APPENDIX B

HYDROCYCLING STUDY REPORT

LOUP RIVER HYDROELECTRIC PROJECT

FERC PROJECT NO. 1256

HYDROCYCLING

Loup Power District
Hydro Project

FEBRUARY 11, 2011

Serving You Electrically
LOUP POWER DISTRICT

Loup Power District
Hydro Project

Loup River Hydroelectric Project
FERC Project No. 1256

Study 2.0
Hydrocycling

February 11, 2011

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List of Tables

List of Figures

List of Attachments

STUDY 2.0 HYDROCYCLING

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.

Upstream of the regulating reservoirs, the Loup Power Canal and the Monroe Powerhouse operate in a run-of-river mode with no storage capacity. Average daily flow in this reach is 1,610 cubic feet per second (cfs). Maximum flow in the canal is limited to 3,500 cfs by both water rights and hydraulic capacity. The interconnected regulating reservoirs, Lake Babcock and Lake North, accumulate water and build head during a portion of each day. Accumulated water is then released through the Columbus Powerhouse to produce energy during high-demand periods of the day as directed by the Nebraska Public Power District (NPPD), the exclusive purchaser of Project power. This sub-daily regulation at the Columbus Powerhouse is called hydrocycling.

Except during brief ramp-up and ramp-down periods, operating discharge from the Columbus Powerhouse ranges from a minimum of about 1,000 cfs with one turbine operating to a high of about 4,800 cfs with all three turbines operating at high efficiency settings. Water discharged from the Columbus Powerhouse flows down the 5-mile-long Tailrace Canal and enters the Platte River at the Outlet Weir. This weir is located approximately 2 miles downstream of the confluence of the Loup River bypass reach and the Platte River. Tailrace Canal flow is recorded at the Nebraska Department of Natural Resources (NDNR) gage at the 8th Street bridge in Columbus. Including local inflows unrelated to the Project (primarily inflows from the Lost Creek Flood Control Channel), Tailrace Canal discharge to the Platte River ranges from less than 100 cfs to over 6,300 cfs.

1.1 Interior Least Tern and Piping Plover Use of the Lower Platte River

Within the study area (discussed in Section 3) and directly downstream, interior least terns (*Sterna antillarum*), Federally listed as endangered, and piping plovers (*Charadrius melodus*), Federally listed as threatened, use the lower Platte River[1] 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

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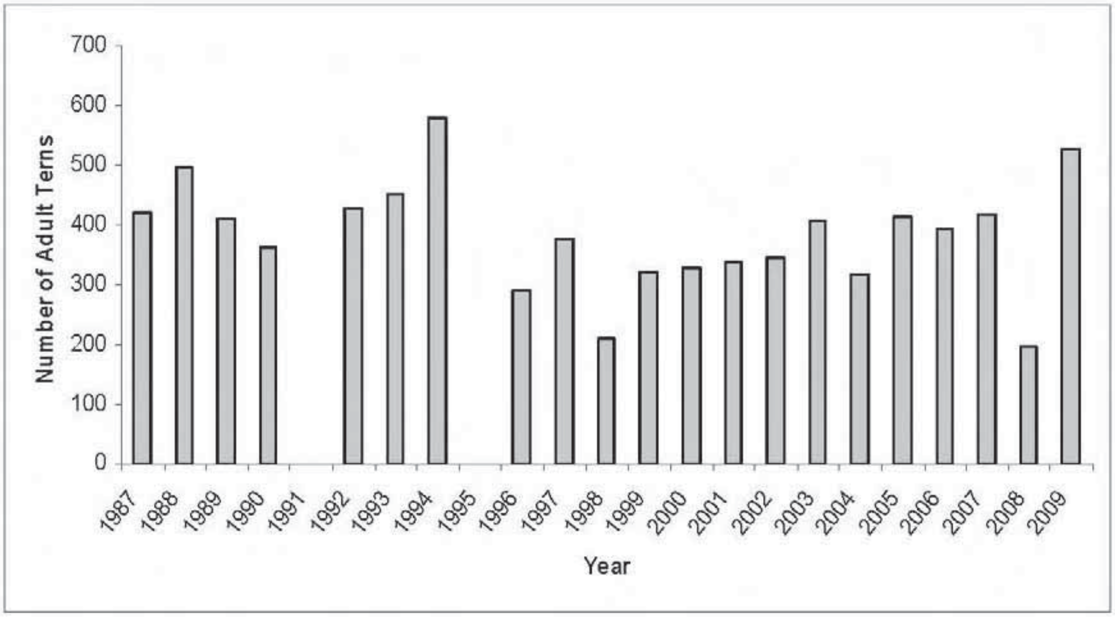
[1] The lower Platte River is defined as the reach between the confluence of the Loup and Platte rivers and the confluence of the Platte and Missouri rivers.

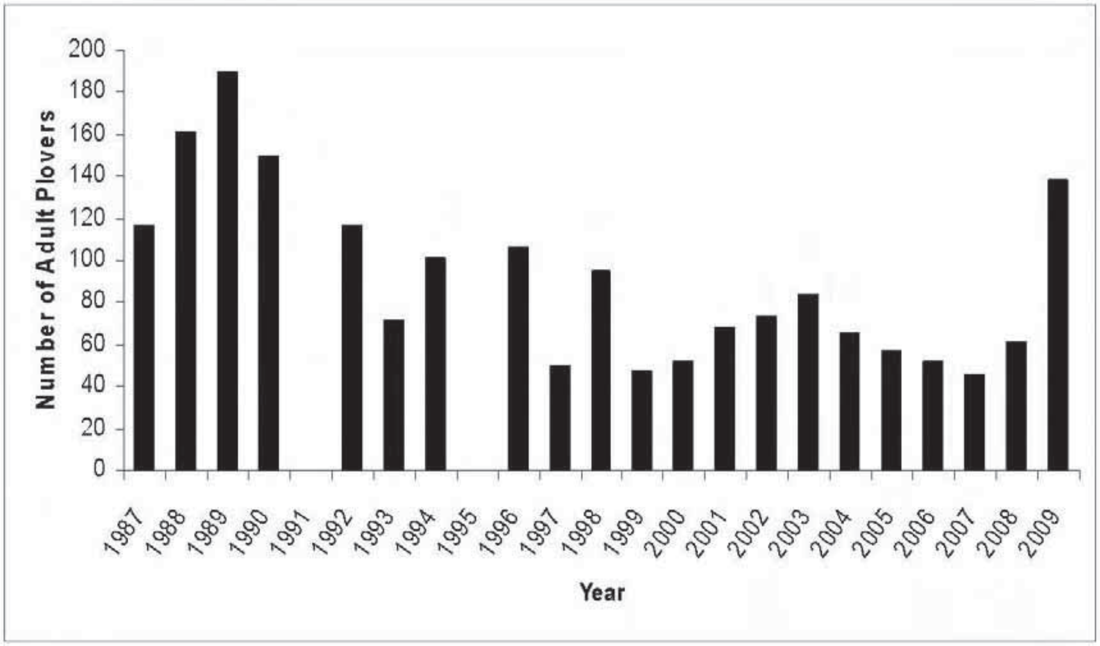
and on gravel and sand beaches on lakes. Their nests are shallow depressions with small stones, twigs, or other debris nearby. Egg-laying begins in late May with an incubation period of 17 to 28 days (U.S. Fish and Wildlife Service [USFWS], September 1990; Thompson et al., 1997). Fledging occurs 3 weeks 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 (U.S. Geological Survey [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 on the lower Platte River indicates that interior least tern numbers have remained relatively stable along the lower Platte River during this period, as shown in Figure 1-1 (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 1-1. 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 on 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 1-2 (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 1-2. Total Number of Adult Piping Plovers Recorded During the Lower Platte River Mid-Summer Survey, 1987 – 2009

1.2 Pallid Sturgeon Use of the Lower Platte River

Pallid sturgeon (*Scaphirhynchus albus*), Federally listed as endangered, are found downstream of the Project within the lower Platte River. 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 furthest 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 UNL study reach (the Platte River from the confluence with the Loup River to the confluence with the Missouri River), 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.

1.3 Reasons for This Study

USFWS has asserted that hydrocycling of Project flows entering the lower Platte River may affect riverine morphology, thereby affecting habitat, including habitat used by interior least terns, piping plovers, and pallid sturgeon. These possible effects are derived from the sub-daily variability, rate of change, and proportion of hydrocycling flows relative to flows already in the Platte River. On the other hand, the District has contended that the morphology of the Loup and Platte rivers is in a state of dynamic equilibrium and that any purported effects on the diverse biological resources of either river are not a result of Project operations. To address this issue, the Loup River Public Power District (Loup Power District or the District) conducted this hydrocycling study. This study focused on four principal questions:

- How do sub-daily Project hydrocycling operation values (maximum and minimum flow and stage) compare to daily values (mean flow and stage)?
- What is the potential for nest inundation due to both hydrocycling and alternative conditions (run-of-river operations)?
- What effects, if any, do hydrocycling and alternative conditions (run-of-river operations) have on sediment transport parameters and channel morphology (that is, habitat)?
- Are there material differences between hydrocycling and alternative conditions (run-of-river operations) in potential effects on habitat of the interior least tern, piping plover, and pallid sturgeon?

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, with modifications, as outlined in its Study Plan Determination on August 26, 2009.

2. GOALS AND OBJECTIVES OF STUDY

The goal of the hydrocycling study is to determine if Project hydrocycling operations benefit or adversely affect the habitat used by interior least terns, piping plovers, and pallid sturgeon in the lower Platte River. The physical effects of hydrocycling (current operations) were quantified and compared to an alternative condition (run-of-river operations). Run-of-river operations are defined as simulated conditions that would exist without regulation for hydrocycling.

The objectives of the hydrocycling study are as follows:

1. To compare the sub-daily Project hydrocycling operation values (maximum and minimum flow and stage) to daily values (mean flow and stage). In addition to same-day comparisons, periods of weeks, months, and specific seasons of interest to protected species will be evaluated to characterize the relative degrees of variance between hydrocycling (current operations) and run-of-river operations in the study area.
2. To determine the potential for nest inundation due to both hydrocycling (current operations) and run-of-river operations.
3. To assess effects, if any, of hydrocycling (current operations) and run-of-river operations on sediment transport parameters and channel morphology (see Study 1.0, Sedimentation).
4. To identify material differences between hydrocycling (current operations) and run-of-river operations in potential effects on habitat of the interior least tern, piping plover, and pallid sturgeon.

3. STUDY AREA

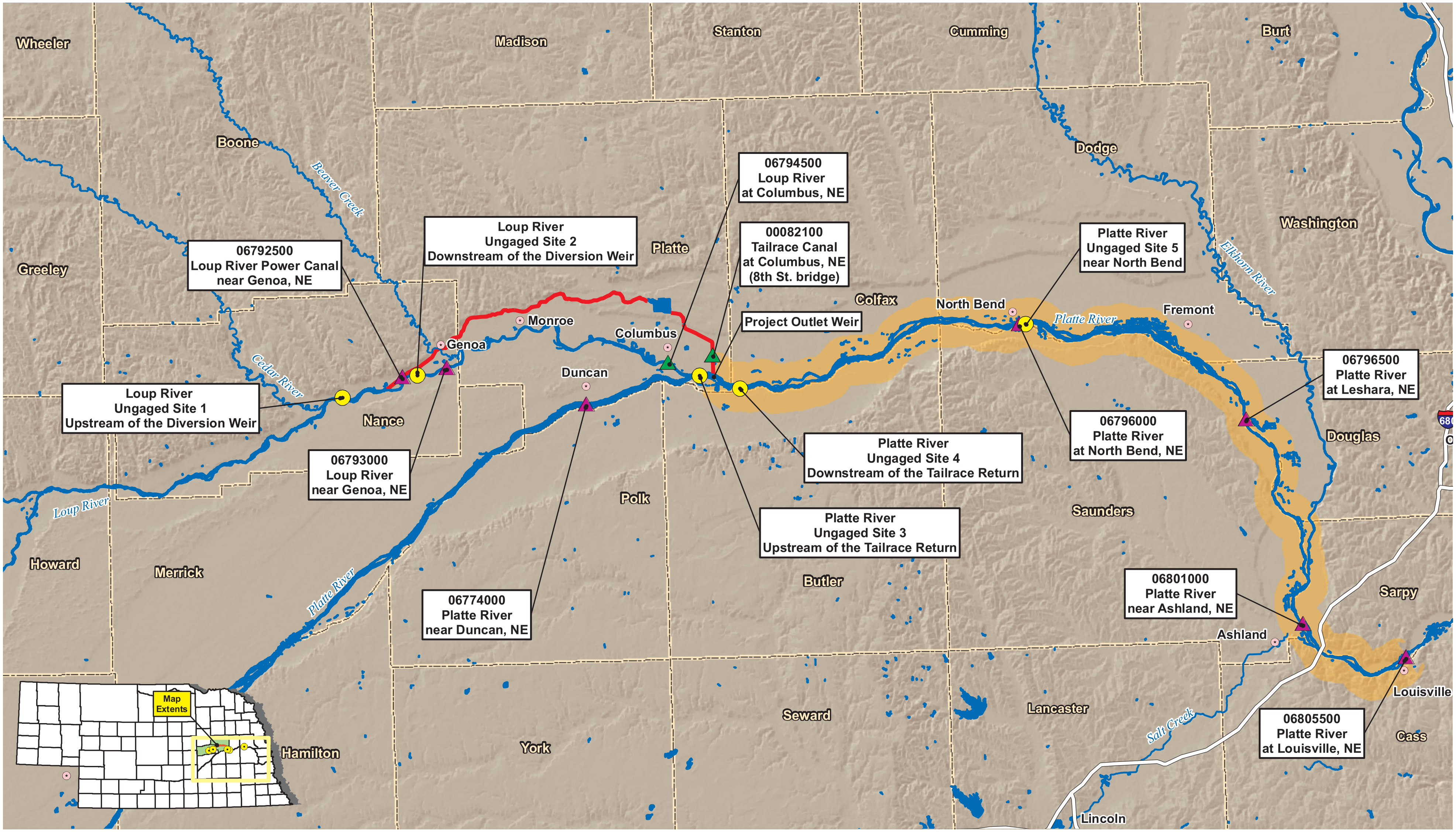
The study area includes the Tailrace Canal and the lower Platte River from the Project Outlet Weir to the USGS gage at Louisville, shown in Figure 3-1. Stream gage information from upstream locations on both the Loup River and central Platte River were used in development of flow information at the Outlet Weir location, as discussed in Section 4.1. The following existing stream gage locations on the lower Platte River served as study sites for analyses:

- USGS Gage 06796000, Platte River at North Bend, NE
- USGS Gage 06796500, Platte River at Leshara, NE
- USGS Gage 06801000, Platte River near Ashland, NE
- USGS Gage 06805500, Platte River at Louisville, NE

In addition to these study sites, FERC, in its Study Plan Determination dated August 26, 2009, required that "ungaged" sites also be evaluated. The approved methodology for the hydrocycling study included a provision that cross-section surveys and calculations of sediment transport indicators, regime analysis, and spatial analysis be conducted at three ungaged sites. In addition, the approved methodology for the sedimentation and the flow depletion and flow diversion studies included a provision that cross-section surveys and calculations of sediment transport indicators be conducted at two additional ungaged sites.

The ungaged sites were chosen in consultation with USFWS and the Nebraska Game and Parks Commission (NGPC) through the use of aerial photographs. The five ungaged sites and the studies with which they are associated are listed below and are shown in Figure 3-1; the three ungaged sites relevant to this hydrocycling study are Sites 3, 4, and 5:

1. Loup River upstream of the Diversion Weir (Site 1) – Sedimentation and flow depletion and flow diversion
2. Loup River immediately downstream of the Diversion Weir (Site 2) – Flow depletion and flow diversion
3. Lower Platte River downstream of the Loup River confluence and upstream of the Tailrace Return confluence (Site 3) – Sedimentation, hydrocycling, and flow depletion and flow diversion
4. Lower Platte River within 5 miles downstream of the Tailrace Return confluence (Site 4) – Sedimentation and hydrocycling
5. Lower Platte River near the USGS North Bend gage (Site 5) – Hydrocycling



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

Legend

⊙	City
▲	NDNR Gaging Station
▲	USGS Gaging Station and/or Study Site
●	Ungaged Study Sites
═	Interstate
—	Stream/River
—	Loup Power Canal
■	Waterbody
☐	County
■	Potentially Affected Reach of the Lower Platte River

Hydrocycling Study Sites

Loup River Hydroelectric Project
FERC Project No. 1256
Study 2.0 - Hydrocycling

DATE
Feb. 11, 2011

FIGURE
3-1

4. METHODOLOGY

The methodology used to complete the hydrocycling analysis is described below. The results of the hydrocycling study are discussed in Section 5, and supporting graphs and tables are included in Attachments A through K. The methodology for the hydrocycling 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: Data Collection
- Objective 1: To compare the sub-daily Project hydrocycling operation values (maximum and minimum flow and stage) to daily values (mean flow and stage). In addition to same-day comparisons, periods of weeks, months, and specific seasons of interest to protected species will be evaluated to characterize the relative degrees of variance between hydrocycling (current operations) and run-of-river operations in the study area.
    - Task 2: Gage Analysis
    - Task 3: Hydrographs for the Project versus Run-of-River Operations
- Objective 2: To determine the potential for nest inundation due to both hydrocycling (current operations) and run-of-river operations.
    - Task 4: Nesting Season Sandbar Inundation Heights
- Objective 3: To assess effects, if any, of hydrocycling (current operations) and run-of-river operations on sediment transport parameters and channel morphology.
    - Task 5: Effects of Hydrocycling on Sediment Transport Parameters
- Objective 4: To identify material differences between hydrocycling (current operations) and run-of-river operations in potential effects on habitat of the interior least tern, piping plover, and pallid sturgeon.
    - Task 6: Effects of Hydrocycling on Interior Least Tern, Piping Plover, Pallid Sturgeon, and Isolation of Backwaters and Side Channels

4.1 Task 1: Data Collection

Daily and sub-daily discharge data, streamflow measurements, and current and historical rating curve data were collected at the study sites as well as at additional USGS and NDNR gages in and near the study area, as listed in Table 4-1 and shown in Figure 3-1. These data were used to determine the timing, frequency, rate of change, travel time, and magnitude of sub-daily flow and stage changes.

Table 4-1. Gaged Sites and 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.
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.
06794000	Beaver Creek at Genoa, NE	677	131	1940 - 2009	Available discharge data from October 1, 1940, to 2009 include daily and sub-daily data.
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.
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[2]	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.

USGS Gage Number	Gage Name and Location	Drainage Area (sq. mi.)	Mean Daily Discharge (cfs)	Period of Record	Comments
06796500[2]	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[2]	Platte River near Ashland, NE	84,200	6,543	1928 - 2009	Available discharge and gage height data from September 1, 1928, to 2009 include daily and sub-daily data.
06805500[2]	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.

Notes:

NA = Not available.

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

[2] Designated as a study site.

Field surveys were conducted at each of the ungaged sites to measure the topography using 9 to 10 closely spaced cross sections and flow parameters of top width and depth. Velocity measurements were not taken during high flows, as described below. Data collection for the ungaged sites was scheduled prior to the interior least tern and piping plover nesting season (the first week of May) and at the end of the nesting season (the first week of August). However, high water experienced in early May and extending through June 2010 (see Figures 4-1 and 4-2) postponed most of the data collection effort until mid- to late June. Data were collected at Site 3 on May 2 and 3, 2010. The second set of data was collected between mid-September and early October 2010.

It was concluded that the sustained high flows observed in May and June were in some respects reflective of the typical annual spring runoff and that the consistent lower flows experienced in July and August were reflective of the typical summer low flows. Velocity measurements were not taken during the high flows experienced in 2010 because a significant portion of the river was not wadeable. Although the District was directed in FERC's Study Plan Determination to collect the data as close in time as possible to when USGS collects data at its gaged sites, the data were collected when flows were conducive to this activity. No attempt was made to coordinate with USGS. Data were collected at the ungaged sites for the following months:

- Site 3, Upstream of the Tailrace Return – May, August, and September 2010
- Site 4, Downstream of the Tailrace Return – June and September 2010
- Site 5, Near North Bend – July and September 2010

During the field surveys, photographs were taken to document the survey effort. The cross-section locations and photographs are provided in Attachment A. The dates when data collection occurred at each cross section are provided in Table 4-2. The times when data collection occurred are not included; multiple 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.

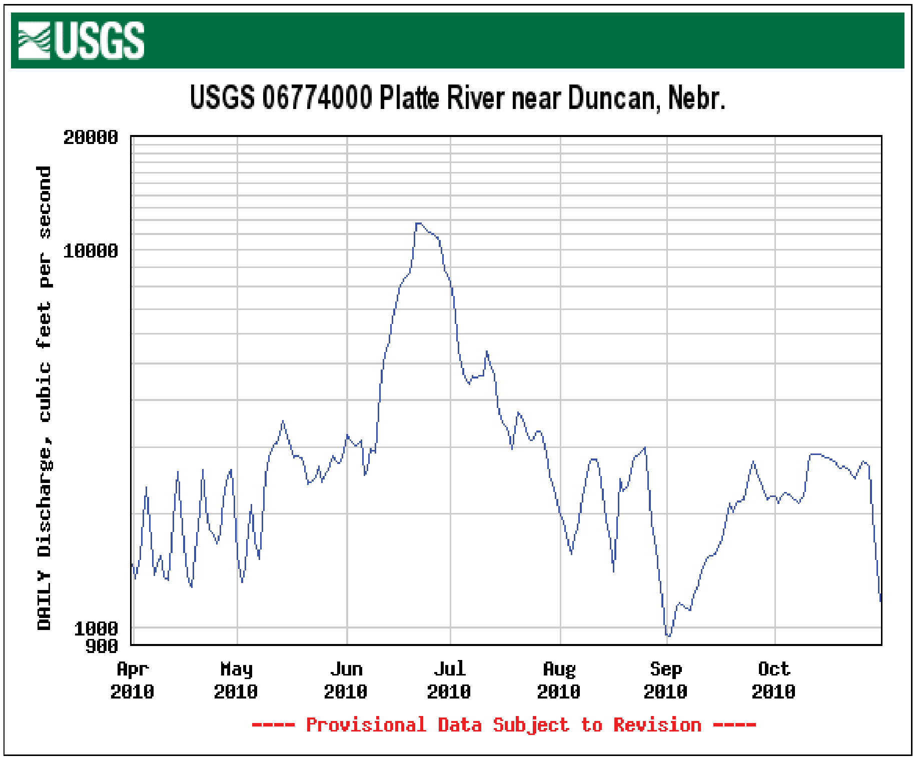


Figure 4-1. Flow on the Platte River near Duncan, Spring, Summer, and Fall 2010

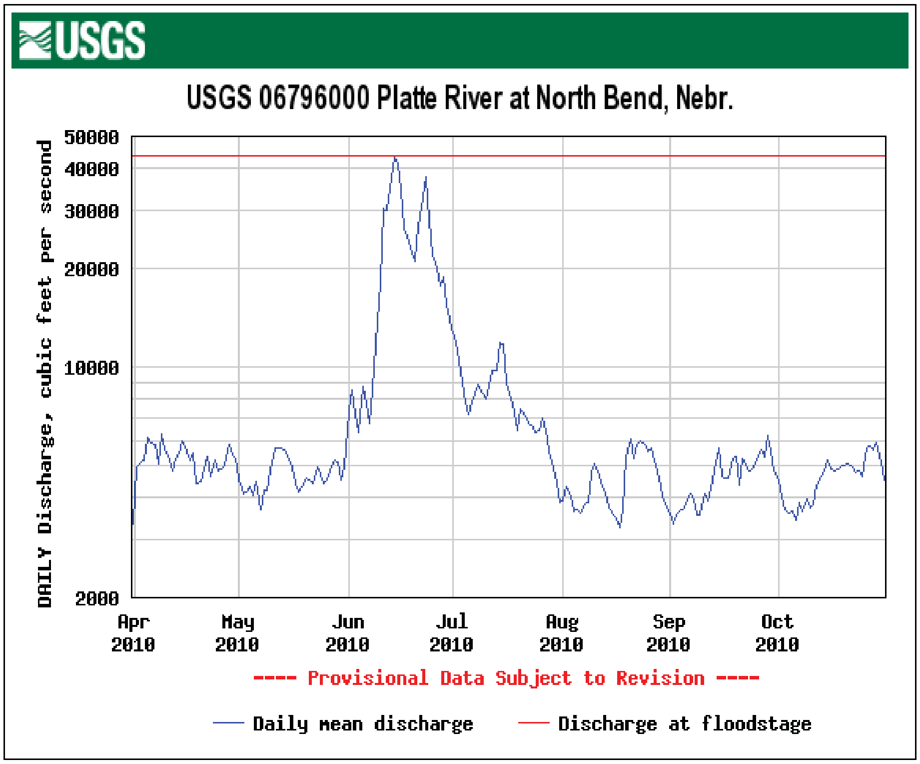


Figure 4-2. Flow on the Platte River at North Bend, Spring, Summer, and Fall 2010

Table 4-2. 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 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	

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).

Objective 1: To compare the sub-daily Project hydrocycling operation values (maximum and minimum flow and stage) to daily values (mean flow and stage). In addition to same-day comparisons, periods of weeks, months, and specific seasons of interest to protected species will be evaluated to characterize the relative degrees of variance between hydrocycling (current operations) and run-of-river operations in the study area.

4.2 Task 2: Gage Analysis

A gage analysis was performed using USGS and NDNR flow and stage data listed in Table 4-1. The following were developed:

- Synthetic hydrographs for current operations at the ungaged sites
- Synthetic hydrographs for run-of-river operations at the gaged and ungaged sites
- Classification of flow records as wet, dry, and normal years
- Flow duration, volume duration, and flood flow frequency relationships

4.2.1 Synthetic Hydrographs for Current Operations at the Ungaged Sites

Synthetic hydrographs for the ungaged sites were developed and plotted for current operations from 2003 to 2009. The period from 2003 to 2009 was selected based on the period during which the Tailrace Canal at Columbus gage (8th Street bridge) has been in operation. This gage measures Loup Power Canal return flows. Reach gain/loss (RGL) between all gaged sites was estimated for current operations based on existing gage data. RGL was calculated on a daily basis using historic mean daily flows at the gaged sites. Average daily RGL was developed for each month during the 7 years and then partitioned into a per-mile RGL. The daily per-mile value was then applied to develop the intermediate gains and losses from the gaged sites to the ungaged sites. This allowed development of synthetic hydrographs at the ungaged sites by interpolation between gaged sites, taking into account RGL and the travel times between gaged sites.

The daily per-mile values of RGL were also sub-divided into 15-minute increment values for use in the development of the sub-daily synthetic hydrographs for current operations at the ungaged sites. Travel time between the gaged and ungaged sites was estimated based on comparisons of the historic daily flow hydrographs between the gaged sites.

RGL for the ungaged site in the Loup River bypass reach (Site 2) was calculated for use in developing the synthetic hydrograph upstream of the Tailrace Canal using daily flow data from the following gaged sites:

- Loup River near Genoa
- Loup Power Canal near Genoa

- Loup River at Columbus
- Beaver Creek at Genoa

The period of record used to develop the RGL for the Loup River bypass reach was based on the available data for the Loup River at Columbus gage, which lapsed on September 30, 1978. The gage was re-established on September 23, 2008. In order to incorporate a consistent period of record for the gages listed above, the RGL data from October 1, 1943, through September 30, 1978, were used. Travel time in the Loup River bypass reach between the Loup River gages near Genoa and at Columbus was estimated based on a comparison of coincident sub-daily data for water year 2009. Travel time varied between 5 and 18 hours; therefore, for daily synthetic hydrographs, travel time was estimated as 1 day.

RGL for the ungaged sites in the Platte River were calculated for each reach on a per-mile basis between Grand Island and North Bend. Daily flow data from the following gages were used to calculate the RGL:

- Grand Island to Duncan
    - USGS Gage 06770500, Platte River near Grand Island, NE
    - NDNR Gage 6772000, Wood River near Alda, NE
    - Platte River near Duncan
- Duncan to North Bend
    - Platte River near Duncan
    - Loup River at Columbus (synthetic from September 30, 1978, to October 1, 2008)
    - Tailrace Canal at Columbus (8th Street bridge)
    - Platte River at North Bend

The period of record used to develop the RGL for all reaches of the Platte River except Grand Island to Duncan was October 1, 1949, through September 30, 2008. Based on the available data for the Wood River near Alda gage, the period of record for the Grand Island to Duncan RGL was October 1, 1953, through September 30, 2008. Travel times for each of the Platte River reaches were also estimated as 1 day (commonly cited by NDNR as appropriate).

The Duncan to North Bend RGL is affected by the Loup River bypass reach and Loup Power Canal return flows. Therefore, the Grand Island to Duncan RGL was applied on the upstream portion of the Duncan to North Bend reach, specifically from Duncan to the confluence of the Loup and Platte rivers. The remaining reaches downstream to the ungaged sites were calculated from the Duncan to North Bend RGL.

The methodology used to develop the synthetic hydrographs at the ungaged sites was validated by using the same procedure to develop synthetic hydrographs for current operations at the next downstream gaged site(s) and comparing the resulting synthetic flows and volumes with gaged flows and volumes.

The methodology applied in the Loup River bypass reach was verified for water year 2009 by comparing the calculated daily synthetic hydrograph at Columbus with the NDNR 2009 gage data for the Loup River at Columbus. In addition, the synthetic hydrograph was compared with the values provided by USFWS regression equations. The USFWS equations are linear regression equations (by month) that estimate daily Columbus flows based on measured daily Genoa data.

It was found that the synthetic hydrograph was consistent with both the USFWS regression equations and the NDNR gage at Columbus. Some discrepancies were noted between the synthetic and NDNR gage data during ice-affected flows when the NDNR gage record indicated that the flow was "estimated." Synthesized versus gaged annual (water year) volumes were also used as verification at the various locations on both the Loup River bypass reach and the lower Platte River.

Figure 4-3 illustrates the comparison of the synthetic hydrograph, NDNR gage data, and USFWS regression equations at Columbus for water year 2009. The following were revealed:

- The synthetic hydrograph predicted the annual volume for water year 2009 within 5 percent (±) of the USFWS regression equations.
- The synthetic hydrograph and the USFWS regression equations were 20 and 15 percent higher, respectively, than the annual volumes for the 2009 historic gage data. This is likely attributed to the fact that the Columbus gage record for water year 2009 contains 81 days (approximately 22 percent) of "estimated" flow values.

A root mean square error (RMSE) analysis was performed to compare the daily flows from the synthetic hydrograph using the calculated RGL to the corresponding values using the USFWS regression equations. The RMSE for the RGL analysis compared favorably with the RMSE for the USFWS regression when comparing both methodologies with the 2009 historical NDNR gage data.

A similar verification of the method's ability to predict downstream flows by combining upstream gage data with RGL data was used for the Platte River synthetic hydrographs at North Bend. Figure 4-4 illustrates a comparison of the historic gage and calculated synthetic hydrographs at North Bend for water years 2003 to 2009. The following were noted:

- On average, for water years 2003 to 2009, the RGL analysis was within 2 percent of the historically gaged volumes at North Bend.
- The RGL analysis varied from -5 percent in water year 2008 to +11 percent in water year 2009 when compared to the historical gaged volume at North Bend.

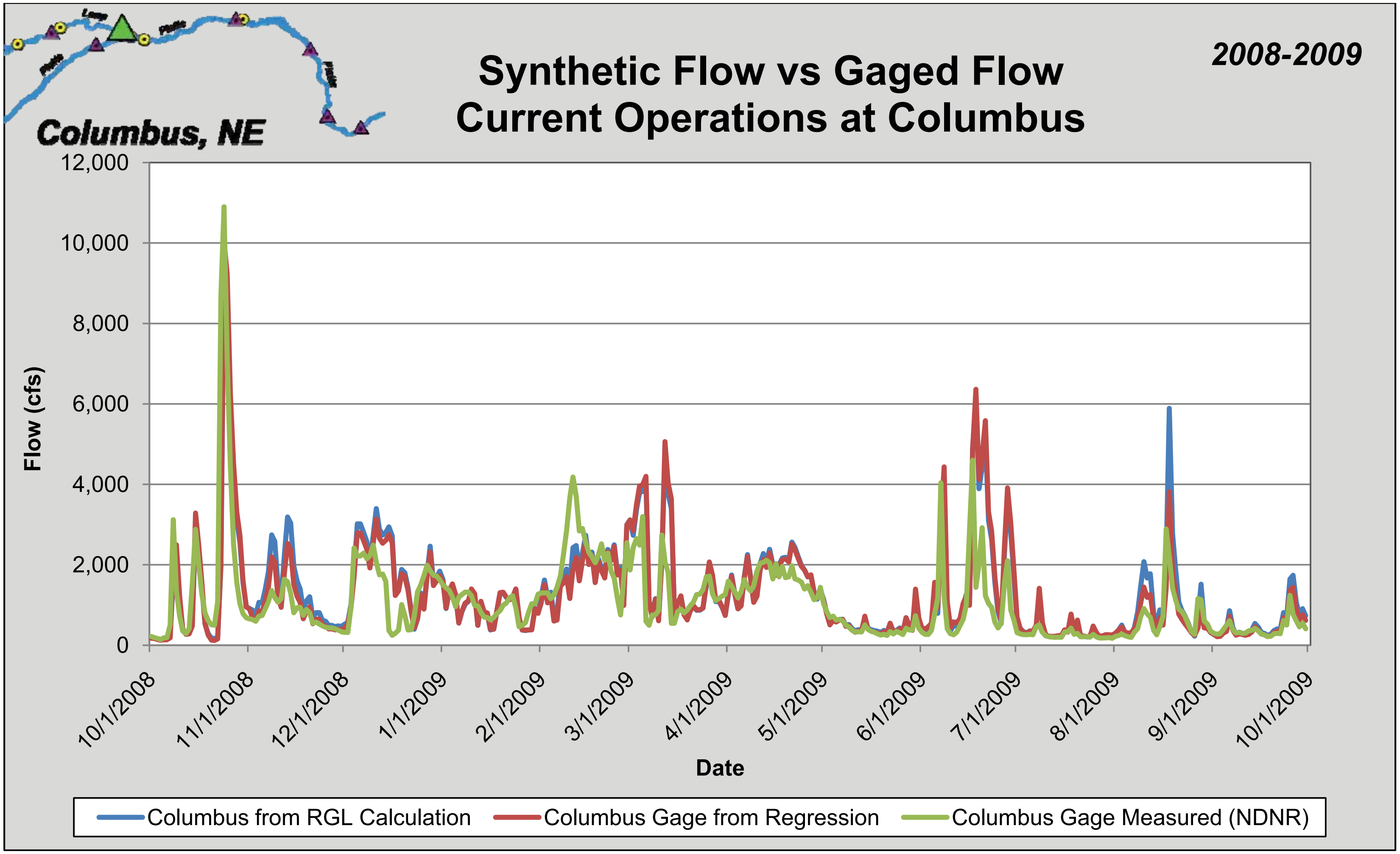


Figure 4-3. Comparison of the Synthetic Hydrograph, NDNR Gage Data, and USFWS Regression Equations at Columbus, Water Year 2009

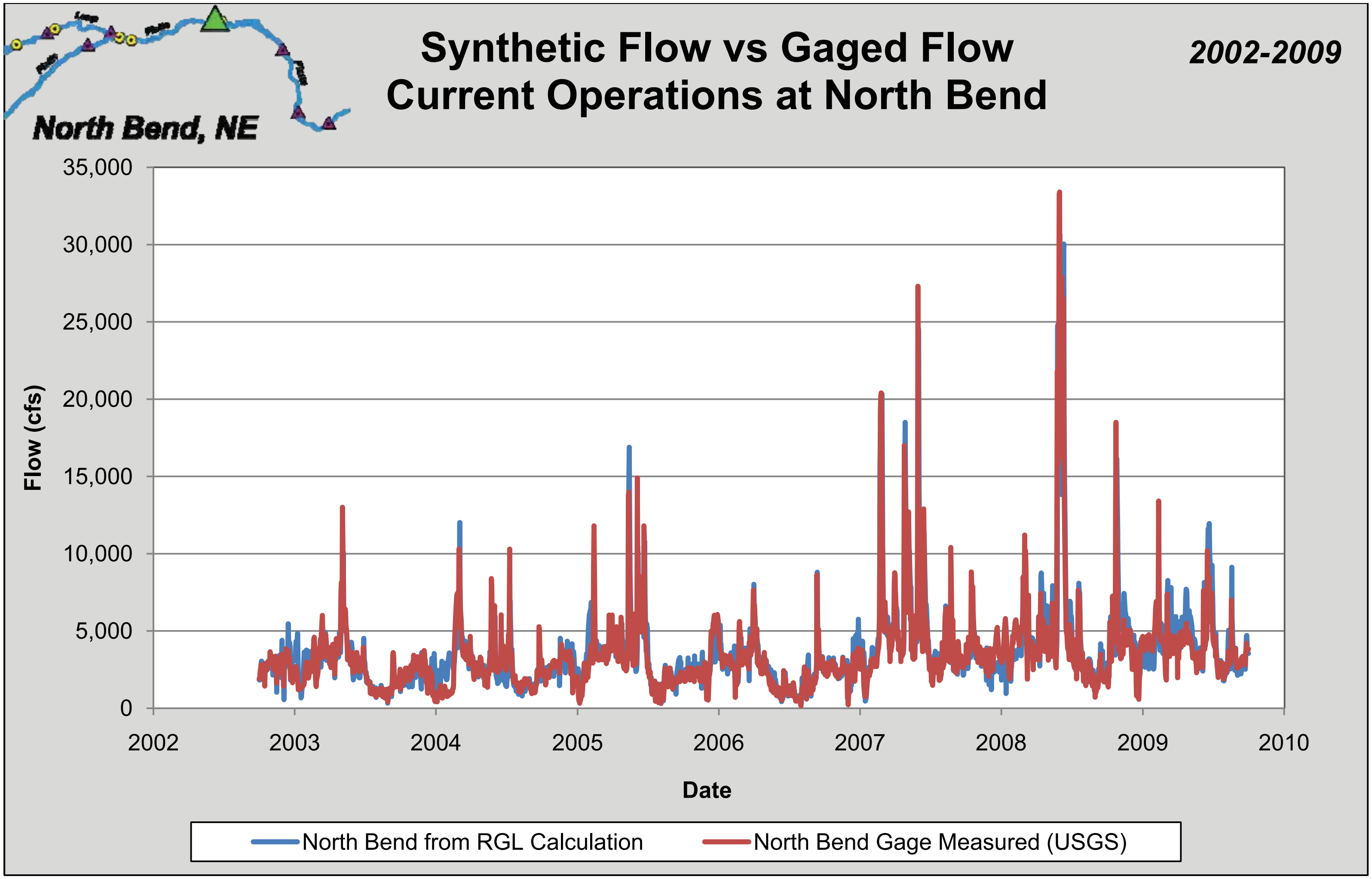


Figure 4-4. Comparison of the Historic Gage and Calculated Synthetic Hydrograph at North Bend, Water Years 2003 to 2009

The verification process incorporated for this hydrocycling study revealed very good agreement between synthetic and measured hydrographs. Therefore, the synthetic hydrographs at the ungaged sites for current operations were adopted for this study. The synthetic hydrographs for the gaged and ungaged sites are shown in Attachment B.

4.2.2 Synthetic Hydrographs for Run-of-River Operations at the Gaged and Ungaged Sites

Sub-daily synthetic hydrographs were also developed for run-of-river[2] operations and are provided in Attachment B. Even though daily flows at impacted gaged and ungaged sites downstream of the Tailrace Return would minimally change under run-of-river operations, it was assumed that the RGL determined from current operations could be applied between gaged and ungaged sites to develop the run-of-river synthetic hydrographs. The RGL values are typically governed by groundwater interchanges between surface waters and their adjacent aquifers and would not likely change significantly under run-of-river operations. Hydrographs of the sub-daily flows during hydrocycling (current operations) show that each day has two periods of sustained flow above and below the average for that day, indicating that periods of flows into and out of bank storage would be sufficiently long to result in matching the average gain or loss that would occur under run-of-river operations.

Because RGL values for the Loup Power Canal (from the Headworks to the Tailrace Return) were needed for the run-of-river analysis, they were calculated using historic mean daily discharges for the period of record at the Tailrace Canal at Columbus (8th Street bridge). Available historic monthly flow volumes between the Loup Power Canal near Genoa and the Tailrace Canal at Columbus (8th Street bridge) were used to provide these RGL values. Monthly diversion and return volumes were tabulated for each year and then distributed into an average daily flow for each month of each year for the selected period of record. The monthly average daily flows were then used to account for the Loup Power Canal RGL in development of the run-of-river synthetic hydrographs.

The procedure for developing the synthetic hydrographs for run-of-river operations at ungaged sites was similar to that of the synthetic hydrographs for current operations and then applied at all gaged sites (for validation) and ungaged sites to create synthetic hydrographs for run-of-river operations at each. One exception was at the Tailrace Canal at Columbus (8th Street bridge). The historical flows for the Tailrace Canal at Columbus were replaced with a synthetic hydrograph that was developed using the historical data for the Loup Power Canal near Genoa, accounting for the Loup Power Canal RGL and travel time. A 1-day travel time was used from the

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[2] For purposes of this hydrocycling study, run-of-river operations are defined as simulated conditions that would exist without regulation for hydrocycling.

Diversion Weir to the Tailrace Return for run-of-river operations based on the canal slope and length.

The RGL calculations and the calculated synthetic hydrograph for the Tailrace Canal at Columbus (8th Street bridge) assume that there are no significant changes in the canal characteristics between current operations and run-of-river operations that could affect the RGL. In addition, based on the verification of the synthetic hydrographs at the gaged sites, the synthetic hydrographs for run-of-river conditions at the gaged and ungaged sites were adopted. The synthetic hydrographs for run-of-river operations at the gaged and ungaged sites are shown in Attachment B.

4.2.3 Classification of Flow Records as Wet, Dry, and Normal Years

Each year from 2003 to 2009 (the study period) was classified as wet, dry, or normal for both the gaged and ungaged sites based on an approach developed by Anderson and Rodney (October 2006). The period from 2003 to 2009 was selected based on the period during which the Tailrace Canal at Columbus gage (8th Street bridge) has been in operation. This approach ranks the mean annual discharge in descending order. The highest 33 percent of the mean annual flows recorded during the study period were classified as wet years. The lowest 25 percent of the mean annual flows recorded during the study period were classified as dry years. The remaining flows were classified as normal years.

The mean annual discharge at each gaged site for the gage's period of record was obtained from USGS and NDNR. The mean annual discharge at each ungaged site was calculated by adding the mean annual discharges from the closest upstream contributing gaged sites. For example, the mean annual discharge for Site 3, upstream of the Tailrace Return, was computed by adding the mean annual discharge for the Platte River near Duncan, Beaver Creek at Genoa, and the Loup River near Genoa. Similarly, the mean annual discharge at Site 4, downstream of the Tailrace Return, was computed by adding the mean annual discharge for the Platte River near Duncan, Beaver Creek at Genoa, the Loup River near Genoa, and the Loup Power Canal near Genoa. Because this is a mean annual discharge, no adjustments were made for travel time or RGL. Additionally, the wet, dry, and normal year analysis is the same for current operations and for run-of-river operations. This allowed for relative assessments of hydrocycling (current operations) and run-of-river operations for years representing all three hydrologic classifications.

The results of the wet, dry, and normal year analysis at each gaged site for the period of record are shown in Attachment C. The results of the wet, dry, and normal year analysis at each gaged and ungaged site for the years 2003 to 2009 are shown in Table 4-3. In some instances, a year was very near the threshold between classifications. In order to have each classification represented between 2003 and 2009, that year may have been placed in the next classification, as shown in Table 4-3. For example, year 2009 at Site 4 had a ranking of 29.85, which is three positions from being classified as a normal year. However, years 2006 and 2008 were well-seated in the dry and wet classifications, respectively, with no normal year represented. Additionally, Sites 3 and 5 were well-seated in the normal classification for 2009. Therefore, year 2009 was considered as a normal year at Site 4 for purposes of this analysis.

4.2.4 Flow Duration, Volume Duration, and Flood Flow Frequency Relationships

Flow duration, volume duration, and flood flow frequency analyses for current operations and run-of-river operations were performed for the gaged and ungaged sites using the U.S. Army Corps of Engineers (USACE) HEC-SSP software package. Model inputs, including period of record analyzed, mean skew, station skew, and adopted skew for each gage, are provided in Attachment D. Computed model results are also listed by gage in Attachment D. Flow duration analyses were performed using spreadsheets for the wet, dry, and normal years for the ungaged sites, with results also included in Attachment D.

4.3 Task 3: Hydrographs for the Project versus Run-of-River Operations

Hydrographs of daily discharges for each gaged study site on the Platte River were plotted annually for the selected wet, dry, and normal years and are provided in Attachment E. From these plots, periods of weeks, months, and specific seasons of interest to protected species could be analyzed. Daily maximum, minimum, and mean flows were plotted for each time interval. The annual synthetic hydrographs for current operations at the ungaged sites, as well as the annual synthetic hydrographs for run-of-river operations for the gaged and ungaged sites, were plotted in the same manner. The HEC-RAS models developed and calibrated for this hydrocycling study were used to approximate the stage hydrographs at the ungaged sites, as discussed in Section 4.6.5, and the most current rating curves were used to develop the stage hydrographs at the gaged locations.

Table 4-3. Calendar Year Classification and Ranking at Each Gaged and Ungaged Site, 2003 through 2009

Calendar Year	Platte River near Duncan		Loup River near Genoa		Loup Power Canal near Genoa		Loup River near Genoa + Loup Power Canal near Genoa		Site 3 – Platte River Upstream of Tailrace Return		Site 4 – Platte River Downstream of Tailrace Return		Platte River at North Bend	
	Flow Classification	Ranking	Flow Classification	Ranking	Flow Classification	Ranking	Flow Classification	Ranking	Flow Classification	Ranking	Flow Classification	Ranking	Flow Classification	Ranking
2003	Dry	94.20	Normal	73.13	Dry	78.08	Dry	82.09	Dry	94.03	Dry	94.03	Dry	91.80
2004	Dry	98.55	Normal	41.79	Dry	91.78	Dry	74.63	Dry	91.04	Dry	92.54	Dry	90.16
2005	Dry	89.86	Wet	32.84	Normal	68.49	Normal	50.75	Dry	76.12	Dry	80.60	Dry	83.61
2006	Dry	97.10	Normal	71.64	Dry	84.93	Dry	83.58	Dry	95.52	Dry	95.52	Dry	95.08
2007	Normal	49.28	Wet	16.42	Wet	27.40	Wet	14.93	Normal	34.33	Wet	28.36	Wet	31.15
2008	Normal	37.68	Wet	5.97	Wet	28.77	Wet	8.96	Wet	22.39	Wet	22.39	Wet	29.51
2009	Normal	50.72	Wet	28.36	Wet	1.37	Wet	11.94	Normal	44.78	Wet[1]	29.85	Normal	49.18

Note:

[1] Site 4, on the Platte River downstream of the Tailrace Return, is ranked statistically as a wet year in 2009. However, the ranking was close to 33 percent, which would be considered a normal year. In addition, the locations upstream and downstream of Site 4 were well-seated as normal years in 2009. Therefore, for the analyses described in this Hydrocycling Study Report, Site 4 was treated as a normal year.

Objective 2: To determine the potential for nest inundation due to both hydrocycling (current operations) and run-of-river operations.

4.4 Task 4: Nesting Season Sandbar Inundation Heights

Synthetic hydrographs developed under Objective 1, Task 2 for the years 2003 to 2009, which is the period during which the Tailrace Canal at Columbus gage (8th Street bridge) has been in operation, were examined. Only Site 4, downstream of the Tailrace Return, was evaluated because the flows at this location and Site 5, near North Bend, are similar in hydrograph shape and magnitude for both current operations and run-of-river operations. Flows were examined for a benchmark flow by species nesting seasons. Although interior least terns and piping plovers are often nesting associates, the two species have slightly different nesting periods in Nebraska. Because of these differences, the potential for exceedance of a benchmark flow and associated stage were evaluated separately for each species.

The highest synthetic sub-daily flow was identified between February 1 and prior to April 25 (the onset of the initial breeding and nesting season for piping plovers). February 1 was chosen as the beginning of the period to capture all potential late winter/early spring flows that occurred close enough to the nesting season to reasonably serve as the surrogate for highest potential nesting elevation each year. A theoretical sub-daily high flow was also identified between February 1 and prior to May 15 (the onset of the initial breeding and nesting season for interior least terns). These sub-daily peak flows prior to the onset of the accepted nesting seasons were set as the benchmark flow for each species.

The benchmark flows were then compared to subsequent synthetic sub-daily flows at the ungaged sites for 2003 to 2009 from April 25 to July 31 (the nesting season for piping plovers) and from May 15 to August 15 (the nesting season for interior least terns) to determine the number of times the benchmark flow was exceeded. If current operations exhibit a higher number of exceedances of the benchmark flow than the run-of-river operations, thereby increasing the potential likelihood of nest inundation, then alternative conditions (run-of-river operations) will be reviewed to determine if a change of operations could reduce this potential. Task 2 flows were reviewed, and flow events equal to or greater than the benchmark flow (determined between February 1 and April 25/May 15) were identified. The first flow higher than the benchmark became the first exceedance, and the number of exceedances following the first exceedance was also determined.

The number of times that theoretical inundation (exceedance of the benchmark flow) occurred under both current operations and run-of-river operations was compared to determine if Project hydrocycling operations increase or decrease the likelihood of potential nest inundation. The number and nature of exceedances of the benchmark flow under current operations were evaluated and compared to the number and nature of exceedances of the benchmark flow under run-of-river operations. Each exceedance was further classified as being part of an event. Events were identified as a date or cluster of dates when the benchmark flow was exceeded that would likely correlate with the rise and fall of the river (hydrograph) as a result of the duration and intensity of run-off flows. For example, in 2003, under current operations, flows exceeded the piping plover benchmark flow on May 1 and 2. On May 5 and 6, flows again exceeded the piping plover benchmark flow. These four exceedances were identified as two separate events.

The following assumptions were made regarding this analysis:

- This study does not evaluate actual sandbars or habitat, but it uses peak sub-daily discharges as a surrogate for potential for sandbar inundation. It is understood that sandbars do not form at the elevation of a single peak sub-daily event, nor does a single peak flow necessarily form the river morphology and subsequent sandbars. It is assumed that the peak daily flow during the pre-nesting season is the highest point of inundation of sandbars prior to nesting. It is also assumed that nesting can occur above the highest pre-season flow due to pre-existing, higher sandbars. If habitat is available, nesting may also occur below this benchmark. This is similar to the approach employed in the past in an agreement between the Central Nebraska Public Power and Irrigation District and USFWS on the central Platte River (Central Nebraska Public Power and Irrigation District, October 15, 2007).
- It is implied that any subsequent flow events that exceed the initial benchmark flow have the potential to inundate sandbars and any nests that could be initiated below the initial benchmark flow after a first nesting attempt, with the understanding that pre-existing habitat may be available above the elevation of an exceedance event.
- Each flow event that exceeds the initial benchmark may affect subsequent nesting attempts.
- It is assumed that birds could and would re-nest if conditions were appropriate after a benchmark exceeding flow. The likelihood of re-nesting decreases with the progression of the breeding season, as it takes a large amount of energy for a bird to develop eggs (Rowe et al., April 1994). A 60-day period for successful nesting was assumed (from egg to fledge) for review of potential for re-nesting.

Objective 3: To assess effects, if any, of hydrocycling (current operations) and run-of-river operations on sediment transport parameters and channel morphology.

4.5 Task 5: Effects of Hydrocycling on Sediment Transport Parameters

Effects of hydrocycling on sediment transport parameters, which are direct indicators of the river morphology and habitat, were evaluated using the same methodologies, where applicable, outlined in the Initial Study Report, Appendix A, Sedimentation Study Report. The District determined effective and dominant discharges and total sediment transported, assuming transport at capacity for current operations and run-of-river operations, using sub-daily hydrographs to allow evaluation of the daily fluctuations under current operations and under run-of-river operations. The time period evaluated was 2003 to 2009, which is the period during which the Tailrace Canal at Columbus gage (8th Street bridge) has been in operation.

The three locations considered relevant to potential hydrocycling impacts on bird species included Site 4, downstream of the Tailrace Return; Site 5, near North Bend; and the USGS gage on the Platte River at North Bend. Site 3, upstream of the Tailrace Return, was used for comparison because it is unaffected by hydrocycling. This effort required the following activities:

- Synthesize current operation and run-of-river operation sub-daily discharges for 2003 to 2009 at Site 3, upstream of the Tailrace Return, and Site 4, downstream of the Tailrace Return (see the methodology discussed in Section 4.2).
- Generate hydraulic geometry relationships using HEC-RAS model results as described in the Second Initial Study Report, Appendix A, Section 4.1.2, at Sites 3, 4, and 5.
- Generate sediment discharge rating curves applicable to the study period (2003 to 2009) at Sites 3, 4, and 5.
- Generate annual flow frequency curves (2003 to 2009) using the approach detailed in the Initial Study Report, Appendix A, Sedimentation Study Report.
- Generate collective sediment discharge plots (histograms of total sediment transported by equal-interval bins of discharge).
- Determine total sediment transported each year and during the entire study period by summing sub-daily (15-minute) estimates of transport from the sediment discharge rating curves for both current operations and run-of-river operations. As shown below, these were compared with results using average daily discharge rates.

- Determine effective and dominant discharges[3] for the annual hydrographs, and determine dominant discharge for the seasonal hydrographs, using the methodology outlined in the Initial Study Report, Appendix A, Sedimentation Study Report.
- Using the hydraulic geometry relationships, determine the average channel characteristics (width and depth) based on dominant discharge.
- Conduct a spatial analysis of the sedimentation results at Sites 3, 4, and 5 as well as at the USGS gage at North Bend.
- For both current operations and run-of-river operations, assess the expected channel morphology using regime relationships developed by Leopold and Maddock (1953) and Karlinger et al. (1983), based on dominant discharge.
- Compare morphologic implications of current operations and run-of-river operations for all of the above.

4.5.1 Hydraulic Geometry Relationships

In addition to synthesizing sub-daily discharges for current operations at Site 4, downstream of the Tailrace Return, relationships among discharge and width, depth, and velocity were needed in order to apply Yang's equation for sediment transport capacity for each sub-daily flow in each scenario. As described in Section 4.6.5, a HEC-RAS model of the 10-cross-section reach downstream of the Tailrace Return was developed and calibrated. These models, assuming fixed-bed geometry, were then applied to a range of low and high flows, allowing the development of hydraulic geometry relationships at the ungaged sites. The curves are included in Attachment F.

Hydraulic geometry relationships at the North Bend gage used for this analysis were those developed and presented in the Initial Study Report, Appendix A, Sedimentation Study Report. The width, depth, and velocity relationships originating from the USGS measurements look different than the width, depth, and velocity relationships created from the HEC-RAS model because the flows used in the USGS-originated relationships are random while the flows in the HEC-RAS-originated relationships are evenly spaced approximately 500 cfs apart, as shown in Attachment F. However, the scatter about the trendlines and the coefficient of determination (R^2) values are similar between the USGS-originated relationships and the HEC-RAS-originated relationships.

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[3] Effective discharge calculations were not developed for any period less than 1 year. The reasons for this are detailed in the Initial Study Report, Appendix A, Sedimentation Study Report.

4.5.2 Sediment Discharge Rating Curves

Sediment discharge rating curves were needed at Sites 3 and 4. The Second Initial Study Report, Appendix A, Sedimentation Addendum describes the development of these curves at all of the ungaged sites.

The sediment discharge relationship at the North Bend gage, developed and presented in the Initial Study Report, Appendix A, Sedimentation Study Report, was used for the hydrocycling analysis.

The sediment discharge rating curves are provided in Attachment G.

4.5.3 Sediment Transport Indicators

Values of effective and dominant discharges and total sediment transport during 2009 for daily discharges for the ungaged sites were described and compared regionally with gaged values in the Second Initial Study Report, Appendix A, Sedimentation Addendum. The same methodology was applied in this hydrocycling study for 2003 to 2009 to develop 7-year average seasonal, annual, and average annual values of the parameters for both current and run-of-river operations using sub-daily discharges.

If the effective discharge, dominant discharge, and total sediment transport values do not materially differ between current and run-of-river operations, then it will be concluded that hydrocycling does not impact sediment transport and thereby does not impact morphology. If the effective discharge, dominant discharge, and total sediment transport values do materially differ between current and run-of-river operations, then an assessment of the potential impact on the braided river morphology will be conducted, possibly followed by development of potential mitigation measures in coordination with the agencies.

4.5.4 Regime Analysis

Another way to analyze the effect of current operations versus run-of-river operations was to evaluate the difference, if any, on the regime classifications. In order to evaluate this effect, the dominant discharges were plotted on Chang and Lane’s regime morphology graphs in similar fashion to the procedure described in the Initial Study Report, Appendix A, Sedimentation Study Report, and in the Second Initial Study Report, Appendix A, Sedimentation Addendum.

4.5.5 Spatial Analysis

A spatial analysis that included all the ungaged sites, including Sites 3 and 4, was conducted as another way to evaluate Project effects on sediment transport. The methodology is described in the Second Initial Study Report, Appendix A, Sedimentation Addendum.

Objective 4: To identify material differences between hydrocycling (current operations) and run-of-river operations in potential effects on habitat of the interior least tern, piping plover, and pallid sturgeon.

4.6 Task 6: Effects of Hydrocycling on Interior Least Tern, Piping Plover, Pallid Sturgeon, and Isolation of Backwaters and Side Channels

4.6.1 Literature Review and Comparison of Other Rivers

Hydrocycling alters the natural flow rate of water and can affect various ecological aspects of a river system. The effects of an altered flow regime on interior least tern, piping plover, and pallid sturgeon have not been extensively studied or well documented; however, these species continue to use habitat in rivers that are subject to regulated fluctuations. Some documentation exists on effects of altered flow regime on other fish species[4] and fish habitat (Cocherell et al., 2010; McKinney et al., 2001; Marchetti and Moyle, 2001; Weyers et al., 2003; Torralva et al., 1997; Hunter, 1992), but little research has been conducted regarding bird species. The effects of manipulated flow operations on interior least tern and piping plover habitat, such as sandbars, and pallid sturgeon habitat, such as backwaters and side channels, on other rivers outside of the Project Boundary were examined and compared to current conditions on the lower Platte River resulting from Project operations.

Available literature was collected and reviewed regarding interior least tern and piping plover habitat conditions on rivers with known nesting populations of these species. In 2005, a range-wide survey of the interior least tern[5] was conducted by several Federal and state agencies and public participants and was compiled by the USACE Engineer Research and Development Center to enhance ongoing efforts to monitor interior least tern populations (Lott, November 2006). In 1991, 1996, 2001, and 2006, an International Piping Plover Census was conducted throughout the range of piping plovers[6] by several Federal and state agencies and public participants and was compiled by USGS in an effort to monitor piping plover population statistics (Elliott-Smith et al., 2009). The population counts from these surveys were used to identify other riverine areas downstream of reservoirs that have interior least tern and/or piping plover populations in order to make a comparison to the lower Platte River downstream of the Tailrace Return (with the understanding that the Loup system is not a reservoir, but does operate with hydrocycling).

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[4] Other fish species that have been studied include rainbow trout (*Oncorhynchus mykiss*), robust redhorse (*Moxostoma robustum*), and salmonids.

[5] The identified breeding range of the interior least tern reaches from Montana in the north to Texas in the south and from southern Indiana in the east to New Mexico in the west. This species winters in South America, although data has not been collected on its wintering range.

[6] The range of the piping plover, both breeding and wintering, stretches from the prairie potholes region in Canada south to Mexico and the Bahamas, and from the east coast west to Texas.

The river segments with frequently nesting populations of interior least terns chosen for analysis include the Red River, the Arkansas River, and the Missouri River. These rivers are frequently monitored and include either hydrocycling operations or the manipulation of flows in a way that mimics hydrocycling. Because piping plovers often use non-riverine nesting sites, the amount of riverine nesting data is limited for this species; however, the Missouri River continues to have a fairly stable population of nesting birds. Through coordination with federal agencies managing and studying these river systems, additional information was obtained on the population statistics of these species and hydrocycling operations on the selected river reaches. After information was collected and reviewed, a comparison table was developed to directly compare river conditions and species population counts among the selected rivers. Manipulated flow operations during bird nesting season (April through September) were also compared.

Literature was collected and reviewed regarding rivers with known populations of pallid sturgeon that also have a regulated flow regime. These rivers are the Missouri River and the Yellowstone River. Little information exists on hydrocycling effects on the pallid sturgeon. As part of the Missouri River Recovery Program (MRRP), a population assessment of the pallid sturgeon on the Missouri River reaches has been conducted annually since 2003 (at Fort Randall Dam) and 2005 (at Gavins Point Dam) and has also been completed for the reaches around the Platte River confluence in Nebraska and the Yellowstone River confluence in North Dakota. Some pallid sturgeon surveys have been completed on the Middle Mississippi and Lower Mississippi river reaches, but none are related to or occur near control structures with hydrocycling. Sampling efforts in the Yellowstone River, downstream of Intake, Montana, to the confluence with the Missouri River, have not been conducted as methodically as the efforts by MRRP. However, research has been conducted within this stretch relative to pallid sturgeon.

In summary, river reaches used for comparison in this hydrocycling study, along with the species that use each reach, are as follows:

- Red River below Denison Dam – interior least tern
- Arkansas River below Keystone Dam – interior least tern
- Missouri River reach below Fort Randall Dam – interior least tern, piping plover, and pallid sturgeon
- Missouri River reach below Gavins Point Dam – interior least tern, piping plover, and pallid sturgeon
- Yellowstone River below Intake, Montana – pallid sturgeon

These river reaches were chosen, as discussed above, based on the population census numbers and frequency of occurrence for the interior least tern, piping plover, and pallid sturgeon. The regulating structures on each of the above-listed river reaches differ in size, operation, and magnitude from the Project's Diversion Weir; however, almost all use a form of hydrocycling or manipulated flows in their operations. Denison, Keystone, Fort Randall, and Gavins Point dams are all dam structures that span the full river and include storage reservoirs. The Yellowstone River site is a diversion weir, similar to the Project's Diversion Weir, built for diverting irrigation flows. This structure does not divert flows for power generation and therefore does not have hydrocycling operations; however, this site has a consistent population of pallid sturgeon and was included in this review due to the similarities and size of its weir relative to the Project's Diversion Weir.

Habitat characteristics of the interior least tern, piping plover, and pallid sturgeon associated with operations on these other rivers were identified for comparative analysis. This comparative analysis identified similarities or differences between Project operations and manipulated flow operations on the other rivers to assess the influence that the respective operations may have on habitat characteristics or species use. If differences are noted that could be acting to reduce interior least tern and piping plover habitat on the lower Platte River below the Tailrace Canal confluence and/or pallid sturgeon habitat on the lower Platte River, then these differences will be evaluated to assess whether these factors are the result of Project operations or are the result of other conditions outside the scope of Project control.

4.6.2 Peters and Parham's Discharge versus Habitat Relationship

In accordance with FERC's Study Plan Determination, the District analyzed the daily percentage of suitable habitat for pallid sturgeon based on the discharge versus habitat relationship presented in Peters and Parham (2008), Chapter 10. The analysis included an evaluation of discharge for both current operations and run-of-river operations using the synthetic hydrographs developed for Objective 1. Discharges were evaluated for minimum, average, and maximum daily flows in a wet year (2008), a dry year (2006), and a normal year (2009), as discussed in Section 4.2.3. All three discharges for both current operations and run-of-river operations were evaluated because of the natural variability of flows throughout the day that would occur under run-of-river operations. This allowed the District to evaluate the difference in available pallid sturgeon habitat under current operations and run-of-river operations.

Peters and Parham (2008) state that "discharge is one of the primary factors which influence habitat quality and habitat connectivity in the Platte River." Because of their theory regarding the importance of discharge on habitat, Peters and Parham developed a model to determine relationships between the observed quantities of instream habitat types for pallid and shovelnose sturgeon and river discharge. This model provided an estimate of suitable pallid sturgeon habitat by combining the depth and velocity criteria with the proportions of depths and velocities in the habitat types. Based on their model, Peters and Parham found that little to no suitable habitat was present in the lower Platte River at low discharge rates up to 2,000 cfs, though percentage of suitable habitat rapidly increased through 6,000 cfs. They also noted that the percentage of suitable habitat for the pallid sturgeon was always lower than that of the shovelnose sturgeon because pallid sturgeon select deeper and swifter waters.

As an initial quality review of the calculations presented in Peters and Parham (2008), the District calculated the percentage of suitable pallid sturgeon and shovelnose sturgeon habitat using the relationships in the Peters and Parham report and compared the results to tabulated results presented in the report. The District was unable to replicate the tabulated results and contacted one of the authors, Dr. James Parham, regarding this issue. Dr. Parham reviewed the report equations and results and informed the District that the equations were incorrectly reported in the Peters and Parham report. Although the equation for percentage of suitable pallid sturgeon habitat was correct, the reported coefficients were incorrect. Dr. Parham provided updated coefficients for the percentage of suitable pallid sturgeon habitat. The correct coefficients for the lower Platte River for this equation are a = 39.275, b = 115.637, c = 55.158, and d = -6.455. In this equation, x = discharge and y = pallid sturgeon habitat suitability.

$$y = \frac{a}{\pi}\left[\arctan\left(\frac{x-b}{c}\right) + \frac{\pi}{2}\right]$$

The District rechecked the updated equation against the tabulated values and was able to replicate the values presented in the Peters and Parham report.

Dr. Parham also provided an updated equation for percentage of shovelnose sturgeon habitat. The coefficients used are those presented in the Peters and Parham report (a = 65.252, b = 11.030, and c = 63.300). In this equation, x = discharge, and y = shovelnose sturgeon habitat suitability.

$$y = a\,\exp\left[-\exp\left(-\frac{x - c\,(\ln(\ln 2)) - b}{c}\right)\right]$$

The adjustment to the equation is the multiplication of (ln(ln2)) by the coefficient c. The District rechecked the updated equation against the tabulated values but was still unable to exactly replicate the values presented in the Peters and Parham report. The results differed between 0 and 2 percent. For purposes of this hydrocycling study, and because FERC's Study Plan Determination required analysis for only pallid sturgeon, analysis related to shovelnose sturgeon is not presented.

4.6.3 Lower Platte River Stage Change Study

The Platte River Recovery Implemenation Program (PRRIP) completed a study of the lower Platte River between the Elkhorn River confluence and the Missouri River confluence, referred to as the Lower Platte River Stage Change Study (HDR et al., December 2009). The purpose of the study was to evaluate the potential effects of PRRIP water management activities on water stage and the effect of those stage changes on physical characteristics of the lower Platte River, including parameters thought to be important to the pallid sturgeon (depth, velocity, temperature, turbidity, and bedforms). The results of the PRRIP study were used to the extent possible to evaluate the effects, if any, of hydrocycling downstream of the Elkhorn River confluence.

4.6.4 Cross-Section Comparison

The District's cross sections, taken during the pre-nesting and post-nesting time frame and provided in Attachment A, were reviewed to identify changes in the cross sections, or river morphology. This included an evaluation of potential interior least tern and piping plover habitat as well as the change in flow area based on the data collection effort described in Section 4.2. The channel cross sections were evaluated based on how the cross section changed relative to when the cross section was initially surveyed. The in-channel cross-sectional area was calculated at each location for each survey. The change in in-channel cross-sectional area between surveys was then compared. Because cross sections were obtained at locations both upstream and downstream of the Tailrace Return, this analysis will provide an assessment of cross-section changes between locations unaffected and affected by hydrocycling that occurred in the 4 months between the two or three sets of measurements.

4.6.5 HEC-RAS Model Development

In addition to the literature review and other river comparison, a steady-state one-dimensional (1-D) HEC-RAS model was developed for Sites 3, 4, and 5, as directed by FERC in its Study Plan Determination. Topographic and water surface elevation data collected in Task 1 were used to develop and calibrate the hydraulic models. The cross-section locations for each of the modeled sites are shown in Attachment A. Water surface elevations were obtained at the left and right banks as well as at any mid-channel island or sandbar. Hydraulic models were developed for each site for each survey period; for example, two models were developed for Site 4: one based on data obtained in June and one based on data obtained in September.

To evaluate tailwater effects from the increase in flows downstream of the Tailrace Return, Sites 3 and 4, upstream and downstream of the Tailrace Return, were combined into one model, with a flow change occurring at the Tailrace Return. Once developed, the models were executed using the location-specific synthetic flow rates for the day or days on which the survey occurred. Table 4-4 lists the discharges for the survey dates at each modeled location. For example, the Site 4 cross sections were surveyed between June 29 and July 1, 2010, when minimum flows ranged from 10,576 to 12,865 cfs. A synthetic hydrograph was developed for the same three days based on sub-daily gage data at the gaged sites. The water surface profiles for the synthetic minimum, mean, and maximum discharge computed results were compared to the measured profiles for those days. The Manning's "n" value was adjusted until a "best fit" was obtained. An exact fit to the observed data using a 1-D model for a braided system using a synthetic hydrograph is unlikely. However, a reasonable fit was obtained for each modeled location using a Manning's "n" value of 0.027. This value is consistent with other studies on lower Platte River, including the Lower Platte River Stage Change Study (HDR et al., December 2009). The water surface profiles at each location detailing these results are shown in Attachment H.

Table 4-4. Discharges at the Ungaged Sites on the Platte River

Site	Survey Date	Flow		
		Minimum	Mean	Maximum
Site 3	5/2/2010	1,641	1,742	1,793
Site 3	5/3/2010	1,594	1,667	1,784
Site 3	9/29/2010	2,494	2,637	2,889
Site 4	6/29/2010	12,865	14,499	17,364
Site 4	6/30/2010	10,811	12,718	14,802
Site 4	7/1/2010	10,576	12,273	13,629
Site 4	9/29/2010	5,854	5,662	3,106
Site 5	7/8/2010	5,090	8,907	11,800
Site 5	7/9/2010	4,870	8,458	10,900
Site 5	9/21/2010	2,320	4,836	7,830
Site 5	9/22/2010	2,050	5,127	7,530

The model results were used to study the effects of hydrocycling on potential interior least tern and piping plover nesting habitat. A meeting was held with USFWS and NGPC on January 5, 2010, to consult with these agencies on what model parameters may be considered important for determining effects on interior least tern and piping plover nesting habitat. USFWS further consulted with NGPC and responded that "understanding the relationship among various discharge alternatives and the number, size, bar height, bar position (mid-channel or point), and channel depths which isolate these bars" would be important information for the model to produce (USFWS, January 22, 2010). Because the model is a steady-state 1-D model with a rigid bed and is limited in the amount of information that could be obtained regarding the above parameters, only the percentage of channel width exposed (above the water surface between high banks) as it relates to interior least tern and piping plover nesting habitat (exposed sandbars within the channel) could be identified through the use of the model.

The percentage of channel width exposed was evaluated at 25 (high-flow), 50 (medium-flow), and 75 (low-flow) percent exceedance daily discharges to determine the effects based on a variety of flow levels. Additionally, representative wet, dry, and normal years, as described in Section 4.2.3, and maximum daily flows were evaluated against the percentage of channel width exposed. Cross sections were taken in early summer and either late summer or early fall. These dates were also compared against the percentage of channel width exposed to evaluate how changes in the cross sections (morphology) throughout the nesting season affect the channel capacity and resultant effect on the percentage of channel width exposed associated with interior least tern and piping plover nesting habitat.

Once calibrated to match measured water surface profiles using synthesized discharges on the dates of measurements, the model was executed over the wide range of discharges for current operations and run-of-river operations for the 25, 50, and 75 percent exceedance discharges. This provides a typical range of flows experienced annually. For each cross section within a study site, the amount of exposed sand that exists above the water surface between high banks was determined. A percentage of this amount was calculated based on the high-bank to high-bank channel width at that cross section. These percentages were summed, and an average for the study site was determined. This process was conducted for each flow hydrograph for both current operations and run-of-river operations.

5. RESULTS AND DISCUSSION

As stated in Section 2, the goal of this hydrocycling study is to determine if Project hydrocycling operations benefit or adversely affect the habitat used by interior least terns, piping plovers, and pallid sturgeon in the lower Platte River. The results of this study, which quantify the physical effects of hydrocycling and compare these effects to run-of-river operations, 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 K.

5.1 Summary of Results

Objective 1: To compare the sub-daily Project hydrocycling operation values (maximum and minimum flow and stage) to daily values (mean flow and stage). In addition to same-day comparisons, periods of weeks, months, and specific seasons of interest to protected species will be evaluated to characterize the relative degrees of variance between hydrocycling (current operations) and run-of-river operations in the study area.

Hydrographs and water surface elevation graphs were plotted annually and seasonally for the selected wet, dry, and normal years and are included in Attachment E. The effects of hydrocycling on the hydrograph are immediately apparent for the 2006 dry year. The difference between the maximum and minimum daily flows for current operations is larger than the difference between the maximum and minimum daily flows for run-of-river operations. These differences are reduced for the wet and normal years for 2008 and 2009, respectively. The average annual difference in water surface elevation between current operations and run-of-river operations is typically less than 1 foot. The natural seasonal flow variability is equal to or greater than the daily flow variability during operations unaffected by high flows.

Objective 2: To determine the potential for nest inundation due to both hydrocycling (current operations) and run-of-river operations.

The pre-nesting season benchmark flow for piping plovers was exceeded more often under run-of-river operations than under current operations for all years evaluated (2003 to 2009). For interior least terns the benchmark exceedances were equal under both operating scenarios. For all exceedances for both species, there were no instances where current operations exceeded the benchmark flow, while run-of-river operations did not exceed the benchmark flow.

The pre-nesting season benchmark flows for both interior least terns and piping plovers for current operations ranged from 7,860 to 26,500 cfs, with an average benchmark flow of 13,716 cfs. The pre-nesting season benchmark flows for both species for run-of-river operations ranged from 5,910 to 25,900 cfs, with an average of 12,686 cfs. In general, the difference between pre-nesting season benchmark flows for current operations is, on average, 8.1 percent higher than that of run-of-river operations.

The nesting season peak maximum daily flow for both interior least terns and piping plovers for current operations ranged from 4,100 to 39,986 cfs, with an average peak flow of 18,985 cfs. The nesting season peak maximum daily flow for both species for run-of-river operations ranged from 3,213 to 35,533 cfs, with an average of 17,788 cfs. The nesting season peak maximum daily flow rate for current operations is, on average, 6.7 percent higher than that of run-of-river operations.

When evaluating the number of exceedances of the pre-nesting season benchmark (peak) flow, it was found that, for interior least terns, on average, the benchmark flow was exceeded 3.9 times per event under both current operations and run-of-river operations. For piping plovers, on average, the benchmark flow was exceeded 3.0 times per event for current operations and 3.1 times per event for run-of-river operations. Run-of-river operations had more distinct events for piping plovers that exceeded the pre-nesting season benchmark than current operations in 2003.

Objective 3: To assess effects, if any, of hydrocycling (current operations) and run-of-river operations on sediment transport parameters and channel morphology.

Using the methodology described in the Initial Study Report, Appendix A, Sedimentation Study Report, dominant and effective discharges and total sediment transport at capacity were calculated for Sites 3, 4, and 5 as well as the USGS gage at North Bend. These values were calculated for the selected wet, dry, and normal years as well as the entire period from 2003 to 2009 using synthetic current operations and run-of-river operations sub-daily flows, included in Attachment G.

The results show that the run-of-river operations would transport less sediment, assuming all sediment is transported at capacity. The effective discharges for current operations are larger than the effective discharges for run-of-river operations. The dominant discharges are only slightly larger for current operations, by about 100 cfs. These differences in dominant and effective discharges would likely result in the channel area being smaller under run-of-river operations.

Objective 4: To identify material differences between hydrocycling (current operations) and run-of-river operations in potential effects on habitat of the interior least tern, piping plover, and pallid sturgeon.

Comparison to Other Rivers

A review and comparison of habitat parameters, species counts, hydrocycling operations, and potential effects on interior least terns, piping plovers, and pallid sturgeon was conducted. Almost all other river reaches identified as important to interior least terns, piping plovers, and pallid sturgeon, based on population numbers, included large-scale dams and reservoirs with limited flow releases. Project operations are different from a large-scale dam in several ways. The Project includes a smaller degree of daily hydrocycling and no cold water releases. In addition, during times of high flow, these flows are bypassed and the Project does not divert water. Although daily hydrocycling occurs on most of these other rivers, limited information was found regarding the potential effect of this practice on the birds and fish and their associated habitat.

In these other river reaches, large releases to relieve flooding or reach navigation targets appear to have a measurable effect on interior least terns and piping plovers and their respective habitat. Furthermore, hypolimnetic releases[7] from the reservoirs behind each large dam can decrease temperature and turbidity downstream, potentially altering preferred pallid sturgeon habitat. The Project does not release water for flooding or navigation and does not have the capability to retain water for a prolonged period, such as these other dams do. Most other dams reviewed have large storage reservoirs and are able to release large quantities of water to meet electric generation or navigational needs, whereas the Project differs from a traditional dam in that it has no significant dam structure, no instream reservoir, and no project spillway. The Project's regulating reservoirs (Lake Babcock and Lake North) are used to provide capacity to pond water during low electrical demand hours of the day and release water during the high electrical demand hours of the day. During low electrical demand hours, flow through the Columbus Powerhouse normally drops to

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[7] Hypolimnetic releases are releases of water from the hypolimnion, the layer of water in a thermally stratified lake that is the lowest and coldest layer.

zero to maximize ponding. Maximum releases are 4,800 cfs during hours of peak electrical demand. Therefore, it is difficult to compare the Project's operations and habitat on the lower Platte River to these other, larger structures and the habitat that exists downstream on these larger rivers.

While studies in other rivers have not been conducted for the direct purpose of determining the effects of daily hydrocycling on interior least terns and piping plovers, changes in operations at Fort Randall Dam in accordance with conditions set forth in the USFWS amended Biological Opinion (BO) (December 16, 2003) have shown that releasing at higher rates prior to the nesting season and during the early nesting season has encouraged the birds to nest at a higher elevation and prevented nest losses due to hydrocycling. Additionally, a study conducted by Leslie et al. (2000) on the effects of hydropower and flood-control operations of the Keystone Dam on the Arkansas River on interior least tern populations found that daily hydropower operations were not affecting the birds; however, subjecting nesting habitat to periodic high river flows prior to the nesting season could be beneficial because availability and quality of the habitat increased with flooding and population numbers expanded in a year following the flood. Because the Project does not have control over stopping or allowing large flood flows to affect the lower Platte River, the Project's effects from daily hydrocycling on sandbar formation are minor when compared to the effects from large flood flows.

Pallid sturgeon have been collected in reaches of the Missouri and Yellowstone rivers. Though precise habitat preferences of pallid sturgeon are not well known, surveys completed in the last decade suggest that pallid sturgeon select turbid, warm, flowing waters. In the upper Missouri River and the Yellowstone River, studies found that pallid sturgeon were located most commonly in areas with sandbars and sandy substrate (Bramblett and White, 2001; Tews, 1994). However, pallid sturgeon have been shown to use habitat with large ranges of characteristics (for example, temperature, flow, and depth) depending on what is available. The pallid sturgeon often selects from the best habitat available, not necessarily the most ideal habitat for the species (National Research Council, 2005; Elliot et al., March 2004; Jacobsen et al., 2009).

Percentage of Suitable Habitat

Using Peters and Parham's (2008) discharge versus habitat relationship for both current operations and run-of-river operations, the minimum yearly average percentage of suitable habitat available in the lower Platte River for a normal flow year increases consistently from a low of 1 percent above the Loup River confluence (near Duncan) to a maximum of 19 percent for current operations and 24 percent for run-of-river operations at Louisville. The increase in suitable habitat when moving downstream is consistent for minimum, maximum, and average daily flows for the selected wet, dry, and normal years. Overall, any differences in the availability of suitable habitat between current operations and run-of-river operations decrease when moving downstream.

Differences in the availability of suitable habitat between flows for current operations and run-of-river operations vary depending on the month of the year. Notable observations related to the monthly average percentage of suitable pallid sturgeon habitat are as follows:

- As with the yearly average, the percentage of suitable habitat increased when moving downstream for both current operations and run-of-river operations for each month.
- There was little to no (5 percent or less) suitable pallid sturgeon habitat above the Loup River confluence (near Duncan) throughout the year with the exception of May and June during the wet year, when as much as 16 percent suitable habitat was available above the Loup River confluence. The largest percentage of suitable habitat is available downstream of Louisville; during normal and wet years, minimum flows provided at least 12 percent suitable habitat for each month under both current operations and run-of-river operations. However, during August and September, minimum flows provided as little as 4 percent suitable habitat under current operations and 10 percent under run-of-river operations.
- During dry years, the lower Platte River upstream of the Elkhorn River confluence (upstream of the Ashland gage) provided little to no suitable habitat during the summer months (May to August) under both current operations and run-of-river operations.
- The months of February through June exhibit the greatest habitat availability for nearly all downstream sites, especially for normal and wet years.

Peters and Parham (2008) reported that pallid sturgeon captures most often occurred in the deepest and swiftest areas of the Platte River and that these habitat types were used more frequently than would be expected if used at random. On the Platte River, radio telemetry data further suggest that pallid sturgeon were typically found in depths ranging from 2 to 5.9 feet and average bottom velocities that ranged from 0.6 to 1.9 feet per second (Peters and Parham, 2008). The Lower Platte River Stage Change Study (HDR et al., December 2009) suggested that changes in habitat availability as a result of a change in discharge, assuming rigid-bed boundaries, would have a negligible influence on pallid sturgeon habitat in the lower Platte River below the confluence of the Elkhorn River.

HEC-RAS Model Results

The results of the 1-D HEC-RAS model were used to determine variations in potential nesting habitat under current operations and run-of-river operations for the selected wet, dry, and normal years based on a maximum daily flow at both Sites 4 and 5 for low-, medium-, and high-flow conditions. Site 3 was used as a control and compared to Site 4 under current operations in order to note any differences. The following summarizes the results of this analysis:

- Site 3:
    - The average channel width (as measured from bank to bank) showed very little change between the June and September cross sections (1,071 and 1,077 feet, respectively).
    - The percentage of exposed channel width decreased from dry to wet years. This is to be expected because it is a property of rigid-boundary hydraulics for the exposed channel width in any irregular boundary channel to decrease with rising stages.
    - When compared to Site 4, Site 3 exhibited, on average, a higher percentage of exposed channel width during the dry year, but less exposed channel width than Site 4 during the normal and wet years, under current operations. When comparing Site 3 to Site 4 under run-of-river operations, in the dry year, both sites exhibit a similar percentage of exposed channel width; however, in the normal and wet years, Site 4 has a higher percentage of exposed channel width than Site 3 under run-of-river operations.
- Site 4:
    - The average channel width was relatively constant for both the June and September cross sections (1,726 and 1,723 feet, respectively).
    - The percentage of exposed channel width generally decreased from the dry year (2006) to normal year (2009) to wet year (2008) for both June and September cross sections for both current operations and run-of-river operations.
    - The percentage of exposed channel width generally decreased from low- to medium- to high-flow conditions. This would be expected, given that channels will show a decrease in exposed channel width for higher discharge rates and wetter conditions.
    - The run-of-river operations generally had a higher percentage of exposed channel width than exhibited under current operations, and the June cross sections yielded a higher percentage of exposed channel width than did the September cross section (with the exception of the medium-flow condition for the normal year [2009]).

- Site 5:
  - The average channel width was relatively constant for both the June and September cross sections (1,610 and 1,604 feet, respectively); however, when compared to Site 4, the channel begins to narrow in this area (1,600 feet at Site 5 compared to 1,700 feet at Site 4).
  - The percentage of exposed channel width was greatest under the dry year (2006) and decreased under the normal (2009) and wet (2008) years, respectively, under both current operations and run-of-river operations.
  - The run-of-river operations generally had a higher percentage of exposed channel width than exhibited under current operations.

No consistent trend in percentage of exposed channel width is evident between Sites 4 and 5. At all sites, there is generally a higher percentage of exposed channel width under run-of-river operations than under current operations. The cause of this decrease in exposed channel width under current operations is likely that the duration of higher-than-average flows during days with hydrocycling compared to the duration on the same days of lower-than-average flows resulted in an accumulation of time when higher overall water levels prevailed, thereby causing overall reduced exposed widths, which would always be true for a rigid-boundary channel.

5.2 Objective 1 – To compare the sub-daily Project hydrocycling operation values (maximum and minimum flow and stage) to daily values (mean flow and stage). In addition to same-day comparisons, periods of weeks, months, and specific seasons of interest to protected species will be evaluated to characterize the relative degrees of variance between hydrocycling (current operations) and run-of-river operations in the study area.

Flow and stage hydrographs were plotted at each gaged and ungaged site for the selected wet, dry, and normal years for current operations as well as for run-of-river operations, as provided in Attachment E. As discussed in Section 4.2.3 for the Platte River within the study area, the following were used:

- 2006 – Dry hydrologic year
- 2008 – Wet hydrologic year
- 2009 – Normal hydrologic year

In addition, the average annual and seasonal differences in flow and water surface elevation between current operations and run-of-river operations are shown in Tables 5-1 through 5-6. For purposes of this analysis, the seasonal analysis (the second table for each year) was conducted for the nesting season (May 1 to August 15).

Table 5-1. 2006 (Dry) Average Annual Differences in Flow and Water Surface Elevation between Current and Run-of-River Operations

Location	Flow Difference (cfs)			Water Surface Elevation Difference (feet)		
	Current Operations Max - Min Difference[1]	Run-of-River Operations Max - Min Difference[1]	Current Operations Max - Run-of-River Max Difference[2]	Current Operations Max - Min Difference[3]	Run-of-River Operations Max - Min Difference[3]	Current Operations Max - Run-of-River Max Difference[4]
Site 3 – Upstream of the Tailrace Return	420	420	0	0.30	0.30	0.00
Site 4 – Downstream of the Tailrace Return	2,820	610	1,090	1.85	0.26	0.50
Platte River at North Bend	2,750	600	990	1.09	0.17	0.30
Platte River at Leshara	2,760	580	1,050	1.02	0.16	0.31
Platte River near Ashland	2,840	660	1,080	1.25	0.22	0.39
Platte River at Louisville	2,800	630	1,040	0.79	0.15	0.27

Notes:

[1] Calculated by taking the average of the difference between the daily maximum and minimum flow.

[2] Calculated by taking the average of the difference between the daily maximum current operations flow and run-of-river operations flow.

[3] Calculated by taking the average of the difference between the daily maximum and minimum gage height.

[4] Calculated by taking the average of the difference between the daily maximum current operations flow and run-of-river operations flow.

Table 5-2. 2006 (Dry) Average Seasonal Differences in Flow and Water Surface Elevation between Current and Run-of-River Operations

Location	Flow Difference (cfs)			Water Surface Elevation Difference (feet)		
	Current Operations Max - Min Difference[1]	Run-of-River Operations Max - Min Difference[1]	Current Operations Max - Run-of-River Max Difference[2]	Current Operations Max - Min Difference[3]	Run-of-River Operations Max - Min Difference[3]	Current Operations Max - Run-of-River Max Difference[4]
Site 3 – Upstream of the Tailrace Return	110	110	0	0.21	0.21	0.00
Site 4 – Downstream of the Tailrace Return	2,370	260	1,300	2.33	0.25	0.82
Platte River at North Bend	2,250	250	1,200	1.25	0.13	0.47
Platte River at Leshara	2,280	260	1,220	1.08	0.13	0.45
Platte River near Ashland	2,400	320	1,280	1.56	0.22	0.64
Platte River at Louisville	2,320	310	1,210	0.72	0.10	0.34

Notes:

[1] Calculated by taking the average of the difference between the daily maximum and minimum flow.

[2] Calculated by taking the average of the difference between the daily maximum current operations flow and run-of-river operations flow.

[3] Calculated by taking the average of the difference between the daily maximum and minimum gage height.

[4] Calculated by taking the average of the difference between the daily maximum current operations flow and run-of-river operations flow.

Table 5-3. 2008 (Wet) Average Annual Differences in Flow and Water Surface Elevation between Current and Run-of-River Operations

Location	Flow Difference (cfs)			Water Surface Elevation Difference (feet)		
	Current Operations Max - Min Difference[1]	Run-of-River Operations Max - Min Difference[1]	Current Operations Max - Run-of-River Max Difference[2]	Current Operations Max - Min Difference[3]	Run-of-River Operations Max - Min Difference[3]	Current Operations Max - Run-of-River Max Difference[4]
Site 3 – Upstream of the Tailrace Return	950	950	0	0.33	0.33	0.00
Site 4 – Downstream of the Tailrace Return	4,160	1,130	1,710	1.31	0.23	0.41
Platte River at North Bend	4,150	1,130	1,510	0.97	0.20	0.31
Platte River at Leshara	4,140	1,170	1,620	0.90	0.18	0.30
Platte River near Ashland	4,320	1,370	1,680	0.84	0.19	0.48
Platte River at Louisville	4,320	1,400	1,610	0.75	0.19	0.27

Notes:

[1] Calculated by taking the average of the difference between the daily maximum and minimum flow.

[2] Calculated by taking the average of the difference between the daily maximum current operations flow and run-of-river operations flow.

[3] Calculated by taking the average of the difference between the daily maximum and minimum gage height.

[4] Calculated by taking the average of the difference between the daily maximum current operations flow and run-of-river operations flow.

Table 5-4. 2008 (Wet) Average Seasonal Differences in Flow and Water Surface Elevation between Current and Run-of-River Operations

Location	Flow Difference (cfs)			Water Surface Elevation Difference (feet)		
	Current Operations Max - Min Difference[1]	Run-of-River Operations Max - Min Difference[1]	Current Operations Max - Run-of-River Max Difference[2]	Current Operations Max - Min Difference[3]	Run-of-River Operations Max - Min Difference[3]	Current Operations Max - Run-of-River Max Difference[4]
Site 3 – Upstream of the Tailrace Return	1,850	1,850	0	0.38	0.38	0.00
Site 4 – Downstream of the Tailrace Return	5,040	2,000	1,910	1.22	0.26	0.39
Platte River at North Bend	5,040	2,010	1,520	0.95	0.26	0.28
Platte River at Leshara	5,110	2,120	1,770	0.88	0.24	0.29
Platte River near Ashland	5,530	2,650	1,850	0.81	0.25	0.52
Platte River at Louisville	5,630	2,740	1,770	0.77	0.28	0.25

Notes:

[1] Calculated by taking the average of the difference between the daily maximum and minimum flow.

[2] Calculated by taking the average of the difference between the daily maximum current operations flow and run-of-river operations flow.

[3] Calculated by taking the average of the difference between the daily maximum and minimum gage height.

[4] Calculated by taking the average of the difference between the daily maximum current operations flow and run-of-river operations flow.

Revised 03/08/11

Table 5-5. 2009 (Normal) Average Annual Differences in Flow and Water Surface Elevation between Current and Run-of-River Operations

Location	Flow Difference (cfs)			Water Surface Elevation Difference (feet)		
	Current Operations Max - Min Difference[1]	Run-of-River Operations Max - Min Difference[1]	Current Operations Max - Run-of-River Max Difference[2]	Current Operations Max - Min Difference[3]	Run-of-River Operations Max - Min Difference[3]	Current Operations Max - Run-of-River Max Difference[4]
Site 3 – Upstream of the Tailrace Return	840	840	0	0.41	0.41	0.00
Site 4 – Downstream of the Tailrace Return	3,750	1,020	1,210	1.30	0.26	0.30
Platte River at North Bend	3,760	1,020	1,090	0.94	0.21	0.23
Platte River at Leshara	3,490	1,040	1,030	0.87	0.21	0.21
Platte River near Ashland	3,610	1,150	1,080	0.83	0.21	0.21
Platte River at Louisville	3,540	1,130	1,010	0.69	0.19	0.18

Notes:

[1] Calculated by taking the average of the difference between the daily maximum and minimum flow.

[2] Calculated by taking the average of the difference between the daily maximum current operations flow and run-of-river operations flow.

[3] Calculated by taking the average of the difference between the daily maximum and minimum gage height.

[4] Calculated by taking the average of the difference between the daily maximum current operations flow and run-of-river operations flow.

Revised 03/08/11

Table 5-6. 2009 (Normal) Average Seasonal Differences in Flow and Water Surface Elevation between Current and Run-of-River Operations

Location	Flow Difference (cfs)			Water Surface Elevation Difference (feet)		
	Current Operations Max - Min Difference[1]	Run-of-River Operations Max - Min Difference[1]	Current Operations Max - Run-of-River Max Difference[2]	Current Operations Max - Min Difference[3]	Run-of-River Operations Max - Min Difference[3]	Current Operations Max - Run-of-River Max Difference[4]
Site 3 – Upstream of the Tailrace Return	890	890	0	0.38	0.38	0.00
Site 4 – Downstream of the Tailrace Return	3,590	1,070	1,010	1.40	0.28	0.29
Platte River at North Bend	3,570	1,060	830	0.93	0.22	0.18
Platte River at Leshara	3,560	1,100	940	0.90	0.21	0.20
Platte River near Ashland	3,700	1,270	1,010	0.90	0.23	0.22
Platte River at Louisville	3,680	1,270	960	0.72	0.21	0.18

Notes:

[1] Calculated by taking the average of the difference between the daily maximum and minimum flow.

[2] Calculated by taking the average of the difference between the daily maximum current operations flow and run-of-river operations flow.

[3] Calculated by taking the average of the difference between the daily maximum and minimum gage height.

[4] Calculated by taking the average of the difference between the daily maximum current operations flow and run-of-river operations flow.

For current operations, the annual trend is consistent among sites regardless of hydrologic classification (wet, dry, or normal). Higher flows are prevalent in the spring (March through May) as the result of spring runoff. The summer months (June through August) generally consist of lower flows due to irrigation and upstream management practices. The fall months (September through November) typically show higher flows than summer, yet slightly lower than spring. This is primarily attributed to the Loup and Platte river systems responding to the end of the irrigation season.

The average seasonal difference (May 1 to August 15) between the daily maximum and minimum flow and stage for Sites 3, 4, and 5 were tabulated. This was completed for current operations and run-of-river operations for the selected wet, dry, and normal years.

As shown in Table 5-6, the average seasonal flow and stage difference for a typical normal hydrologic year for current operations at Site 3 is 890 cfs and 0.38 foot, respectively. The flow and stage differences are greater at Site 4, at 4,870 cfs and 1.40 feet, respectively, due to hydrocycling. At Site 5, this difference is reduced to 3,570 cfs and 0.93 foot, respectively. The average seasonal flow and stage difference for a typical normal hydrologic year for run-of-river operations for Site 4 is 1,070 cfs and 0.28 foot, respectively. At Site 5, this difference is reduced to 1,060 cfs and 0.22 foot, respectively.

The natural variability of the flow as well as upstream influences were also investigated. Figures 5-1 and 5-2 show flows at Sites 3 and 4 for a typical normal year. Visual inspection of the hydrographs shows daily fluctuations in flow, the likely result of upstream water management practices.

Although the average seasonal difference at Site 4 between maximum and minimum flow is 4,870 cfs for current operations and 1,070 for run-of-river operations, the difference between the maximum flow for current operations and run-of-river operations is 1,010 cfs. Similarly, from visual inspection of hydrographs of wet and dry years at Site 4, provided in Attachment E, the natural seasonal flow variability was equal to or greater than the daily flow variability during operations unaffected by storm events. For example, the daily variability at Site 4 for current operations between May 1 and May 15, 2009, was approximately 3,000 cfs (see Figure 5-2). For the same time period, the flow under run-of-river operations decreased from 6,000 to 3,000 cfs, which is also a variability of 3,000 cfs.

Figure 5-3 shows flows at the North Bend gage for November 25 through December 11, 2010. The daily fluctuations in flow and stage occurred during a period when the Project was not in operation. An examination of Figures 5-1 through 5-3 shows that storm events result in greater fluctuation of flow and stage than do Project operations.

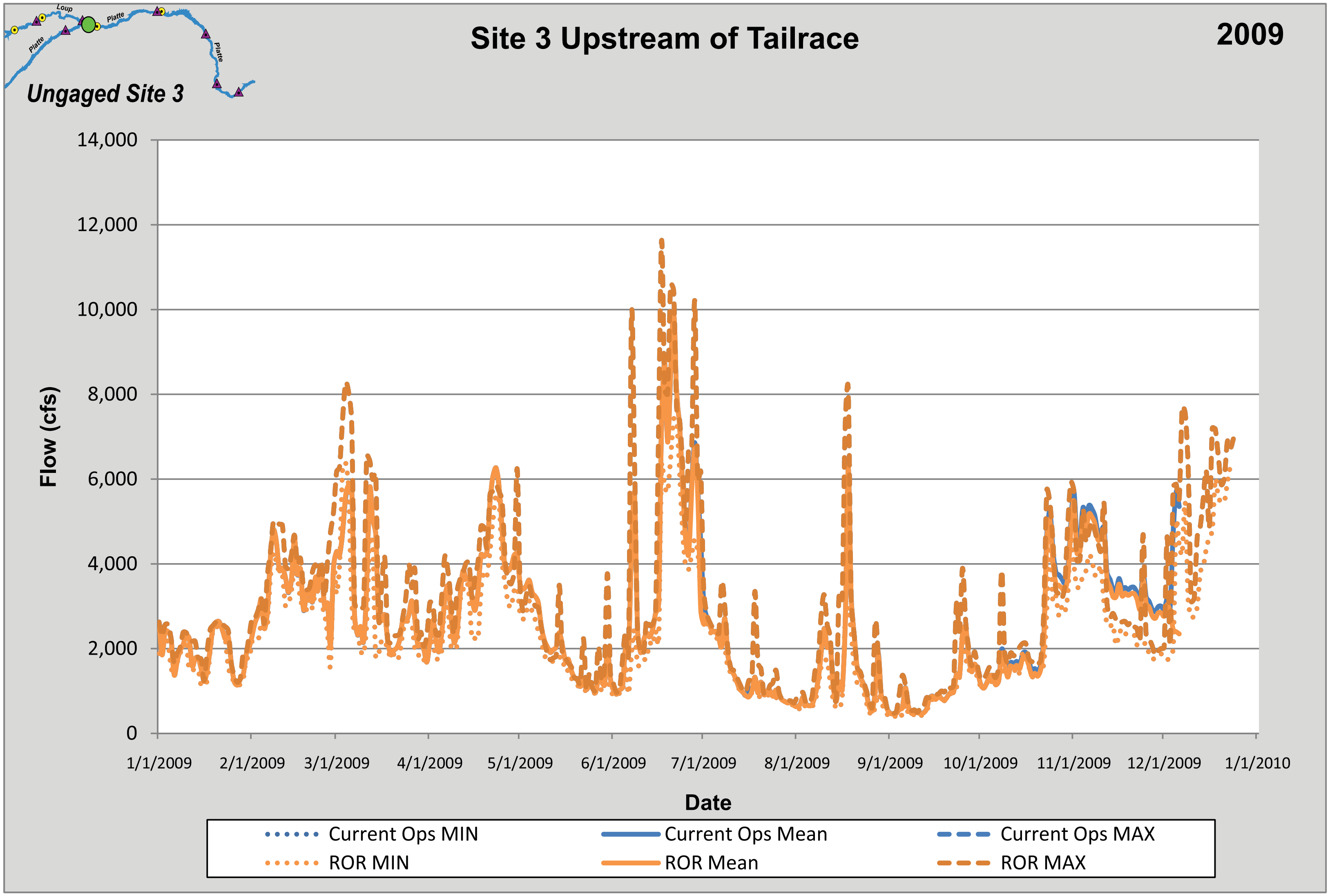


Figure 5-1. Daily Mean, Maximum, and Minimum Flows at Site 3 for Current and Run-of-River Operations

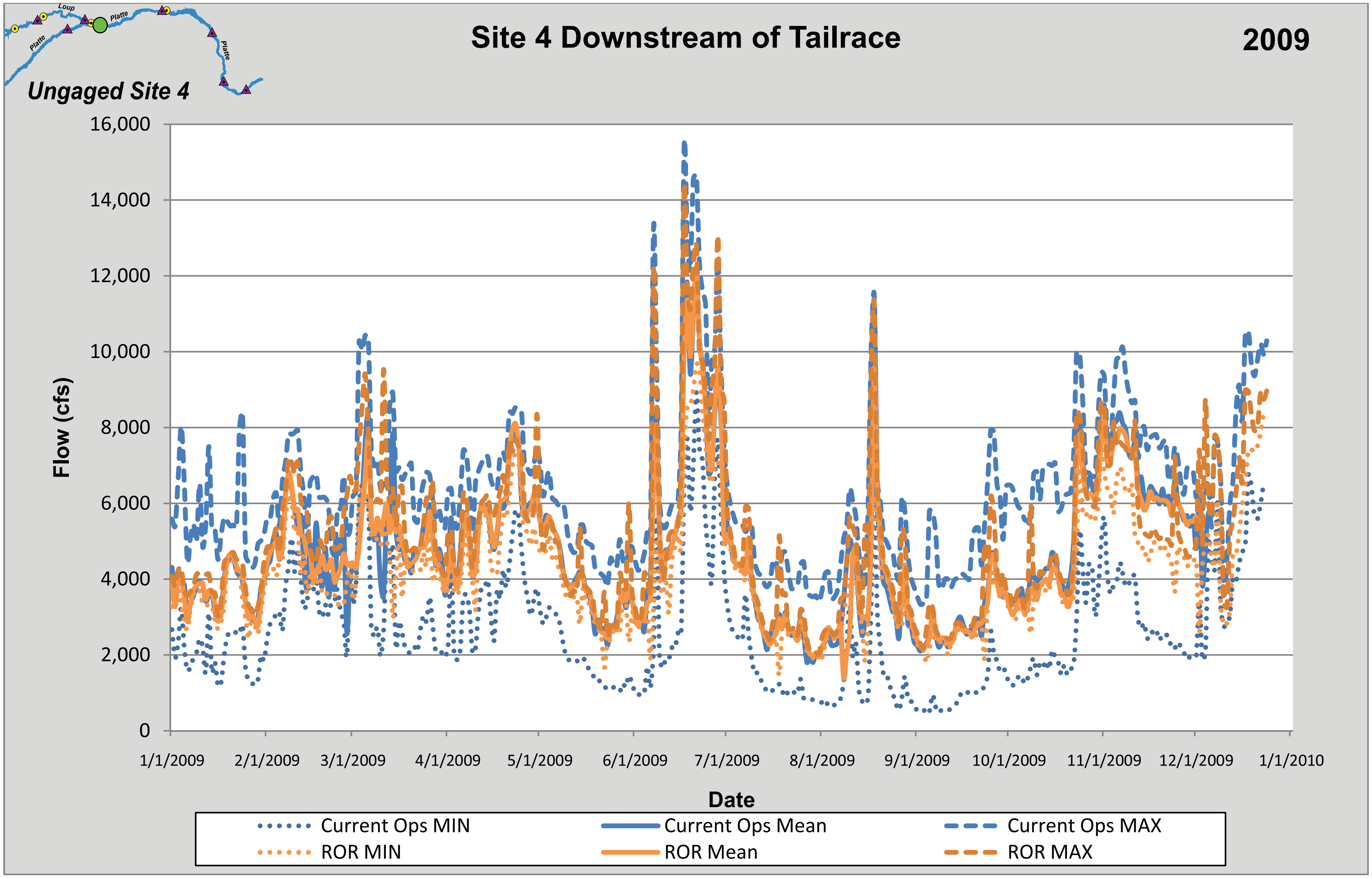


Figure 5-2. Daily Mean, Maximum, and Minimum Flows at Site 4 for Current and Run-of-River Operations

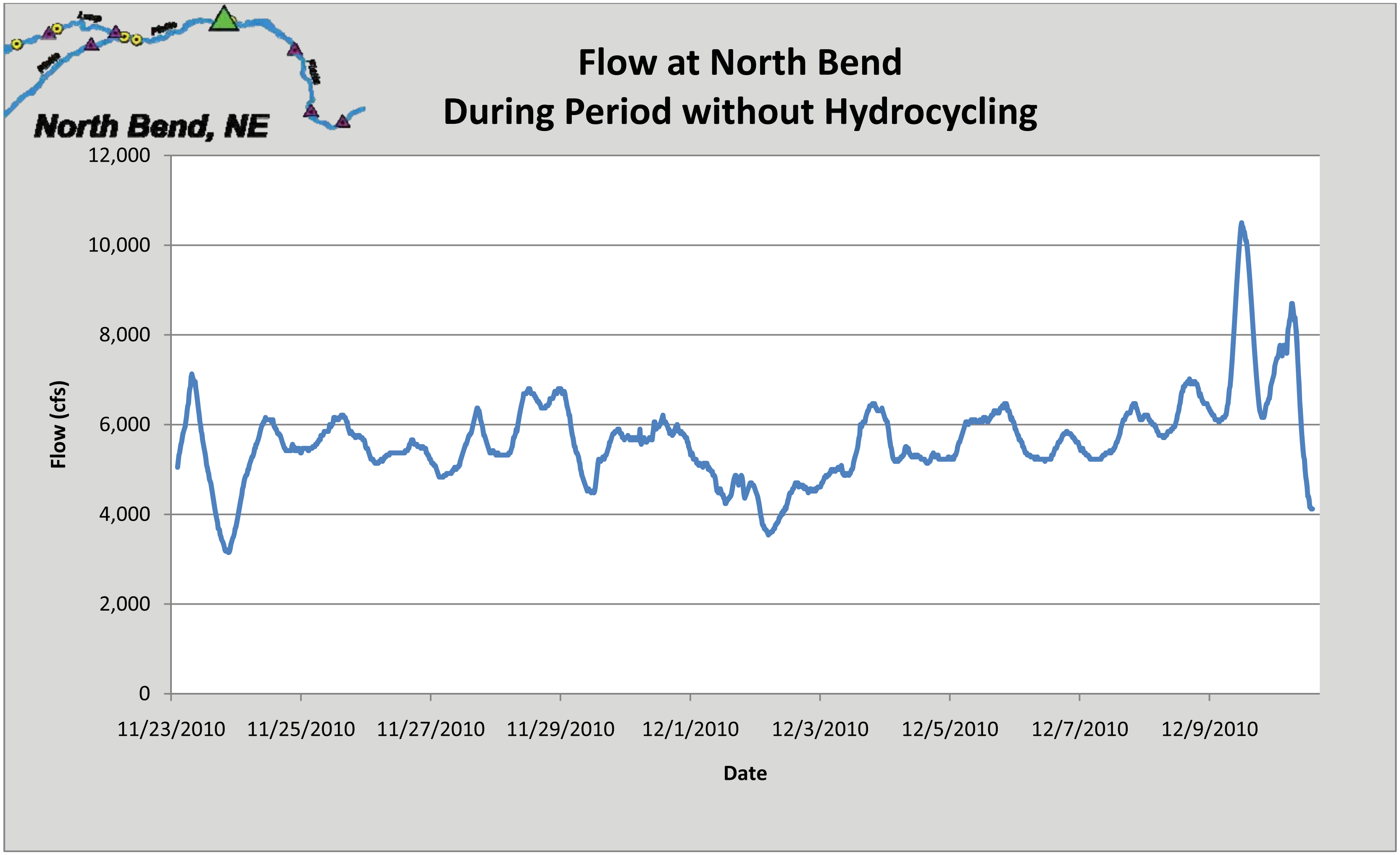


Figure 5-3. Flow at North Bend During a Period with No Hydrocycling

5.3 Objective 2 – To determine the potential for nest inundation due to both hydrocycling (current operations) and run-of-river operations.

5.3.1 Nesting Season Flows

Tables 5-7 and 5-8 summarize and compare, by year, the following variables for interior least tern and piping plover, respectively:

- Pre-nesting season sub-daily peak (cfs) (benchmark flow)
- Date of pre-nesting season benchmark flow
- Number of daily benchmark exceedances during the nesting season
- Date of the final nesting season exceedance
- Whether subsequent nesting was possible
- Whether run-of-river operations nesting season peaks exceeded the current operations pre-nesting season benchmark flow

The bar charts in Attachment I provide a graphical representation of maximum peak daily flows, by year, at Site 4 (RM 99) as compared to both interior least terns and piping plovers. Figure 5-4 is an example chart that is typical of the bar charts generated and included in Attachment I. This graph identifies the benchmark flow that was established during the piping plover pre-nesting season period in 2005 (on February 5 at approximately 10,231 cfs under current conditions). The run-of-river operations piping plover pre-nesting season benchmark peaked the same day at slightly over 9,872 cfs. Following April 24, the peak sub-daily flow under current conditions exceeded the pre-nesting season benchmark 10 times during four distinct events, the first from May 13 to 16 (four times), the second from June 4 to June 6 (three times), the third on June 12 (one time), and the fourth on June 22 and 23 (two times). These peaks could have potentially disrupted early attempts to nest as well as any later nesting attempts. A successful nest attempt requires roughly 60 days from egg to fledge. The peaks around June 23 may not have allowed enough time in the nesting season for successful re-nesting attempts, considering most adult piping plovers leave Nebraska in late July. The same results occurred for run-of-river operations; the peak sub-daily flow for run-of-river operations exceeded the pre-nesting season run-of-river benchmark 10 times for the same four events on the same dates. The peaks could have potentially disrupted both early attempts as well as any later attempts to nest.

Table 5-7. Benchmark Analysis Summary – Interior Least Tern

Variable	2003		2004		2005		2006 (Dry)		2007		2008 (Wet)		2009 (Normal)	
	Current Operations	Run-of-River Operations	Current Operations	Run-of-River Operations	Current Operations	Run-of-River Operations	Current Operations	Run-of-River Operations	Current Operations	Run-of-River Operations	Current Operations	Run-of-River Operations	Current Operations	Run-of-River Operations
Pre-nesting Season Benchmark Flow (cfs)	11,772.8	11,423.8	13,385.7	12,557.7	19,140.8	18,076.3	9,077.3	7,573.7	26,522.9	25,970.4	12,231.8	10,709.0	10,431.7	9,529.2
Date of Pre-nesting Season Benchmark Flow	5/6/2003	5/6/2003	3/2/2004	3/2/2004	5/14/2005	5/14/2005	3/31/2006	4/1/2006	2/26/2007	2/26/2007	5/12/2008	5/12/2008	3/5/2009	3/11/2009
Number of Daily Benchmark Exceedances During Nesting Season (days)	0	0	0	0	0	0	0	0	2	2	22	22	10	10
Number of Exceedance Flow Events	0	0	0	0	0	0	0	0	1	1	1	1	3	3
Number of Exceedances Per Flow Event	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	2.0	22.0	22.0	3.3	3.3
Nesting Season Maximum Peak Sub-daily Flow (cfs)	6,127.9	6,053.9	10,157.7	10,144.8	16,260.9	15,714.8	4,800.2	3,835.5	3,6217.5	35,354.3	39,985.9	35,533.3	15,433.9	14,321.6
Date of Final Nesting Season Exceedance (dd/mm/yyyy)	NA	NA	NA	NA	NA	NA	NA	NA	6/1/2007	6/1/2007	6/14/2008	6/14/2008	6/28/2009	6/28/2009
Subsequent Nesting Possible (Yes or No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Number of Times Run-of-River Operations Nesting Season Peaks Exceeded Current Operations Pre-nesting Season Benchmark	NA	0	NA	0	NA	0	NA	0	NA	2	NA	22	NA	10

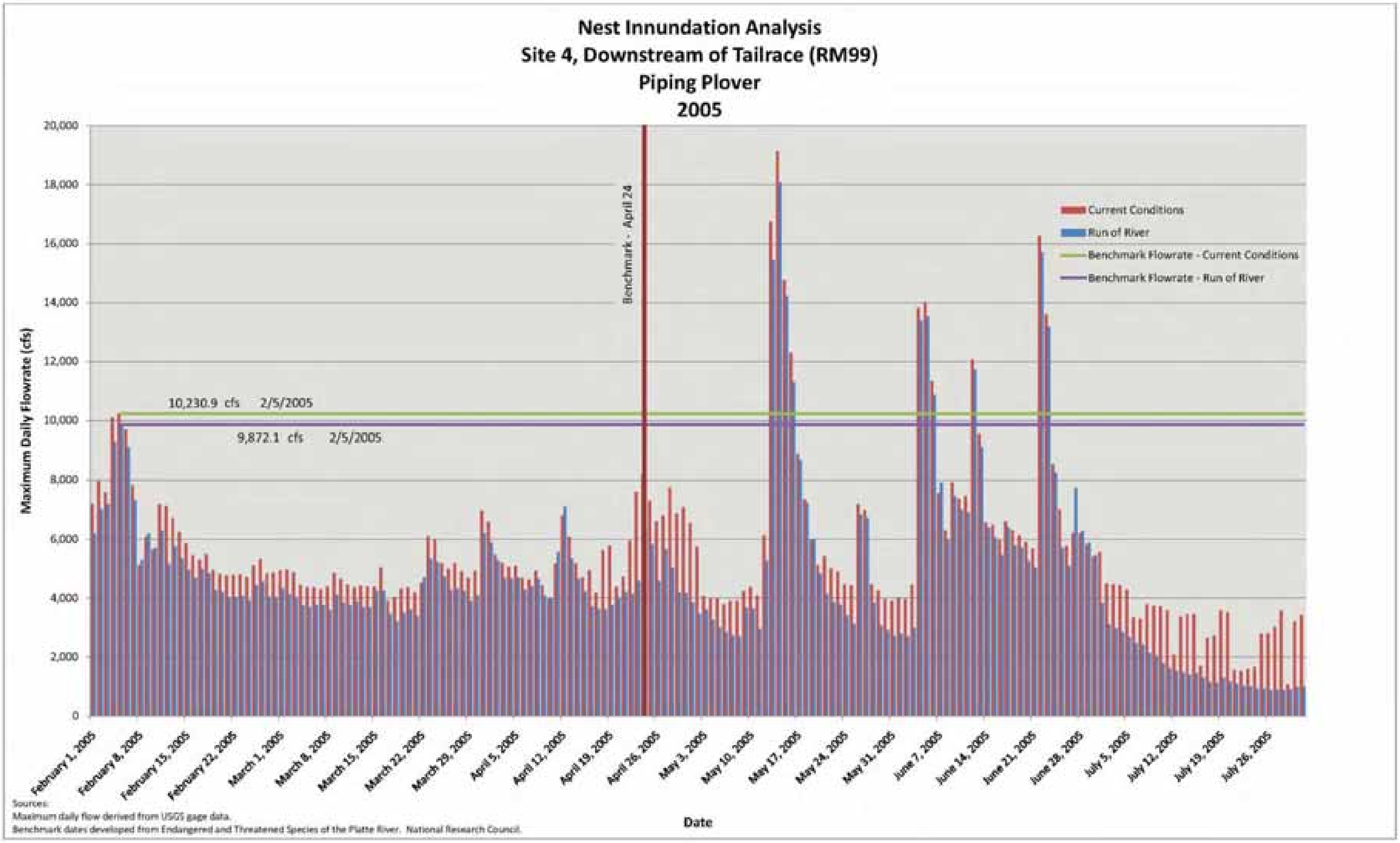
Note:
NA = Not applicable.

Table 5-8. Benchmark Analysis Summary – Piping Plover

Variable	2003		2004		2005		2006 (Dry)		2007		2008 (Wet)		2009 (Normal)	
	Current Operations	Run-of-River Operations	Current Operations	Run-of-River Operations	Current Operations	Run-of-River Operations	Current Operations	Run-of-River Operations	Current Operations	Run-of-River Operations	Current Operations	Run-of-River Operations	Current Operations	Run-of-River Operations
Pre-nesting Season Benchmark Flow (cfs)	7,856.7	5,905.4	13,385.7	12,557.7	10,230.9	9,872.1	9,077.3	7,573.7	26,522.9	25,970.4	11,949.9	10,356.9	10,431.7	9,529.2
Date of Pre-nesting Season Benchmark Flow	3/8/2003	3/9/2003	3/2/2004	3/2/2004	2/5/2005	2/5/2005	3/31/2006	4/1/2006	2/26/2007	2/26/2007	4/12/2008	4/12/2008	3/5/2009	3/11/2009
Number of Daily Benchmark Exceedances During Nesting Season (days)	4	12	0	0	10	10	0	0	2	2	23	23	10	10
Number of Exceedance Flow Events	2	5	0	0	4	4	0	0	1	1	2	2	3	3
Number of Exceedances Per Flow Event	2.0	2.4	0.0	0.0	2.5	2.5	0.0	0.0	2.0	2.0	11.5	11.5	3.3	3.3
Nesting Season Maximum Peak Sub-daily Flow (cfs)	11,772.8	11,423.8	10,157.7	10,144.8	19,140.8	18,076.3	4,100.2	3,213.4	36,217.5	35,354.3	39,985.9	35,533.3	15,433.9	14,321.6
Date of Final Nesting Season Exceedance (dd/mm/yyyy)	5/6/2003	6/28/2003	NA	NA	6/23/2005	6/23/2005	NA	NA	6/1/2007	6/1/2007	6/14/2008	6/14/2008	6/28/2009	6/28/2009
Subsequent Nesting Possible (Yes or No)	Yes	No	Yes	Yes	No	No	Yes	Yes	Yes	Yes	No	No	No	No
Number of Times Run-of-River Operations Nesting Season Peaks Exceeded Current Operations Pre-nesting Season Benchmark	NA	4	NA	0	NA	10	NA	0	NA	2	NA	23	NA	10

Note:

NA = Not applicable.



Sources:
Maximum daily flow derived from USGS gage data.
Benchmark dates developed from Endangered and Threatened Species of the Platte River. National Research Council.

Figure 5-4. Example Bar Chart for 2005 for Site 4, Downstream of the Tailrace Return – Piping Plover

5.3.2 Conclusions

The majority of current operations peak daily discharge rates are generally higher than the run-of-river operations peak daily flows. However, there are several instances where this situation is reversed. Reasons for this are the timing of flow, the diversion amount and relative proportion to the total amount, Project operations, and regional and local flow events.

For interior least terns from 2003 to 2006, the peak sub-daily flow did not exceed the current operations or run-of-river operations pre-nesting season benchmarks. For piping plovers, the current operations and run-of-river operations pre-nesting season benchmarks were not exceeded in 2004 and 2006. These data indicate that potentially available habitat at or above the pre-nesting season benchmark flow in these years was not inundated during the nesting season as a result of either current operations or run-of-river operations.

Interior least tern pre-nesting season benchmarks were exceeded the same number of times under both current and run-of-river operations from 2007 to 2009. Piping plover pre-nesting season benchmarks were exceeded under both current and run-of-river operations in 2003; however, 12 exceedances occurred under run-of-river operations, whereas only 4 exceedances occurred under current operations. Piping plover pre-nesting season benchmarks were exceeded the same number of times in 2005 as well as from 2007 to 2009. For the purposes of this study, a successful nesting attempt was estimated to require 60 days from egg to fledge. The events that produced these higher river flows for both current operations and run-of-river operations generally occurred early in the nesting season for both interior least terns and piping plovers, potentially disrupting initial riverine nesting attempts but allowing adequate time for successful nesting and/or re-nesting attempts after the exceedance flow. In 2003, a late season sub-daily peak (June 28) exceeded the run-of-river operations pre-nesting season benchmark. Any nesting attempts after this date could potentially be unsuccessful because most adult piping plovers leave Nebraska in late July and may abandon unhatched eggs and unfledged chicks. This exceedance also also occurred in 2009 for interior least terns under both current operations and run-of-river operations, and in 2005, 2008, and 2009 for piping plovers under both current operations and run-of-river operations. These later peaks could have disrupted early attempts to nest as well as any later nesting attempts.

A comparison of peak sub-daily flows for both current operations and run-of-river operations to the pre-nesting season benchmark flows for both species revealed that there were no occasions during which a nesting season peak that exceeded the benchmark under current operations could have been avoided under run-of-river operations.

5.4 Objective 3 – To assess effects, if any, of hydrocycling (current operations) and run-of-river operations on sediment transport parameters and channel morphology.

5.4.1 Effects of Hydrocycling on Sediment Transport for Current and Run-of-River Operations

To assess the effects of hydrocycling on sediment transport, sediment transport indicators were calculated consistent with the methodology outlined in the Initial Study Report, Appendix A, Sedimentation Study Report. In addition, the regime classification and a spatial analysis were also conducted in the same manner described in the Initial Study Report, Appendix A.

Results of the calculations for both current operations and run-of-river operations are shown in Tables 5-9 through 5-11 for the selected normal, wet, and dry years, respectively. Table 5-12 provides the long-term values of the parameters for the study period from 2003 to 2009 at Sites 3, 4, and 5 and the North Bend gage. In addition, Table 5-12 shows the 1985 to 2009 values at the North Bend gage. This allowed comparison of individual year results in Tables 5-9 through 5-11 with longer-term (7-year and 25-year) equilibrium values.

For comparison of impacts of using published or synthesized average daily discharge rates versus sub-daily rates (15-minute increments), values of the parameters for current operations at Sites 3, 4, and 5 and the North Bend gage using daily versus sub-daily flows are also shown in Tables 5-9 through 5-11.

Values at the North Bend gage were included in Tables 5-9 through 5-12 for spatial analysis. The 5,300- and 5,600-cfs dominant and effective discharges and 1,890 tons per year of transported sediment for the North Bend gage shown in Table 5-12 are the long-term, 1985 to 2009 values previously reported in the Initial Study Report, Appendix A, Sedimentation Study Report.

Table 5-9. Sediment Transport Indicator Results for Hydrocycling Analysis, 2009 (Normal)

Location on the Platte River	Current Operations						Run-of-River Operations (Sub-daily)		
	Daily			Sub-daily					
	Q_d (cfs)	Q_e (cfs)	Sediment Capacity (1,000 tons)	Q_d (cfs)	Q_e (cfs)	Sediment Capacity (1,000 tons)	Q_d (cfs)	Q_e (cfs)	Sediment Capacity (1,000 tons)
Site 3 – Upstream of the Tailrace Return	2,700	2,100	1,100	2,600	2,400	1,100	2,600	2,400	1,100
Site 4 – Downstream of the Tailrace Return	4,800	4,900	2,970	4,700	5,600	2,950	4,600	4,800	2,840
USGS gage at North Bend	4,400	3,900	2,050	4,700	4,500	2,200	4,700	4,500	2,210
Site 5 – Near North Bend	4,000	4,200	2,140	4,200	4,500	2,300	4,200	4,400	2,310

Note:

Q_d = dominant discharge; Q_e = effective discharge.

Table 5-10. Sediment Transport Indicator Results for Hydrocycling Analysis, 2008 (Wet)

Location on the Platte River	Current Operations						Run-of-River Operations (Sub-daily)		
	Daily			Sub-daily					
	Q_d (cfs)	Q_e (cfs)	Sediment Capacity (1,000 tons)	Q_d (cfs)	Q_e (cfs)	Sediment Capacity (1,000 tons)	Q_d (cfs)	Q_e (cfs)	Sediment Capacity (1,000 tons)
Site 3 – Upstream of the Tailrace Return	4,000	2,100	2,260	4,100	3,000	2,270	4,100	3,000	2,270
Site 4 – Downstream of the Tailrace Return	5,600	4,100	4,100	5,900	4,400	4,310	5,700	4,700	4,120
USGS gage at North Bend	5,900	3,900	3,430	6,000	4,400	3,610	6,000	3,300	3,570
Site 5 – Near North Bend	5,300	3,900	3,540	5,400	4,400	3,490	5,400	3,300	3,500

Note:

Q_d = dominant discharge; Q_e = effective discharge.

Table 5-11. Sediment Transport Indicator Results for Hydrocycling Analysis, 2006 (Dry)

Location on the Platte River	Current Operations						Run-of-River Operations (Sub-daily)		
	Daily			Sub-daily					
	Q_d (cfs)	Q_e (cfs)	Sediment Capacity (1,000 tons)	Q_d (cfs)	Q_e (cfs)	Sediment Capacity (1,000 tons)	Q_d (cfs)	Q_e (cfs)	Sediment Capacity (1,000 tons)
Site 3 – Upstream of the Tailrace Return	1,300	1,500	430	1,30	1,400	445	1,300	1,400	445
Site 4 – Downstream of the Tailrace Return	2,700	3,100	1,490	2,800	4,100	1,570	2,700	3,000	1,500
USGS gage at North Bend	2,700	3,000	1,020	2,900	3,600	1,110	2,900	2,900	1,100
Site 5 – Near North Bend	2,500	2,900	1,240	2,600	3,600	1,300	2,700	2,900	1,320

Note:

Q_d = dominant discharge; Q^e = effective discharge.

Table 5-12. Sediment Transport Indicator Results for Hydrocycling Analysis, 2003-2009

Location on the Platte River	Current Operations						Run-of-River Operations (Sub-daily)		
	Daily			Sub-daily					
	Q_d (cfs)	Q_e (cfs)	Sediment Capacity (1,000 tons)	Q_d (cfs)	Q_e (cfs)	Sediment Capacity (1,000 tons)	Q_d (cfs)	Q_e (cfs)	Sediment Capacity (1,000 tons)
Site 3 – Upstream of the Tailrace Return	2,400	2,100	1,040	2,400	2,400	1,040	2,400	2,400	1,040
Site 4 – Downstream of the Tailrace Return	3,900	3,600	2,440	4,000	3,800	2,530	3,900	3,400	2,440
USGS gage at North Bend[1]	5,300	5,600	2,890	--	--	--	--	--	--
USGS gage at North Bend	4,100	3,400	1,880	4,200	3,900	2,000	4,100	3,400	1,940
Site 5 – Near North Bend	3,600	3,200	2,030	3,800	3,900	2,120	3,700	3,400	2,080

Notes:

Q_d = dominant discharge; Q_e = effective discharge.

[1] Based on 1985 to 2009 data; see the Initial Study Report, Appendix A, Sedimentation Study Report.

Table 5-12 reveals that the average 2003 to 2009 sub-daily values of all three of the sedimentation indicators at Site 4 (the location of highest interest) are equal or nearly equal (within 3 percent) to the values determined using daily synthesized flows. Both the effective discharge and total sediment transport values are essentially unchanged, but the dominant discharge is 100 cfs larger when using sub-daily values. Because the sediment rating curves are parabolic, calculated values of transport during 15-minute increments of each day when the flows exceeded the average daily values do not completely offset the reduced amounts of transport during times of each day when the flows were below the average daily value. Although the difference is small, this is probably the cause of this small difference in dominant discharges at Site 4.

This effect of the parablolic rating curve is further revealed in Table 5-12 for current operations at the North Bend gage and Site 5 (rows 4 and 5), where all three of the transport (and morphology) indicators are slightly higher when using 15-minute data versus daily averages. Thus, it is concluded that the apparent increases in sediment transport parameters using sub-daily (15-minute) flows rather than average daily discharges is the result of the parabolic shape of the rating curves. Comparison of the indicators in Table 5-12 for current operations (columns 5 through 7) versus for run-of-river operations (columns 8 through 10) show that there are either no or little differences, with some being slightly larger and others slightly smaller. These sets of data are comparable because 15-minute (sub-daily) time steps were used for both.

As expected, Table 5-12 shows that no differences between current operations and run-of-river operations occur at Site 3, upstream of the Tailrace Return. At Sites 4 and 5 and at the North Bend gage, all three sedimentation parameters were either the same or decreased slightly under run-of-river operations, when hydrocycling was "eliminated." Even though the current operations hydrograph at the North Bend gage clearly reveals flow fluctuations due to hydrocycling, Table 5-12 (and the regime analysis described in Section 5.4.3) shows that hydrocycling has no significant impact on longer-term (7-year to 25-year) sediment transport parameters relative to run-of river operations.

When either the effective or dominant discharges are entered in the regime graphs (see Section 5.4.3), their positions are well-situated in the braided river portions of the graphs, revealing that in addition to having no significant effect on sediment transport parameters, hydrocycling has virtually no effect on morphology. Because the morphology of the river is the habitat, this leads to the conclusion that there is no effect of hydrocycling on overall braided-river habitat.

In addition to the parabolic shape of the sediment rating curves, another factor in analyzing the small differences described above should be noted. Yang's equation and the sediment transport indicators are valid tools for analyzing sediment transport, morphology, and hydrocycling impacts on habitat. However, using the tools in this fashion (especially with 15-minute time steps) and making management decisions based on these limited results should be tempered by several physical-process and modeling considerations, regardless of whether the differences in the indicators for current operations and run-of-river operations are small or large.

Sediment transport capacity equations assume that the time being simulated is sufficiently long for the physical processes of channel geometry adjustments and mobilization and transport of bed material to stabilize during each time step in order for the equation to accurately determine the average transport during the interval. Most published reports on Yang's equation apply it to average daily discharge.

For purposes purposes of this study, 15-minute time steps were used. Because the flow rates rise and fall as dramatically as they do in this Project, a sensitivity analysis was performed. The records at the North Bend gage and the synthetic hydrograph at Site 4 show that hydrocycling consists of two periods during each day when flow rates are relatively constant, accompanied by two other periods with rapidly changing flow rates between the two plateaus. The relatively equal values (within 5 percent) in Table 5-12 of total sediment transported using daily average discharges compared to 15-minute time steps suggests that the method still provides useful information. However, known physical processes and an understanding of transport capacity calculations need to be considered in any interpretation of the results.

The physical process being approximated by these calculations, which would be the same in a HEC-RAS analysis of aggradation and degradation using the sediment transport module, is that both treat a continuous hydrograph as a sequence of discrete, steady flow events. Once a stream experiences an incremental 15-minute increase in flow during the rising portion of the hydrograph, time must be sufficient for additional material in the bed to mobilize in order to be transported at capacity by the flow. This is unlikely and may not be possible in 15-minute intervals.

Similarly, when flows decline, the capacity to transport sediment is reduced, and the equations are only accurate if the time step being simulated is sufficiently long to change and for the transport rate to stabilize at the capacity rate predicted by the equation.

Aside from these considerations, the relatively equal values (within 5 percent) in Table 5-12 of total sediment transported using daily average discharges compared to 15-minute time steps suggests that the method still provides useful information. With regard to the last row in Table 5-12, the 2003 to 2009 results show that the average annual current operations sub-daily and run-of-river sub-daily effective and dominant discharge values at North Bend are about 40 percent less than the long term (1985 to 2009) values at that site (included in row 3). As shown in the Initial Study Report, Appendix A, Sedimentation Study Report, annual flows go through cycles, having experienced a temporary decline in recent years, resulting in temporary cycling downward of both sediment transport indicators.

These comparisons should not be interpreted as signs of aggradation, degradation, or regime change, and instead are the result of the differences in flows occurring during the two analysis periods (2003 to 2009 versus 1985 to 2009). As was revealed in the Initial Study Report, Appendix A, Figures 5-6 through 5-12, effective and dominant discharges (and total sediment transport) amounts vary every year but cycle around long-term dynamic equilibrium trends, all of which remain well-centered in the braided river regime. Rather than interpreting a decrease or increase in any parameter with or without hydrocycling during any particular time interval as a sign of adverse (or beneficial) impacts on the morphology, the standard of practice requires that the indicator values be inserted in regime relationships to assist with drawing any conclusions in morphology.

5.4.2 Hydraulic Channel Geometry Characteristics

Figures 5-5 through 5-12 present graphs of the width and depth values for each site, for each year and for the study period (2003 to 2009), as well as for both current operations and run-of-river operations. The results show that the channel widths and depths would probably be slightly smaller under run-of-river operations. The differences in channel area (width times depth) between current operations and run-of-river operations are larger just downstream of the Tailrace Return than at North Bend, where there is very little difference.

5.4.3 Regime Analysis

Figures 5-13 and 5-14 show the results of inputting the 2009 (normal year) dominant discharges for current operations and run-of-river operations on Chang's and Lane's regime morphology graphs (see the Initial Study Report, Appendix A, Figures 5-3 and 5-5). All of the points plot in positions well within braided river morphology zones, with none being near any threshold of transitioning to another morphology.

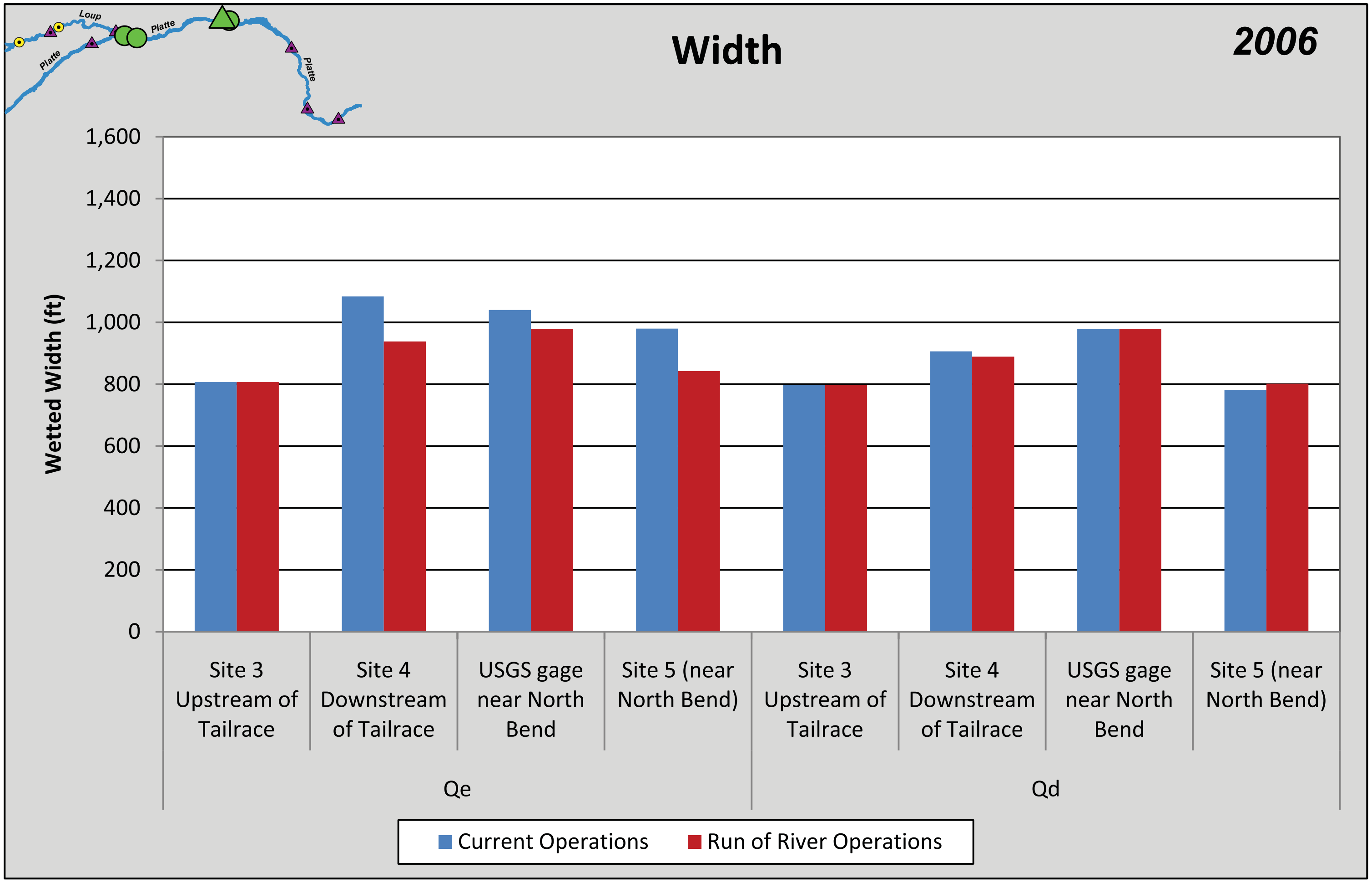


Figure 5-5. Width Values for Current and Run-of-River Operations, 2006

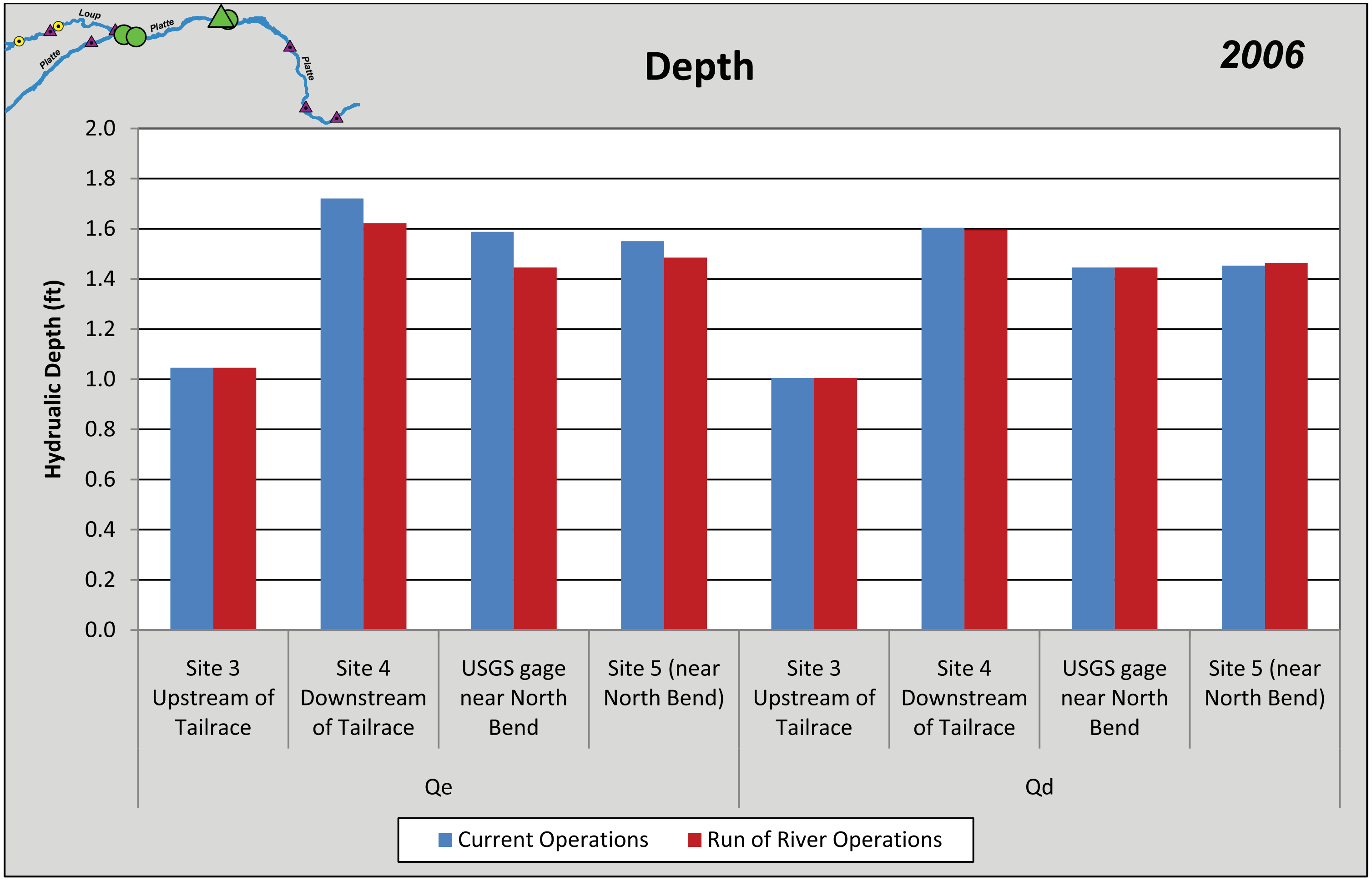


Figure 5-6. Depth Values for Current and Run-of-River Operations, 2006

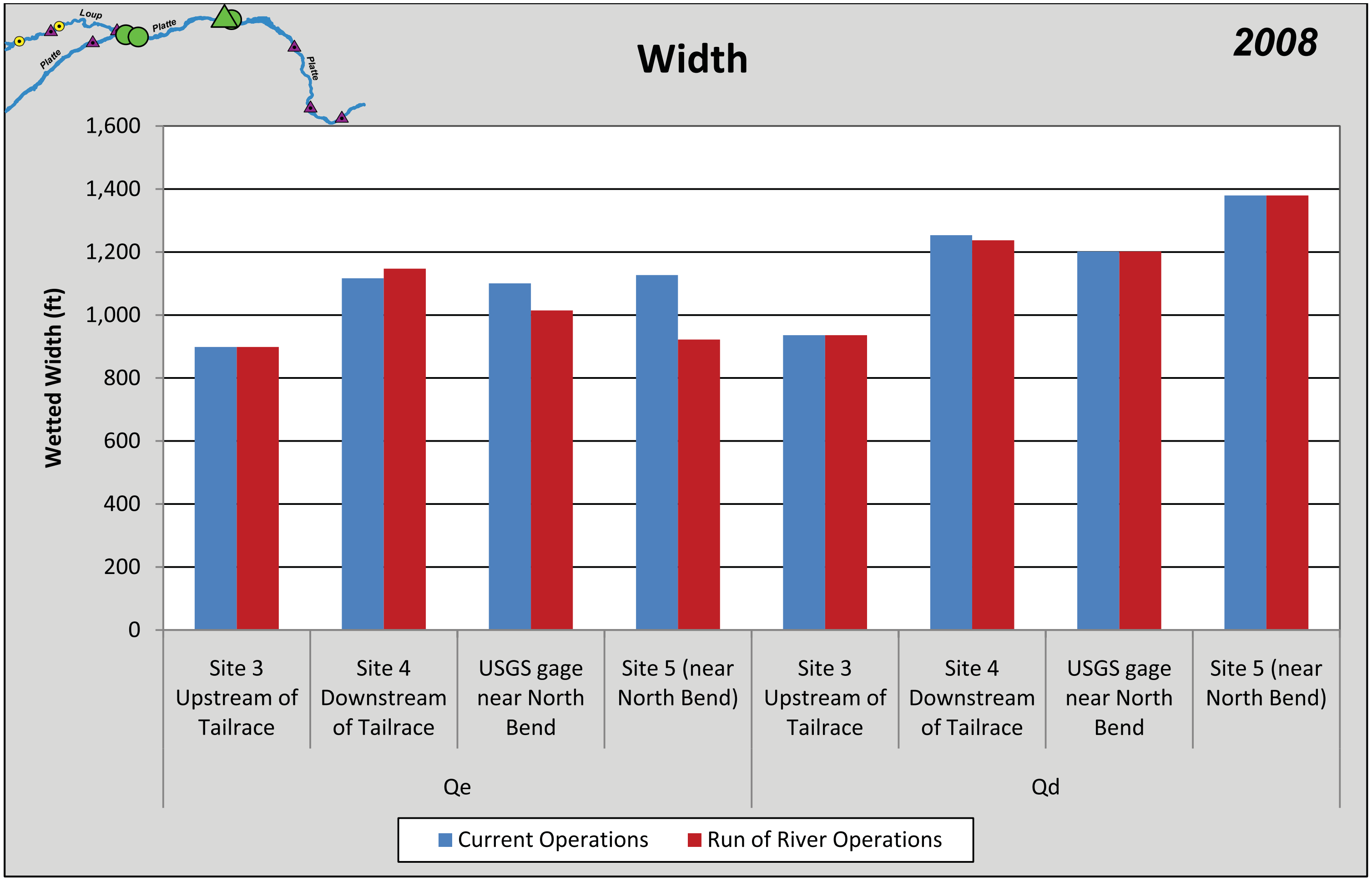


Figure 5-7. Width Values for Current and Run-of-River Operations, 2008

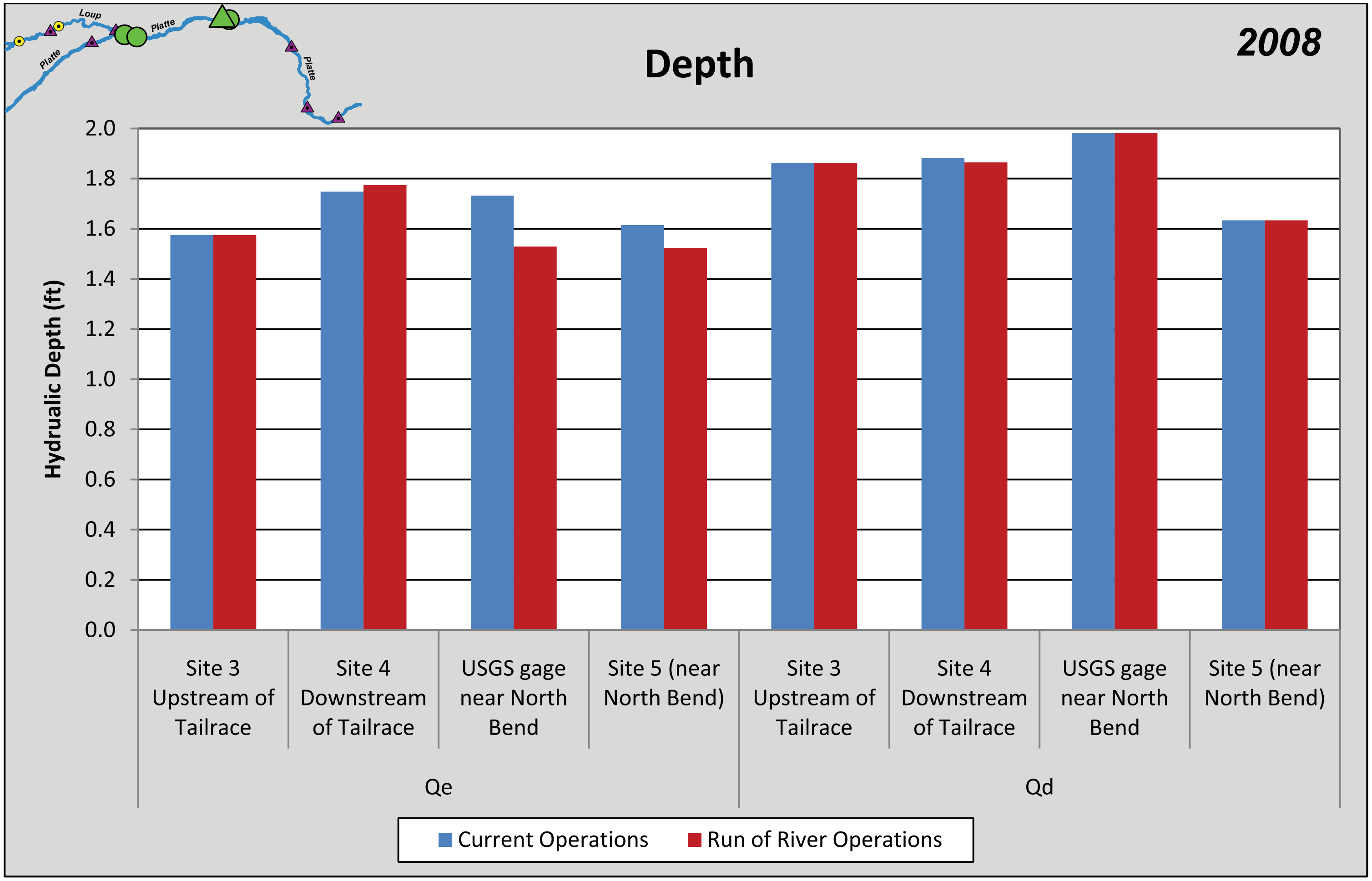


Figure 5-8. Depth Values for Current and Run-of-River Operations, 2008

Figure 5-9. Width Values for Current and Run-of-River Operations, 2009

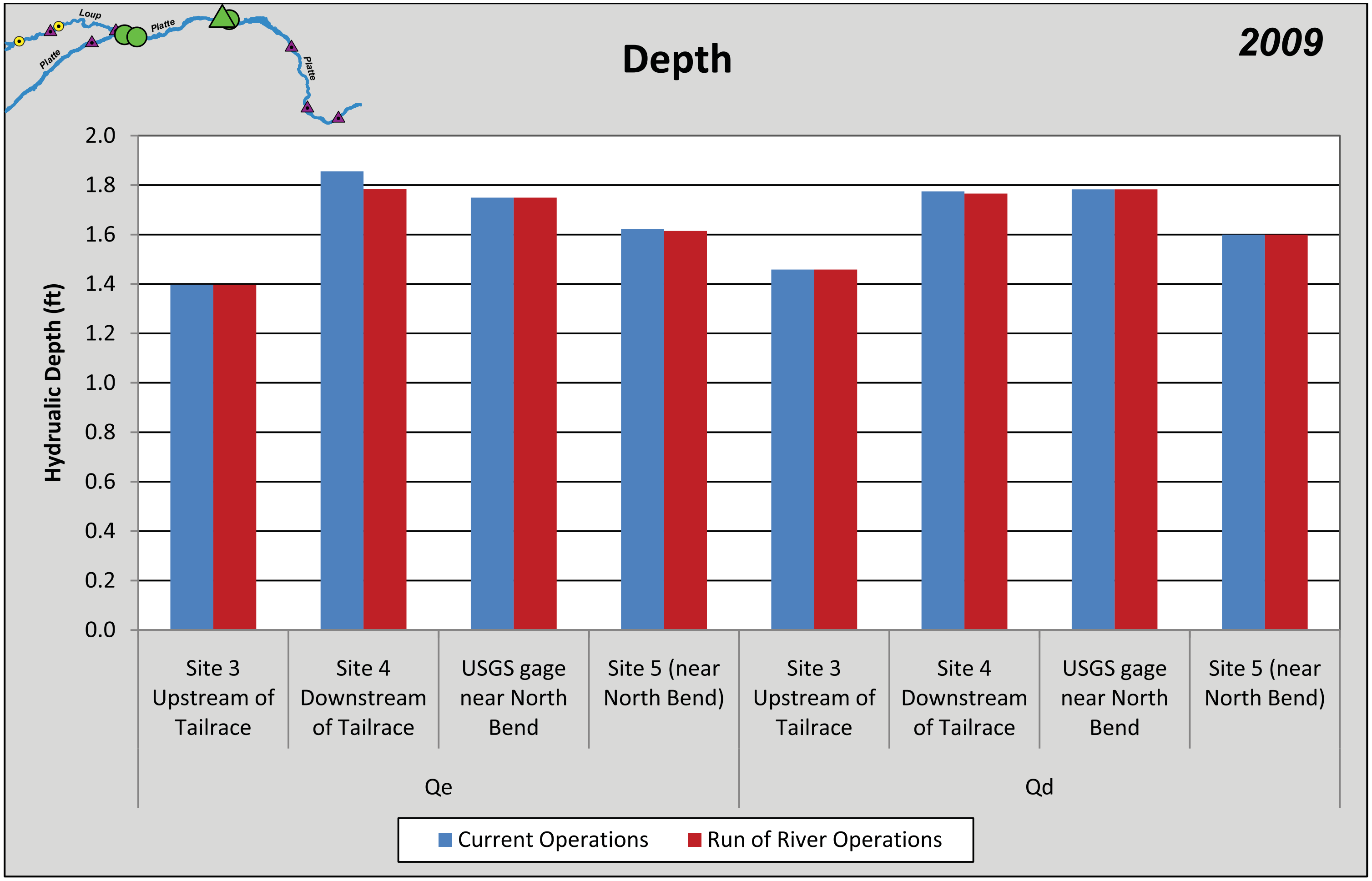


Figure 5-10. Depth Values for Current and Run-of-River Operations, 2009

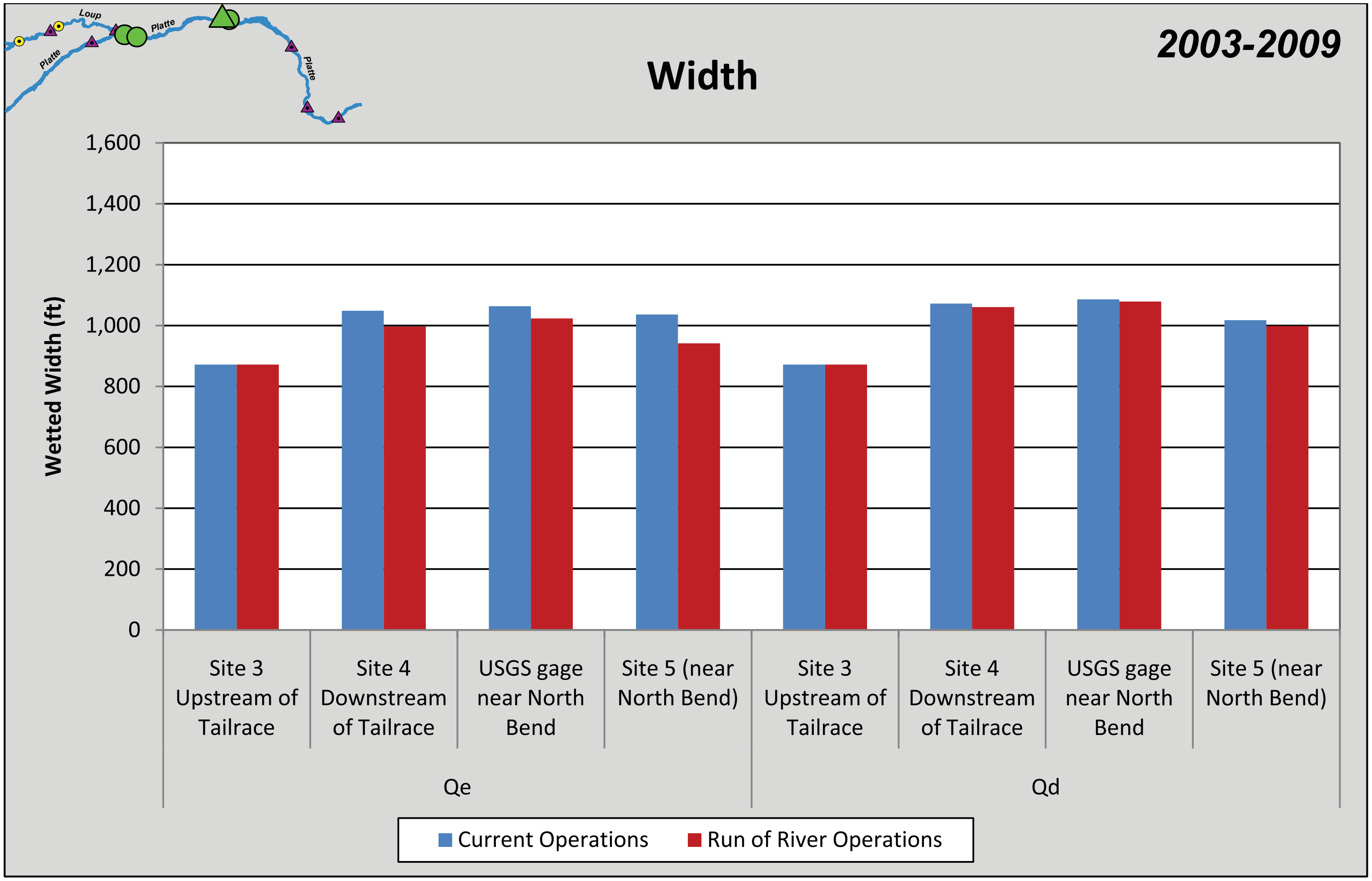


Figure 5-11. Width Values for Current and Run-of-River Operations, 2003-2009

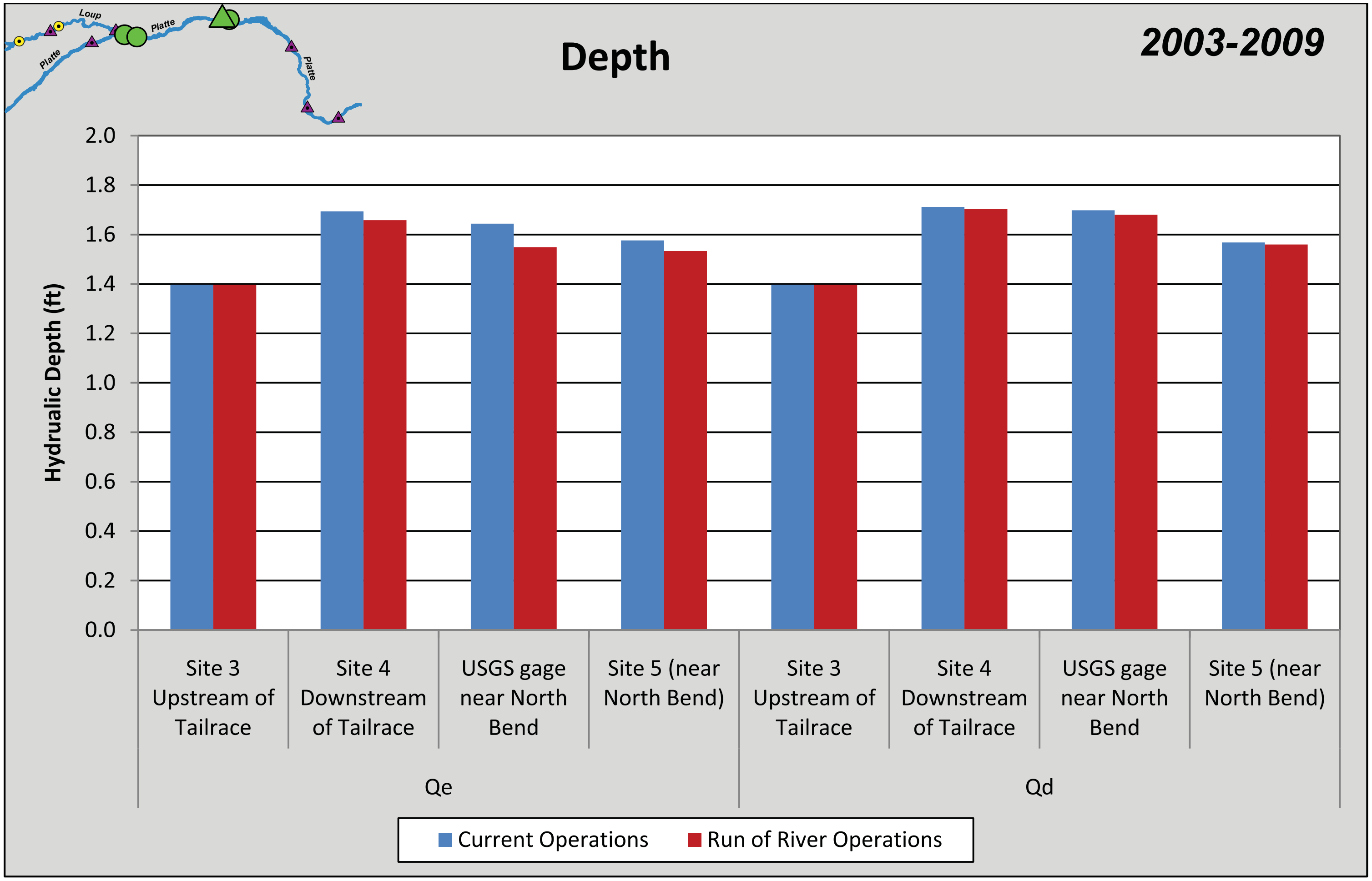
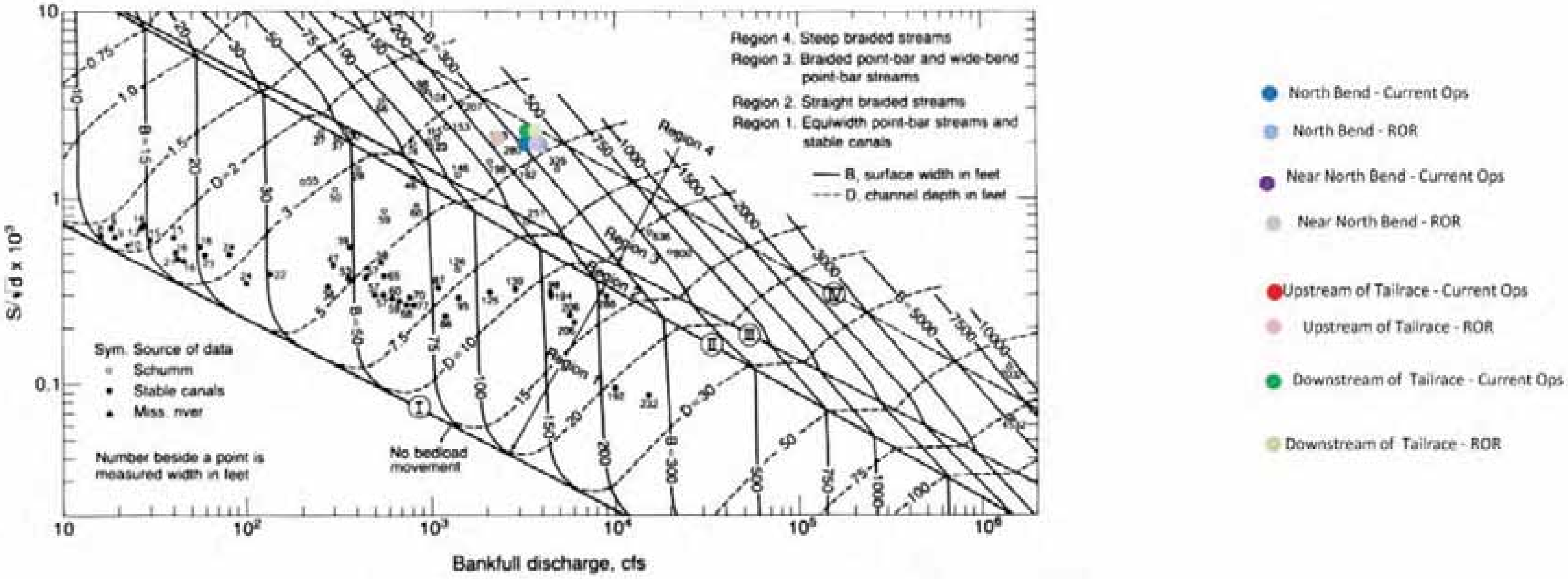
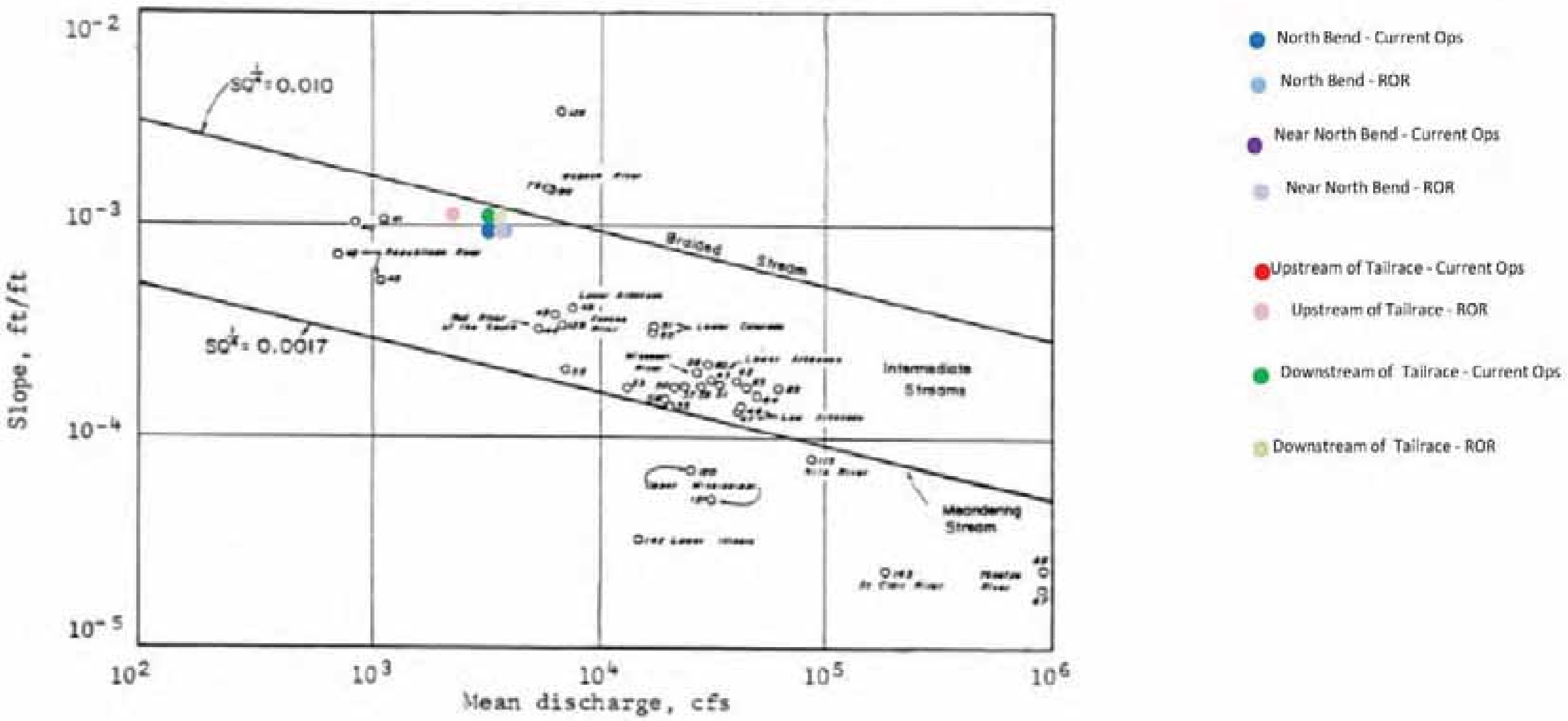


Figure 5-12. Depth Values for Current and Run-of-River Operations, 2003-2009



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 5-13. Chang's (March 1985) Regime Morphology Chart for Sand Bed Rivers with Hydrocycling 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 5-14. Lane's (1957) Regime Morphology Chart for Sand Bed Rivers with Hydrocycling Study Results

USFWS asserted, in a letter to FERC dated June 24, 2009, that hydrocycling of Project flows entering the lower Platte River may affect riverine morphology by 'clearwater' releases causing increased erosion in the reach of the Platte River immediately downstream of the Tailrace Return. However, in a letter dated October 20, 2010, USFWS referenced an article by Joekel and Henbry (2008) and stated that the reach of the Platte River immediately downstream of the Tailrace Return is not in dynamic equilibrium because Figure 11 of the Joeckel and Henbry article shows there is a continued slight decline in channel area. In addition, USFWS believes that the Joekel and Henbry study was at a spatial scale better suited for assessing Project effects on the Platte River than the current methodology for this hydrocycling study.

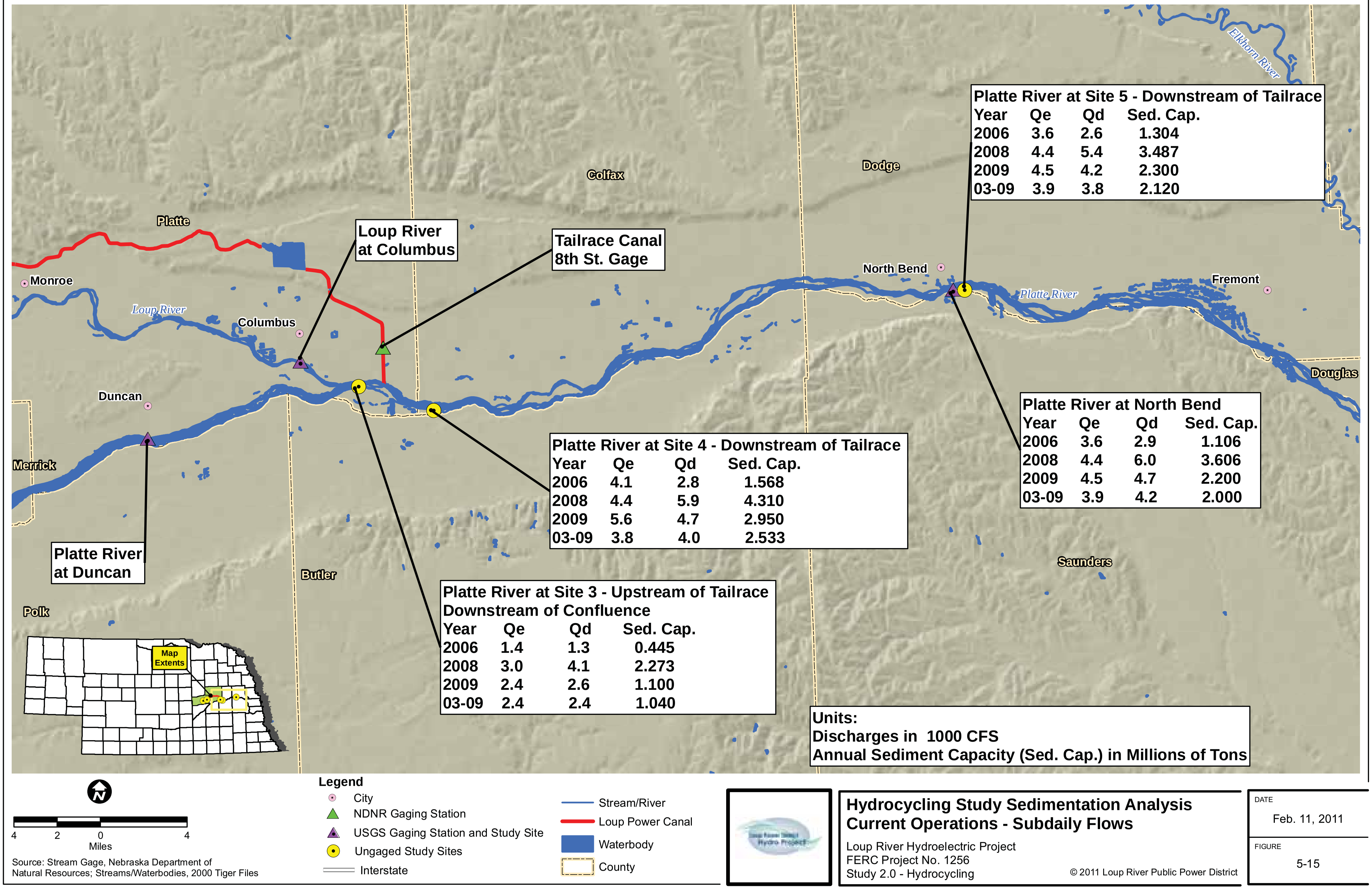
First, Figure 11 of the Joeckel and Henbry article indicates that since approximately 1955, there has been little to no change in channel area. As shown in the cross sections in Attachment A, dramatic changes in cross-section geometry can occur over even short time spans, which is a characteristic of a braided river and not evidence of disequilibrium. Figure 11b of the Joeckel and Henbry article shows that the percentage of change of channel area between 1956 and 2005 is approximately 2 percent (from 80 to 78 percent), all of which occurred between 1994 and 2006, but the same data show that there was no change in percentage of channel area between 1956 and 1994. A 2 percent change in area would likely fall within the degree of uncertainty in the data used, especially when remotely sensed information rather than on-site data are used to determine channel widths and areas.

Further, the results presented in the Initial Study Report, Appendix A, Sedimentation Study Report, and the results presented in the Second Initial Study Report, Appendix A, Sedimentation Addendum, show that the reach was in dynamic equilibrium. The analysis was conducted on a reach basis, is supported by other research, and was considered sufficient to address the equilibrium question near the Tailrace Return. Thus, the results of the Joeckel and Henbry study, which USFWS believes are at a spatial scale better suited for assessing Project effects on the Platte River, in fact corroborate the analysis presented in the Sedimentation Study Report and Sedimentation Addendum.

Lastly, as previously noted, USFWS has asserted that hydrocycled 'clearwater' releases from the Tailrace Return have caused erosion and degradation downstream of the Tailrace Return, yet the Joekel and Henbry (2008) article states that the depth of the channel downstream from the Tailrace Return is unchanged and the channel surface area has consistently decreased. A steady depth and a decrease in surface area are the hallmarks of aggradation, the exact opposite of the degradation that USFWS asserts is occurring.

5.4.4 Spatial Analysis

A spatial analysis that included all of the ungaged sites, including Sites 3 and 4, was described in the Second Initial Study Report, Appendix A, Sedimentation Addendum. The results in Table 5-12 for Sites 4 and 5 and the North Bend gage reveal that there is no significant or consistent difference in any of the three sediment transport indicators with hydrocycling eliminated under run-of-river operations. The conclusions derived in the Initial Study Report, Appendix A, Sedimentation Study Report, regarding spatial variations in the indicators at gaged sites are not altered by this more detailed analysis of hydrocycling impacts on morphology at the ungaged sites.. Figures 5-15 and 5-16 present spatially the data in Tables 5-9 through 5-12 for both current operations and run-of-river operations.



Platte River at Site 5 - Downstream of Tailrace

Year	Qe	Qd	Sed. Cap.
2006	3.6	2.6	1.304
2008	4.4	5.4	3.487
2009	4.5	4.2	2.300
03-09	3.9	3.8	2.120

Platte River at North Bend

Year	Qe	Qd	Sed. Cap.
2006	3.6	2.9	1.106
2008	4.4	6.0	3.606
2009	4.5	4.7	2.200
03-09	3.9	4.2	2.000

Platte River at Site 4 - Downstream of Tailrace

Year	Qe	Qd	Sed. Cap.
2006	4.1	2.8	1.568
2008	4.4	5.9	4.310
2009	5.6	4.7	2.950
03-09	3.8	4.0	2.533

Platte River at Site 3 - Upstream of Tailrace Downstream of Confluence

Year	Qe	Qd	Sed. Cap.
2006	1.4	1.3	0.445
2008	3.0	4.1	2.273
2009	2.4	2.6	1.100
03-09	2.4	2.4	1.040

Units:
Discharges in 1000 CFS
Annual Sediment Capacity (Sed. Cap.) in Millions of Tons

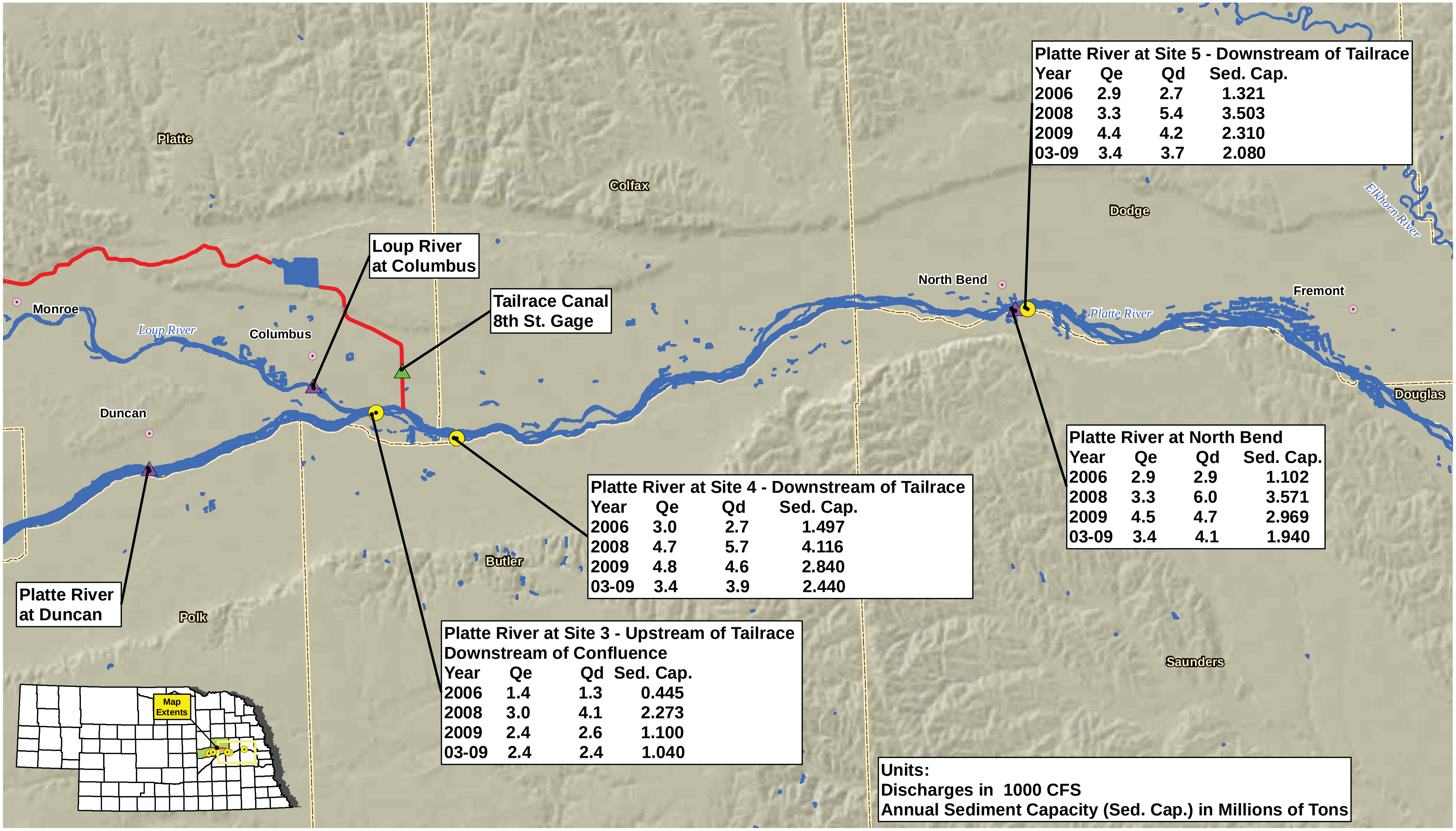
Source: Stream Gage, Nebraska Department of Natural Resources; Streams/Waterbodies, 2000 Tiger Files

Hydrocycling Study Sedimentation Analysis Current Operations - Subdaily Flows

Loup River Hydroelectric Project
FERC Project No. 1256
Study 2.0 - Hydrocycling

DATE
Feb. 11, 2011

FIGURE
5-15



Platte River at Site 5 - Downstream of Tailrace

Year	Qe	Qd	Sed. Cap.
2006	2.9	2.7	1.321
2008	3.3	5.4	3.503
2009	4.4	4.2	2.310
03-09	3.4	3.7	2.080

Platte River at North Bend

Year	Qe	Qd	Sed. Cap.
2006	2.9	2.9	1.102
2008	3.3	6.0	3.571
2009	4.5	4.7	2.969
03-09	3.4	4.1	1.940

Platte River at Site 4 - Downstream of Tailrace

Year	Qe	Qd	Sed. Cap.
2006	3.0	2.7	1.497
2008	4.7	5.7	4.116
2009	4.8	4.6	2.840
03-09	3.4	3.9	2.440

Platte River at Site 3 - Upstream of Tailrace Downstream of Confluence

Year	Qe	Qd	Sed. Cap.
2006	1.4	1.3	0.445
2008	3.0	4.1	2.273
2009	2.4	2.6	1.100
03-09	2.4	2.4	1.040

Units:
Discharges in 1000 CFS
Annual Sediment Capacity (Sed. Cap.) in Millions of Tons

4 2 0 4
Miles

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

Hydrocycling Study Sedimentation Analysis
Run of River Operations - Subdaily Flows

Loup River Hydroelectric Project
FERC Project No. 1256
Study 2.0 - Hydrocycling

DATE
Feb. 11, 2011

FIGURE
5-16

5.5 Objective 4 – To identify material differences between hydrocycling (current operations) and run-of-river operations in potential effects on habitat of the interior least tern, piping plover, and pallid sturgeon.

5.5.1 Literature Review and Comparison to Other Rivers – Interior Least Tern and Piping Plover

Other river reaches with interior least tern and piping plover nesting populations and flow regime modifications, such as flood storage and hydropower dams and associated reservoirs, were reviewed and compared to Project operations and conditions on the lower Platte River. Table 5-13 summarizes the other rivers' structures, morphology, bird numbers, and flow modification operations.

Discussion

Denison Dam and Keystone Dam

USACE has conducted bird surveys from the 1990s to the present below the Denison and Keystone dams (USACE, June 26, 2009). Interior least tern surveys are currently conducted only below the dam, but colonies may occur upstream as well. A direct correlation between flow releases from the dams and the locations of the interior least tern colonies has not been evaluated (American Bird Association, June 22, 2009).

The location of interior least terns appears to correlate directly to the areas of creation of their habitat (sandbars). If flood conditions occur on a river such as the Arkansas or Red River, the potential for sandbar creation above the ordinary high water mark occurs. Sandbars created above the ordinary high water mark are considered potential interior least tern habitat for the remainder of the nesting season. This creation of sandbars also requires rivers with higher sediment loading. Therefore, there is no relationship found at this point to hydropower flow releases and the location of interior least tern nesting colonies. The most appropriate relationship between river morphology and the locations of nesting interior least tern colonies appears to correlate to flooding conditions and sediment loading of the rivers (American Bird Association, June 22, 2009). In a study conducted by Leslie et al. (2000), it was found that periodic high water releases due to flood flows prior to the nesting season created habitat and increased interior least tern population numbers. The Denison and Keystone dams differ in many ways from the Columbus Powerhouse. The Columbus Powerhouse has a maximum flow of 4,800 cfs, while the Denison and Keystone dams have a maximum flow of 12,000 cfs. Additionally, Denison and Keystone dams have the capability of storing large flow events, while under these same scenarios, the Project does not divert flows and large flows are bypassed.

Table 5-13. Other River Operation Comparison – Interior Least Tern and Piping Plover

Structure	River	Description	Morphology	Flow Information (below the structure)			Interior Least Tern Data (Piping Plover Data where available)	Frequency Water is Released[3]	Quantity of Water Released	References
				Average Annual Flows	Maximum Flow Capacity	Flow Capacity Range				
Project Diversion Weir[1]	lower Platte	Diversion Weir installed in 1937 for power generation on the Loup River	Sand bottom, braided system with several smaller channels dissecting sandy deposits into several elevated bar islands	Min: 2,170 cfs Mean: 4,500 cfs Max: 10,070 cfs USGS Gage 06796000	4,800 cfs through the units	1,000 to 4,800 cfs	Loup River confluence to Missouri River confluence: 53 adults and 2 colonies on-river (2005) NGPC data available from 1983-2009	During high-demand periods: daily hydrocycling Monday through Friday and mostly in the evenings and afternoons during summer	Typically the same amount being taken into the system – between 1,000 to 4,800 cfs	Project PAD, USGS gaging station 06796000 website
Denison Dam	Red	Dam and associated reservoir (Lake Texoma) installed in 1944 for flood storage and power generation; two national wildlife refuges have been developed along shores of the reservoir	Classic braided river before flowing into Lake Texoma; meandering system downstream of the dam	Min: 1,120 cfs Mean: 4,777 cfs Max: 16,030 cfs USGS Gage 07331600	Above 12,000 cfs through the units	0 to 12,000 cfs	Below Denison Dam to Index, AR: 812 adults and 48 colonies (2005) USACE Tulsa data available from 2002-2008	During flood conditions During high-demand periods: daily hydrocycling	Above 12,000 cfs during flood conditions; baseline around 6,000 cfs	1, 2, 3, 4, 6, 7, 11
Keystone Dam	Arkansas	Dam and associated reservoir (Lake Keystone) installed in 1964 for flood storage and power generation	Meandering system; very sandy substrate allowing for continuous changes of the geomorphology	Min: 1,810 cfs Mean: 8,910 cfs Max: 22,930 cfs USGS Gage 07164500	Above 12,000 cfs through the units	0 to 12,000 cfs	Keystone Dam to Zink Lake: 54 adults and 1 colony (2005) USACE Tulsa data available from 2002-2008	During flood conditions During high-demand periods: daily hydrocycling	Above 12,000 cfs during flood conditions; baseline around 6,000 cfs	5, 6, 7, 11
Fort Randall Dam	Missouri	Dam and associated reservoir (Lake Francis Case) installed in 1954 for energy production; other purposes are flood damage reduction, navigation support, irrigation, municipal water supply, fish and wildlife management, and recreation	Remnant unchannelized length between Lake Francis Case and Lewis and Clark Lake; displays a moderate to high degree of braiding with frequent sandbars and islands; meandering wide channel; few side channels and backwaters present, except at the lower end in Lewis and Clark Lake delta	Calculated Outflow – Min Daily Discharge: 0 cfs Mean Daily Discharge: 26,100 cfs Max Daily Discharge: 67,500 cfs No USGS gages recording flow in this reach	44,500 cfs	NA	Fort Randall Dam to confluence with Niobrara River: 76 adults and 5 colonies (2005); Most recent count available: 237 adult terns, 138 adult plovers (2009) USACE Omaha data available from 1986-2009	During high-demand periods: daily hydrocycling, but see conditions below During fish spawn period: pool elevation near 1,355 feet MSL During nesting period: peak stages, daily average flows increased every third day to preserve the capability of increasing releases later in the summer with little to no incidental take if drier conditions occur	Peaking is limited to 7 of 8 power production units for no more than 6 hours per day. Every Third Day Cycling has also been used in this reach.	8, 9, 10, 11, 12, 13, 14

Structure	River	Description	Morphology	Flow Information (below the structure)			Interior Least Tern Data (Piping Plover Data where available)	Frequency Water is Released[3]	Quantity of Water Released	References
				Average Annual Flows	Maximum Flow Capacity	Flow Capacity Range				
Gavins Point Dam	Missouri	Dam and associated reservoir (Lewis and Clark Lake) installed in 1956 originally for power production and for navigation; other purposes are flood control, irrigation, improved water supply, fish and wildlife management, and recreation	Downstream of the dam; fairly wide meandering system with many backwaters, side channels, and man-made sandbars; morphs downstream of Sioux City, Iowa, into a single channel with stabilized river banks that allows commercial barge navigation	Calculated Outflow – Min Daily Discharge: 6,000 cfs Mean Daily Discharge: 28,900 cfs Max Daily Discharge: 70,100 cfs Average Annual Flow – Min: 15,640 cfs Mean: 18,450 cfs Max: 20,830 cfs USGS Gage 06467500	36,000 cfs	NA	Gavins Point Dam to Ponca State Park; 476 adults and 25 colonies (2005); Most recent count available: 211 adult terns, 238 adult plovers (2009) USACE Omaha data available from 1986-2009	Not operated to provide peaking power. Daily releases from Gavins Point are constant to allow for stable downstream navigation and other project purposes. Prior to interior least tern and piping plover nesting season: adjusted to meet the water-level targets During interior least tern and piping plover nesting season: regulated via several methods to encourage the birds to nest at high elevations Every Third Day Cycling has been used in early nesting season; Steady Release and Flow to Target have been used. Currently, Gavins Point is practicing a combination flow regime of Steady Release – Flow to Target.	Every Third Day Cycling: In early nesting season, discharge increases every third day by 8,000 to 10,000 cfs until a future navigation target is met and then decreases. Steady Release: Discharge to potential levels of future navigation targets to discourage nesting at future navigation elevations Flow to Target: Discharge increases as demand for downstream navigation waters increases	8, 9, 11, 12, 14

Notes:

NA = Not available.

[1] The Project Diversion Weir is approximately 35 miles upstream of the confluence of the Loup and Platte rivers. Diverted water is released back into the lower Platte River at approximately RM 100 (downstream of the Loup and Platte river confluence), and hydrocycling effects on the hydrograph occur downstream of the Tailrace Return on the lower Platte River.

[2] This flow includes water from the central Platte River, upstream of the Tailrace Return.

[3] During the bird nesting season (April through September).

Sources:

[1] USGS. 2011b. USGS Surface-Water Annual Statistics for Texas. USGS 07331600 Red River at Denison Dam near Denison, TX. Available online at http://waterdata.usgs.gov/tx/nwis/annual/?referred_module=sw&site_no=07331600&por_07331600_9=232347,00060,9,1924,2009&year_type=W&format=html_table&date_format=YYYY-MM-DD&rdb_compression=file&submitted_form=parameter_selection_list.

[2] USACE. No date. WCDS Tulsa District U.S. Army Corps of Engineers. Available online at http://www.swt-wc.usace.army.mil/.

[3] University of Utah. No date. Weather conditions fro DSNT2. Available online at http://mesowest.utah.edu/cgi-bin/droman/meso_base.cgi?stn=DSNT2&product=&time=LOCAL.

[4] The Geological Society of America. April 12, 2002. The Red River Delta, Lake Texoma: A Remote Sensing Study of Delta. Available online at http://gsa.confex.com/gsa/2002SC/finalprogram/abstract_33033.htm.

[5] USGS. 2011a. Site Map for Oklahoma. USGS 07164500 Arkansas River at Tulsa, OK. Available online at http://waterdata.usgs.gov/ok/nwis/nwismap/?site_no=07164500&agency_cd=USGS.

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[7] USACE. June 23, 2009. Personal communication between Dallas Tomlinson, USACE, and Rebecca Baker, HDR.

[8] HDR. May 20, 2009. Gavin's Point Dam Cycling and Flow Releases for Terns and Plovers. Technical memorandum from Melissa Marinovich, HDR, to Lisa Richardson, Bill Sigler, and Matt Pillard, HDR.

[9] USACE. December 2008. Missouri River Mainstem System 2008-2009 Final Annual Operating Plan. Missouri River Basin Water Management Division, Northwestern Division, U.S. Army Corps of Engineers, Omaha, Nebraska.

[10] USACE. No date. Fort Randall Dam & Powerplant. Available online at http://www.nwo.usace.army.mil/html/Lake_Proj/fortrandall/dam.html.

[11] Lott, C.A. November 2006. Distribution and Abundance of the Interior Population of the Least Tern (*Sternula antillarum*), 2005. U.S. Army Corps of Engineers. ERDC/EL TR-06-13.

[12] Tracy-Smith, E. 2006. Relation of Missouri River Flows to Sandbar Morphology with Implications for Selected Biota. Master's Thesis. University of Missouri, Columbia, Missouri.

[13] Elliot, C.M., R.B. Jacobsen, and A.J. DeLonay. March 2004. "Physical Aquatic Habitat Assessment, Fort Randall Segment of the Missouri River, Nebraska and South Dakota." USGS Open-file Report 2004-1060.

[14] USACE. March 2006. Missouri River Mainstem Reservoir System Master Water Control Manual Missouri River Basin. Omaha, Nebraska.

Fort Randall Dam and Gavins Point Dam

During the nesting season, releases are briefly increased every several days to encourage interior least terns and piping plovers to nest above the normal water level. Although this method has not been extensively studied, nesting data and observational data have shown that this method appears to be working and is successfully encouraging the birds to nest high enough to avoid inundation later in the year when releases are used for navigation or energy production; however, there are no published studies yet (USACE, June 2, 2009). Once egg hatching has begun, the higher releases are suspended to avoid inundation of nests on lower level sandbars (USACE, March 2006).

Conclusions

Almost all other river sections that were identified as important to interior least terns and piping plovers (based on population numbers) include large-scale dams with limited flow releases. Although daily hydrocycling occurs on some of the other rivers, limited information was found regarding the potential effect of this practice on the birds. Large releases to relieve flooding or reach navigation targets appear to have a measurable effect on interior least terns and piping plovers and their respective habitat in these reaches. The Project does not release water for flooding or navigation and does not have the capability to retain water for a prolonged period, such as these other dams do. The other dams reviewed have large storage reservoirs and are able to release large quantities of water to meet electricity needs, whereas the Project differs from a traditional dam in that it has no significant dam structure, no instream reservoir, and no project spillway. The regulating reservoir is used to provide capacity to pond water during low electrical demand hours of the day and release water during the high electrical demand hours of the day. During low electrical demand hours, flow through the Columbus Powerhouse normally drops to zero to maximize ponding. Maximum releases are 4,800 cfs during hours of peak electrical demand. Therefore, it is difficult to compare the Project's operations and habitat on the lower Platte River to these other, larger structures and the habitat that exists downstream on these larger rivers.

While studies have not been conducted for the direct purpose of determining the effects of daily hydrocycling on interior least terns and piping plovers, changes in operations at Fort Randall Dam in accordance with conditions set forth in the USFWS amended Biological Opinion (BO) (December 16, 2003) have shown that releasing at higher rates prior to the nesting season and during the early nesting season has encouraged the birds to nest at a higher elevation and prevented nest losses from hydrocycling. This is similar to the results of the nest inundation study (as presented in Section 5.3) in that current operations (that include hydrocycling) had fewer instances of exceeding pre-nesting season benchmarks than did run-or-river operations. Additionally, a study conducted by Leslie et al. (2000) on the effects of hydropower and flood-control operations of the Keystone Dam on the Arkansas River on interior least tern populations found that daily hydropower operations were not affecting the birds; however, subjecting nesting habitat to periodic high river flows prior to the nesting season could be beneficial because availability and quality of the habitat increased with flooding and population numbers expanded in a year following the flood. Because the Project does not have control over stopping or allowing large flood flows to affect the lower Platte River, the Project's effects from daily hydrocycling on sandbar formation are minor when compared to the effects from large flood flows.

5.5.2 Literature Review and Comparison to Other Rivers – Pallid Sturgeon

Other river reaches with pallid sturgeon populations include the Missouri River reaches below Fort Randall and Gavins Point dams as well as the Yellowstone River below Intake, Montana. The morphological and ecological characteristics of each of these reaches are described below and compared to the reach of the lower Platte River below the Tailrace Return confluence. Table 5-14 summarizes the other rivers' structures, fisheries habitat, and hydrocycling operations.

Discussion

Fort Randall Dam

Fort Randall Dam, operated by USACE, is located on the Missouri River within South Dakota with the primary purpose of power generation. This stretch of river is defined by Lewis and Clark Lake, the most downstream reservoir of the Missouri River, formed by the closure of Gavins Point and by Fort Randall Dam on the upstream side.

Maximum depth of the riverine section of Lewis and Clark Lake is about 12 meters and channel width ranges from 45 to 90 meters (Shuman et al., April 12, 2010). Sediment from the Niobrara River has formed a large braided delta near the upper portions of Lewis and Clark Lake and has slowly progressed downriver into the reservoir. The riverine section of Lewis and Clark Lake retains many natural characteristics, such as sandbars, sandbar pools, side channels, backwater areas, islands, old-growth riparian forest, and year-round flows (Shuman et al., April 12, 2010). However, water levels can substantially fluctuate daily and seasonally as historical temperature and flow have been altered due to the operation of Fort Randall Dam (Pegg et al., 2003; Troelstrup and Hergenrader, 1990).

Table 5-14. Other River Operation Comparison – Pallid Sturgeon

Structure	River	Description	Morphology	Average Discharge	Hydrocycling Operations	Primary Substrate	Hypolimnetic Releases	References
Project Diversion Weir[1]	lower Platte	Diversion Weir installed in 1937 for power generation on the Loup River	Sand bottom, braided system with several smaller channels dissecting sandy deposits into several elevated bar islands	4,500 cfs	During high-demand periods: daily hydrocycling Monday through Friday and mostly in the evenings and afternoons during summer	Sand	None	1, 2, 3
Intake Dam	Yellowstone	Dam installed by the Bureau of Reclamation to create sufficient head to allow diversion of water into the main canal for irrigation	Stream remains in a relatively natural state below Intake Dam.	24,720 cfs	No cycling operations	Cobble and gravel	None	4, 5, 6, 7, 8
Fort Randall Dam	Missouri	Dam and associated reservoir (Lake Francis Case) installed in 1954 for energy production; other purposes are flood damage reduction, navigation support, irrigation, municipal water supply, fish and wildlife management, and recreation	Remnant unchannelized length between Lake Francis Case and Lewis and Clark Lake; displays a moderate to high degree of braiding with frequent sandbars and islands; meandering wide channel; few side channels and backwaters present, except at the lower end in Lewis and Clark Lake delta	26,100 cfs	During high-demand periods: daily hydrocycling, but see conditions below During fish spawn period: pool elevation near 1,355 feet MSL	Sand	Present	9, 10, 11, 12
Gavins Point Dam	Missouri	Dam and associated reservoir (Lewis and Clark Lake) installed in 1956 originally for power production and for navigation; other purposes are flood control, irrigation, improved water supply, fish and wildlife management, and recreation	Downstream of the dam, fairly wide meandering system with many backwaters, side channels, and man-made sandbars; morphs downstream of Sioux City, Iowa, into a single channel with stabilized river banks that allows commercial barge navigation	28,900 cfs	Not operated to provide peaking power. Daily releases from Gavins Point are constant. A large spring release has been implemented to stimulate spawning migration behavior in fish.	Sand	Present	13, 14, 15, 16

Note:

[1] The Project Diversion Weir is approximately 35 miles upstream of the confluence of the Loup and Platte rivers. Diverted water is released back into the lower Platte River at approximately RM 100 (downstream of the Loup and Platte river confluence), and hydrocycling effects on the hydrograph occur downstream of the Tailrace Return on the lower Platte River.

Sources:

[1] Loup Power District. October 16, 2008. Pre-Application Document. Volume 1. Loup River Hydroelectric Project. FERC Project No. 1256.

[2] Peters, Edward J., and James E. Parham. October 27, 2008. Pallid Sturgeon Literature Review. Final Report to the Platte River Recovery Implementation Program.

[3] National Research Council. 2005. *Endangered and Threatened Species of the Platte River*. Washington, D.C.: The National Academies Press.

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[8] Jaeger, M.E. 2004. An Empirical Assessment of Factors Precluding Recovery of Sauger in the Lower Yellowstone River: Movement, Habitat Use, Exploitation, and Entrainment. Masters Thesis. Montana State University, Bozeman, MT.

[9] Shuman, D.A., R.A. Klumb, and G.A. Wanner. April 2009. 2008 Annual Report, Pallid Sturgeon Population Assessment and Fish Community Monitoring for the Missouri River: Segments 5 and 6. Prepared for the U.S. Army Corps of Engineers – Missouri River Recovery Program. United States Fish and Wildlife Service. Great Plains Fish and Wildlife Conservation Office. Pierre, SD.

[10] Shuman, D.A., R.A. Klumb, K.L. Grohs, and G.A. Wanner. April 12, 2010. 2009 Annual Report, Pallid Sturgeon Population Assessment and Associated Fish Community Monitoring for the Missouri River: Segments 5 and 6. Prepared for the U.S. Army Corps of Engineers – Missouri River Recovery Program. United States Fish and Wildlife Service. Great Plains Fish and Wildlife Conservation Office. Pierre, SD.

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The upper portion of this stretch of the river (between the dam and the Niobrara River confluence) has depressed water temperatures and low turbidity caused by hypolimnetic discharges from Fort Randall Dam (Shuman et al., April 2009). The lower portion of this reach (from the Niobrara River confluence and the headwaters of Lewis and Clark Lake) has increased water temperatures and turbidity caused by inflows from the Niobrara River. The lower section of the reach includes the large braided delta formed in the headwaters of Lewis and Clark Lake. Below the Niobrara confluence, the river becomes increasingly braided in the transition zone between the riverine portion of this segment and Lewis and Clark Lake (Elliot et al., March 2004). Diel water levels within this stretch are subjected to changes of almost 1 meter, and lowest daily flows generally occur at 6:00 a.m. with peak flows occurring between 12:00 and 7:00 p.m. in support of power generation demands (USACE, March 2006).

Surveys for pallid sturgeon have been conducted on the reach between Fort Randall Dam and the headwaters of Lewis and Clark Lake since 2003 (Shuman et al., April 2009). Annual capture rates of pallid sturgeon in this reach have increased since 2004, but may be biased due to new sampling methods in 2005 and 2009. Capture rates have also coincided with restocking efforts within the Missouri River (Shuman et al., April 12, 2010). This reach of the Missouri River was divided into two sections. The top section was between the dam and the confluence of the Niobrara River, and the bottom section was between the Niobrara River confluence and the headwaters of Lewis and Clark Lake. Surveyors found that pallid sturgeon had no affinity towards either the upper or lower portions of this stretch of river (Shuman et al., April 12, 2010), though summaries of the 7 years of monitoring within this stretch of river found that pallid sturgeon were congregating in three areas: one area was 1 mile downstream of the Niobrara confluence and two areas were within the braided channel caused by the Niobrara confluence. Ninety-nine percent of pallid sturgeon captured were found within channel border mesohabitat.[8] Jordan et al. (2006) found that pallid sturgeon selected main channel habitat associated with large sandbars over other types (for example, side channels).

Gavins Point Dam

Gavins Point Dam, operated by USACE, is located on the Missouri River along the South Dakota and Nebraska border. The dam provides stable releases to downstream areas, allowing for reliable navigation and water supplies. The natural sediment transport is impeded by the dam, causing downstream incision and decreased turbidity. Most of the Missouri River downstream of Gavins Point Dam is a single channel with stabilized river banks that allows commercial barge navigation.

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[8] Channel border mesohabitat is a visually distinct habitat within a stream or river.

Though greatly reduced, other habitats are found in this stretch, including sandbars, backwaters, secondary channels, and wooded islands (Stukel et al., 2009). Bank stabilization is sporadic, allowing some erosion to occur as the channel meanders from bank to bank.

Discharge from Gavins Point Dam typically peaks in late summer at about 30,000 cfs and declines to near 12,000 cfs during the winter. Diel variations are not as substantial as those found upriver (between Fort Randall and Gavins Point dams). Much of this river segment is less than 2 meters deep, but holes deeper than 15 meters exist (Stukel et al., 2009). River width is highly variable below the dam. The James and Vermillion rivers are major tributaries contributing to flows in this reach.

Surveys for pallid sturgeon have been conducted on Gavins Point Dam for numerous years. The MRRP has been conducting population assessments in the reach below Gavins Point Dam to Ponca, Nebraska, since 2005. Pallid sturgeon capture rates have generally increased in the last 5 years, but those rates are concurrent to stocking efforts in the Missouri River (Stukel et al., 2009). Additionally, improved capture methodology may also explain the increase in capture rates.

The river reach below Gavins Point Dam has a highly altered flow regime and high width to depth ratios. Annual suspended sediment load is low in this section due to the retention of sediment in Lewis and Clark Lake. Although natural spawning substrate is available in this stretch and channel complexity is relatively high, low turbidity and water quality conditions likely limit habitat functions for the pallid sturgeon (DeLonay et al., 2009).

Intake Dam – Yellowstone River

Intake Dam is located in Montana on the Yellowstone River approximately 110 km from its confluence with the Missouri River. Intake Dam is owned by the Bureau of Reclamation and was built as a diversion dam to provide irrigation water to the region. The purpose of the dam is to create sufficient head to allow diversion of water into the main canal for distribution throughout the rest of the project. The diversion dam crest becomes fully submerged at river flows above about 20,000 cfs; however, the dam continues to produce some head drop to flows in excess of 100,000 cfs.

The Yellowstone River below Intake Dam consists primarily of gravel and cobble throughout most of the lower reaches, but fine sediment and sand is common within 50 km of the Missouri River confluence (Bramblett and White, 2001). Islands and bars range from large vegetated islands to unvegetated point and mid-channel bars (White and Bramblett, 1993). Substrate is primarily gravel and cobble upstream of river kilometer 50 and is primarily fines and sand below (Bramblett and White, 2001).

In this section of the Yellowstone River, studies found that pallid sturgeon were located most commonly in areas with sandbars and sandy substrate (Bramblett and White, 2001; Tews, 1994). In the Yellowstone River, pallid sturgeon used bottom velocities that ranged from 0.0 to 1.37 m/s (Bramblett and White, 2001). Surveys conducted at the confluence of the Yellowstone to the Missouri found that pallid sturgeon selected channel border mesohabitats. During the last 4 years of monitoring on Missouri River in the reach including the Yellowstone River confluence, the majority of pallid sturgeon was collected in cross-over macrohabitats, inside bend macrohabitats, or outside bend macrohabitats (Wilson et al., 2009).

The lower portions of the Yellowstone Dam has also retained much of their natural riverine features. Though Intake Dam is present on the river, much of the morphological features of the river remain the same. The stream has coarse substrates that are thought to be conducive to pallid sturgeon spawning, yet none has been recorded for this reach. Studies have suggested that the dam impedes upstream migration of pallid sturgeon and their access to spawning and larval drift habitats (Bramblett and White, 2001; Helfrich et al., 1999). Furthermore, entrainment studies on other native fish in the Yellowstone River suggest that once passage is provided, pallid sturgeon may be entrained in the main canal (Heibert et al, 2000; Jaeger, 2004).

Conclusions

Morphology of the rivers, along with dam structure and dam purpose, differs significantly between these reaches. For these reasons, it is difficult to make inferences about pallid sturgeon habitat availability and hydrocycling effects on the Platte River by comparing it to the stream reaches on the Missouri and Yellowstone rivers. Only Fort Randall Dam produces diel fluctuations in flow regime (based on power production needs). Gavins Point Dam produces flow alterations on a seasonal basis for flood control and navigation. Intake Dam has modified flow regime for the lower stretch of the Yellowstone River, but those modifications are relatively stable. All dams create a barrier for fish passage, though the effectiveness as a barrier varies among dams.

Habitat below each dam varies among reaches. The Yellowstone River below Intake Dam consists of gravel and cobble in some areas while sand/silt is common in the lowest reaches just above the Missouri River. Below Fort Randall Dam, habitat and stream morphology change significantly from directly below the dam to more lake-like features above Lewis and Clark Lake. Gavins Point Dam produces lower temperatures and low turbidity directly below the dam, but both increase as tributaries merge with the Missouri River and erosion increases downstream.

Pallid sturgeon have been collected throughout these stream reaches. Though precise habitat preferences of pallid sturgeon are not yet well-known, surveys completed in the last decade suggest that pallid sturgeon select turbid, warm, flowing waters. In the upper Missouri River and the Yellowstone River, studies found that pallid sturgeon were located most commonly in areas with sandbars and sandy substrate (Bramblett and White, 2001; Tews, 1994). Furthermore, pallid sturgeon have been shown to use habitat with large ranges of characteristics (such as temperature, flow, and depth) depending on what is available. Pallid sturgeon often select from the best habitat available, not necessarily the most ideal habitat for the species (National Research Council, 2005; Elliot et al., March 2004; Jacobsen et al., 2009).

The habitat preferences of pallid sturgeon can also change depending on the life stage of the fish (Wildhaber et al., 2007). Shallow water habitat is thought to be important for larval and juvenile pallid sturgeon and also for other native fish that juvenile pallid sturgeon may feed on (USFWS, December 16, 2003; Jacobsen et al., 2009). Convergent flows and coarse substrate are thought to be important to spawning for pallid sturgeon, and edge habitat type areas (energy dissipation areas) are thought to be important to migration and foraging (Orth and White, 1999; Jacobsen et al., 2009). Bramblett and White (2001) found that wild adult pallid sturgeon in the Yellowstone River, Montana, and in the Missouri River, North Dakota, selected sinuous and dynamic river reaches with many islands and secondary channels. Transitional zones between habitat types and the arrangement of habitat patches and features may be among the more significant factors in determining where sturgeon are found and how they migrate (Reuter et al., 2009). All female pallid sturgeon that were tracked appeared to have spawned in areas of swift, converging flow on outside bends, over or adjacent to gravel and cobble (DeLonay et al., 2009).

Studies have examined how flow is related to pallid sturgeon habitat on the Missouri River (DeLonay et al., 2007; Jacobson et al., 2007; Jacobson and Laustrup, 2000; Laustrup et al., 2007; Wildhaber et al., 2007). However, very little evidence exists to show that discharge rates directly affect pallid sturgeon. For example, DeLonay and others (2009) found no known direct link between discharge (independent from other factors) and sturgeon reproductive physiology. However, the indirect effects because of discharge-mediated water temperature changes are possible (DeLonay et al., 2009) depending on source of release. Studies have suggested that pallid sturgeon select velocities in proportion to its availability (Elliot et al., March 2004; Jacobsen et al., 2009; DeLonay et al., 2009). Pallid sturgeon in the Missouri River near Fort Randall Dam were found to generally select velocities in the same proportion as their availability. One could infer that no velocity is preferred (Elliot et al., March 2004). Depth and substrate within the Fort Randall Dam area, on the other hand, were selected by pallid sturgeon, using deeper areas and sandy substrates, perhaps suggesting these characteristics are more important factors for pallid sturgeon habitat than flow velocities.

Other effects of hydrocycling can include habitat use and availability for pallid sturgeon. On large dams that release water from their reservoir systems, decreased temperatures could modify cues that the pallid sturgeon need for migrating and spawning. Altered flow rates could alter patch habitat[9] used by pallid sturgeon. Altered flow regimes below Fort Randall, Gavins Point, and Intake dams can shift the use of habitat by pallid sturgeon. Each dam alters the historic hydrograph and habitat

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[9] Patch habitat is defined as distinct portions of habitat within an overall habitat complex.

resulting in spawning behavior disruptions (National Research Council, 2002 and 2005). As a result, for some distance downstream from each dam, the thermal habitat for pallid sturgeon is altered, especially with respect to spawning habitats (Kallemeyn, 1983; Keenlyne, 1989; Keenlyne, 1995; Pflieger and Grace, 1987). Along with day length, temperature may be one of the most important environmental cues for pallid sturgeon to spawn (DeLonay et al., 2009). Project hydrocycling does not alter temperature, and there are no hypolimnetic discharges. Because little to no water is stored for longer lengths of time, water temperature is not affected.

Peters and Parham (2008) suggest that an analysis of lower Platte River flows in relation to pallid sturgeon and shovelnose sturgeon habitat indicated the need to protect at least a portion of the current flows and the annual discharge pattern to maintain the existing habitat. From the available literature, discussed above, it appears that although habitat may be affected by an altered flow regime, pallid sturgeon will use the habitat available to them. Adult and juvenile pallid sturgeon currently occupy the rivers with altered flow regimes and with a variety of habitat parameters. Furthermore, pallid sturgeon have been found within the Platte River below the point where Project hydrocyling operations affect the hydrograph. Research is ongoing to determine what factors facilitate pallid sturgeon spawning. No eggs or larval pallid sturgeon have been recorded on the Yellowstone River reach where no hydrocycling is present, or for any of the Missouri River reaches where hydrocycling is present. This suggests that factors other than flow regime are influencing pallid sturgeon spawning.

5.5.3 Peters and Parham's Discharge versus Habitat Relationship

The District's analysis of percentage of suitable pallid sturgeon habitat using Peters and Parham's discharge versus habitat relationship, as discussed in Section 4.6.2, is provided below. Peters and Parham determined that percentage of suitable habitat available in the Platte River reached a maximum of approximately 30 percent at discharges of 10,000 cfs and higher.

The District analyzed flows at the following gaged and ungaged sites:

- Duncan gage
- Site 3, upstream of the Tailrace Return
- Site 4, downstream of the Tailrace Return
- North Bend gage
- Leshara gage
- Ashland gage
- Louisville gage

The results are summarized for yearly averages as well as monthly averages for the selected wet (2008), dry (2006), and normal (2009) years for minimum, average, and maximum daily flows. Daily evaluation of flows and percentage of suitable habitat for each year are included in Attachment J.

Yearly Average Percent Suitable Pallid Sturgeon Habitat

Tables 5-15 through 5-17 show the yearly average percentage of suitable pallid sturgeon habitat. This information is shown graphically in Figures 5-17 through 5-19.

Table 5-15. Percentage of Suitable Pallid Sturgeon Habitat, Yearly Average – Dry

Location	Current Operations			Run-of-River Operations		
	Minimum Flow	Maximum Flow	Average Flow	Minimum Flow	Maximum Flow	Average Flow
Duncan Gage	0	0	0	0	0	0
Site 3	1	3	2	1	3	2
Site 4	2	13	6	5	8	6
North Bend Gage	2	12	6	5	8	6
Leshara Gage	3	14	8	7	10	8
Ashland Gage	6	18	11	10	13	11
Louisville Gage	9	21	15	14	16	15

Table 5-16. Percentage of Suitable Pallid Sturgeon Habitat, Yearly Average – Wet

Location	Current Operations			Run-of-River Operations		
	Minimum Flow	Average Flow	Maximum Flow	Minimum Flow	Average Flow	Maximum Flow
Duncan Gage	2	3	3	2	3	3
Site 3	5	6	5	5	6	5
Site 4	5	21	12	11	13	12
North Bend Gage	5	20	12	10	13	12
Leshara Gage	7	22	14	12	15	14
Ashland Gage	16	26	21	21	23	21
Louisville Gage	19	27	23	23	25	23

Table 5-17. Percentage of Suitable Pallid Sturgeon Habitat, Yearly Average – Normal

Location	Current Operations			Run-of-River Operation		
	Minimum Flow	Average Flow	Maximum Flow	Minimum Flow	Average Flow	Maximum Flow
Duncan Gage	1	2	2	1	2	2
Site 3	5	8	6	5	8	6
Site 4	6	21	15	13	17	15
North Bend Gage	6	21	14	12	16	14
Leshara Gage	8	22	16	15	18	16
Ashland Gage	16	26	22	22	24	22
Louisville Gage	19	27	24	24	26	24

Notable observations related to the yearly average percentage of suitable pallid sturgeon habitat are as follows:

- The percentage of suitable habitat increases when moving downstream for both current operations and run-of-river operations.
- The percentage of suitable habitat increased with increased flow that resulted downstream of confluences with major tributaries (such as the Loup River, Elkhorn River, and Salt Creek).
- There is little to no suitable pallid sturgeon habitat above the Loup River confluence (near Duncan); habitat ranged from 0 percent suitable habitat in a dry year to 3 percent suitable habitat in a wet year.
- The largest percentage of suitable habitat is available downstream of Louisville; the yearly average minimum percentage of suitable habitat for a normal flow year ranged from 14 to 24 percent for run-of-river operations and from 9 to 19 percent for current operations.
- On an average yearly basis, there is little difference in the percentage of suitable habitat between current operations and run-of-river operations. Using an average of minimum daily flows, approximately a 5 percent increase in suitable habitat was found for run-of-river operations compared to current operations. For average maximum daily flows, current operations showed a higher percentage of suitable habitat, by as much as 8 percent, compared to run-of-river operations.

- Less than 5 percent suitable pallid sturgeon exists above the Loup River. In most cases, greater than 5 percent suitable habitat was available for pallid sturgeon below the Tailrace Return.

Under both current operations and run-of-river operations, the minimum yearly average percentage of suitable habitat available increases consistently from a low of 1 percent above the Loup River confluence (near Duncan) to a maximum of 19 percent for current operations and 24 percent for run-of-river operations at Louisville. The increase in suitable habitat when moving downstream is consistent for minimum, maximum, and average daily flows for the selected wet, dry, and normal years. Overall, any differences in the availability of suitable habitat between current operations and run-of-river operations decrease when moving downstream.

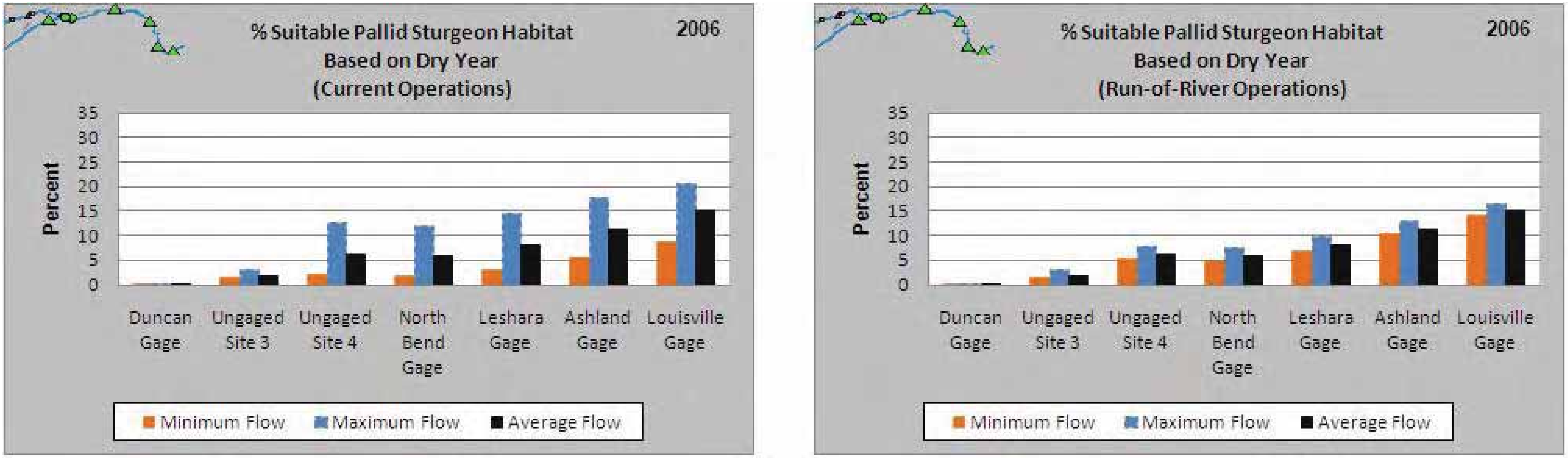

Figure 5-17. Average Percentage of Suitable Pallid Sturgeon Habitat During a Dry Year (2006)

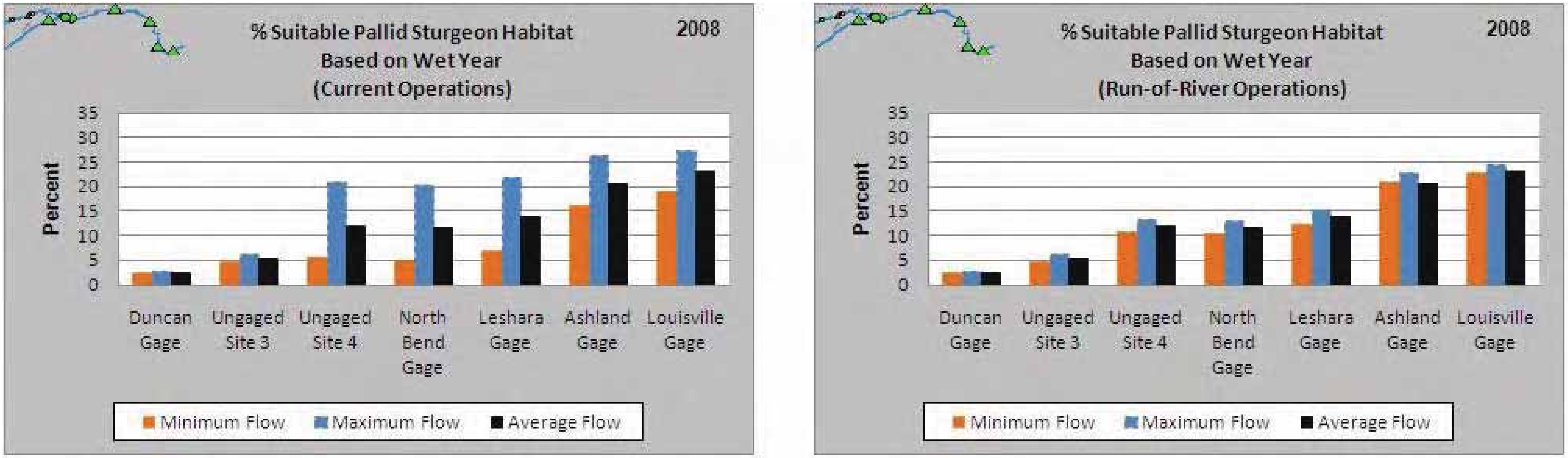

Figure 5-18. Average Percentage of Suitable Pallid Sturgeon Habitat During a Wet Year (2008)

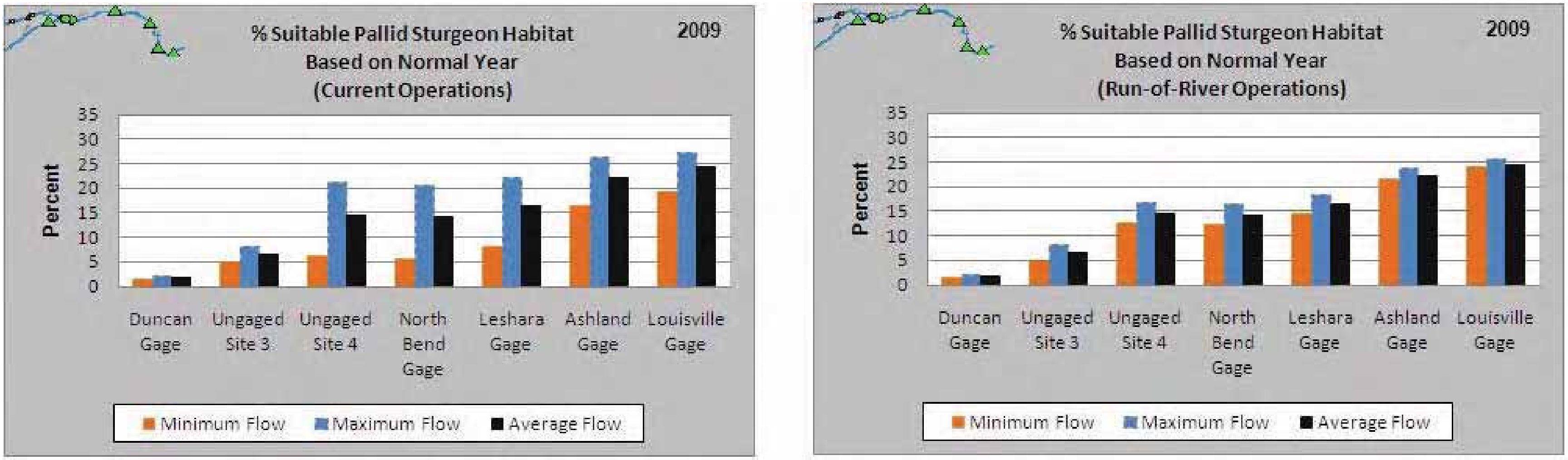

Figure 5-19. Average Percentage of Suitable Pallid Sturgeon Habitat During a Normal Year (2009)

Monthly Average Percentage of Suitable Pallid Sturgeon Habitat

Tables 5-18 through 5-29, located at the end of this section, show the average percentage of suitable habitat by month. This information is shown graphically in Figures 5-20 through 5-31, also located at the end of this section.

Differences in the availability of suitable habitat between flows for current operations and run-of-river operations vary depending on the month of the year. Notable observations related to the monthly average percentage of suitable pallid sturgeon habitat are as follows:

- As with the yearly average, the percentage of suitable habitat increased when moving downstream for both current operations and run-of-river operations for each month.
- There was little to no (5 percent or less) suitable pallid sturgeon habitat above the Loup River confluence (near Duncan) throughout the year with the exception of May and June during the wet year, when as much as 16 percent suitable habitat was available above the Loup River confluence.
- The largest percentage of suitable habitat is available downstream of Louisville; during normal and wet years, minimum flows provided at least 12 percent suitable habitat for each month under both current operations and run-of-river operations. However, during August and September, minimum flows provided as little as 4 percent suitable habitat under current operations and 10 percent under run-of-river operations.
- During dry years, the lower Platte River upstream of the Elkhorn River confluence (upstream of the Ashland gage) provided little to no suitable habitat during the summer months (May to August) under both current operations and run-of-river operations.
- The months of February through June exhibit the greatest habitat availability for nearly all downstream sites, especially for normal and wet years.

In addition to the Peters and Parham analysis, the preliminary results of the ongoing UNL research study, the Shovelnose Sturgeon Population Dynamics Study (Hamel et al., January 2010; Hamel and Pegg, January 2011),[10] were reviewed for insight into suitable pallid sturgeon habitat. The UNL study results are consistent with the Peters and Parham (2008) analysis in that pallid sturgeon are most frequently captured downstream of the Elkhorn confluence where flows are higher.

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[10] The District has requested the individual pallid sturgeon capture data from this study for comparison to flows (and habitat) on the date of capture; however, this information is not currently available.

UNL researchers captured 66 pallid sturgeon individuals in the sample segment near the confluence of the Platte and Missouri rivers and only 3 individuals in the sample segment near the confluence of the Loup and Platte rivers. Although the sampling effort was weighted toward the segment nearest the Missouri River confluence (two sampling points for every one sampling point in the upper segment nearest the Loup River confluence), approximately 96 percent of pallid sturgeon were captured in the lower segment.

The researchers did not weight the lower reach in the 2010 sampling effort. In 2010, the researchers evenly distributed sampling sites within Segments 1 and 2 (that is, 20 sites above and below the Elkhorn River confluence) (Hamel and Pegg, January 2011). In 2010, fewer pallid sturgeon were captured throughout the study reach, and the majority of captures were also in the lower reaches. Researchers captured 34 pallid sturgeon (89 percent) in the lower segment compared to 4 in the upper segment.

During 2009, the first year of the UNL study, UNL researchers collected substantially more pallid sturgeon during the fall sampling period (43 individuals) than during the spring and summer sampling periods (9 and 17 individuals, respectively). However, UNL researchers noted that "only one-third the sampling effort was put forth during the spring due to weather restraints, gear malfunctions, and learning how to sample in a shallow, highly braided river system" (Hamel et al., January 2010).

During the 2010 sampling year, more pallid sturgeon were collected in the spring than those caught in the summer or fall (Hamel and Pegg, January 2011). Researchers captured 24 pallid sturgeon in the spring compared to 2 during the summer and 12 during the fall.

Notable results from the UNL studies in relation to the percentage of suitable habitat analysis are as follows:

- During the 2009 spring sampling period, which was conducted from March through May, only 9 of the 69 pallid sturgeon were captured. However, according to Peters and Parham's relationship, the greatest amount of habitat available for pallid sturgeon should be during this period. This difference may be due, at least in part, to the higher spring flows in 2009 and the researcher's inability to access the river for sampling for a portion of the time. In 2010, 24 pallid sturgeon were captured in the spring, which is greater than summer and fall. The 2010 captures coincide with the habitat analysis based on Peters and Parham (2008).
- During the summer sampling period, which was conducted from June through August, 17 pallid sturgeon were captured in 2009 and 2 were captured in 2010; this period included months among both the highest available pallid sturgeon habitat percentage (June) and the lowest (August).

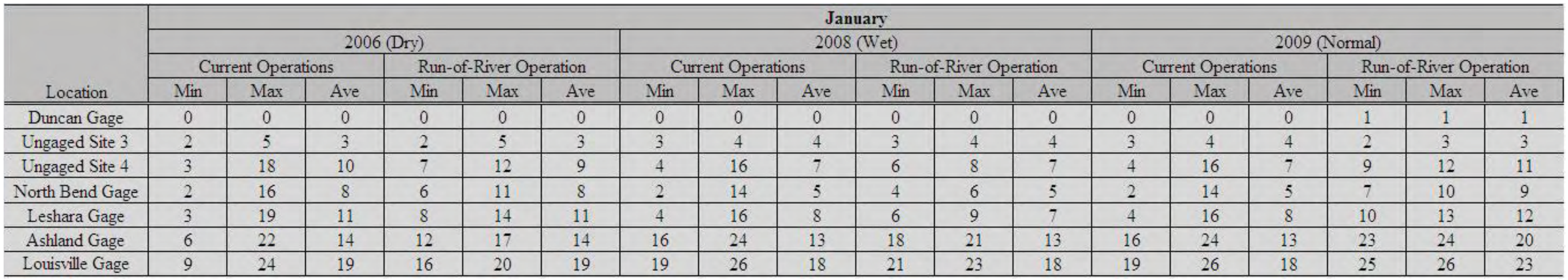
- During the fall sampling period, which was conducted from September through early November, a total of 43 pallid sturgeon were captured in 2009 and 12 were captured in 2010; this period corresponds to the period in the Platte River when available habitat is transitioning from its yearly low in August and September to a period of higher habitat percentages in October and November.

UNL's first of year of data suggests that pallid sturgeon are using the lower Platte River, primarily in fall. However, because the 2009 spring sampling effort was only one-third of the sampling effort put forth in the summer and fall, pallid sturgeon use of the lower Platte River during the spring may be slightly greater than that reported for 2009. The second year of sampling suggests that pallid sturgeon are using the lower Platte River primarily in the spring and fall, with the majority of pallid sturgeon caught in the spring. Research is ongoing, and no evidence has been presented to determine whether the sturgeon are using the Platte River in the upper or lower segments for spawning or migration.

Both the Peters and Parham analysis and the UNL studies have shown that pallid sturgeon prefer the lower reaches of the Platte River. Bailey and Cross (1954) also noted that pallid sturgeon historically prefer large mainstem rivers, such as the Missouri and Mississippi rivers, and prefer the lower reaches (lower 30 km) of large tributaries. UNL research on the Platte River coincides with observations made by Bailey and Cross. A majority of pallid sturgeon were captured below the Elkhorn River confluence in the Platte River. Furthermore, results from the Peters and Parham analysis suggested that more habitat is available when moving downstream towards the Missouri River because of increased flows.

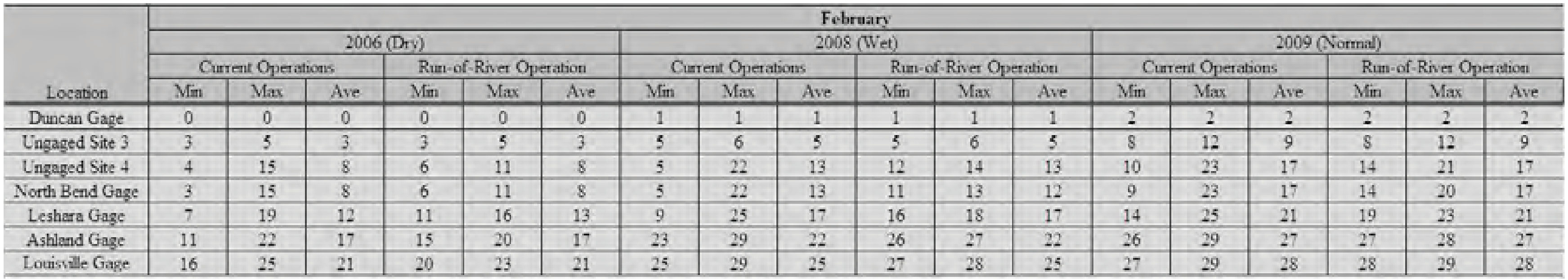
Based on the District's analysis, run-of-river operations would have little effect on pallid sturgeon habit compared to current operations except during minimum flow conditions, when the maximum monthly difference ranged from 1 percent to as much as 13 percent, with a yearly average of approximately 6 percent more suitable habitat available under run-of-river conditions at minimum flows. Peters and Parham (2008) concluded that the discharge versus habitat relationship changes more rapidly at lower discharges than at high discharges. Therefore, increases in flow between minimum and average discharges would likely see a greater increase in available habitat. Peters and Parham (2008) also noted that at higher rates of discharge, increases in habitat began to level off, which was also the case in the District's analysis. Peters and Parham explained this as two transitional phases as discharge increases. The first phase begins as water floods the dry river bed at low discharges and there is a rapid transition of habitat from exposed sandbars to shallow sandbar complexes and an overall increase in wetted width of the river bed. The second transition phase begins at moderate discharges where there is a transition from sandbar complexes to open water. If the river is near either of these transition phases, large changes in habitat availability can occur

Table 5-18. Percentage of Suitable Pallid Sturgeon Habitat, Monthly Average – January



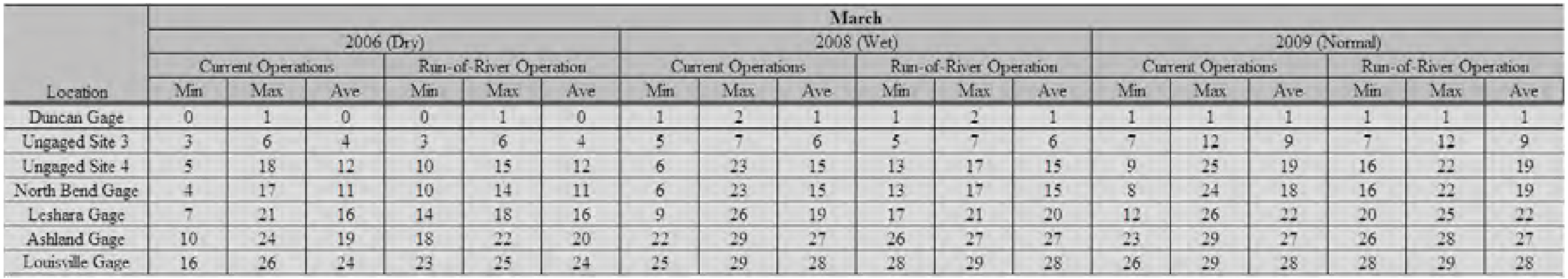
Location	January																	
	2006 (Dry)						2008 (Wet)						2009 (Normal)					
	Current Operations			Run-of-River Operation			Current Operations			Run-of-River Operation			Current Operations			Run-of-River Operation		
	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
Duncan Gage	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
Ungaged Site 3	2	5	3	2	5	3	3	4	4	3	4	4	3	4	4	2	3	3
Ungaged Site 4	3	18	10	7	12	9	4	16	7	6	8	7	4	16	7	9	12	11
North Bend Gage	2	16	8	6	11	8	2	14	5	4	6	5	2	14	5	7	10	9
Leshara Gage	3	19	11	8	14	11	4	16	8	6	9	7	4	16	8	10	13	12
Ashland Gage	6	22	14	12	17	14	16	24	13	18	21	13	16	24	13	23	24	20
Louisville Gage	9	24	19	16	20	19	19	26	18	21	23	18	19	26	18	25	26	23

Table 5-19. Percentage of Suitable Pallid Sturgeon Habitat, Monthly Average – February



Location	February																	
	2006 (Dry)						2008 (Wet)						2009 (Normal)					
	Current Operations			Run-of-River Operation			Current Operations			Run-of-River Operation			Current Operations			Run-of-River Operation		
	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
Duncan Gage	0	0	0	0	0	0	1	1	1	1	1	1	2	2	2	2	2	2
Ungaged Site 3	3	5	3	3	5	3	5	6	5	5	6	5	8	12	9	8	12	9
Ungaged Site 4	4	15	8	6	11	8	5	22	13	12	14	13	10	23	17	14	21	17
North Bend Gage	3	15	8	6	11	8	5	22	13	11	13	12	9	23	17	14	20	17
Leshara Gage	7	19	12	11	16	13	9	25	17	16	18	17	14	25	21	19	23	21
Ashland Gage	11	22	17	15	20	17	23	29	22	26	27	22	26	29	27	27	28	27
Louisville Gage	16	25	21	20	23	21	25	29	25	27	28	25	27	29	28	28	29	28

Table 5-20. Percentage of Suitable Pallid Sturgeon Habitat, Monthly Average – March



Location	March																	
	2006 (Dry)						2008 (Wet)						2009 (Normal)					
	Current Operations			Run-of-River Operation			Current Operations			Run-of-River Operation			Current Operations			Run-of-River Operation		
	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
Duncan Gage	0	1	0	0	1	0	1	2	1	1	2	1	1	1	1	1	1	1
Ungaged Site 3	3	6	4	3	6	4	5	7	6	5	7	6	7	12	9	7	12	9
Ungaged Site 4	5	18	12	10	15	12	6	23	15	13	17	15	9	25	19	16	22	19
North Bend Gage	4	17	11	10	14	11	6	23	15	13	17	15	8	24	18	16	22	19
Leshara Gage	7	21	16	14	18	16	9	26	19	17	21	20	12	26	22	20	25	22
Ashland Gage	10	24	19	18	22	20	22	29	27	26	27	27	23	29	27	26	28	27
Louisville Gage	16	26	24	23	25	24	25	29	28	28	29	28	26	29	28	28	29	28

Table 5-21. Percentage of Suitable Pallid Sturgeon Habitat, Monthly Average – April

	April																	
	2006 (Dry)						2008 (Wet)						2009 (Normal)					
	Current Operations			Run-of-River Operation			Current Operations			Run-of-River Operation			Current Operations			Run-of-River Operation		
Location	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
Duncan Gage	0	1	1	0	1	1	1	2	2	1	2	2	2	3	3	2	3	3
Ungaged Site 3	3	5	4	3	5	4	5	9	7	5	9	7	8	13	11	8	13	11
Ungaged Site 4	5	17	12	10	13	12	7	26	18	16	19	17	10	25	21	18	22	21
North Bend Gage	5	17	12	10	13	12	5	26	17	15	19	17	8	24	20	17	21	20
Leshara Gage	8	20	15	13	16	15	9	27	19	18	21	19	13	26	22	20	23	22
Ashland Gage	16	26	23	21	24	23	21	29	27	26	27	27	22	28	27	26	27	27
Louisville Gage	20	27	25	24	26	25	24	30	28	27	28	28	25	29	28	27	28	28

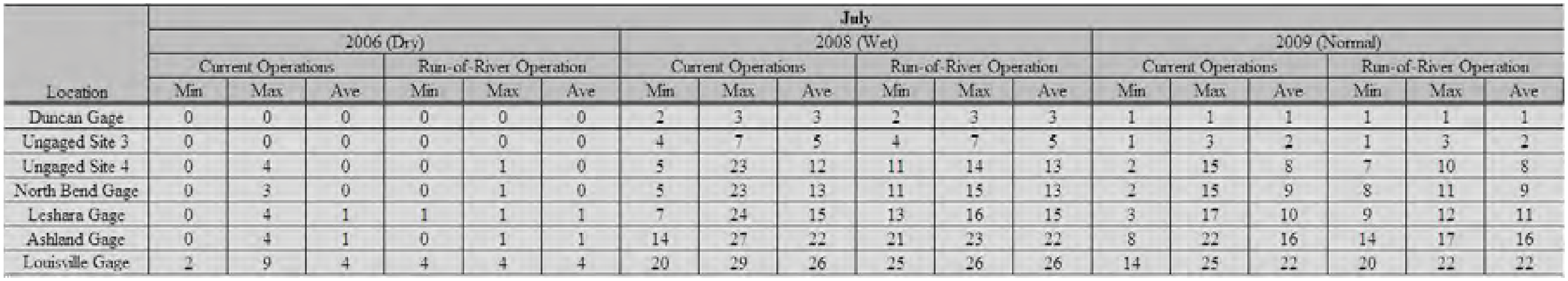
Table 5-22. Percentage of Suitable Pallid Sturgeon Habitat, Monthly Average – May

	May																	
	2006 (Dry)						2008 (Wet)						2009 (Normal)					
	Current Operations			Run-of-River Operation			Current Operations			Run-of-River Operation			Current Operations			Run-of-River Operation		
Location	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
Duncan Gage	0	0	0	0	0	0	7	8	7	7	8	7	1	1	2	1	1	2
Ungaged Site 3	0	0	0	0	0	0	9	12	10	9	12	10	2	4	4	2	4	4
Ungaged Site 4	0	9	3	3	3	3	10	25	18	16	19	17	3	19	12	9	13	12
North Bend Gage	1	10	4	4	4	4	10	25	18	17	19	18	4	20	14	11	15	14
Leshara Gage	2	16	7	7	8	7	13	27	21	20	22	21	7	23	18	16	19	18
Ashland Gage	7	22	15	14	15	15	25	30	28	28	29	28	17	27	25	23	25	25
Louisville Gage	15	25	22	21	22	22	28	30	29	29	30	29	23	28	27	26	27	27

Table 5-23. Percentage of Suitable Pallid Sturgeon Habitat, Monthly Average – June

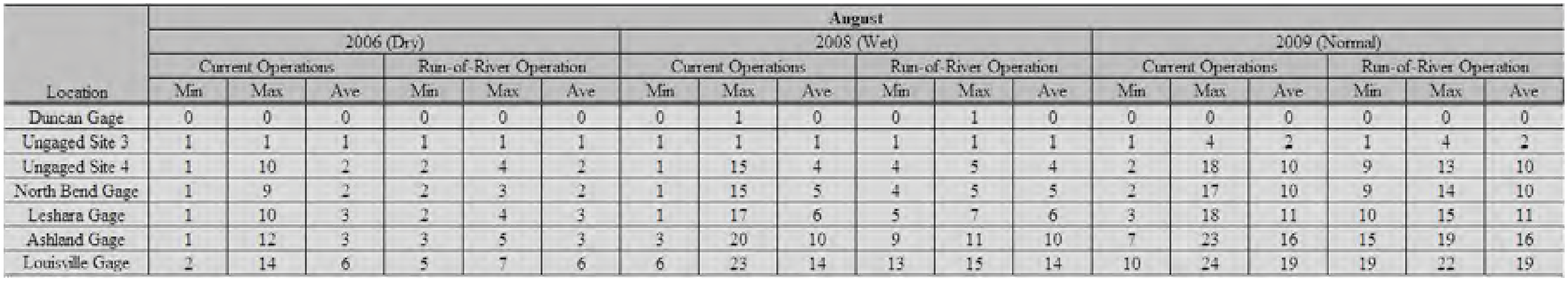
	June																	
	2006 (Dry)						2008 (Wet)						2009 (Normal)					
	Current Operations			Run-of-River Operation			Current Operations			Run-of-River Operation			Current Operations			Run-of-River Operation		
Location	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
Duncan Gage	0	0	0	0	0	0	14	16	15	14	16	15	4	5	5	4	5	5
Ungaged Site 3	0	0	0	0	0	0	18	21	19	18	21	19	10	16	13	10	16	13
Ungaged Site 4	0	6	1	1	1	1	19	28	25	23	26	25	12	25	21	18	22	21
North Bend Gage	0	5	1	1	1	1	19	28	25	23	26	25	10	24	20	17	21	20
Leshara Gage	0	6	2	1	2	2	20	28	26	24	27	26	12	25	21	17	22	21
Ashland Gage	1	10	4	3	4	4	28	31	30	29	30	30	19	28	25	24	27	25
Louisville Gage	5	18	11	9	11	11	29	31	30	30	31	30	23	29	28	27	29	28

Table 5-24. Percentage of Suitable Pallid Sturgeon Habitat, Monthly Average – July



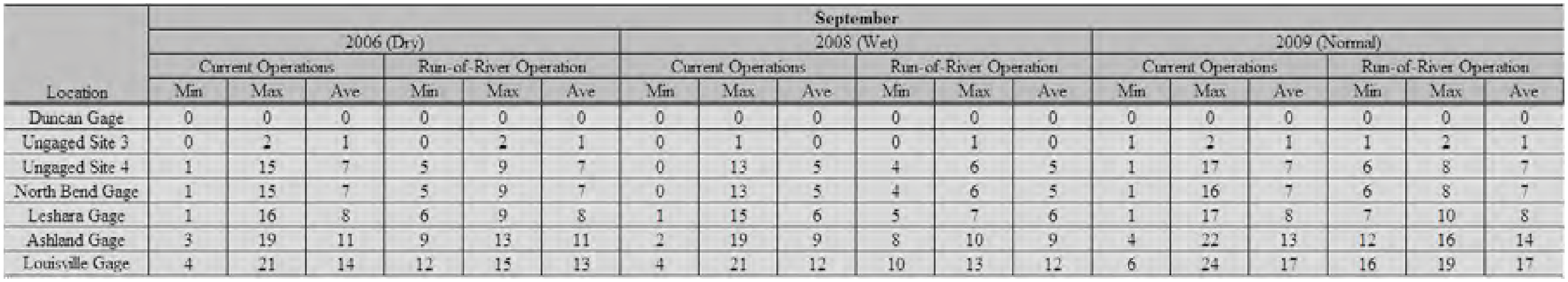
Location	July																	
	2006 (Dry)						2008 (Wet)						2009 (Normal)					
	Current Operations			Run-of-River Operation			Current Operations			Run-of-River Operation			Current Operations			Run-of-River Operation		
	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
Duncan Gage	0	0	0	0	0	0	2	3	3	2	3	3	1	1	1	1	1	1
Ungaged Site 3	0	0	0	0	0	0	4	7	5	4	7	5	1	3	2	1	3	2
Ungaged Site 4	0	4	0	0	1	0	5	23	12	11	14	13	2	15	8	7	10	8
North Bend Gage	0	3	0	0	1	0	5	23	13	11	15	13	2	15	9	8	11	9
Leshara Gage	0	4	1	1	1	1	7	24	15	13	16	15	3	17	10	9	12	11
Ashland Gage	0	4	1	0	1	1	14	27	22	21	23	22	8	22	16	14	17	16
Louisville Gage	2	9	4	4	4	4	20	29	26	25	26	26	14	25	22	20	22	22

Table 5-25. Percentage of Suitable Pallid Sturgeon Habitat, Monthly Average – August



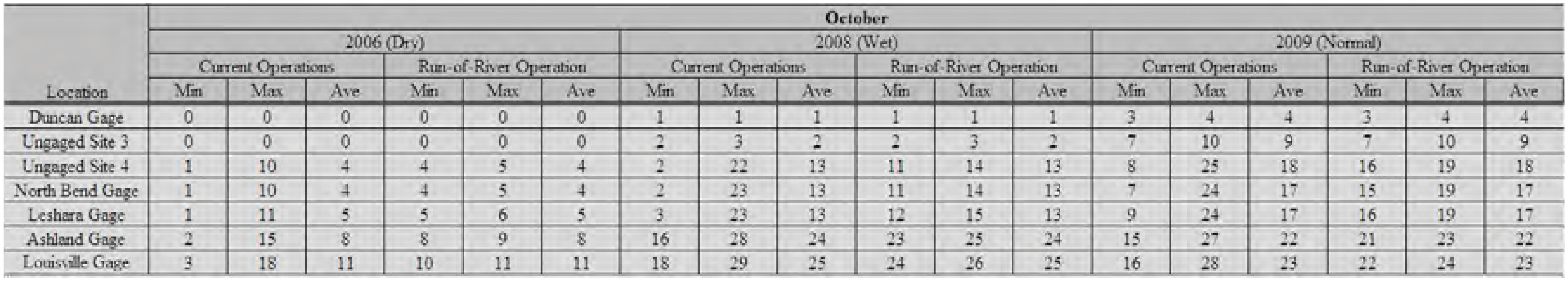
Location	August																	
	2006 (Dry)						2008 (Wet)						2009 (Normal)					
	Current Operations			Run-of-River Operation			Current Operations			Run-of-River Operation			Current Operations			Run-of-River Operation		
	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
Duncan Gage	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0
Ungaged Site 3	1	1	1	1	1	1	1	1	1	1	1	1	1	4	2	1	4	2
Ungaged Site 4	1	10	2	2	4	2	1	15	4	4	5	4	2	18	10	9	13	10
North Bend Gage	1	9	2	2	3	2	1	15	5	4	5	5	2	17	10	9	14	10
Leshara Gage	1	10	3	2	4	3	1	17	6	5	7	6	3	18	11	10	15	11
Ashland Gage	1	12	3	3	5	3	3	20	10	9	11	10	7	23	16	15	19	16
Louisville Gage	2	14	6	5	7	6	6	23	14	13	15	14	10	24	19	19	22	19

Table 5-26. Percentage of Suitable Pallid Sturgeon Habitat, Monthly Average – September



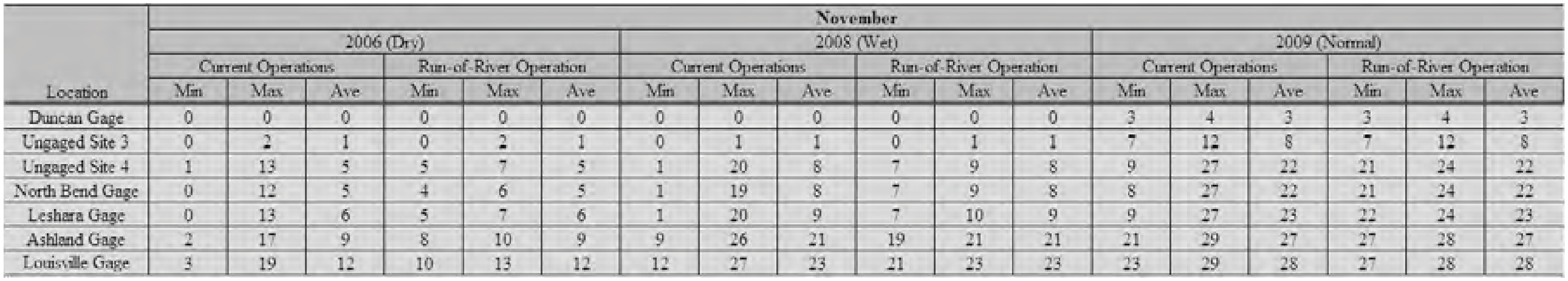
Location	September																	
	2006 (Dry)						2008 (Wet)						2009 (Normal)					
	Current Operations			Run-of-River Operation			Current Operations			Run-of-River Operation			Current Operations			Run-of-River Operation		
	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
Duncan Gage	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ungaged Site 3	0	2	1	0	2	1	0	1	0	0	1	0	1	2	1	1	2	1
Ungaged Site 4	1	15	7	5	9	7	0	13	5	4	6	5	1	17	7	6	8	7
North Bend Gage	1	15	7	5	9	7	0	13	5	4	6	5	1	16	7	6	8	7
Leshara Gage	1	16	8	6	9	8	1	15	6	5	7	6	1	17	8	7	10	8
Ashland Gage	3	19	11	9	13	11	2	19	9	8	10	9	4	22	13	12	16	14
Louisville Gage	4	21	14	12	15	13	4	21	12	10	13	12	6	24	17	16	19	17

Table 5-27. Percentage of Suitable Pallid Sturgeon Habitat, Monthly Average – October



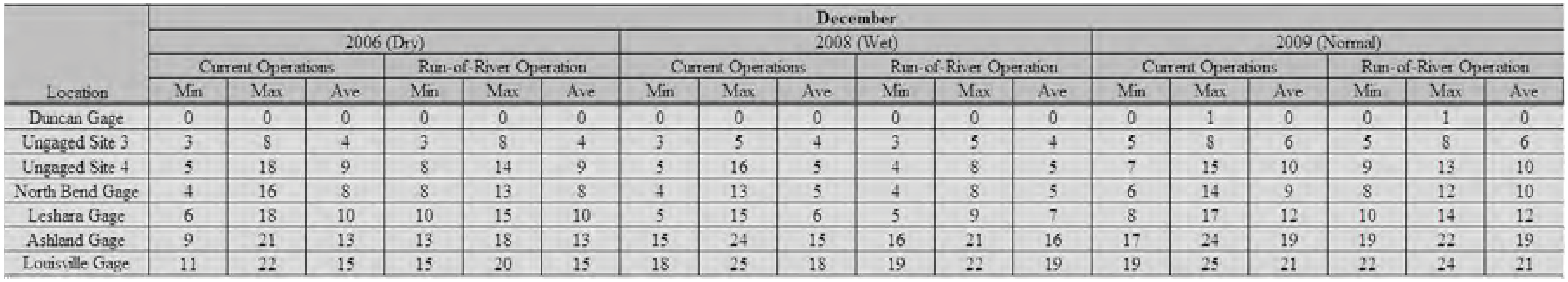
	October																	
	2006 (Dry)						2008 (Wet)						2009 (Normal)					
	Current Operations			Run-of-River Operation			Current Operations			Run-of-River Operation			Current Operations			Run-of-River Operation		
Location	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
Duncan Gage	0	0	0	0	0	0	1	1	1	1	1	1	3	4	4	3	4	4
Ungaged Site 3	0	0	0	0	0	0	2	3	2	2	3	2	7	10	9	7	10	9
Ungaged Site 4	1	10	4	4	5	4	2	22	13	11	14	13	8	25	18	16	19	18
North Bend Gage	1	10	4	4	5	4	2	23	13	11	14	13	7	24	17	15	19	17
Leshara Gage	1	11	5	5	6	5	3	23	13	12	15	13	9	24	17	16	19	17
Ashland Gage	2	15	8	8	9	8	16	28	24	23	25	24	15	27	22	21	23	22
Louisville Gage	3	18	11	10	11	11	18	29	25	24	26	25	16	28	23	22	24	23

Table 5-28. Percentage of Suitable Pallid Sturgeon Habitat, Monthly Average – November



	November																	
	2006 (Dry)						2008 (Wet)						2009 (Normal)					
	Current Operations			Run-of-River Operation			Current Operations			Run-of-River Operation			Current Operations			Run-of-River Operation		
Location	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
Duncan Gage	0	0	0	0	0	0	0	0	0	0	0	0	3	4	3	3	4	3
Ungaged Site 3	0	2	1	0	2	1	0	1	1	0	1	1	7	12	8	7	12	8
Ungaged Site 4	1	13	5	5	7	5	1	20	8	7	9	8	9	27	22	21	24	22
North Bend Gage	0	12	5	4	6	5	1	19	8	7	9	8	8	27	22	21	24	22
Leshara Gage	0	13	6	5	7	6	1	20	9	7	10	9	9	27	23	22	24	23
Ashland Gage	2	17	9	8	10	9	9	26	21	19	21	21	21	29	27	27	28	27
Louisville Gage	3	19	12	10	13	12	12	27	23	21	23	23	23	29	28	27	28	28

Table 5-29. Percentage of Suitable Pallid Sturgeon Habitat, Monthly Average – December



	December																	
	2006 (Dry)						2008 (Wet)						2009 (Normal)					
	Current Operations			Run-of-River Operation			Current Operations			Run-of-River Operation			Current Operations			Run-of-River Operation		
Location	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
Duncan Gage	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0
Ungaged Site 3	3	8	4	3	8	4	3	5	4	3	5	4	5	8	6	5	8	6
Ungaged Site 4	5	18	9	8	14	9	5	16	5	4	8	5	7	15	10	9	13	10
North Bend Gage	4	16	8	8	13	8	4	13	5	4	8	5	6	14	9	8	12	10
Leshara Gage	6	18	10	10	15	10	5	15	6	5	9	7	8	17	12	10	14	12
Ashland Gage	9	21	13	13	18	13	15	24	15	16	21	16	17	24	19	19	22	19
Louisville Gage	11	22	15	15	20	15	18	25	18	19	22	19	19	25	21	22	24	21

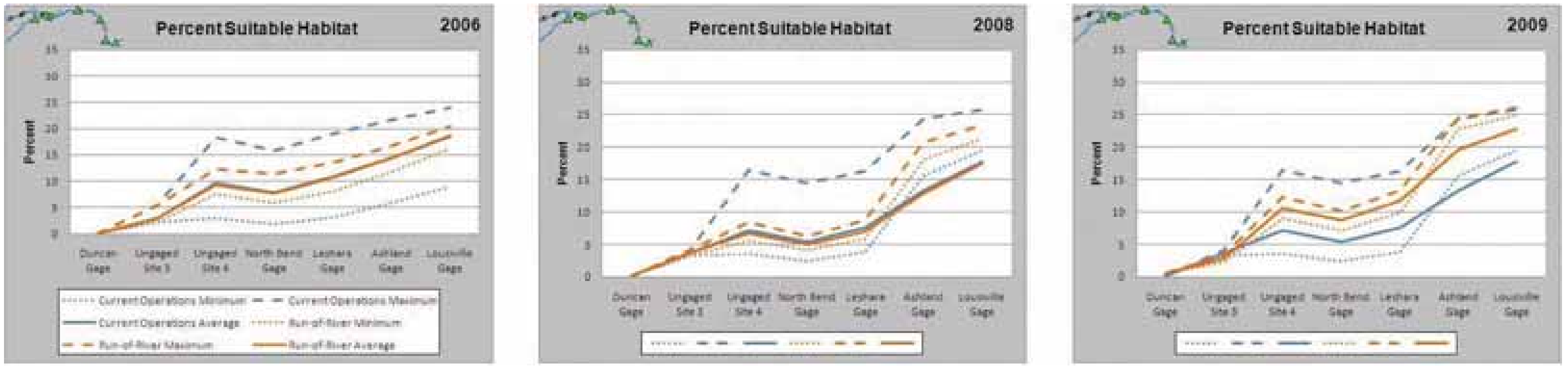


Figure 5-20. January Percentage of Suitable Habitat for Wet, Dry, and Normal Years at Each Site for Current and Run-of-River Operations

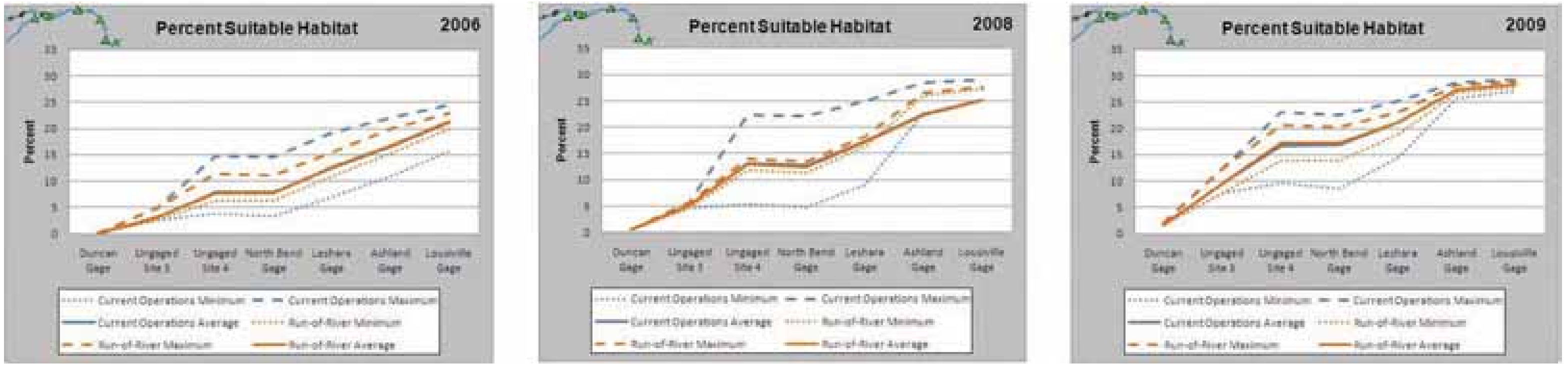


Figure 5-21. February Percentage of Suitable Habitat for Wet, Dry, and Normal Years at Each Site for Current and Run-of-River Operations

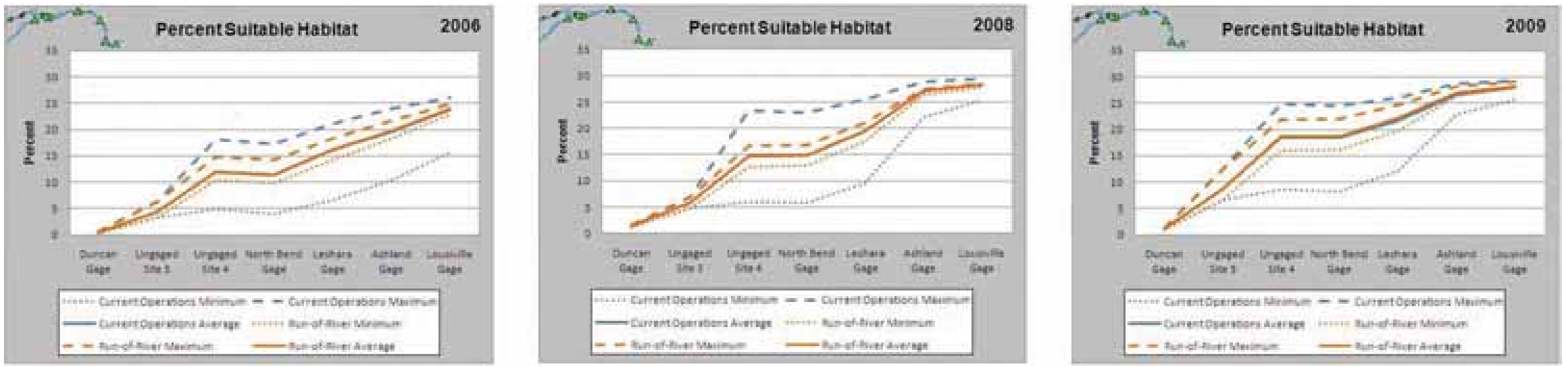


Figure 5-22. March Percentage of Suitable Habitat for Wet, Dry, and Normal Years at Each Site for Current and Run-of-River Operations

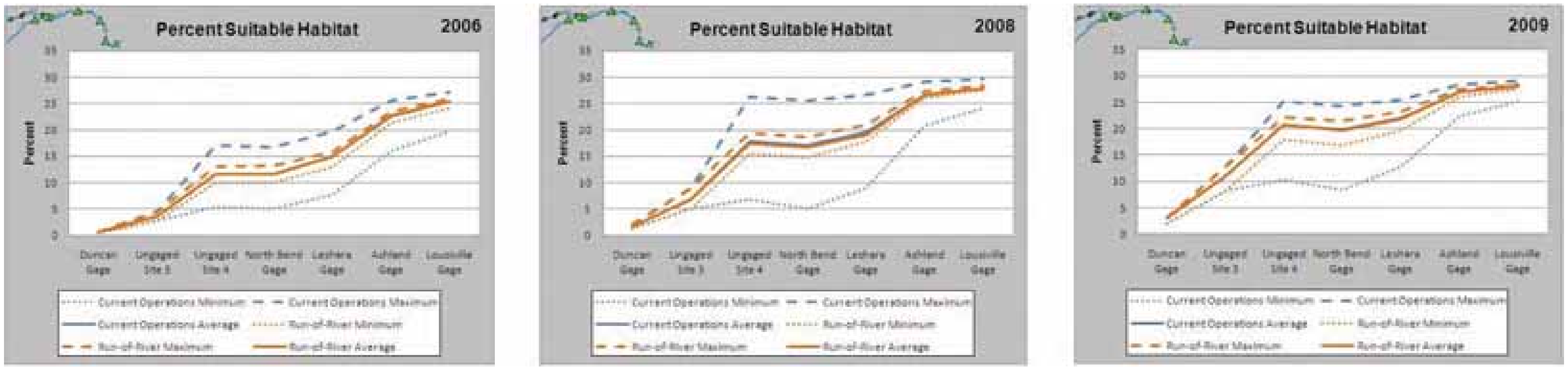


Figure 5-23. April Percentage of Suitable Habitat for Wet, Dry, and Normal Years at Each Site for Current and Run-of-River Operations

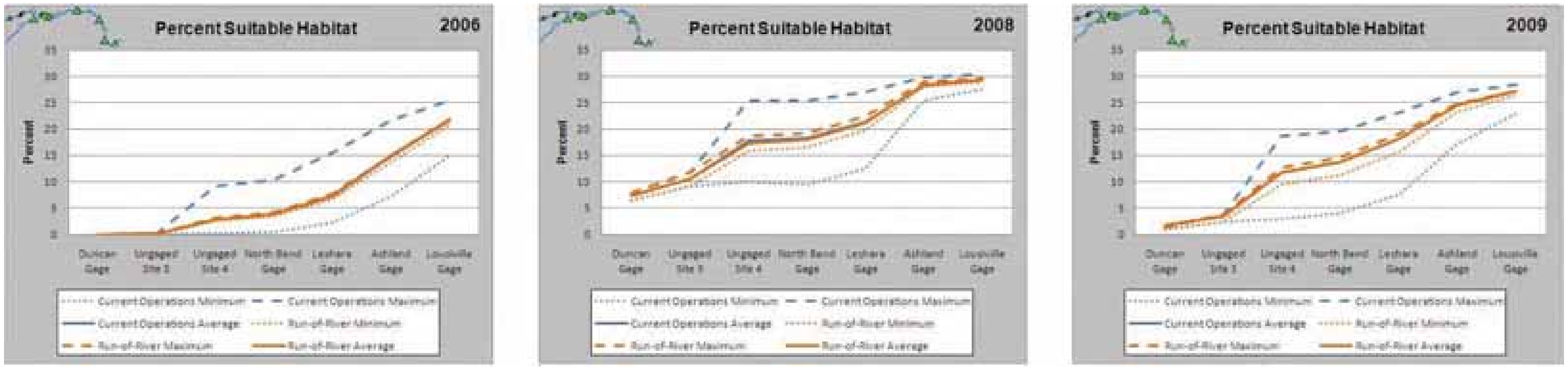


Figure 5-24. May Percentage of Suitable Habitat for Wet, Dry, and Normal Years at Each Site for Current and Run-of-River Operations

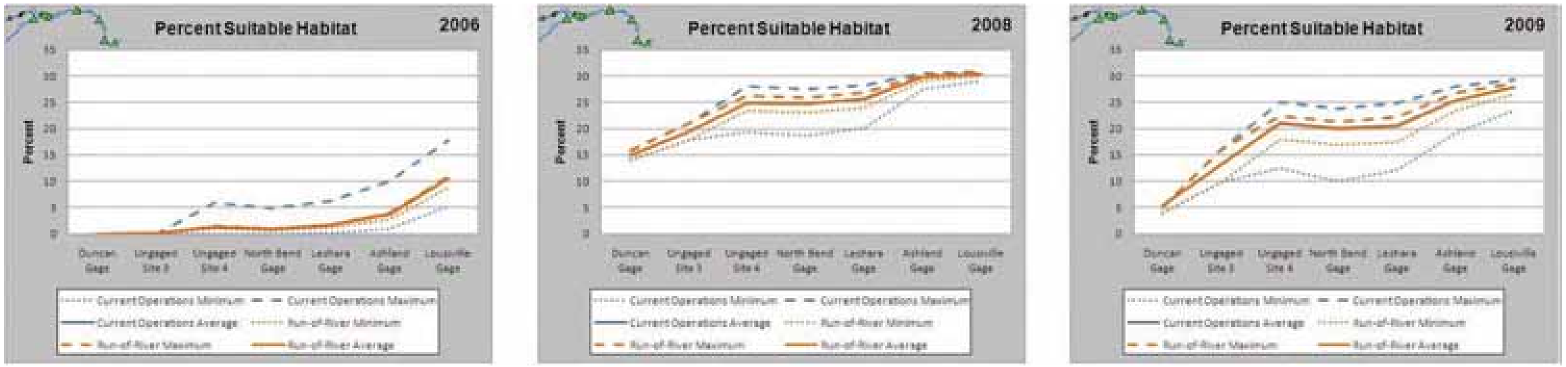


Figure 5-25. June Percentage of Suitable Habitat for Wet, Dry, and Normal Years at Each Site for Current and Run-of-River Operations

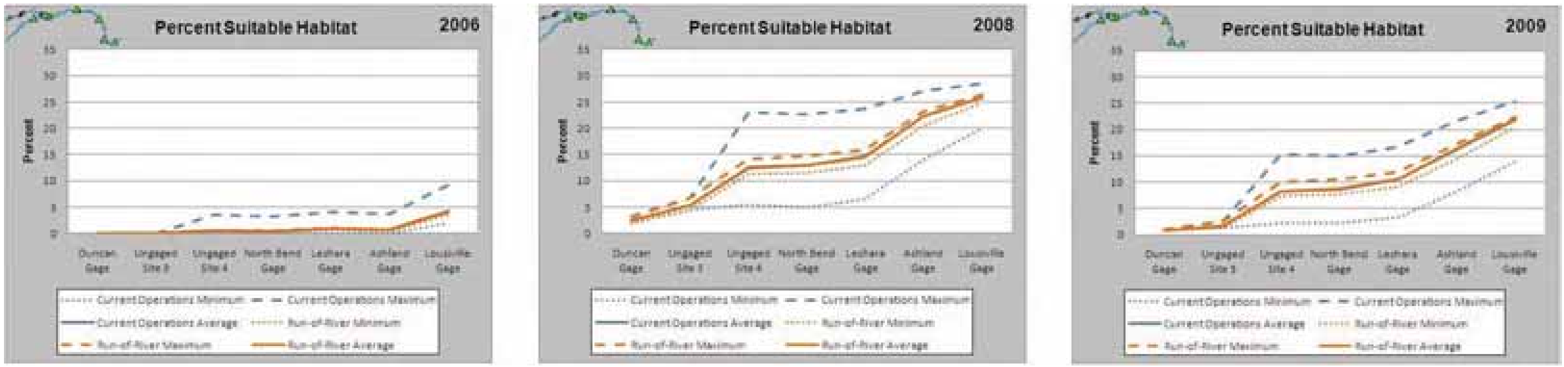


Figure 5-26. July Percentage of Suitable Habitat for Wet, Dry, and Normal Years at Each Site for Current and Run-of-River Operations

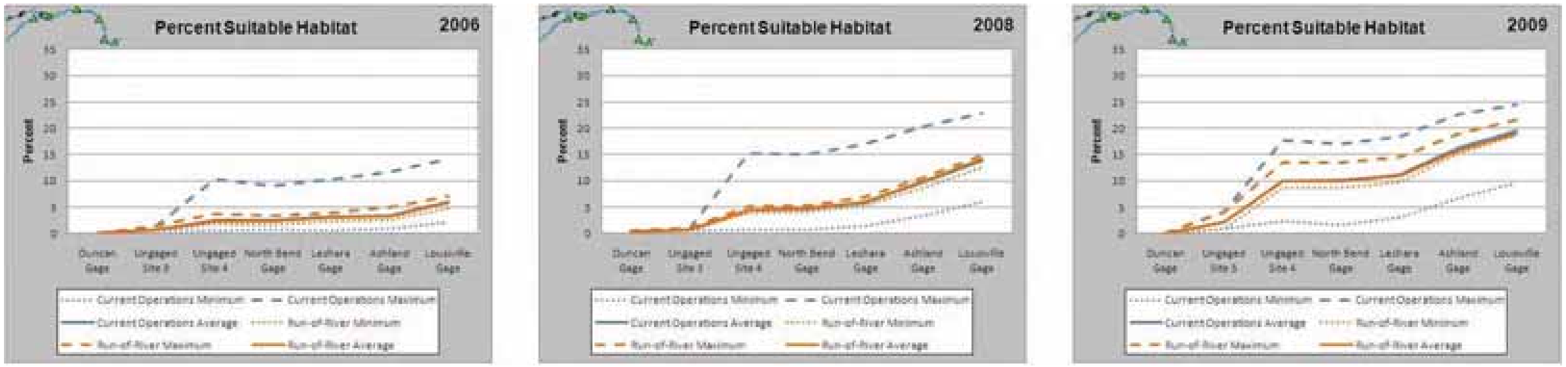


Figure 5-27. August Percentage of Suitable Habitat for Wet, Dry, and Normal Years at Each Site for Current and Run-of-River Operations

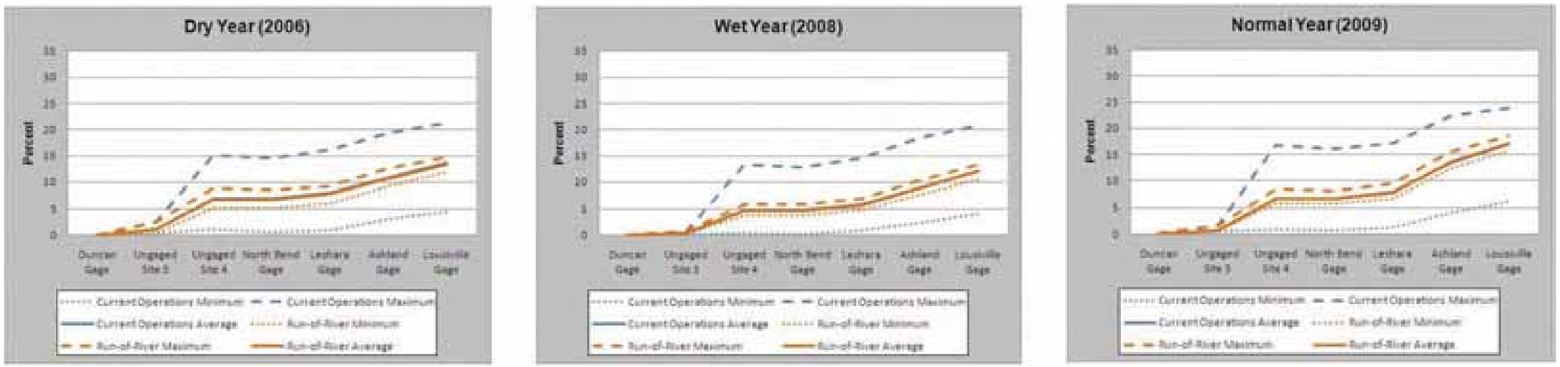


Figure 5-28. September Percentage of Suitable Habitat for Wet, Dry, and Normal Years at Each Site for Current and Run-of-River Operations

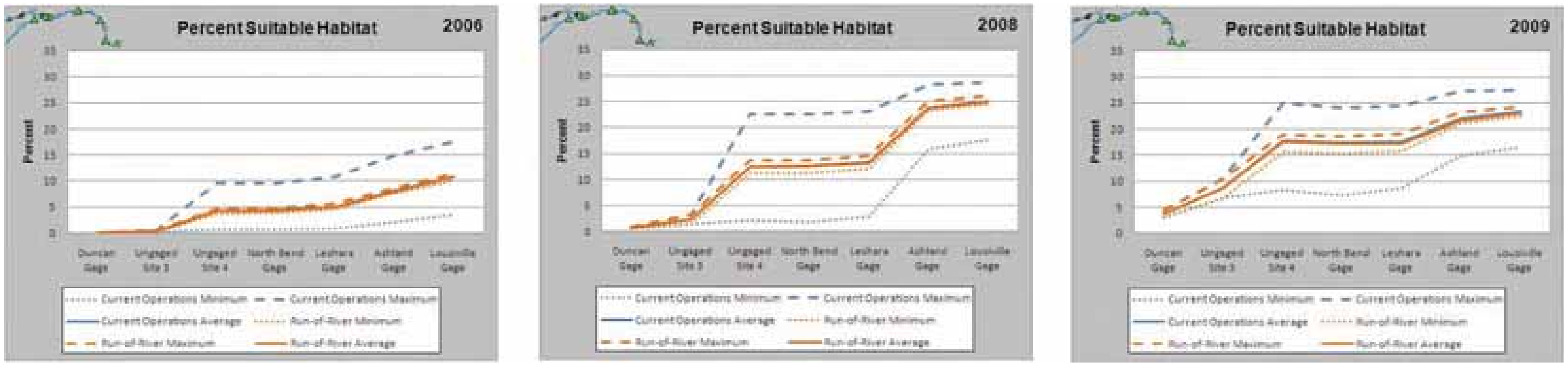


Figure 5-29. October Percentage of Suitable Habitat for Wet, Dry, and Normal Years at Each Site for Current and Run-of-River Operations

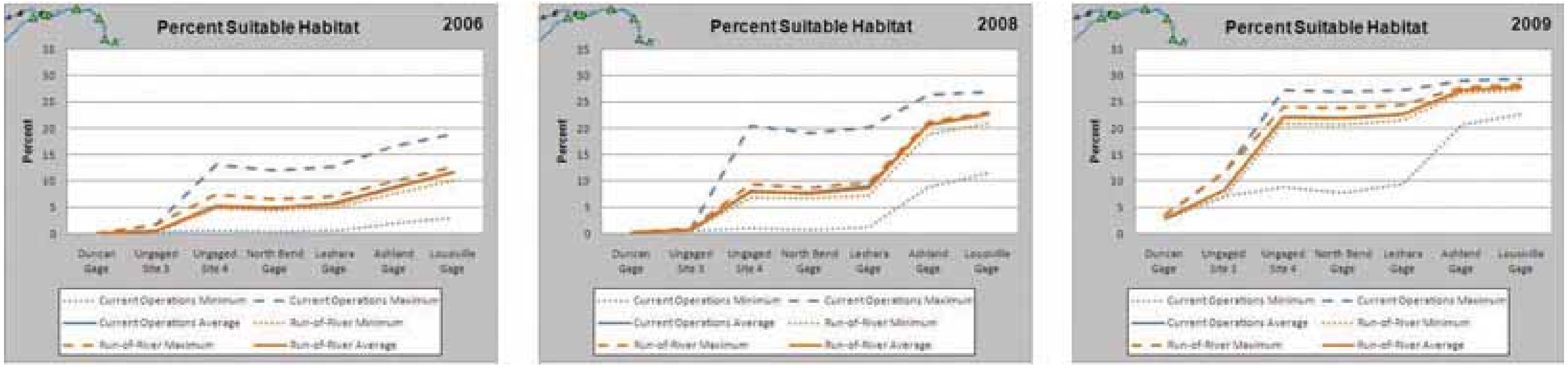


Figure 5-30. November Percentage of Suitable Habitat for Wet, Dry, and Normal Years at Each Site for Current and Run-of-River Operations

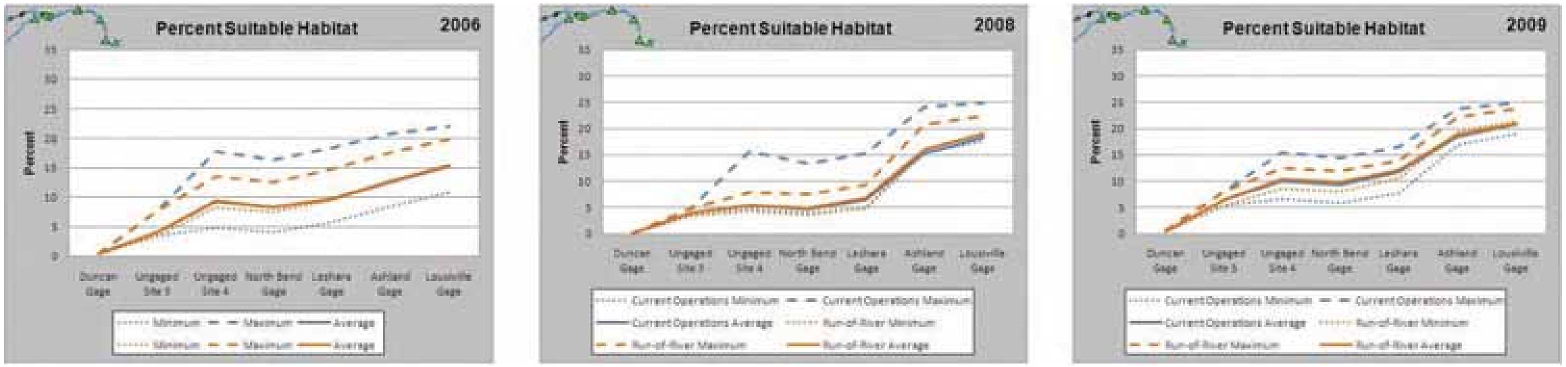


Figure 5-31. December Percentage of Suitable Habitat for Wet, Dry, and Normal Years at Each Site for Current and Run-of-River Operations

5.5.4 Lower Platte River Stage Change Study

As discussed in Section 4.6.3, the PRRIP completed the Lower Platte River Stage Change Study (HDR et al., December 2009) to evaluate the potential effects of PRRIP water management activities on water stage and the effect of those stage changes on physical characteristics of the lower Platte River, including parameters thought to be important to the pallid sturgeon (depth, velocity, temperature, turbidity, and bedforms). For purposes of the Stage Change Study, the lower Platte River was defined as the reach between the Elkhorn River confluence and the Missouri River confluence. A hydrologic analysis was conducted to analyze the lower Platte River flow regime to determine the range of flows for the data collection and hydraulic modeling efforts, to determine if natural flows can be differentiated from PRRIP activities, and to evaluate hydrograph translation from Grand Island to Louisville. Results from the 2-D hydraulic model were used to evaluate changes in pallid sturgeon habitat with discharge and stage based on the local depth and velocity.

The Lower Platte River Stage Change Study provides some information as to what degree changes in flow as a result of PRRIP management activities would affect pallid sturgeon habitat. It concluded that little change to the amount of habitat available to the pallid sturgeon would occur. However, the Stage Change Study did not consider connectivity issues that may occur during low flows or the seasonal use of the lower Platte River by pallid sturgeon.

5.5.5 Cross-Section Comparison

Cross sections for each ungaged site were plotted for each survey date, as shown in Attachment A. The change in in-channel cross-section area between surveys was determined and is listed in Tables 5-30 through 5-32; overall changes for each site are listed in Table 5-33. In general, the average in channel cross-section area decreased, suggesting that the reaches aggraded between surveys. Consistent with findings in the Lower Platte River Stage Change Study (HDR et al., December 2009), following high flow events, the channel typically becomes deeper and more efficient, generally consolidating flow into one deep channel. However, after sustained lower or normal flows, the channel begins to shallow, filling in the deeper channel, breaking down the high ground, with flow separating into several channels, becoming less efficient. This is consistent between Sites 3 and 4, upstream and downstream of the Tailrace Return, and Site 5, near North Bend.

In addition, this is reflected in the hydraulic modeling. For the same discharge, there was typically an increase in water surface elevation of approximately 0.4 foot between the early and late summer surveys.

Table 5-30. Cross Sections for Site 3, Platte River Upstream of the Tailrace Return

Cross Section	Approximate Area (ft^2)			Change in Flow Area					
	May	August	September	May to August		August to September		May to September	
				(ft^2)	(%)	(ft^2)	(%)	(ft^2)	(%)
1	6,602	7,200	6,856	597	9%	-344	-5%	253	4%
2	8,505	8,488	8,166	-16	0%	-322	-4%	-338	-4%
3	5,974	5,269	5,139	-704	-12%	-130	-2%	-834	-14%
4	7,573	6,907	7,091	-665	-9%	183	3%	-482	-6%
5	5,259	5,260	4,515	1	0%	-745	-14%	-744	-14%
6	4,761	4,781	4,415	19	0%	-366	-8%	-346	-7%
7	4,983	5,011	4,729	27	1%	-282	-6%	-255	-5%
8	5,460	5,319	5,328	-141	-3%	9	0%	-132	-2%
9	6,689	6,825	6,534	136	2%	-291	-4%	-155	-2%

Table 5-31. Cross Sections for Site 4, Platte River Downstream of the Tailrace Return

Cross Section	Approximate Area (ft^2)		Change in Flow Area	
	June	September	June to September	
			(ft^2)	(%)
1	6,497	6,585	88	1%
2	10,902	11,286	384	4%
3	7,039	6,676	-363	-5%
4	10,851	9,895	-957	-9%
5	6,522	6,060	-462	-7%
6	7,812	7,283	-529	-7%
7	7,433	6,809	-624	-8%
8	8,703	7,992	-711	-8%
9	9,034	8,491	-543	-6%
10	7,640	7,930	290	4%

Table 5-32. Cross Sections for Site 5, Platte River near North Bend

Cross Section	Approximate Area (ft^2)		Change in Flow Area	
			July to September	
	July	September	(ft^2)	(%)
1	8,343	7,914	-429	-5%
2	7,230	6,914	-316	-4%
3	6,471	6,643	172	3%
4	8,542	8,327	-215	-3%
5	7,250	7,149	-101	-1%
6	8,122	7,746	-376	-5%
7	7,331	7,055	-275	-4%
8	9,678	9,533	-144	-1%
9	6,999	6,597	-402	-6%

Table 5-33. Overall Change in Channel Area at Each Ungaged Site

Location	No. of Cross Sections	Current Operations		
		Average Change[1] in Area	Max. Change in Area	Min. Change in Area
Site 3 – Upstream of the Tailrace Return	9	(6%)	4%	(14%)
Site 4 – Downstream of the Tailrace Return	10	(4%)	4%	(9%)
Site 5 – Near North Bend	9	(3%)	3%	(6%)

Note:

[1] The change in cross-sectional area was measured from the spring to the fall. A negative value, shown in parentheses, means that the cross-sectional area was smaller in the fall than in the spring. This suggests a shallower channel.

The change in cross sections at Site 4, consistent with the change in cross sections at Site 3, would indicate a general increase (or aggradation) of the channel bottom and a reduction in some of the bar heights between the June and September surveys. However, the macroforms in various cross sections that existed in June were still prevalent in September. The same can be said for the cross sections at Site 5, near North Bend.

5.5.6 Habitat Analysis Using HEC-RAS Model

The HEC-RAS analysis was developed to show how changes in Project operations would affect potential interior least tern and piping plover habitat. Tables 5-34 through 5-36 show how the habitat parameters change as a result of different flow, operation, and hydrologic (wet/dry/normal) conditions. Table 5-37 compares Site 3, upstream of the Tailrace Return, which was used as a control site, and Site 4, downstream of the Tailrace Return, under current operations. Table 5-38 shows the overall average channel width and the percentage of channel width exposed among all years and all flow conditions for Sites 3, 4, and 5. Figures that show the average percentage of channel width exposed for Sites 3, 4, and 5 for the various flow, operation, and hydrologic (wet/dry/normal) conditions described in Section 4.6.5 are provided in Attachment K.

Table 5-34. Percentage of Exposed Channel Width – Site 3, Upstream of the Tailrace Return

Calendar Year of Analysis	Low Flow (75% Exceedance)		Medium Flow (50% Exceedance)		High Flow (25% Exceedance)	
	Early Summer	Late Summer	Early Summer	Late Summer	Early Summer	Late Summer
2006 (Dry)	47	59	56	66	22	22
2009 (Normal)	29	32	18	19	11	16
2008 (Wet)	28	30	19	20	11	15

Table 5-35. Percentage of Exposed Channel Width – Site 4, Downstream of the Tailrace Return

Calendar Year of Analysis	Low Flow (75% Exceedance)				Medium Flow (50% Exceedance)				High Flow (25% Exceedance)			
	Current Operations		Run-of-River Operations		Current Operations		Run-of-River Operations		Current Operations		Run-of-River Operations	
	Early Summer	Late Summer	Early Summer	Late Summer	Early Summer	Late Summer	Early Summer	Late Summer	Early Summer	Late Summer	Early Summer	Late Summer
2006 (Dry)	50	36	57	43	41	25	60	45	28	20	43	27
2009 (Normal)	41	24	48	32	35	22	30	21	24	18	32	21
2008 (Wet)	34	21	44	28	29	21	45	29	23	18	24	18

Table 5-36. Percentage of Exposed Channel Width – Site 5, Near North Bend

Calendar Year of Analysis	Low Flow (75% Exceedance)				Medium Flow (50% Exceedance)				High Flow (25% Exceedance)			
	Current Operations		Run-of-River Operations		Current Operations		Run-of-River Operations		Current Operations		Run-of-River Operations	
	Early Summer	Late Summer	Early Summer	Late Summer	Early Summer	Late Summer	Early Summer	Late Summer	Early Summer	Late Summer	Early Summer	Late Summer
2006 (Dry)	60	27	76	48	48	16	24	14	50	17	56	21
2009 (Normal)	40	15	50	17	50	16	26	14	17	9	13	5
2008 (Wet)	35	15	59	25	24	14	28	15	19	10	20	11

Table 5-37. Average Percentage of Exposed Channel Widths Comparison Between Upstream (Site 3) and Downstream (Site 4) of the Tailrace Return

Calendar Year of Analysis	Low Flow (75% Exceedance)				Medium Flow (50% Exceedance)				High Flow (25% Exceedance)			
	Site 3		Site 4		Site 3		Site 4		Site 3		Site 4	
	Early Summer	Late Summer	Early Summer	Late Summer	Early Summer	Late Summer	Early Summer	Late Summer	Early Summer	Late Summer	Early Summer	Late Summer
2006 (Dry)	47	59	50	36	56	66	41	25	22	22	28	20
2009 (Normal)	29	32	41	24	18	19	35	22	11	16	24	18
2008 (Wet)	28	30	34	21	19	20	29	21	11	15	23	18

Table 5-38. Overall Average Percentage of Exposed Channel Widths[1]

Calendar Year of Analysis	Site 3	Site 4		Site 5	
		Current Operations	Run-of-River Operations	Current Operations	Run-of-River Operations
Channel Width (linear feet)	1,074	1,725	1,725	1,608	1,608
2006 (Dry)	45	33	46	36	40
2009 (Normal)	21	27	31	25	21
2008 (Wet)	21	24	31	20	26

Note:

[1] Averages for channel widths and for all flow conditions for both early and late summer.

When considering the results of this analysis, a key understanding is that the percentage of exposed channel width was considered only as potential habitat. However, the analysis did not make a distinction as to suitable habitat. Suitable habitat, or habitat in which interior least terns and piping plovers would choose to nest, would factor in conditions such as percentage of bare sand, location and configuration of the percentage of exposed channel width, and potential for predation. Therefore, differences in exposed channel width do not necessarily indicate more or less suitable nesting habitat.

Further, the time periods when the cross sections were taken also need to be considered when comparing between the early and late summer conditions. Depending on when high-flow events occurred that affected the wet, dry, and normal year determinations, the river morphology may have reflected a drier or wetter condition than the wet, dry, and normal year determination actually would represent.

Comparison of Current Operations at Sites 3 and 4

At Site 3, upstream of the Tailrace Return, the percentage of exposed channel width decreased as flow increased for most years of analysis. The one anomaly is that during the dry year, between the low-flow and medium-flow events, the percentage of exposed channel width increased between these two periods, as shown in Table 5-34.

In comparing Site 3 and 4, it is also observed that the percentage of exposed channel width increased from the early summer to late summer cross sections, but decreased during this same period at Site 4. This is likely due to the steady reduction in flow at Site 3, while at Site 4, flows remain more constant due to the inflows from the Tailrace Canal. This situation is present in nearly all conditions analyzed, as shown in Table 5-36 and in the cross-section figures in Attachment K.

In general, Site 3 under current operations had a higher percentage exposed channel width during the dry year of analysis than did Site 4 under current operations. However, in the normal and dry years of analysis, this result is reversed. The variation in difference diminishes between the two sites as flows increase in at both sites, as shown in Table 5-36. This could be explained by evaluating channel width at the two sites and the potential effect of increased flow. The channel width at Site 3 is 1,074 feet and at Site 4 is 1,725 feet, which is approximately 650 feet wider than at Site 3. Under very dry conditions, the relative flow is lower; therefore, the percentage of exposed channel width is higher at Site 3. However, as flow increases, the wider channel at Site 4 may more evenly distribute this flow, thereby having less of a decrease in percentage of exposed channel width than is seen at Site 3, where a narrower channel exists. The narrower channel at Site 3 would cause a higher flow to be distributed in a shorter distance, thereby inundating more area of exposed sand.

Comparison of Current Operations to Run-of-River Operations at Sites 4 and 5

Dry Year (2006)

The analysis of percentage of exposed channel width at Site 4, downstream of the Tailrace Return, for the dry year yielded fairly predictable results. In all flow conditions, the early summer cross sections had higher percentages than the late summer cross sections. The percentage of exposed channel width for late summer ranged from 20 to 45 percent, while for early summer, it ranged from 28 to 60 percent. This is likely due to the decrease in the channel capacity of this time period, thus creating more shallow water areas versus deeper, more efficient channels.

For all flow conditions for both early and late summer cross sections, the current operations had a lower percentage of exposed channel width than did run-of-river operations. The percentage of exposed channel width under current operations ranged from 20 to 50 percent, while the percentage of exposed channel width under run-of-river operations ranged from 27 to 60 percent. This is likely because the average daily maximum flows, as identified in the hydrographs provided in Attachment B, are typically higher than run-of-river operations.

One anomaly is that the medium flow for run-of-river operations had higher percentage of exposed channel width percentages for both the early and late summer cross sections than the low flow. The highest percentage occurred under the medium-flow condition at the early summer survey for run-of-river operations (60 percent). However, the early summer cross sections at both Sites 4 and 5 fit the trend of less exposed channel width at higher flow conditions.

The analysis at Site 5, near North Bend, produced some consistent results as well as some results not within the trend of analysis. The low-flow and high-flow conditions in early and late summer were consistent with run-of-river operations percentages being higher than that of current operations. However, the results for the medium-flow condition were reversed. In addition, the high-flow condition had more exposed channel width than that of the medium-flow condition at both early and late summer surveys for both current and run-of-river operations. Overall, there was little difference in percentage of exposed channel widths between current and run-of-river operations when considering all flow conditions for the early summer survey. However, run-of-river operations did have a higher percentage of exposed channel width during the late summer survey than current operations when considering all flow conditions.

Comparison between Sites 4 and 5 shows that in general, Site 5 has a greater magnitude of differences between current and run-of-river operations, meaning that there was more fluctuation in percentage of exposed channel width between the various scenarios. This may be due to a more routine flow condition due to the proximity to the Tailrace Return. When considering all flow conditions, Site 5 has more exposed channel width than Site 4 for the early summer survey. This situation is reversed for the late summer survey.

Normal Year (2009)

The analysis of percentage of exposed channel width at Site 4, downstream of the Tailrace Return, for the normal year yielded fairly predictable results. Other than under the medium-flow condition, the early summer cross sections had higher percentages than the late summer cross sections. In addition, under the medium-flow condition, there was slightly more exposed channel width under current operations than run-of-river operations (35 percent for current operations to 30 percent for run-of-river operations for early summer and 22 percent for current operations to 21 percent for run-of-river operations for late summer). There was little difference in percentages between current and run-of-river operations for the late summer survey between the medium- and high-flow conditions (22 to 18 percent for current operations and 21 percent for both flow conditions for run-of-river operations).

Overall, when considering all flow conditions, the late summer survey yielded a higher percentage difference in percentage of exposed channel width between current and run-of-river operations. The early summer survey did not have, overall, much difference in total percentage of exposed channel width when factoring in all flow conditions.

The analysis at Site 5 showed that for the normal year, current operations had higher percentages of exposed channel width than did run-of-river operations for both the medium- and high-flow conditions for both early and late summer. The low-flow period is the reverse of this condition. Further, under the normal year, the medium-flow condition during the early summer survey had a higher amount of exposed channel width than the low-flow condition. The medium-flow condition showed the greatest difference between the early and late summer cross sections in the normal year.

Wet Year (2008)

The analysis of percentage of exposed channel width at Site 4, downstream of the Tailrace Return, for the wet year yielded predictable results. In all flow conditions, the early summer cross sections had higher percentages than did the late summer cross sections. The percentage of exposed channel width for early summer ranged from 23 to 44 percent, while for late summer, it ranged from 18 to 29 percent. This is likely due to the decrease in the channel capacity of this time period, thus creating more shallow water areas versus deeper, more efficient channels.

For all flow conditions for both early and late summer cross sections, there was a lower percentage of exposed channel width for current operations than for run-of-river operations. The percentage of exposed channel width under current operations ranged from 18 to 34 percent, while under run-of-river operations, percentage of exposed channel width ranged from 18 to 45 percent. This is likely because the average daily maximum flows, as identified in the hydrographs provided in Attachment B, are typically higher than run-of-river operations.

Overall, the early summer survey had a higher percentage of exposed channel width than the late summer survey, and run-of-river operations had a higher percentage of exposed channel width than current operations.

The analysis at Site 5, near North Bend, yielded consistent results. The percentage of exposed channel width decreased with increasing low-flow conditions. The early summer survey had higher percentages than the late summer survey, and run-of-river operations had higher percentages for all flow and time period conditions than did current operations.

The greatest magnitude of difference occurred during the low-flow condition for the early summer cross section, with percentage of exposed channel width under current operations being 35 percent and under run-of-river operations being 59 percent. The remainder of the differences between current operations and run-of-river operations for each flow condition was very similar in magnitude. This indicates that as the flow increases, there is less difference between the percentage of exposed channel width between current and run-of-river operations.

Comparison between the study sites shows that, in general, when considering all flow conditions, Site 4, downstream of the Tailrace Return, has more exposed channel width than Site 5, near North Bend, for the both early and late summer surveys for both current and run-of-river operations. This is generally consistent with the overall results for the normal year of analysis.

Conclusions

For each year of analysis (wet, dry, and normal years), while some variation exists during different flow conditions within a flow classification year, current operations provide a lower percentage of exposed channel width than run-of-river operations. Early summer cross sections yielded a higher percentage of exposed sand than late summer cross sections, which is likely due to a decrease in channel efficiency (less deep channels, more shallow water areas, less exposed channel width). From a study site perspective, percentage of exposed channel width was generally higher at Site 4, downstream of the Tailrace Return, than at Site 5, near North Bend. The normal year (2009) did not follow this trend.

When reviewing these results, it must be considered that increasing exposed channel width does not necessarily provide more suitable interior least tern and piping plover nesting habitat. Increased size of exposed channel width where interior least terns were nesting did not appear to be a selected feature in Brown and Jorgenson (2009), where "the mean surface area without nesting least tern colonies was greater than that of sandbars with nesting colonies." Further, the processes for sandbar formation are complex. The conditions exhibited in this hydrocycling study provided only a difference in the surface water elevations that would be present at surveyed cross sections under the various operation and flow conditions. By examining the cross sections taken during different times of the year, effects of seasonal sandbar erosion and channel morphology changes that existed under actual conditions (precipitation events and operations) between the early summer and late summer periods were also considered. While the percentage of exposed channel width is a good indicator of potential habitat (defined in this study as dry, exposed sandbars), other factors that influence sandbar formation, habitat suitability, and general river morphology—such as frequency and occurrence of precipitation events, bank protection, riparian area land use, percentage of vegetation cover on sandbars, and valley width—are all factors that ultimately affect the development of potentially suitable habitat.

6. STUDY VARIANCE

This study has been performed consistent with the Hydrocycling study plan, which was approved with modifications by FERC in its Study Plan Determination on August 26, 2009. The only study variance that has occurred is regarding Peters and Parham's (2008) discharge versus habitat relationship. As discussed in Section 4.6.2, as an initial quality review of the calculations presented in the Peters and Parham report, the District calculated the percentage of suitable pallid sturgeon and shovelnose sturgeon habitat using the relationships in the Peters and Parham report and compared the results to tabulated results presented in the report. The District was unable to replicate the tabulated results and contacted one of the authors, Dr. James Parham, regarding this issue. Dr. Parham reviewed the report equations and results and informed the District that the equations were incorrectly reported in the Peters and Parham report. Although the equation for percentage of suitable pallid sturgeon habitat was correct, the reported coefficients were incorrect. Dr. Parham provided updated coefficients for the percentage of suitable pallid sturgeon habitat. The District rechecked the updated equation against the tabulated values and was able to replicate the values presented in the Peters and Parham report. Dr. Parham also provided an updated equation for percentage of shovelnose sturgeon habitat. The District rechecked the updated equation against the tabulated values but was still unable to exactly replicate the values presented in the Peters and Parham report. The results differed between 0 and 2 percent. For purposes of this hydrocycling study, and because FERC's Study Plan Determination required analysis for only pallid sturgeon, analysis related to shovelnose sturgeon is not presented.

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