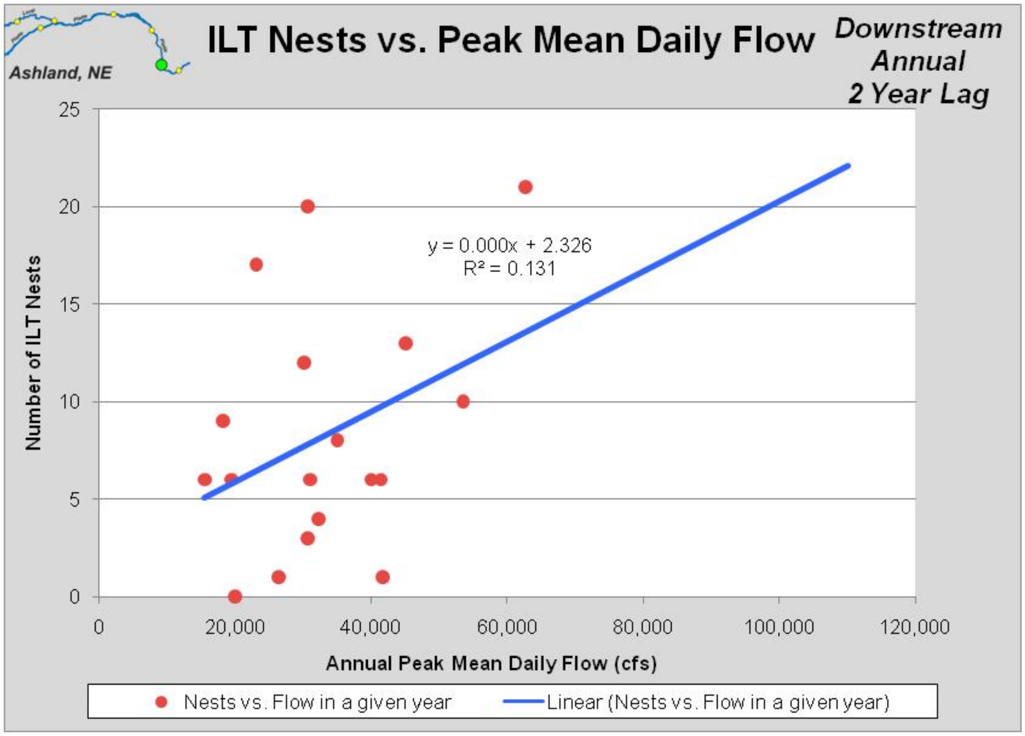


Figure 5-39. 1-year Lag, Combined River Segment Upstream and Downstream of the Platte River at North Bend (USGS Gage 06796000)



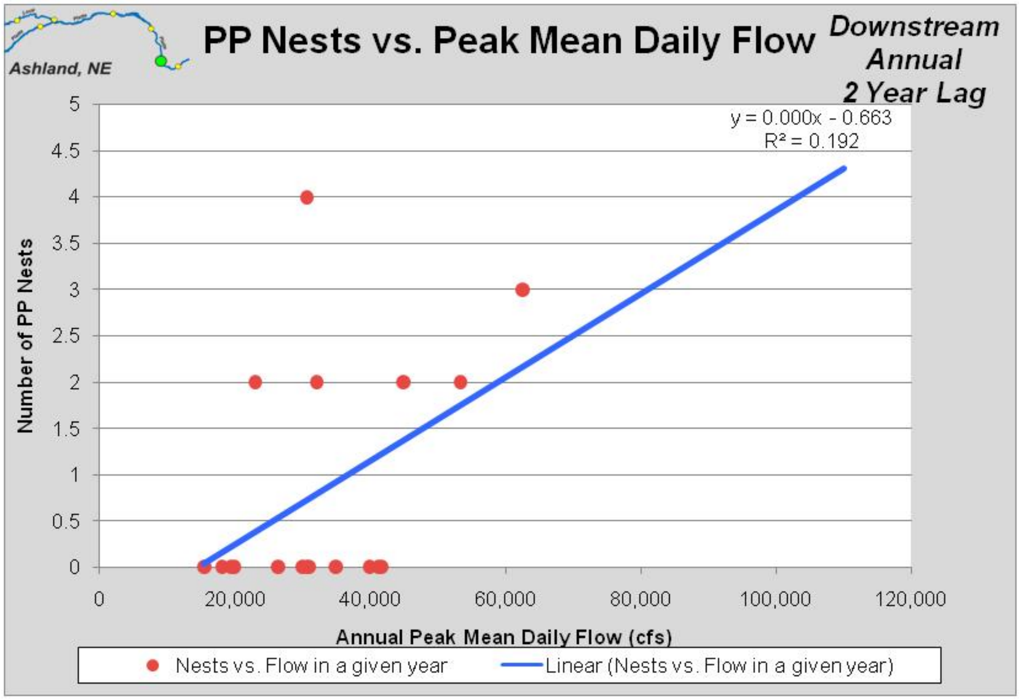


Figure 5-40. 2-year Lag, Downstream of the Platte River near Ashland (USGS Gage 06801000)

Revised 09/06/11

[The following text and figures were added after the Updated Study Report was submitted.]

5.4.3 Statistical Analysis of Interior Least Tern Data by River Mile

The interior least tern nest count data was analyzed using various statistical methods. The results of the analysis are presented in the following sections.

Analysis of Nest Counts in Relation to Data Collection Visits

As discussed in Section 4.5.1, the frequency of data collection visits for collection of interior least tern nest count data has been inconsistent over the course of the data collection period (1987 to 2010). As such, an evaluation of nest counts in relation to data collection visits was conducted to determine if the nest count data were skewed or otherwise affected by the inconsistency in data collection visits.

The potential relationship between data collection visits and total number of recorded nests was assessed by a bivariate regression analysis with log transformed nest count sums per year as the dependent variable and log transformed sum of data collection visits per year as the independent variable. This relationship was further investigated via a multiple regression analysis in which log transformed sum of adult least terns per year was added as a second independent variable. In this analysis both independent variables entered the regression equation simultaneously. Log-transformed nest count sums were weakly correlated with the log-transformed number of data collection visits per year (r [752] = 0.198, $P < 0.01$). Although this association is statistically significant (owing in part to the large sample size, which augments power), its practical significance is questionable. Slightly less than 4 percent of the variance in nest counts is explained by co-variance in the number of data collection visits. The proportion of variance in nest counts unambiguously associated with the number of data collection visits drops to approximately 2 percent when log-transformed interior least tern adult counts are included as a second predictor variable. As would be expected, nest counts are strongly associated with interior least tern adult counts (r [752] = 0.625, $P < 0.01$), which are also weakly correlated with number of data collection visits. After accounting for shared variance with interior least tern adult counts, the relationship between nest counts and number of data collection visits appears to be trivial.

Analysis of Nest Counts in Relation to Distance from the Tailrace Return

Interior least tern nest counts were evaluated with respect to location on the lower Platte River relative to the Tailrace Return for RM 102 to RM 72. This analysis was performed based on the assumption that if return flows from the Project Tailrace are affecting nest site selection, there would be a correlation with distance from the Tailrace due to the attenuating effect of distance on flow.

Figure 5-41 is a box plot of total interior least tern nest counts summed by river mile for the area immediately downstream of the Tailrace Return (RM 72 to RM 102) for all sample years. No association is detected between summed nest counts and river mile (r [136] = 0.013, $P > 0.05$), indicating variability in nest count sums is not associated with distance from the Tailrace Return.

Figure 5-42 is a box plot of highest nest counts per year averaged over river miles. Although no significant relationship is detected, per linear regression analysis, between calendar year and summed highest nest counts per river mile (r [136] = 0.124, $P > 0.05$), a marked drop in highest nest counts is apparent after 1995. This trend appears dichotomous rather than linear, with nest counts before and after 1995 relatively stable, but markedly lower between 1996 and 2010. This trend is not apparent if nest counts are summed over years for all river miles (RM 106 to RM 0), as shown in the box plot in Figure 5-43.

An independent samples *t*-Test was performed on summed mean nest counts per year within RM 102 to RM 72 partitioned by sample years less than 1995 and sample years greater than or equal to 1995. This test indicated a significant difference in log mean nest counts for the two periods (t [116] = 2.601, $P = 0.010$). For this contrast, equal variances were not assumed per Levene's test. Mean nest counts prior to 1995 (5.01 ± 6.111) were significantly higher than those recorded after 1995 (2.63 ± 3.976) within RM 102 to RM 72. This dichotomy before and after 1995 was not apparent in sand pit nest counts for RM 102 to RM 72, as shown in Figure 5-44, or nest counts for RM 71 to RM 0, as shown in Figure 5-45.

All of the above methods assume an inherently linear relationship between the dependent and independent variables and also assume independent observations. Because the data were not collected in accordance with a specific research design for this analysis and neither linearity nor independence of observations was ensured, the data were also analyzed by nonparametric methods. This analysis constituted the most conservative approach to the analysis and acted as a check on any potentially misleading results stemming from use of the general or generalized linear models. In this context, the degree of association between nest counts and independent variables was assessed by Kendall's Tau, which is an unbiased estimator of the degree of association between paired observations (Gibbons and Chakraborti, 2011) and which carries no assumptions of linearity or independence. Significant differences in dichotomized nest counts were assessed by Mann-Whitney U-test, a nonparametric procedure that examines the combined arrangement of X and Y variables in increasing order of magnitude to assess the relationship between two samples (Gibbons and Chakraborti, 2011).

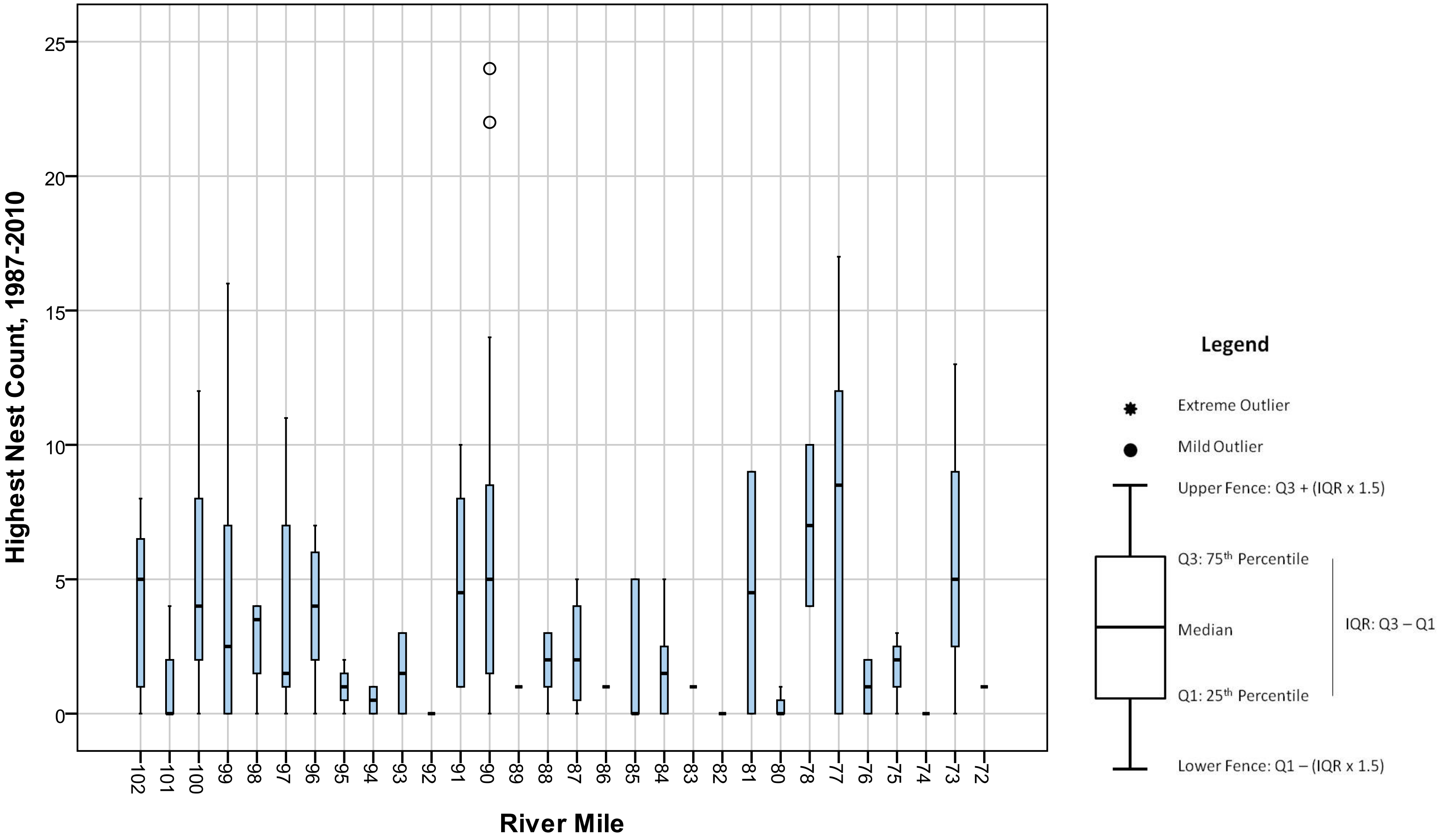


Figure 5-41. Box Plot of Highest Nest Count Summed by River Mile (1987-2010)

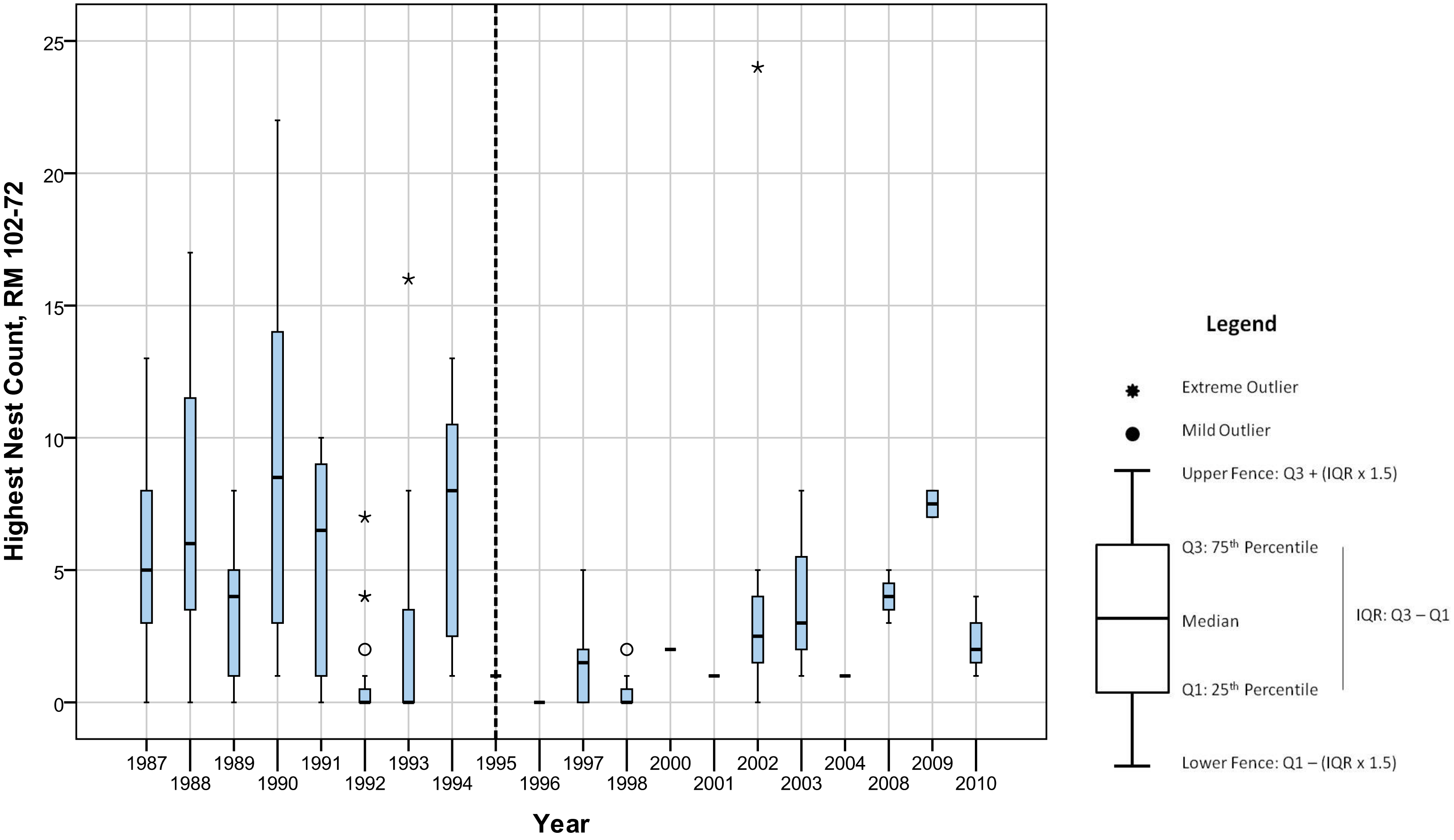


Figure 5-42. Box Plot of Highest Nest Count Summed by Year (RMs 102-72)

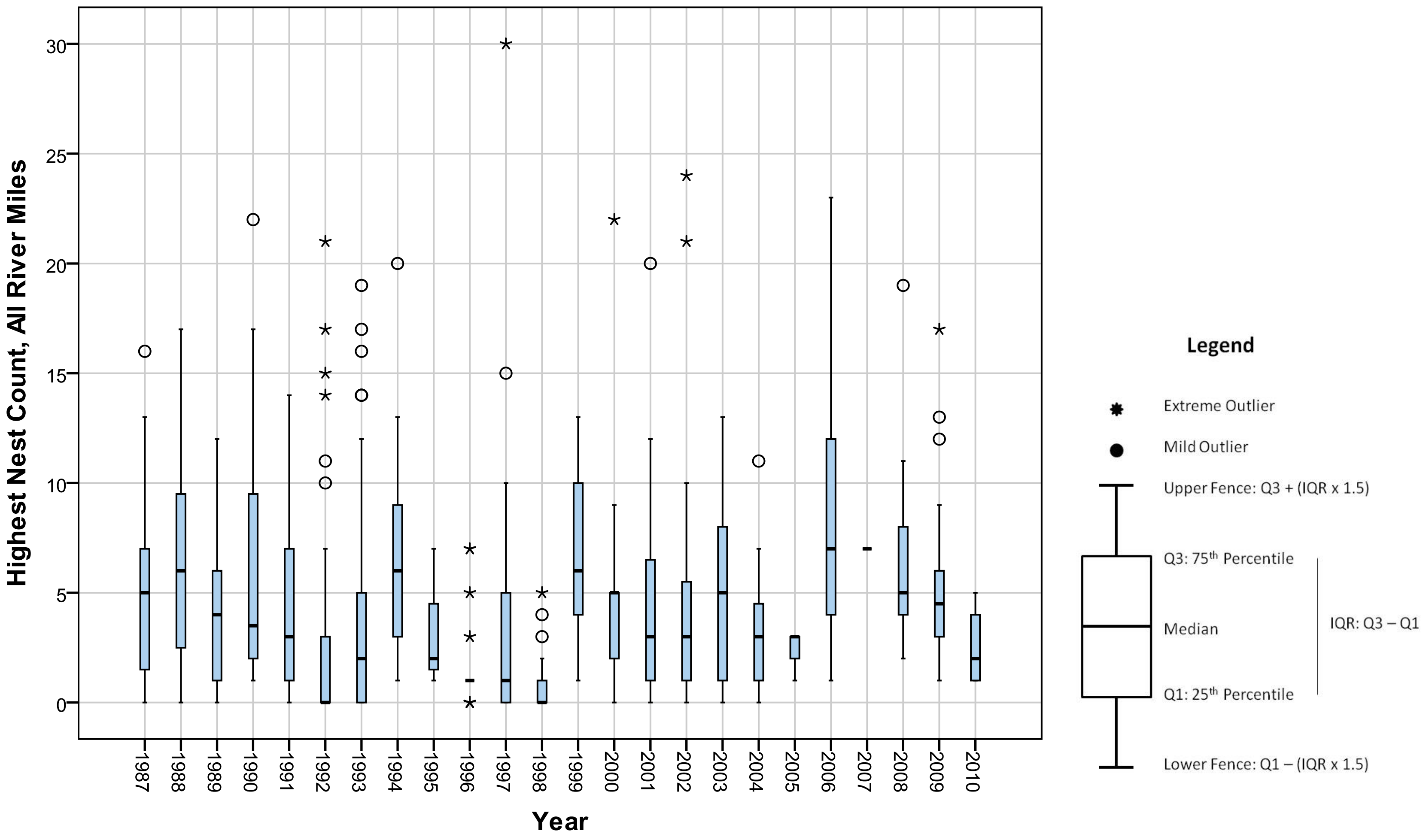


Figure 5-43. Box Plot of Highest Nest Counts Summed by Year (RMs 106-0)

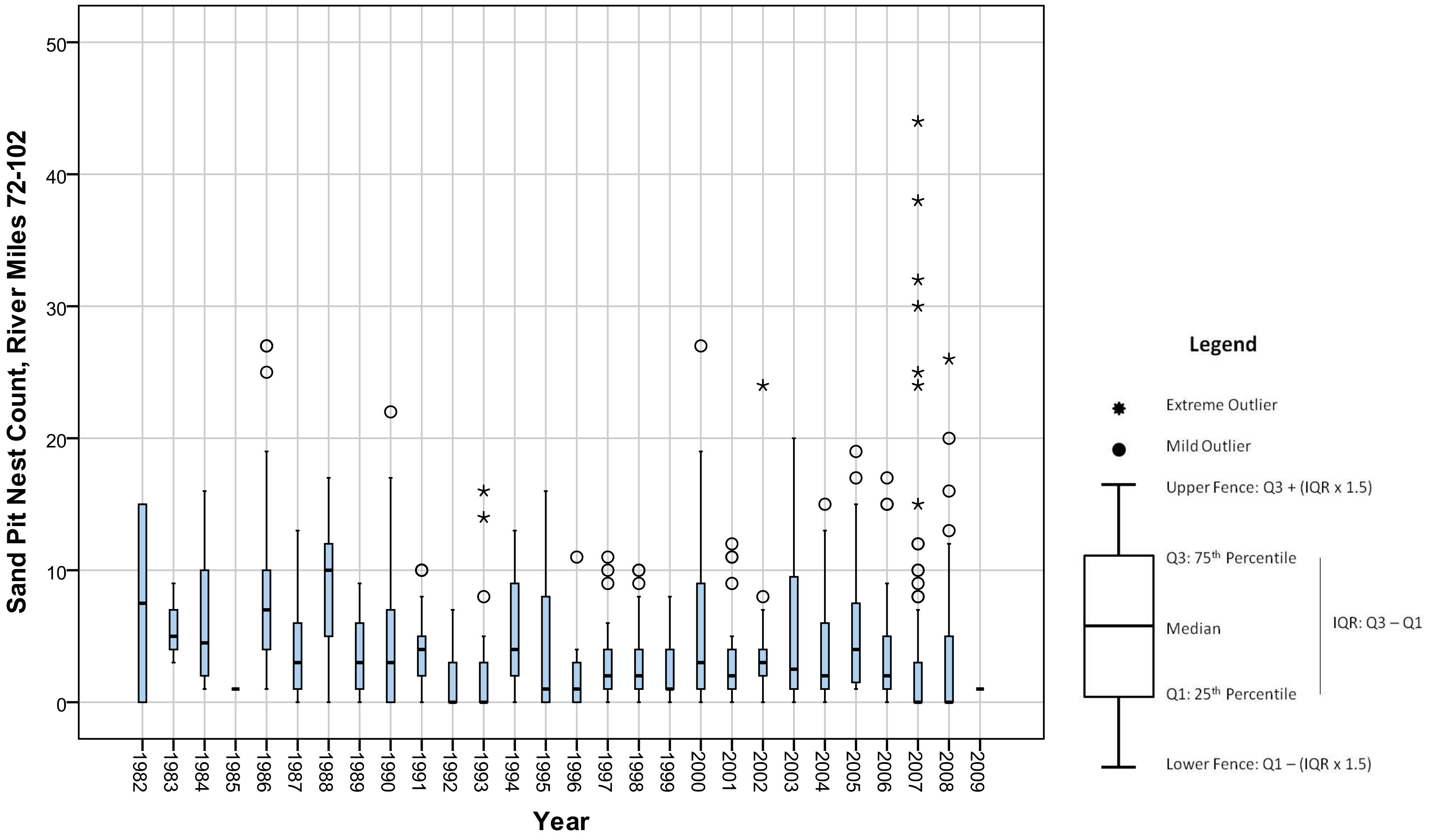


Figure 5-44. Box Plot of Highest Nest Count at Sand Pits by Year (RMs 102-72) (2010 data are not available)

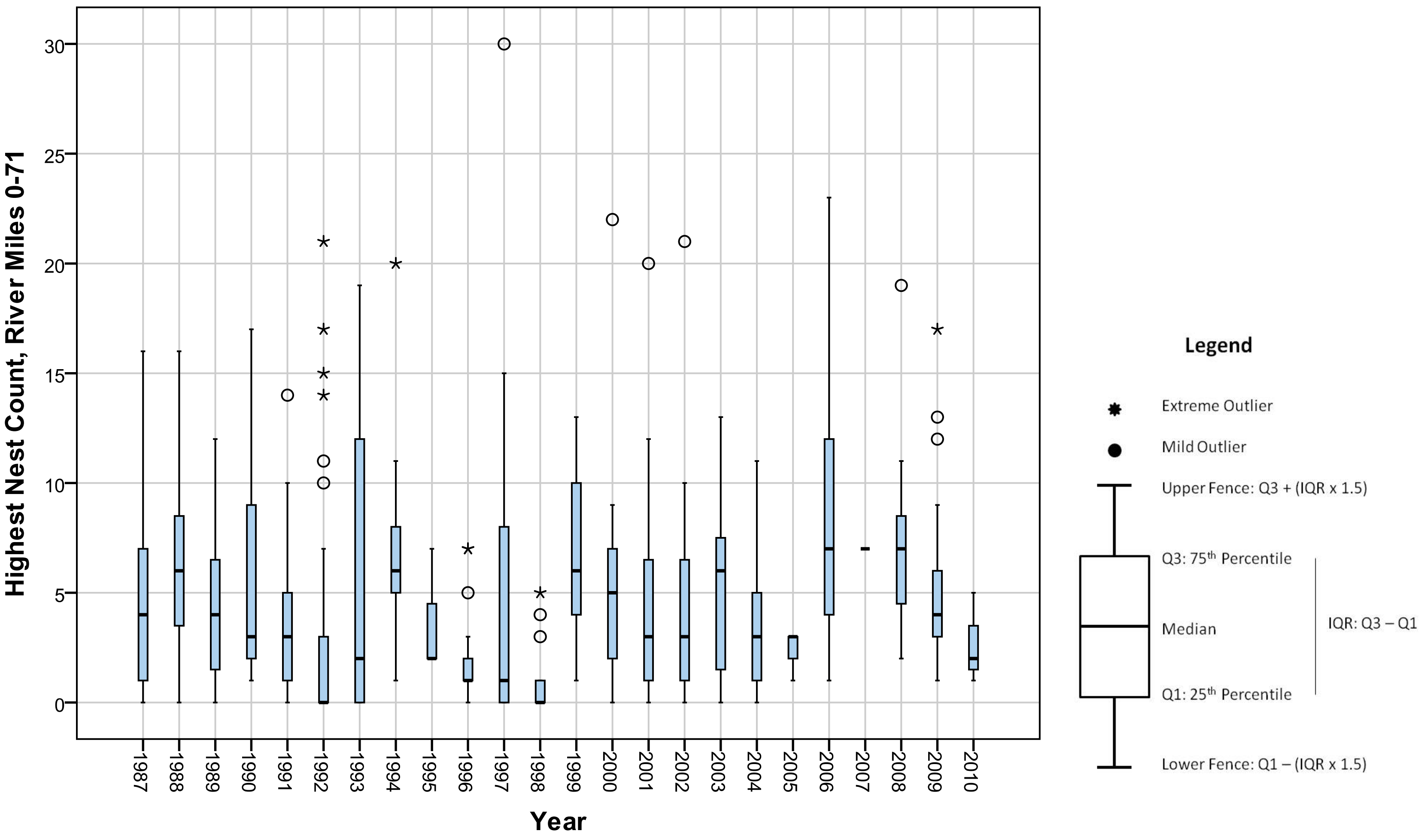


Figure 5-45. Box Plot of Highest Nest Counts by Year (RMs 71-0)

The highest nest count data partitioned by years before or after 1995, which was subjected to a parametric t-Test above, was subjected to the nonparametric Kendall's Tau. Results of this more conservative but less powerful test indicate a strong trend toward significance but fail to reach the 0.05 threshold of statistical significance ($P = 0.071$).

The *t-Test analysis* and, to a lesser extent, the Kendall's Tau results, indicate that RM 102 to RM 72 have seen two periods of relatively stable nest counts; however, these two periods are separated by an intervention that caused a statistically significant reduction in the total nest counts during the second period. The cause of the intervention is unknown; however, it is unlikely that Project operations were related to the intervention because operations were consistent across both time periods.

Binary Logistic Regression

The simplest approach to analyzing a potential relationship between summed highest nest counts per mile and hydrologic factors was reduction of the nest counts to a binary presence/absence variable and evaluation of that variable's relationship to peak mean daily flow and other factors via binary logistic regression. Within RM 102 to RM 72, 71.10 percent of sampled miles per year contained at least one interior least tern nest. Consequently, the prior probability of obtaining a response of 1 (nest present) in the absence of any moderating factors was 0.711. No combination of independent variables (year, river mile, peak mean daily flow with and without 1-year lag, wetted width, and annual percent diverted flow, with and without 1-year lag) changed the outcome of the logistic regression analysis from a correct classification rate of 71.10 percent. Log odds (the unit change in nest count associated with a unit change in a predictor variable) clustered near 0 for all variables except percent diverted, and Wald Chi-square scores were trivial, as were pseudo R^2 scores.

Binary logistic regression analysis failed to detect a measurable relationship between presence or absence of interior least tern nests and ranked calendar year, river mile, peak mean daily flow, annual percent diverted flow, wetted width, or any combination of those variables. Wetted width and annual percent diverted flow were of limited utility because those measurements were available only for RM 102, RM 99, and RM 72.

Although binary logistic regression circumvented potential problems associated with non-normal distributions, this approach sacrificed a large amount of potentially important data by reducing nest counts to a binary variable and ignoring variance and covariance among nest counts and independent variables. Because no effects were detected by this method, efforts were made to transform the data to formats suitable for more powerful analytic methods.

Multiple Regression

Highest nest count data, summed by RM 102 to RM 72 failed to normalize when transformed to natural logarithms. River mile and year were uniform distributions. Annual percent diverted flow, wetted width, and peak mean daily flow data also could not be normalized and were not uniform. Despite these limitations, a multiple linear regression analysis using log transformed nest count and raw independent variable scores was performed

An exploratory correlation matrix that generated both the Pearson r for linear correlations and Kendall's Tau (*T*) for nonparametric associations, indicated a strong association between least tern adult counts and highest nest counts (r [138] = 0.765, $P < 0.001$; T [138] = 0.578, $P < 0.001$). Both tests also indicated a weaker correlation with annual percent diverted flow (r [138] = 0.0.184, $P = 0.031$; T [138] = 0.133, $P = 0.039$).

A more powerful analysis of the potential relationship between highest nest counts and annual percent diverted flow required the use of linear regression. Knowing that annual percent diverted flow was problematic in a logistic regression analysis, it was necessary to rule out whether the variable was creating a spurious correlation in the linear and nonparametric procedures. Three multiple linear regression analyses were run, primarily to examine the regression residuals, which indicate how well the analysis is conforming to underlying requirements of a general linear model and how much confidence can be placed in the results.

The first analysis used raw summed nest counts per mile as the dependent variable and river mile, year, peak mean daily flow, and annual percent diverted as predictors. This analysis yielded unacceptable standardized residuals scores ranging from -1.239 to 4.495 (strongly right skewed). Ideally such scores should be distributed symmetrically within a range of about -2.00 to 2.00. The analysis indicated no significant correlation between the independent variables and nest counts.

The second analysis used log transformed nest counts as the dependent variable. This analysis provided acceptable standardized residuals ranging from -1.980 to 2.123 (very slightly right skewed). A weak but statistically significant correlation was indicated ($R = 0.234$, $R^2 = 0.055$) with annual percent diverted flow capturing about half of the variance shared with log transformed nest counts after removing the effects of the other predictors ($r_{sp} = 0.162$; $r^2_{sp} = 0.026$). However, both of these analyses indicated a strong correlation ($r = 0.801$) between peak mean daily flow and annual percent diverted flow, such that the two variables were collinear and likely inflating apparent correlations with log converted nest counts.

The third analysis removed annual percent diverted flow from the dependent variables. This analysis exhibited fair residuals scores ranging from -2.876 to 1.795 (slightly left skewed), and indicated no significant correlations among the independent variables. This analysis also indicated no relationship between log transformed nest counts and the predictor variables ($R = 0.168$, $P = 0.283$).

Analysis of Nest Counts in Relation to Annual Change in Peak Mean Daily Flow

Change in peak mean daily flow between years is significant per one-way ANOVA (F [21, 194] = 1,183.399, $P < 0.000$) whereas change in mean flow between river miles in the same year is virtually nonexistent per one-way ANOVA (F [30, 185] = 0.801, $P = 0.760$). Figure 5-46 illustrates maximum readings in peak mean daily flow as a percentage of the highest peak mean daily flow for the period of analysis (1987 to 2010). High-flow years followed by low-flow years occurred most notably in 1993 and 1994, 1999 and 2000, and 2005 and 2006.

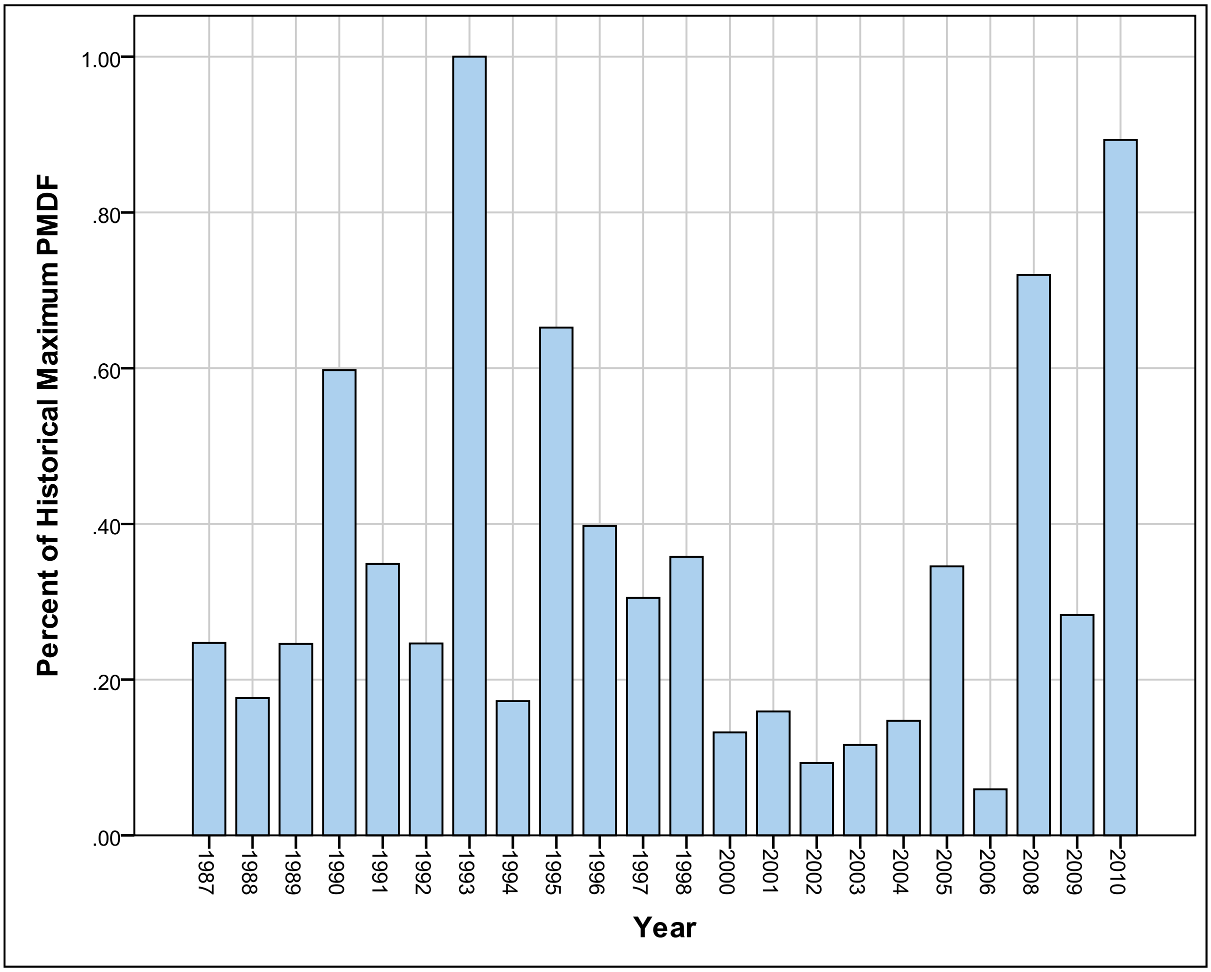


Figure 5-46. Yearly Proportion of Peak Mean Daily Flow (Averaged over RMs)

The highest flow in RMs 102 to 72 during the summer of 1993 was also the highest flow for the period of analysis (1987 to 2010). During summer 1993, nest count data was collected at 17 river miles, with interior least tern nest counts ranging to 16 nests per river mile. The mean nest count sum per river mile was 2.76, and the median nest count sum per river mile was 1 nest. The following year peak flow was less than 20 percent of the maximum for the period of analysis. During summer 1994, 10 river miles were sampled, with nest counts ranging to 18 nests per river mile. The mean nest count sum per river mile was 7.9, and the median nest count sum per river mile was 8.50 nests. Figure 5-47 illustrates the relationship between peak mean daily flow for May through August of 1993 and 1994 and raw interior least tern nest counts. The two variables are expressed as percentages of historical maximums to place the disparate data sets on a common scale with a range of 0 to 1. The trend shown in Figure 5-47 supports the concept of high-flow years followed by low-flow years resulting in improved nesting conditions. Additional examples of this trend are lacking in the current data. In 1990 and 1991, for instance, a less dramatic difference in peak flow resulted in a reverse trend in nest count sums, as shown in Figure 5-48. However, sufficient count data are not available for other years in which high flow is followed by very low flow. It appears that annual maximum flow patterns such as occurred in 1993 and 1994, when 20 data collection visits were recorded, are genuinely beneficial to nesting interior least tern populations. However, the "luck of the draw" in data collection visits failed to capture similar events in 1999 and 2000, when only 1 data collection visit was reported, and in 2005 and 2006, when no data collection visits for nest counts were reported. It is possible that the low number of data collection visits for 1999/2000 and 2005/2006 masked a continuing trend of increased nest counts when high flows are followed by low flows the following year.

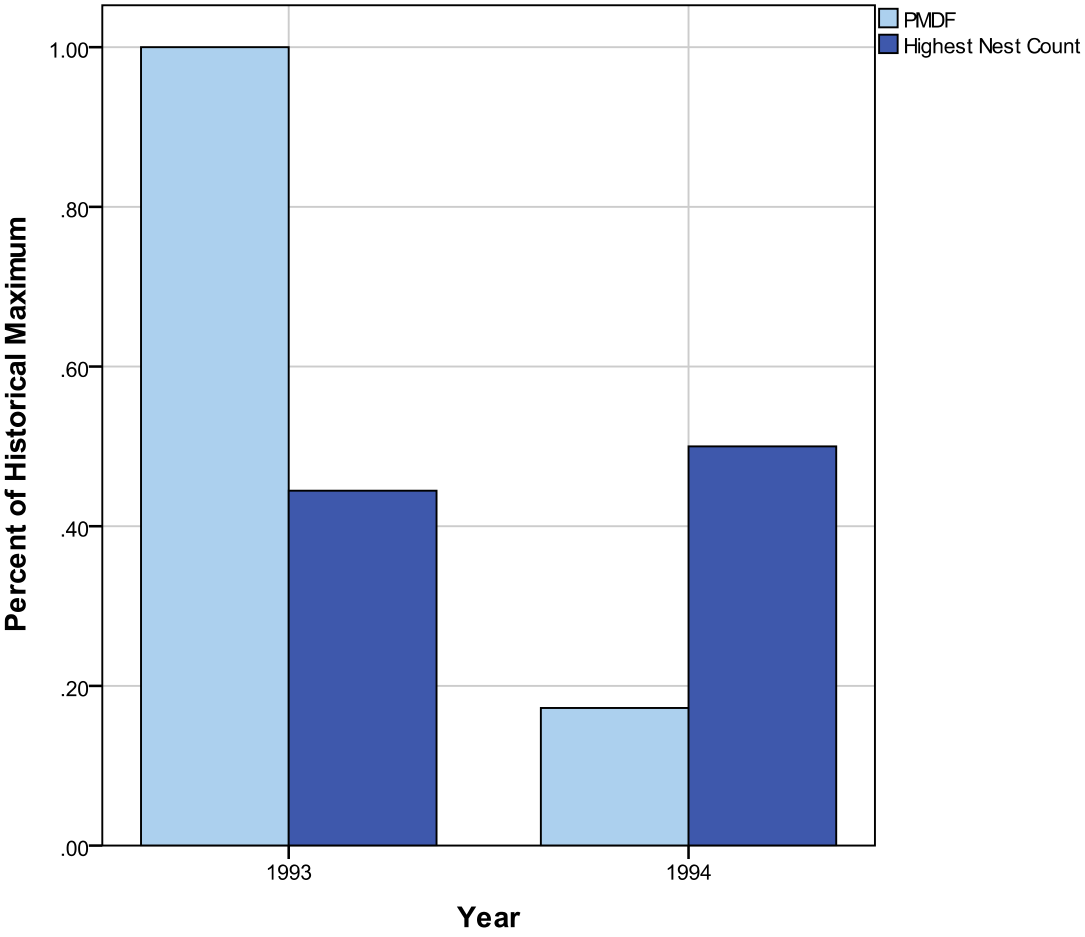


Figure 5-47. Standardized Peak Mean Daily Flow and Nest Count Sums for the Years 1993 and 1994

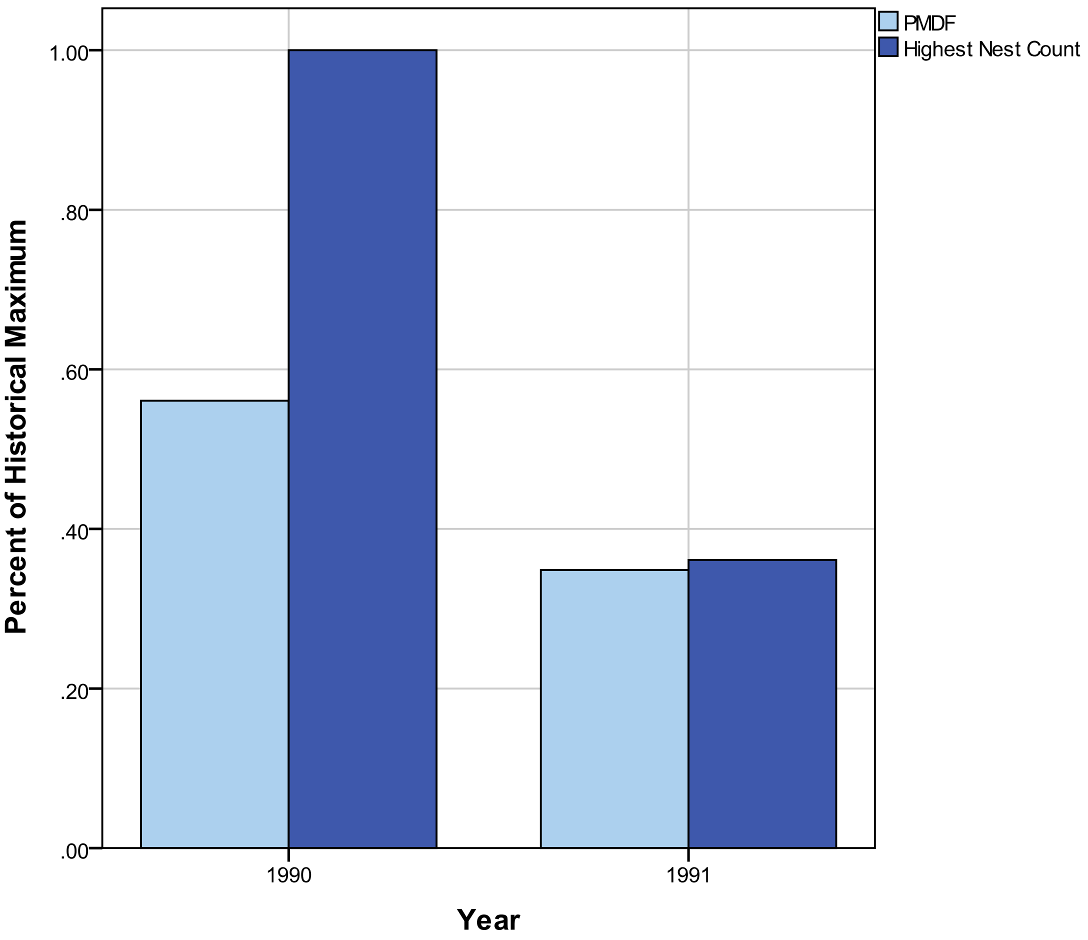


Figure 5-48. Standardized Peak Mean Daily Flow and Nest Count Sums for the Years 1990 and 1991

5.4.4 Objective 3 Conclusions

The initial statistical analysis of interior least tern and piping plover data by hydrologic river segment yielded results of no significant relationship between interior least tern and piping plover nest counts and sediment transport indicators. No evidence from these analyses was discovered that would suggest that a relationship exists between nest counts and sediment transport indicators or hydrologic parameters.

Supplemental statistical analysis of interior least tern data by river mile for RM 102 to RM 72, as developed with recommendations from NGPC, used binary logistic regression, multiple linear regression, nonparametric methods, and one-way ANOVA to evaluate if the hydrologic variables could explain nest count numbers and may be an influencing factor in nesting of interior least terns on the lower Platte River. The results of these analyses found the following:

- Nest counts were weakly associated with number of data collection visits per year, but strongly associated with interior least tern adult counts, which were also weakly associated with number of data collection visits.
- No association was detected between summed nest counts and river mile, which indicates that variability in nest counts is not associated with proximity to the Tailrace Return.
- A period of relatively high nest counts from 1987 to 1995 was followed by a period of lower but also static nest counts from 1995 to 2008 between RM 102 and RM 72; this dichotomy is not associated with Project operations.
- Binary logistic regression analysis failed to detect a measurable relationship between presence or absence of interior least tern nests and ranked calendar year, river mile, peak mean daily flow, percent diverted flow, or any combination of these variables.
- Nonparametric correlation studies suggested annual percent diverted flow as a weak but statistically significant predictor of nest counts summed by river mile. This relationship was demonstrated to be spurious following more thorough examination of results of multiple linear regression analyses.
- One-way ANOVA determined that changes in peak mean daily flow between years in relation to nest counts is statistically significant, providing evidence in support of the theory that high flows followed by low flows may be beneficial for interior least tern nesting. However, effect of flow on nest frequency is difficult to gauge from the current data because of extreme variability in the frequency and locations of annual nest counts.
- One-way ANOVA also determined that changes in flow between river miles is not statistically significant in relation to nest counts.

End of Revisions

[The following text has not been revised, but page numbers have been updated.]

5.5 Objective 4 – To determine if sediment transport is a limiting factor for pallid sturgeon habitat in the lower Platte River below the Elkhorn River.

5.5.1 Platte River Sturgeon Population Dynamics Study

Researchers at UNL are currently conducting a 5-year Shovelnose Sturgeon Population Dynamics Study within the Platte River that is to end in 2012 (NGPC, April 19, 2009). The study is to document movement and population of shovelnose sturgeon, but a side benefit of the study has also been the capture and documentation of pallid sturgeon as it is subject to the same capture techniques as the shovelnose sturgeon. Because the shovelnose sturgeon is more abundant than the pallid sturgeon, and is morphologically and physiologically similar to the pallid sturgeon, there is the opportunity to use the shovelnose as a useful surrogate model for the less prevalent pallid sturgeon. Because the pallid sturgeon tends to occupy similar habitat, UNL researchers also capture pallid sturgeon during their efforts to capture shovelnose sturgeon.

Capture efforts have been conducted along the Platte River from its confluence with the Missouri River to an upstream location approximately 30 miles west of Columbus. Gear used during these efforts consists of trotlines and drifting trammel nets. In 2009, 69 pallid sturgeon were captured. An additional 20 to 25 pallid sturgeon were captured through mid-summer 2010. No sturgeon have been collected upstream of Columbus; however, several shovelnose sturgeon and a pallid sturgeon were collected approximately 0.5 mile below the Loup Power Canal confluence (UNL, July 14, 2010).

5.5.2 Pallid Sturgeon Use of the Lower Platte River

As more information is gathered on pallid sturgeon life history and movement within the Missouri River system (including tributaries), it is becoming more evident that the lower Platte River is important habitat for the development and growth of the pallid sturgeon. Peters and Parham (2008) stated that "…the fact that we caught pallid sturgeon during spring, summer and fall months of the year indicates to us that the lower Platte River is an important part of RPMA 4…, which includes all of the Missouri River downstream from Gavins Point Dam to its confluence with the Mississippi River (approximately 800 river miles)." In addition, Peters and Parham (2008) noted that "…the capture of six pallid sturgeon that were stocked into the Missouri River suggests that conditions in the Platte River are attractive to stocked pallid sturgeon."

Researchers at UNL are currently conducting a 5-year Shovelnose Sturgeon Population Dynamics study within the Platte River that is to end in 2012 (NGPC, April 19, 2009).

Of the 69 pallid sturgeon that were collected in 2009 during the UNL Shovelnose Sturgeon Population Dynamics Study, discussed in Section 5.5.1, only 3 were potential "wild" spawn fish (UNL, July 15, 2010). That is, 95 percent of the captured pallid sturgeon were produced in hatcheries or as the result of state and federal stocking programs. It appears that the lower Platte River, as a tributary to the Missouri River, serves as a feeding and developmental area that young sturgeon seek out and occupy (UNL, July 15, 2010) until water quality such as elevated temperature (≥ 28°F) and dissolved oxygen (≤ 4 ppm) result in the departure from the Platte River back into the Missouri River (USGS, July 15, 2010).

Until further information is collected and as pallid sturgeon continue to mature, it is not known whether adults use the Platte River as a spawning area. Current studies have reported that pallid sturgeon spawning has not been documented in Missouri River tributaries (Bergman et al., May 2008). USFWS (July 16, 2010) further agreed that there is currently no evidence that confirms that sandy bottom tributaries, such as the Platte River, are used for spawning by pallid sturgeon. Additionally, no gravid females have been collected and recaptured to prove there is spawning activity actually occurring within the Platte River (USGS, July 15, 2010). Local fishery experts generally agree that hard rocky substrate spawning sites are limited within the Platte River, unlike the Missouri River with its abundance of revetment works along the shoreline bends and guide structures. Preliminary evidence suggests that pallid sturgeon seek out the revetment areas on the outside bends of the main channel of the Missouri River for spawning (DeLonay et al., 2009). Observations of pallid sturgeon attempting to spawn on riprap in the Missouri River further supports the idea “that availability of habitats with necessary substrate characteristics may not be limiting for sturgeon spawning” (DeLonay et al., 2009).

Despite the preceding discussion, the findings that may suggest that the lower Platte River does not support pallid sturgeon spawning are inconclusive. The “Research Needs and Management Strategies for Pallid Sturgeon Recovery” report states that “Spawning habitat was viewed as special and limited, but researchers now have evidence that…spawning of shovelnose and pallid sturgeon occurs over a wide range of areas” (Bergman et al., May 2008). In addition, Peters and Parham (2008) documented the capture of a female pallid sturgeon that was carrying eggs on May 3, 2001, near Louisville (RM 15.5); however, no confirmation of spawning by this fish was documented. Areas around and along Platte River bridges may be conducive for spawning. There may be scour areas at these locations that result in deep water areas with hard substrate (bedrock) that may allow for the development of spawning habitat. Further, an assessment conducted by NGPC (December 2008) states that “suspended solids concentrations in the lower Platte River increase three- to four-fold during the spring…. These springtime sediment concentrations are equivalent to those found in the Yellowstone River, where other pallid sturgeon populations are concentrated and spawning has been documented.” Further, these sediment concentrations may trigger sturgeon spawning in the lower Platte River if adequate spawning substrate is available.

5.5.3 Objective 4 Conclusions

Through the capture of several juvenile pallid sturgeon in recent studies, it has been determined that the lower Platte River provides appropriate pallid sturgeon habitat and supports the growth and development of these fish. The following statement from the Platte River Recovery Implementation Program (PRRIP) Document (PRRIP, October 24, 2006) supports these findings:

> Consistent with the April 28, 2004 finding of the National Academy of Sciences (NAS), it is now agreed that current habitat conditions on the lower Platte River do not adversely affect the likelihood of survival and recovery of the pallid sturgeon because that reach of the river appears to retain several habitat characteristics apparently preferred by the species.

The following excerpts from the noted USGS Scientific Investigations Reports specific to pallid sturgeon in the lower Missouri River indicate that channel morphology, in addition to flow regime, directly corresponds to physical pallid sturgeon habitat:

- Physical components of habitat can be managed directly by changes in flow regime or channel morphology (Jacobson and Galat, 2006, as cited in Reuter et al., 2009).
- Among the stresses imposed on the river, the large magnitude of changes in flow regime and channel morphology have been assumed to be the most influential in species declines, largely through their influence on physical habitat availability (National Research Council, 2002; U.S. Fish and Wildlife Service, 2003, as cited in Reuter et al., 2009)
- In addition to changes in channel morphology that result from purposeful re-engineering of channel, there are complex readjustments of channel morphology that take place as a result of influxes or effluxes of sediment related to seasonal patterns of sediment transport, tributary flows, and large flood events (Elliott and others, 2009, as cited in Jacobson, Johnson, and Dietsch, 2009). These factors can result in background variability in the quality and quantity of habitat availability to river organisms (Jacobson, Johnson, and Dietsch, 2009).

When the findings of this sedimentation study, which determined that the lower Platte River geomorphology and corresponding riverine habitat are in dynamic equilibrium, are compared to the numbers of shovelnose and pallid sturgeon collected during ongoing capture efforts, it can be inferred that current Project operations relative to sediment removal from Loup River inflows at the Headworks are not acting to limit sturgeon habitat or the success of these species in the lower Platte River.

6. STUDY VARIANCE

Changes to the Sedimentation study plan, which was approved with modifications by FERC in its Study Plan Determination on August 26, 2009, were necessary to produce a more robust report. Specifically, this sedimentation study was to develop indicators of sediment transport capacity using effective discharge.

In the literature, “effective” and “dominant” discharge are used interchangeably to mean the channel-forming discharge, although they require a slightly different calculation. Because of the interchangeable use of these terms in the literature, this sedimentation study also calculated dominant discharge. The values for both at each of the study sites are provided in Table 5-2. The values compare well, and the differences are insignificant.

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