MISSOURI RIVER HABITAT PROJECT DESIGN, PERFORMANCE, AND ASPECTS OF THE 2011 FLOOD

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Abstract: The Missouri River Recovery Program (MRRP) has constructed over thirty chute and backwater habitat areas on the Missouri River within the Omaha District that were consistent with shallow water habitat (SWH) creation requirements specified within the Biological Opinion (2000) and the Amended Biological Opinion (2003). Design and construction practices have evolved over the last 10 years due to project performance, objectives, and constraints. In addition, the 2011 Missouri River event within the Omaha District resulted in a sustained high peak flow with unprecedented duration. As a result, the Missouri River and entire floodplain experienced large areas of sediment erosion and deposition. Habitat project design process, construction aspects, and the observations related to 2011 flood impacts are presented. Conclusions regarding project performance with recommendations for future design improvements are provided.

INTRODUCTION

In 1989, The U.S. Army Corps of Engineers (Corps) initiated consultation with the U.S. Fish and Wildlife Service (Service) regarding operation of the Missouri River Main Stem Reservoir System. Consultation covered operation of the Missouri and Kansas Rivers as well as the Missouri River Bank stabilization and Navigation Project (BSNP). The 2000 Biological Opinion found that the actions proposed by the Corps would jeopardize the Interior least tern, pallid sturgeon, and piping plover. With the intent of precluding jeopardy to the species, the Service provided a Reasonable and Prudent Alternative (RPA). The Corps requested a re-initiation of the formal consultation and an amended Biological Opinion was provided in 2003. The Missouri River Biological Opinion and the Amended Biological Opinion (BiOp) set forth the requirements for the creation of shallow water habitat (USFWS, 2003). The RPA consisted of numerous elements pertaining to flow management, habitat diversity, and habitat area. The RPA performance standard for shallow water habitat acres established a goal of 20 to 30 acres per mile for the Missouri River from Ponca, Nebraska, located about 60 river miles downstream of Gavins Point Dam, to St. Louis, Missouri, a distance of 752 river miles. Since 2003, the Corps has completed construction of numerous projects intended to create shallow water habitat in this reach of the Missouri River. Following construction, monitoring activities have been conducted to evaluate the project performance. Activities have been conducted in both Omaha and Kansas City Corps of Engineers Districts (USACE, 2013). The Missouri River geometry and hydraulic characteristics change significantly between the two Corps Districts, which results in major differences in project formulation. The high floodplain energy associated with the flows and duration of the 2011 event resulted in significant changes within the floodplain including the constructed habitat projects. This paper focuses on observations related to habitat projects and

project performance within the Omaha District and the portion of the channelized Missouri River between Ponca, Nebraska, at river mile 752, and Rulo, Nebraska, at river mile 498.

Pallid Sturgeon Habitat: The pallid sturgeon is native to the Missouri and Mississippi Rivers and is adapted to the free flowing, warm water, and turbid habitats that are in a constant state of change. Floodplains, backwater, chutes, sloughs, islands, sandbars, and main channel waters formed the large river ecosystem that historically provided habitat for all life stages of pallid sturgeon in the river. Evidence of reproduction for wild origin pallid sturgeon is lacking. Destruction and alteration of big river ecological functions and habitat that was once provided by the Missouri River that followed Corps dam construction and channelization actions is believed to be the primary cause of declines in reproduction, growth, and survival of pallid sturgeon.

Shallow Water Habitat Definition: As set within the biological opinion, the parameters used to define shallow water habitat are Missouri River flow depths less than five feet (1.5m) and velocities less than two fps (0.6 m/s) (USFWS, 2003). For the purposes of assessing habitat creation, the effective discharge is defined as the 50% exceedance discharge from the August flow duration curve(s). Although the habitat accounting system is based on the effective discharge, data are also gathered and analyzed for a range of flows to provide an assessment of habitat diversity. Within the context of the RPA, shallow water habitat refers to:

- 50% exceedance August flow rate
- Flow depth less than 5 feet (1.5m)
- Flow velocity less than 2 ft/sec (0.6 m/s)

Channelized River Background:

Between 1912 and 1945, Congress, by funding and authorizing seven different acts, charged the U.S. Army Corps of Engineers with reservoir system construction, stabilizing the banks of the Missouri River, and providing a 9-feet deep by 300-feet wide navigation channel. Management activities resulting from these acts have included removing snags, protecting the river banks from erosion, and constructing and maintaining the navigation channel. This collection of projects is known as the Missouri River Bank Stabilization and Navigation Project (BSNP) (USACE, 2011). The Missouri River navigation project extends from its confluence with the Mississippi River at St Louis, Missouri, to Sioux City, Iowa, for a total distance of 734.2 river miles. For reference, Gavins Point Dam, the furthest downstream of the Missouri River reservoir system of six dams, is located at river mile 811. The reservoir system is operated to meet multiple authorized purposes, including navigation, as described in the Master Manual (USACE, 2006).

Stabilization and navigation objectives were accomplished through revetment of banks, construction of permeable dikes, cutoff of oxbows, closing minor channels, removal of snags and dredging. The BSNP is designed as a self-scouring channel that has not required maintenance dredging within Omaha District. In order to achieve the project objectives of bank stabilization and navigation, the river was shaped into a series of smoothly curved bends of the proper radii and channel width. Stabilization of the bank along the concave alignment of the design curve was accomplished with pile and rock-fill revetments. Dikes were constructed approximately perpendicular to the flow or slightly angled downstream along the convex bank, that were oriented to promote project objectives. BSNP structures are constantly attacked by river flows. Maintenance is conducted to ensure the structures provide river stability and channel dimensions

necessary for commercial navigation and other authorized purposes. Within the Omaha District portion of the navigation channel, the Missouri River has a top width generally between 600 and 700 feet. Dike spacing is also on the order of 600 to 700 feet. The typical BSNP components within the navigation channel are illustrated in Figure 1.

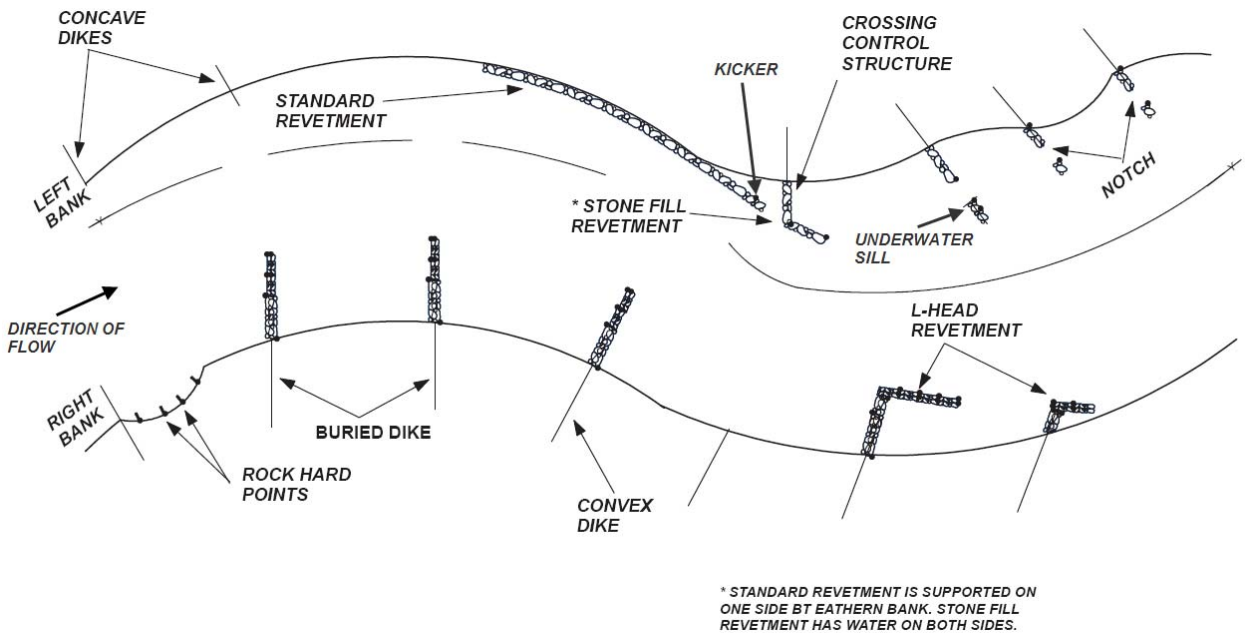

Figure 1 Typical Missouri River Navigation Channel Plan View

Habitat Project Types: Shallow water habitat is created using many different approaches that are generally classified according to the habitat type and location. Some projects are created within the main channel while other methods are within the adjacent floodplain. Habitat project types that have been used within the Omaha District include:

- Structure Modifications - Dike Notching (in-channel revetment and dikes)
- Backwater (off-channel)
- Pilot Channel (off-channel)
- Chute (off-channel)
- Major Dike Modification (in-channel dike lowering and chevron construction)

Employment of the various methods is often limited by physical parameters, available real estate, and other factors. For instance, bend curvature, site topography, adjacent infrastructure, and other factors may prevent sustainable construction of an off-channel chute. No actions are conducted without acquiring a real estate interest in all lands encompassing the project.

2011 EVENT

The duration and magnitude of the 2011 Missouri River flood event exceeds all other events in the recorded history of the river. Annual runoff volume frequency has been characterized as a 0.2 percent annual chance exceedance (500-year) event (Grigg et al., 2012). Historic events were

reviewed to provide context regarding 2011 event river flows. Sustained periods of prolonged floodplain flow indicate flow energy acting within the floodplain. In a simple method used to compare the 2011 event flow energy to historic events, the number of days when the Missouri River flowed within the floodplain were tabulated. When comparing contemporary to historic events, it should be recognized that historic river flows were affected by Missouri River main stem dam construction and reservoir filling, primarily from 1953 to 1967. All flow-frequency values reported in the comparison are post dam construction (USACE, 2003). As a result, comparing contemporary to historic events is somewhat misleading since the reservoir system has significantly altered its peak flows. For this simplified evaluation of floodplain energy, the 2-year event was assumed to roughly correspond with floodplain flow initiation. Data from the USGS gage at Nebraska City, Nebraska, which is located about 250 river miles downstream of Gavins Point Dam, is shown in
Figure **2**.

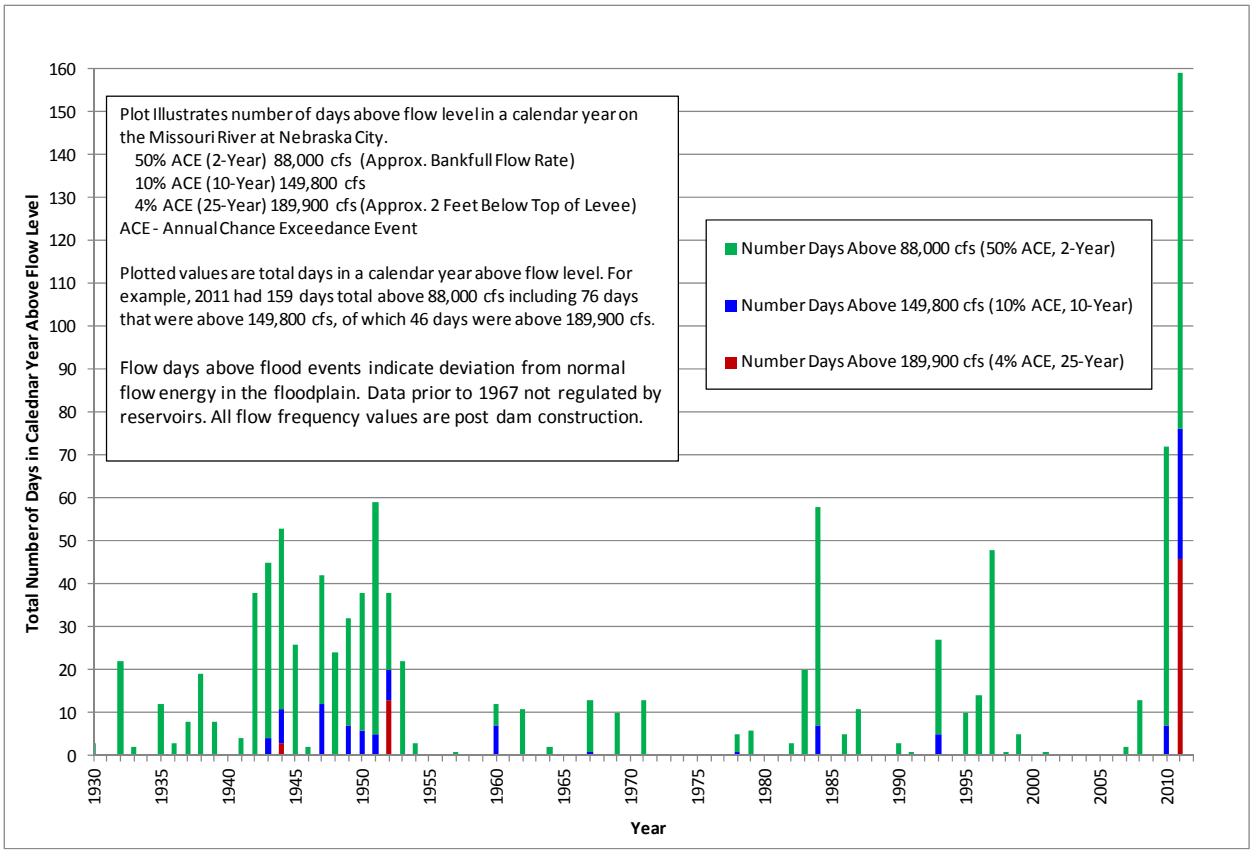

Figure 2 Nebraska City Days above Flow Value by Year

The above figure illustrates the severity of the 2011 event. The 2011 flow year at Nebraska City had 159 days with average daily flow above a 50% ACE (2-year) which roughly corresponds to the duration of floodplain flow or flow above the channel bank height. Furthermore, the 2011 event had 46 days with an average daily flow in excess of the post dam construction 4% (25-year) annual chance exceedance (ACE) event of 189,900 cfs. The prolonged duration of the 2011 event with flows above channel capacity dwarfs all other events which occurred on the historic

Missouri River. The 2011 event is the only event since mainstem dam construction was completed in the mid 1950s to have even a single day with the daily average flow greater than the 4% ACE (25-year). The average daily flow comparison illustrates that the 2011 event was unique with floodplain energy at a very high level for a prolonged duration that is unprecedented in the historic record.

HABITAT PROJECT PERFORMANCE EVALUATION

Habitat Projects Prior to the 2011 Event: Prior to the 2011 event, a total of 33 off-channel chute and backwater projects had been constructed in the Omaha District with varying size and location as shown in Table 1.

Table 1 Omaha District Off-Channel Projects Constructed Prior to 2011 Event

Site No.	Off Channel Projects	RM DS	RM US	Year	Length	State	SWH 2010 Acres[1]
1	Ponca State Park Backwater	753		2004		NE	70
2	Glovers Pt Backwater	711.5		2005		Tribal	28.6
3	Glovers Point Chute	711.2	713.4	2005	11,100	Tribal	15
4	Hole In the Rock Backwater	706		2006		Tribal	5
5	Blackbird-Tieville-Decatur Flow Thru	688	698	2006		IA	7
6	Middle Decatur Chute	687.4	688.2	2009	4,640	NE	20
7	Lower Decatur Revet. Lower	685.7	687.3	2008	8,200	NE	7
8	Lower Decatur Chute	684.9	687.3	2008	2,400	NE	9
9	Louisville Bend Backwater	682	685	1995		IA	60
10	Fawn Island Chute	673.3	674.1	2010	2,979	IA	9
11	Three Rivers Revet. Lowering	669.4	670	2010	2,810	NE	12
12	Bullard Bend Backwater	663		2009		NE	25
13	Soldier Bend Backwater	660.4		2004		IA	26.8
14	Tyson Backwater	653.2		2009		IA	63.9
15	California Bend, IA, Chute	649.5	650.1	1999	4,000	IA	11.6
16	California Bend (IA) Backwater	649.5		2004		IA	16.3
17	California Bend, NE, Chute	648.5	650.1	2003	9,230	NE	36
18	Lower Calhoun Chute	637.1	637.6	2009	2,750	NE	9
19	Boyer Backwater	634.2		2010		NE	43
20	Boyer Chute	633.7	637.8	1994	16,760	IA	56
21	Council Bend Chute	616.8	617.8	2007	5,630	IA	18
22	Plattsmouth Lake Connect. Backwater	592.8	593.8	2005		NE	25
23	Plattsmouth Backwater Phase 2	592.3		2008		NE	25
24	Plattsmouth Chute	592.1	594.5	2005	12,070	NE	90
25	Tobacco Island Chute	586.3	588.4	2002	15,450	NE	23
26	Upper Hamburg Chute	552.2	555.9	1996	15,950	NE	97
27	Lower Hamburg Backwater	552		2005		MO	7
28	Lower Hamburg Chute	550.6	553.4	2005	13,200	MO	34
29	Kansas Bend Chute	544.5	546.4	2005	9,150	NE	23
30	Nishnabotna Chute	542.4	543.3	2005	5,780	NE	19
31	Langdon Bend Backwater	529		2000		NE	10
32	Deroin Bend Chute	516.4	520.5	2002	18,140	MO	85
33	Rush Bottoms Chute	499	502	2008	8,400	MO	12
	1 - Refers to the shallow water habitat acres as determined in a 2010 evaluation. This is pre-2011 high flow acres.						

The Corps utilized a monitoring and adaptive management program to verify that projects were within design objectives, that all Missouri River authorized purposes were functioning, and to inform future project design. In general, project performance prior to the 2011 event had been as expected. Critical points regarding constructed project performance through 2010 are:

- Projects were in different stages of development due to the time period since construction and other site specific factors such as historic flows, soil types, etc.
- Due to many factors, multiple habitat project types and sizes were constructed. Within the framework of the various project objectives and performance expectations, no significant performance differences were noted between habitat types.
- Several chute projects required minor maintenance on rock structures.

- No chutes experienced problematic erosion or widening and were within an acceptable range.
- Performance of habitat enhancement projects, such as features to promote depth diversity and add woody debris, had been reasonably successful.
- Sediment deposition had been noted in backwater areas as expected, with routine maintenance performed at some sites to maintain their function.

Habitat Project Assessment Following the 2011 Event: Following the 2011 event, the Omaha District performed numerous design and repair projects of critical infrastructure including dams and levees throughout the basin. Although a lower priority, habitat projects were also assessed and repairs performed as resources allowed. Inspection indicated that SWH habitat was lost in many constructed projects and gained in others. This also applied to the overall river corridor. However, much of the post-flood habitat does not appear to be sustainable and will likely experience future deposition. Flood damage varied significantly between constructed SWH projects. The high flood flows traveled downstream following the valley slope in the most energy-efficient manner crossing river bends. Erosion and deposition patterns typically associated with flow turbulence and velocity reduction due to primary flow direction exiting and entering the channel and floodplain were observed throughout the river corridor. Floodplain infrastructure and features, such as roads and levees, constricted the floodplain width and concentrated flows. Floodplain features as well as constructed habitat projects in the path of this flow zone were often severely impacted. Visible erosion and deposition areas were apparent throughout the floodplain corridor without an observed correlation to the presence or absence of SWH projects. Typical floodplain conditions post 2011 flood are shown in
Figure **3**.

Figure 3 Typical Floodplain Conditions Post 2011 Flood.

Flood flows traveled across the river bends which resulted in degraded BSNP dikes and revetments at most bend entry and exit points, regardless of the presence of SWH projects. Floodplain material dynamics were noted throughout the Missouri River flow corridor with zones of both scour and deposition that occurred as the flood flows traveled linearly down the valley floodplain regardless of navigation channel alignment. Depending upon the location and river dynamics, constructed chute and backwater habitat projects in the floodplain were subject to the same floodplain dynamics and experienced both scour and deposition. Flood flow patterns in a typical area are illustrated in
Figure **4**.

Off Channel Chutes: Chute project response to the 2011 flow event varied significantly with location. A little less than half of the chutes required no or minor repairs. Constructed chute projects at about one-third of the sites experienced deposition that prevented flow-through chute connectivity at normal Missouri River flows and threatened sustainability. Minor sediment removal projects have been conducted at two sites, planning continues at a third site, and three sites likely will not be repaired due to excess sediment deposition. Many chutes experienced both erosion and deposition with varying levels. Chutes experienced rock structure damage, flanking of control structures, and both widening and deepening. These geometry changes resulted in chute flow above the amount desirable for both habitat and adjacent project purposes. Minor issues were addressed with repair of rock structures in many sites. At three other chutes which experienced significant erosion, new control structures were added to reduce the flow to an acceptable level and improve performance to meet design objectives.

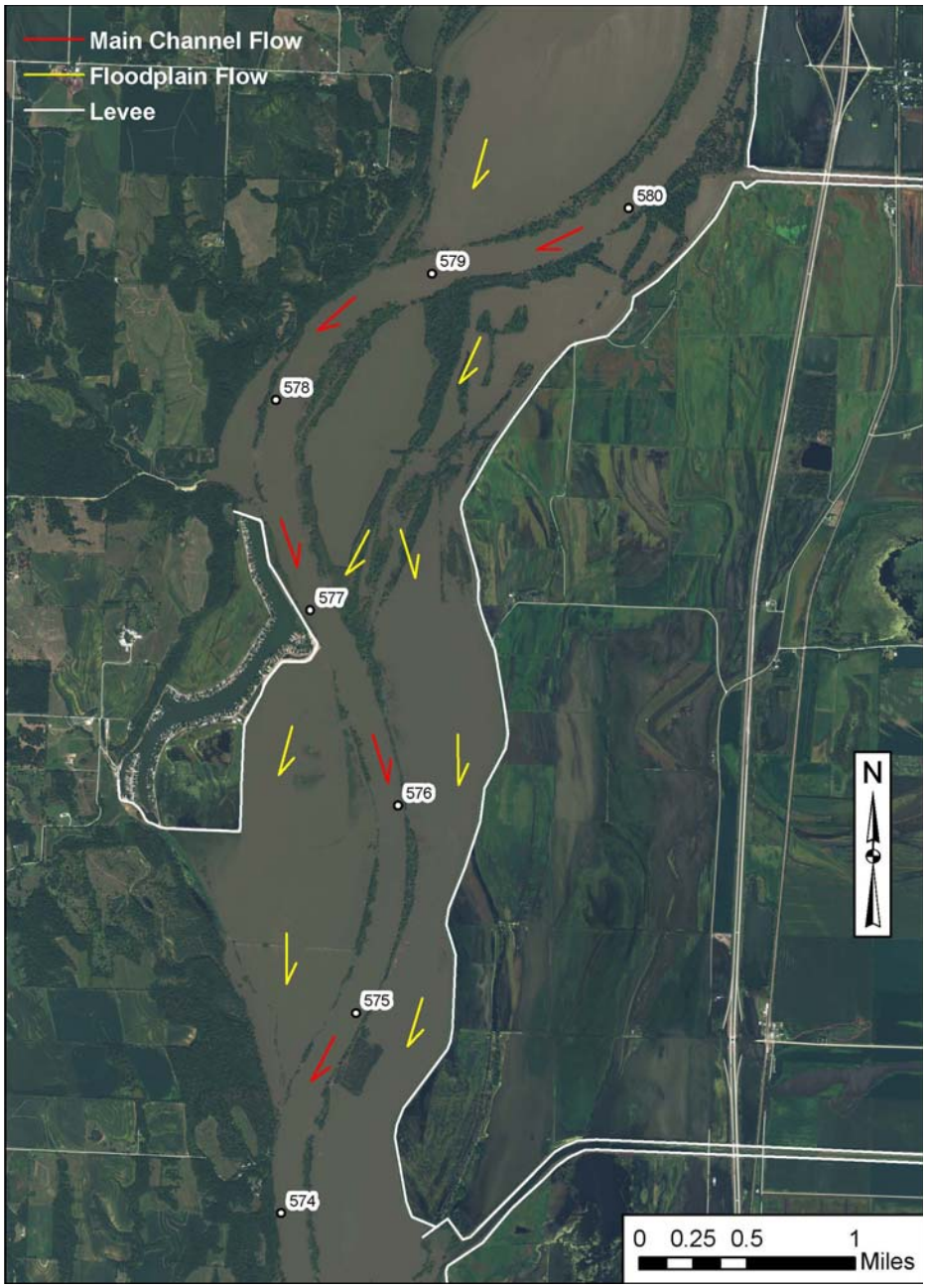

Figure 4 Typical Flood Flow Patterns

An inspection and subsequent evaluation of chute projects for factors which influenced the severity of damage noted a correlation to the previously discussed floodplain flow constrictions such as roads and levees, main channel curvature, and flow transfer across bends. For example, several chute projects that experienced erosion also were located in areas of floodplain constrictions which likely contributed to higher flow energy. Several chutes that experienced deposition were oriented against the path of prevailing floodplain flows. An example of a typical chute entrance that required repair is shown in
Figure **5**.

Figure 5 Typical Post Flood Chute Entrance Requiring Repair

Backwater Area Evaluation: Backwater projects experienced variable levels of scour and deposition as a result of flood flows. It should be noted that backwater areas are known to be depositional during normal flow periods due to the Missouri River sediment load. However, post-flood surveys and observations indicated that the 2011 flood deposition generally raised bottom elevations within backwater areas. This deposition will likely reduce the interval before remedial sediment removal is necessary to maintain optimum function and provide shallow water depths during normal river flows.

A quantitative evaluation of backwater deposition volume directly attributed to the 2011 event has not been conducted. Qualitatively, observations indicated greater deposition tended to occur in backwater areas that had been constructed with variable depths and non-linear shorelines. Backwaters which were located in the lower portion of a bend with upstream features which reduced floodplain flow such as natural topography, road crossings, levees, and heavily forested areas generally experienced lesser amounts of deposition from the flood event. Conversely, backwaters that were located in the typical floodplain sediment deposition zone as floodplain topography created low velocity areas experienced greater deposition volumes. Most backwater areas experienced deposition at the entrance from the Missouri River that was in excess of the typical formation at normal flows. An example of a backwater area illustrating the entrance sediment deposition bar is included in
Figure **6**.

Figure 6 Typical Backwater at Low Winter Water Level Illustrating Entrance Sediment Bar

SUMMARY

The Omaha District Corps of Engineers has conducted significant SWH design, construction, and monitoring activities since 2004. The 2011 Missouri River event within the Omaha District resulted in a sustained high peak flow with unprecedented duration which significantly impacted the floodplain and constructed projects. Significant observations include:

- The 2011 event was unique with excess floodplain energy at a very high level for a prolonged duration that was unprecedented in the historic record.
- Prior to the 2011 event, no constructed chutes had experienced significant or problematic erosion and were operating within an acceptable range.
- The entire floodplain and features were severely altered by the 2011 flood event.
- Following the 2011 event, the Omaha District performed numerous design and repair projects on critical infrastructure including dams and levees throughout the basin. Although a lower priority, habitat projects were also assessed and repairs performed as resources allowed.
- Habitat and channel conditions are known to be dynamic. Future changes are expected as the river continues to recover during a more normal flow range following the 2011 event.
- The factors which correlated to constructed project response appeared to be surrounding floodplain features such as levee constriction and roads, bend layout with respect to transfer of flood flows, and floodplain topographic irregularities.
- Chute response varied significantly. About half of the chutes required no or minor maintenance. Several sites experienced deposition, several sites had significant scour.
- Chute changes usually consisted of degradation of the entrance control structure, flanking of internal control structures, and both chute widening and deepening.

- Measured chute:river flow ratios are useful to assess chute geometry changes as a result of the event.
- Backwaters had varying degrees of deposition that appeared to correlate with bend alignment, location within the floodplain, and upstream floodplain features.
- While backwaters are known to require periodic maintenance, the sediment deposited during the 2011 event generally reduced the interval before remedial sediment removal is necessary to maintain optimum function.

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