EVALUATION OF LEVEE SETBACKS AS A SUSTAINABLE SOLUTION ALONG THE MISSOURI RIVER

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ABSTRACT

The use of levee setbacks provides a sustainable strategy to reduce flood risk by enhancing protection of people and property, providing economic benefits, and improving established ecosystems. Following the 2011 Missouri River flood two efforts to evaluate levee setbacks were conducted; the Assessment of Conceptual Nonstructural Alternative Levee Setbacks along the Missouri River (ACNALS) (USACE, 2012), and the implementation of levee setbacks in two locations as part of the 2011 flood recovery. These efforts have shown levee setbacks as a viable alternative to in-place repairs of existing levee alignments.

The U.S. Army Corps of Engineers (USACE) portfolio of levees was constructed over a long time period stretching back to the early 1900s. As such, levee design and implementation is varied due to the multiple agencies engaged with levee programs, evolving societal goals with regard to the benefits and risk associated with levees, and evolving state of the practice both for levee design and environmental compliance. The 1994, the Galloway Report (IFMRC, 1994) similarly noted that:

> *The current flood damage reduction system in the upper Mississippi River Basin (including the Missouri River Basin) represents a loose aggregation of federal, local, and individual levees and reservoirs. This aggregation does not ensure the desired reduction in the vulnerability of floodplain activities to damages. Many levees are poorly sited and will fail again in the future. (Executive Summary)*

There are locations in levee systems where historic levee performance issues, hydraulic pinch points, and disconnected floodplain habitat intersect. These locations provide an ideal site for implementing levee setbacks.

The purpose of this paper is to discuss USACE Omaha District efforts to evaluate and construct levee setbacks along the Missouri River following the flood of 2011. This evaluation relies primarily upon the information in the ACNALS report as wells as the evaluations for the constructed levee setbacks.

INTRODUCTION

Since the passage of the Flood Control Acts in 1928 and 1936, the Federal Government has taken a lead role in the construction of flood-risk reduction projects. Levees have been one of the primary tools used to accomplish this task. The USACE inventory of levees is significant, with over 14,000 miles of levee segments identified in the National Levee Database (NLD). The majority of the inventory was constructed prior to modern water resource management requirements such as the National Flood Insurance Program (NFIP) floodway and National Environmental Policy Act. The Missouri River levee systems, located in between Omaha and Rulo, are representative of the inventory with levee alignments protecting large areas with recognized flood risk, life-cycle funding, and ecosystem concerns.

The Missouri River downstream of Omaha, Nebraska, and Council Bluffs, Iowa, consists of a navigation project with stabilized banks, an engineered channel, and a system of agricultural and urban levees protecting vast acres of farmland and residential areas. During the 1930s, protection of land was considered an incidental benefit of the navigation project. As discussed in the 1939 Missouri River Improvement Report (USACE, 1939):

> *While intended primarily for the improvement of navigation, works constructed on the Missouri River by the Federal Government have resulted in considerable benefits of other kinds. The most obvious of such incidental benefits is the protection afforded to bottom lands along the improved sections of the river. … The resulting security in the tenure of land has fostered a more stable agriculture in the valley, and increased the value of the lands and improvements.*

During the 1940s, protecting land with levees became a prominent part of the overall Missouri River plan with authorization for levee construction in the 1944 Flood Control Act (FCA).

Design for the Missouri River levees was authorized to provide minimum conveyance widths set by the FCA at 3,000 feet from Sioux City to the mouth of the Kansas River. Additionally, a buffer of 1,000 feet from the established bank line was identified. While much of the system does maintain these minimum conveyance widths, numerous locations exist with widths less than the 3,000-foot minimum. This issue exists most notably at bridge crossings where widths commonly vary from 1,200 to 1,600 feet. These alterations from the authorized buffer were primarily to include features in the protected area of the levee or reduce the cost of construction by building onto existing levees. The 1947 Definite Project Report (DPR) Supplemental on Levee Unit L-575 identifies locations where the levee was aligned without the minimum conveyance width in order to protect individual farmsteads and occupied residences, tie in with and increase the height of existing levees, or conform to existing bridge abutments.

Since the construction of the levee systems, a number of flood events have occurred causing levee breaches, significant damage, and routine wear and tear. Notably, the 1952, 1993, and 2011 floods resulted in levee breaches on the L-550 and L-575. In addition to the breach events, more frequent, less severe flood events such as the 1984 and 2010 events caused damage in the form of erosion and scouring to the levee systems, which was repaired through the PL 84-99 program. The Federal cost-shared Public Law 84-99 (PL 84-99) program provides assistance to repair damages caused by flood events. These repair costs are in-addition to routine non-cost-shared sponsor O&M costs.

Following the 1993 flood event, the Interagency Floodplain Management Review Committee was tasked to delineate the major causes and consequences of the 1993 Midwest flood. The committee evaluated the performance of existing floodplain management and related watershed management programs, which resulted in the publication of *Sharing the Challenge: Floodplain Management into the 21st Century*. Some of the conclusions from the this report include (IFMRC, 1994):

- *The need to consider both structural and nonstructural means to mitigate flood damages*
- *Levees can cause problems in some critical reaches by backing water up on other levees or lowlands*
- *Many levees are poorly sited and will fail again in the future*
- *Human activity throughout the basin has caused significant loss of habitat*

Adverse impacts to the ecosystem have been identified and linked to the disconnection between the Missouri River and its natural floodplain. Most notably, the US Fish and Wildlife Service (USFWS) 2000 (and 2003 amended) Biological Opinion on the Operation of the Missouri River Mainstem Reservoir System, Operation and Maintenance of the Missouri River Bank Stabilization and Navigation Project, and Operation of the Kansas River Reservoir System (BiOp) identifies the USACE as providing primary operational management of the Missouri River and is therefore responsible under the Endangered Species Act to take action within its authorities to conserve listed species impacted by the operation of the

Missouri River (USFWS, 2000 and 2003). The BiOp provided the USACE with a Reasonable and Prudent Alternative that, if accomplished, would likely avoid jeopardizing three listed species (pallid sturgeon, least tern, and piping plover).

EXISTING CONDITIONS

The current alignment of the Missouri River Levee System is based primarily on design concepts developed in the 1940s and early 1950s. Like most levee systems of that era, the overriding design goal included maximizing the size of the protected area behind the levee. Alignments for the levees were guided by available and affordable real-estate, minimizing levee lengths, and building onto existing locally-constructed levees to minimize project costs. The 1947 Missouri River Levees Detailed Project Report (DPR) notes (USACE, 1947):

> *Consistent with design criteria, prime consideration is given to protection of the maximum amount of land that is under cultivation or can be reclaimed after the levees are constructed. Attention is also given to alignment factors affecting the cost of construction and maintenance…*

By maximizing the amount of protected area and minimizing project costs, it was thought the levees would provide the highest benefit to the nation, both in terms economic development potential and flood risk reduction. At that time, the concept of maximizing the protected area was well received. This approach resulted in levee systems that are located in the active high-energy floodplain. Review of the levee alignments with historical imagery and mapping identifies numerous locations where alignments cut across abandoned meander channels, ridge and swale point bar morphology, chutes, and cutoff channels.

Flood Risk Conditions Multiple hydraulic constrictions exist along the Missouri River as a result of current levee and bridge alignments. A hydraulic constriction is a location with reduced conveyance in relation to upstream and downstream areas. To identify hydraulic constrictions, velocities for the 100-year flood event were modeled using the 2008 Missouri River Floodway model. Figure 1 shows modeled velocities in the Missouri River between Omaha and Rulo with annotation at various velocity peaks. Each of these velocity peaks is associated with a hydraulic constriction.

In general, the Missouri River levee systems are located near the river banks and their alignments are founded on a blanket of silts and clays, underlain by pervious sand and gravel. The geology corresponds to the historic braided channels typical to the Missouri River floodplain. The blanket of silts and clays provide an important layer of protection in the flood risk reduction function of the levee systems as a control of underseepage. The increased velocity associated with constrictions leads to increased flood risk through two primary methods, increased potential for erosion and scouring, and increased stages. Higher velocities are associated with higher potential for erosion and scour. Erosion and scour have the ability to alter stream and cross-section geometry, migrate riverine features, and/or damage the silt and clay blanket. At constriction points, the increased potential for erosion and scour makes the blanket layer more susceptible to damage.

The Galloway Report provided a review of the levee breaches in the 1993 flood event noting that 72% of the studied breaches were associated with areas occupied by one or more channels that had been active within the past 120 years. This report recommends the following (IFMRC, 1994):

> *Recommendation 8.1: The USACE in cooperation with the USGS and should conduct a detailed historical analysis of levee breaching to document specific levee locations and causes of high failure rates. This study should include geotechnical data and new field studies of hydraulic and geomorphologic factors that directly affect levee erosion and failure.*
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> *Recommendation 8.2: On the basis of detailed floodplain mapping and historical levee evaluation, the USACE in cooperation with the USGS and SCS should identify alternative alignments for levees with high failure rates.*

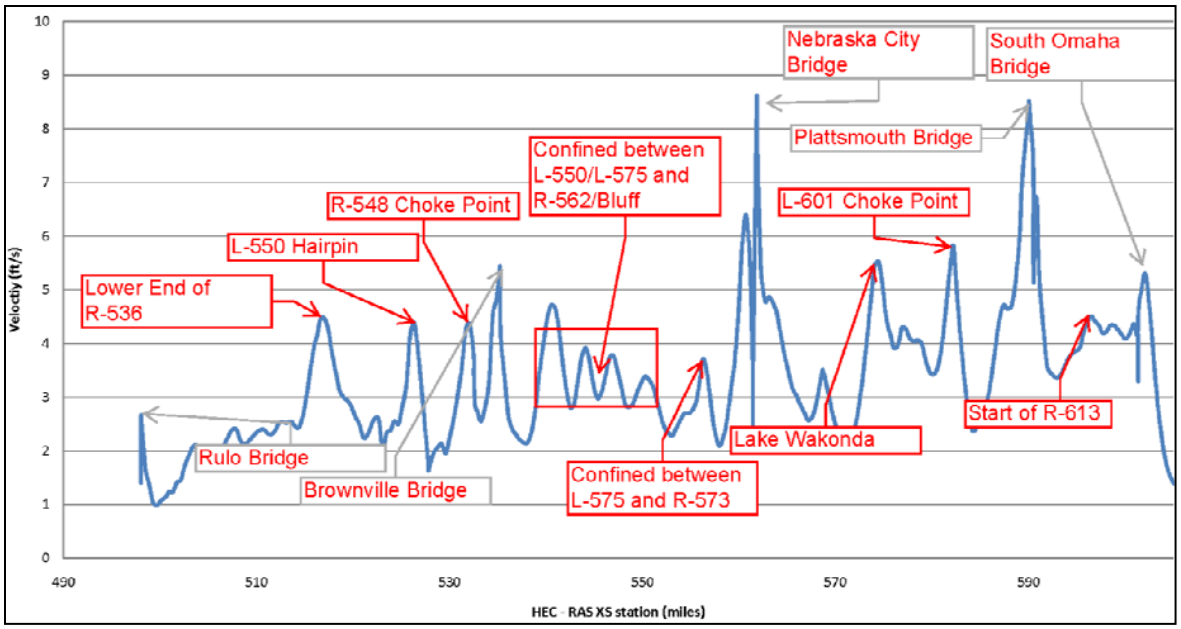

Figure 1 Missouri River 100-year velocities, Omaha to Rulo

Increased velocities at constriction points also result in increased water surface elevations, requiring larger amounts of energy to push water through the constricted conveyance locations. This was noted in the Galloway report (IFMRC, 1994):

> *Levees can cause problems in some critical reaches by backing water up on other levees or lowlands.*

Similarly, the Great Flood of 1993 Post-Flood Report (USACE, 1994) states:

> *By protecting the areas behind the levees, flood flows are partially constrained by the levees and forced to flow through a narrower cross section. This constriction causes flood levels to be higher for a specified distance upstream.*

Figure 2 presents stage trends of the Missouri River at Nebraska City, Nebraska from the 2012 Missouri River State Trends Report (USACE, 2012). This figure shows increasing stages for flows above 50,000 cfs. Following the 1984 Missouri River flood event, an evaluation of the adequacy of the Missouri River Levee System identified decreased levels of protection provided by the levee systems (USACE, 1986). The Upper Mississippi River System Flow Frequency Report (USACE, 2003) identified increasing stage trends at Omaha and Nebraska City, Nebraska. While it is certain that a rise in the stage-discharge relationship has occurred since the time of construction, this impact may come from many sources including the levee systems and floodplain aggradations. Estimates of the levee specific impacts was provided in multiple reports following the 1993 flood, including 0.5-2 feet with isolated areas having impacts as large as 4 feet (USACE, 1994) and 2-4 feet (USACE, 1995). These increased stages led to increased overtopping frequency for levee systems, as well as increased hydrostatic forces resulting in increased seepage potential.

Economic Conditions Figure 3 graphically presents the inter-relationship of levee site location, flood risk, habitat, and life cycle costs. On the Missouri River, these increased costs are incurred in a number of ways, including Federal costs through the Rehabilitation and Inspection Program (RIP), flood fight costs through the PL 84-99 expenditures, and habitat restoration costs through the Missouri River Recovery Program (MRRP). Local sponsor costs include ongoing O&M of levee systems. These costs are both

event-driven as well as ongoing. Due to the dispersed nature of the expenses amongst different entities, for different purposes, and in different time scales, they are difficult to fully quantify.

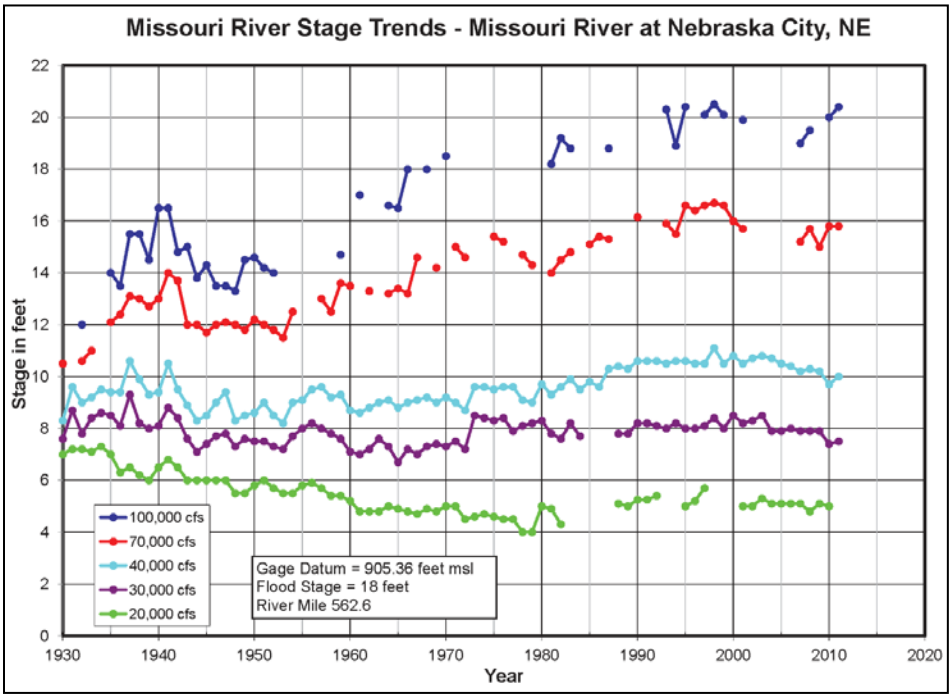

Figure 2 Missouri River at Nebraska City (USGS0680700) Stage Trends

Reviewing the costs of activities along the Missouri River does show that there are significant costs being incurred. Repair costs for levee systems L-575 and L-550 following the 2011 flood event were approximately $166.8 million. Total PL84-99 costs following the 1993 flood event for the Omaha District were approximately $7.6 million (~$12.1 million adjusted to 2014 dollars). Average annual costs for the MRRP, between 1992 and 2013, was approximately $30.8 million, this includes all activities involved in mitigating habitat lost due to construction of the BSNP along the entirety of the Missouri River.

Ecosystem Conditions Isolating the Missouri River from its floodplain has greatly impacted the river's ability to maintain its natural and beneficial ecological functions, and significantly changed the environmental conditions native species rely upon. Connectivity between a river and its floodplain are important to the flow, exchange, and pathways that move organisms, energy, and matter throughout watersheds (MNDNR, 2012). The high biodiversity typically found across natural floodplains cannot be maintained without the rejuvenating forces of floods and channel meandering (NRC, 2002).

Species-specific impacts due to today's degraded conditions can be observed across a suite of riparian and riverine flora and fauna. Disconnecting the land from the river has disrupted the periodic overbank flooding and erosion/deposition processes necessary for regenerating and maintaining cottonwood forests (Dixon, 2010). As a result of these alterations to the river-floodplain ecosystem, cottonwood forests that were once dominant along the river have ceased reproduction. Under the altered river conditions, 51 of 67 native mainstem fish species are now listed as uncommon or decreasing across all or part of their historic range. Benthic macroinvertebrate production has declined by 70% along the unchannelized river reaches (NRC, 2002). Over 80 species on the Missouri River have been listed under state statutes as rare, threatened, or endangered, including 24 fish, 22 birds, 14 plants, 6 reptiles, 6 mammals, 6 insects, and 2 mussels (Whitmore and Keenlyne, 1990).

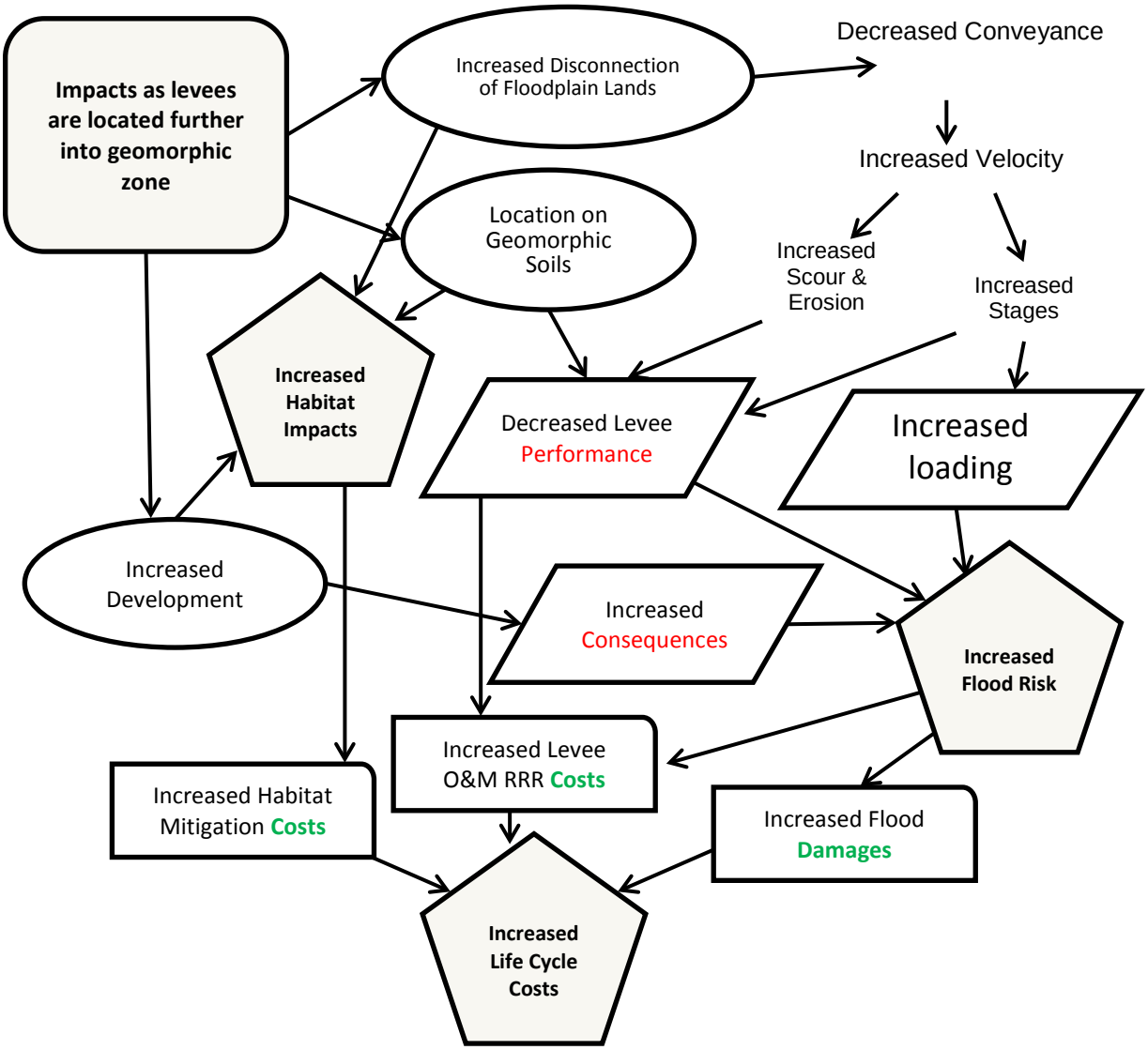

Figure 3 Interrelationships of Levee Locations in Geomorphic Zone and Lifecycle Costs

LEVEE SETBACK EVALUATION

Balancing flood risk reduction benefits with the impacts associated with levees in a financially beneficial manner is the goal of properly designed, constructed, operated, and maintained levee systems. The current understanding of riverine system management including flood-risk management, economic benefits, and habitat interactions has altered the way in which engineers approach levee system design. Implementing levee setbacks at select locations, such has hydraulic constrictions, provides a strategy to modify existing infrastructure with this modern understanding. Figure 4 provides a cross-sectional view of the levee setback concept.

The following sections discuss efforts to identify and quantify these benefits from the ACNALS, implementation of levee setbacks following the 2011 flood, and monitoring of those levee setbacks in subsequent years. The ACNALS evaluated three large-scale levee setbacks on L-575 and L-550 (each ~2.3 sq mi of floodplain connectivity). As a part of the post-2011 reconstruction, two hydraulic levee

setbacks were constructed on L-575 in Fremont County, Iowa. One setback is located at the Nebraska City constriction along Highway 2 within the Copeland Bend Wildlife Management Area (WMA), which reconnected approximately 760 acres of floodplain.

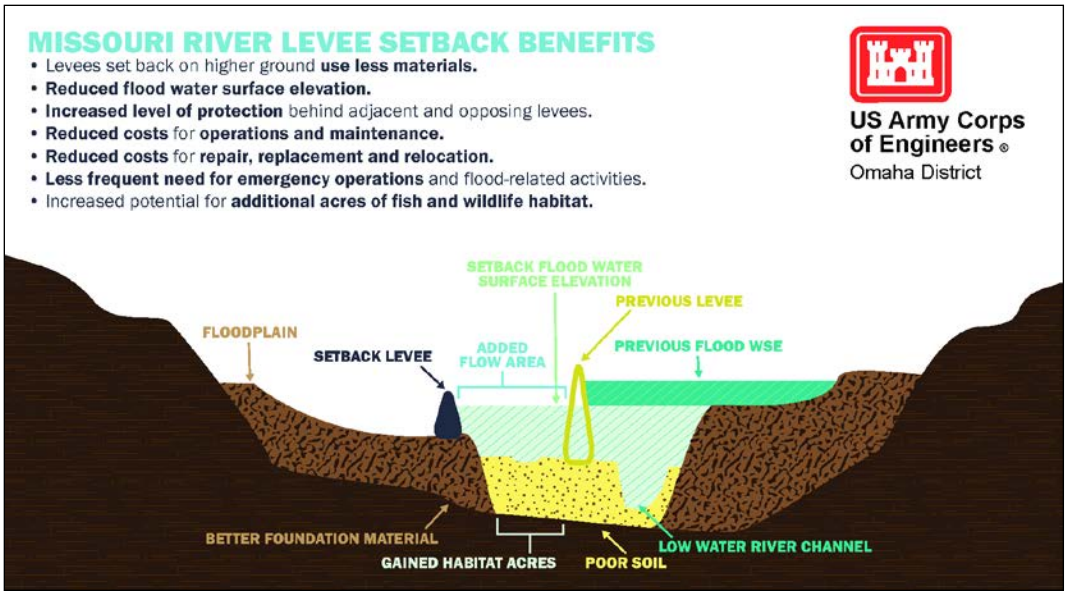

Figure 4 Levee Setback Concept Cross Section

The second setback is located at River Mile 557 within the Frazer Bend WMA, which reconnected approximately 980 acres of floodplain. Figure 5 provides an example of the levee setbacks assessed as part of the ACNALS. Figure 6 identifies the constructed levee setbacks on L-575. Overlaying the 1879 MRC mapping and historic performance of the levees shows similar themes as the Galloway report (IFMRC, 1994) which identified a correlation between breach locations and areas occupied by one or more active channels in the past. Figure 5 shows six historic breach locations, all of the four inlet breaches (as well as the two outlet breaches) are located in areas identifiable as active channels in the 1897 MRC maps.

Flood Risk Evaluation The ACNALS indentifies velocity reductions at identified pinch points; these reductions dropped pre-project velocities of 7.5 fps - 8.5 fps (feet per second) to 4.5 fps - 6.5 fps. Stage reductions resulting from this were four feet just upstream of the setbacks, and showed benefits of 0.10 feet 20 miles upstream. This level of benefit is in line with the estimated hydraulic impacts of levees in the post-1993 reports. These stage decreases have a significant effect on the calculated frequency of levee loading. For the L-575 and L-550 systems, the overtopping frequency could be decreased by 50% with similar decreases in loading frequency on the levee system prior to overtopping. Benefits to the adjacent systems (R-548, R-562, and R-573) are similar, with calculated loading frequencies cut in half.

The implemented levee setbacks show that at hydraulic constrictions, significant hydraulic benefits can be obtained with modest floodplain connectivity. The Nebraska City hydraulic constriction was one of the largest velocity peaks on the Missouri River from Omaha to Rulo (see Figure 1). The constructed levee setback altered the 100-yr velocity from 9.7 fps to 4.2 fps, dropping stages 1-2 feet through the project area. Frequency of overtopping the L-575 levee system (above Hwy 2) was altered from an 80-year to a 120-year frequency, and loading to 3 feet below the levee crest was altered from a 25-year to a 35-year frequency. This shows an overall reduction in loading of ~33%. At the River Mile 557 setback, 100-year velocities were reduced from 4.1 fps to 2.7 fps providing a stage reduction of 1.44 feet. This benefit is also experienced by the adjacent levee on the right bank of the river, R-573, which provides protection for the Omaha Public Power District Nebraska City Power Plant.

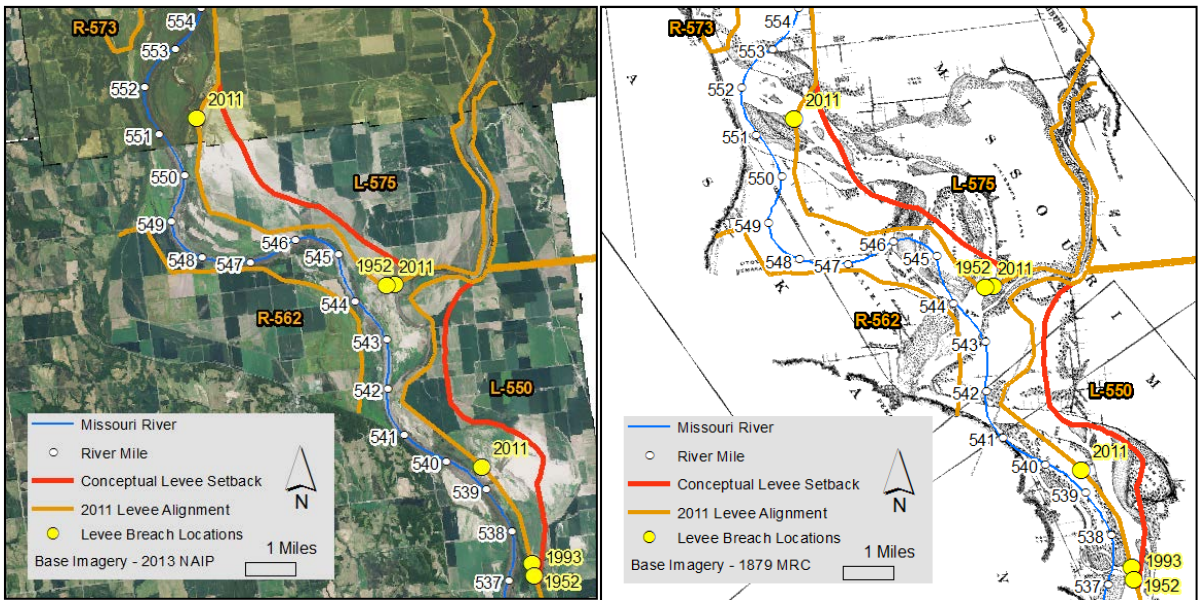

Figure 5 ACNALS Levee Setback (2013 Aerial Imagery and 1879 MRC)

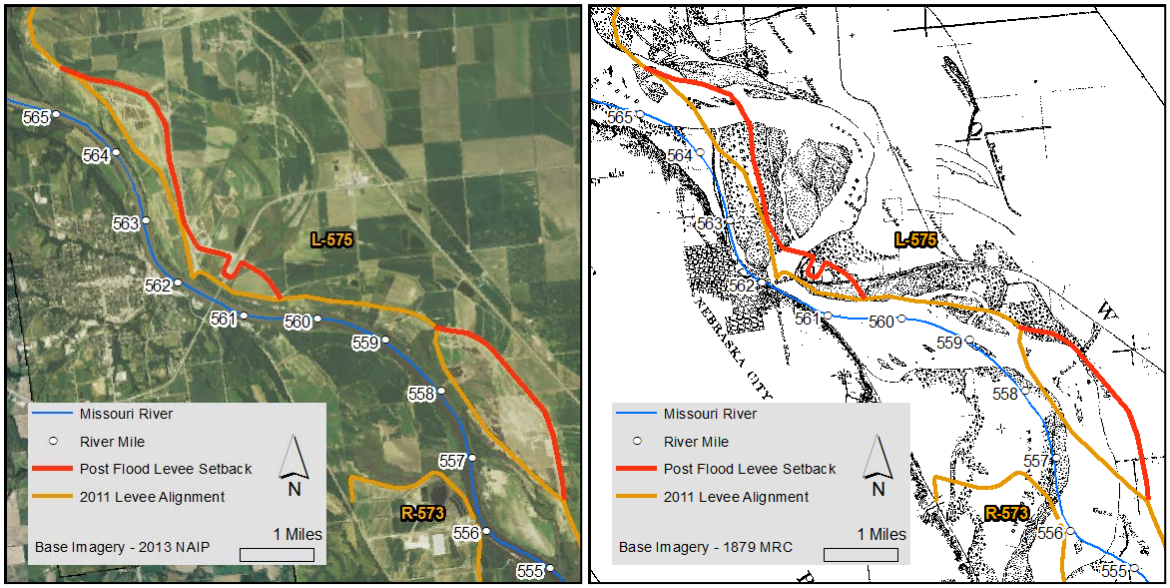

Figure 6 Constructed Levee Setbacks on L-575 (2013 Aerial Imagery and 1879 MRC)

While neither the ACNALS nor the constructed setbacks documentation included evaluation of levee performance, there were items of note. For the ACNALS evaluation, the distance of the levee setback was such that it was possible to identify higher elevations on which the levee could be founded. As a result, the frequency of loading the levee toe and maximum hydrostatic forces that the levee could be exposed to could be reduced. Similarly the River Mile 557, the setback alignment was based on a natural elevation change and benefits from reduced frequency of exposure. For both of the constructed setbacks, poor geotechnical characteristics of the site were a primary concern in deciding to realign the levee. This supports the assumption that movements away from the channel bank and toward the lower energy flood plain areas can obtain more resilient geotechnical conditions.

Economic Evaluation The objective of the ACNALS was to provide a comparison of levee setbacks in the framework of post-flood PIRs. Two alternatives were considered: the first looked at levee setbacks constructed with the same top of levee elevation as repair-in-place alternatives, the second looked at levee setbacks where the levee crest was lowered to provide the same frequency of overtopping protection provided by the repair in place alternatives. The ACNALS results showed that while levee setbacks were a more costly alternative, largely due to increased construction and real-estate costs, they still provided Benefit-Cost Ratios (2.3 to 2.52) comparable with the repair-in-place alternatives (3.11). The ACNALS also noted that many of the benefits of levee seatbacks were not quantified using this methodology. Unaccounted for benefits include reduced adjacent and/or upstream levee system exposure, less frequent emergency operations, reduced flood-related expenses, and ecosystem benefits. The Galloway report similarly noted (IFMRC, 1994):

> *The principal federal water resources planning document, Principles and Guidelines, is outdated and does not reflect a balance among the economic, social, and environmental goals of the nation. This lack of balance is exacerbated by a present inability to quantify, in monetary terms, some environmental and social impacts. As result, these impacts are frequently understated or omitted. Many critics of Principles and Guidelines see it as biased against nonstructural approaches.*

Table 1 provides a summary for the Benefit-Cost Ratio computations in the ACNALS.

With regard to the two implemented levee setbacks on L-575, these efforts were constructed as a least-cost alternative. As such, no benefit-cost analysis was conducted. Table 2 provides a cost comparison of the repair-in-place quantities and costs against the levee setback alternative. It shows a total cost savings of $5 million for the levee setback option, primarily due to increased quantities for the measures necessary for the repair-in-place option to protect against erosion and underseepage. Should a benefit-cost review be conducted it would show lower cost and increased benefits for the levee setback alternative.

Table 1 Benefit-Cost Summary for Conceptual Levee Setback Alternatives in the ACNALS Report

	Repair In Place Alternative	**Setback Alternative with Pre-Flood LOP**	**Setback Alternative with Pre-Flood Levee Top Elevation**
L-550 Level of Overtopping Protection	20 years	20 years	28 years
L-575 Level of Overtopping Protection	30 years	30 years	30 years upper L-575 56 years lower L-575
System Protected Area	72.9 sq mi	64.6 sq miles	64.6 sq mi miles
Traditional BCR computations:			
Total Cost ($M)	$166.00	$193.00	$212.00
Annual Cost ($M)	$10.70	$12.70	$14.00
Annual Benefit ($M)	$33.30	$32.10	$32.30
BCR	**3.11**	**2.52**	**2.30**
Other Benefits Associated with Levee Setback Alternatives Not Quantified:			
Reduced damage to critical infrastructure: • Two Public Power Stations, $6.8 million cost-savings based on 2011 event • Reduced damage to transportation and other infrastructure and decreased traffic disruption **Ecosystem restoration benefits** • Increased potential for 6,471 additional acres of fish and wildlife habitat	**System benefits:** • Increased level of protection behind adjacent and opposing levees • Reduced O&M and R,R&R costs for adjacent and opposing levees • Emergency, evacuation and cleanup cost-savings: • Less frequent need for emergency operations and flood-related activities		

Table 2 L-575 In-Place vs. Levee Setback quantities and Costs at Hwy 2

Item	Repair In-Place	Levee Setback
North of HWY 2		
Riprap	15,000 tons	5,400 tons
Temporary Stockpiling of Riprap	0	5,400 tons
Stripping	56,500 cu yd	95,500 cu yd
Sand Fill	350,000 cu yd	303,000 cu yd
Temporary Stockpiling of Sand	0	97,000 cu yd
Random Fill	23,400 cu yd	571,000 cu yd
Underwater Fill	50,000 cu yd	
Geotextile	11,000 sq yd	7,400 sq yd
Cohesive Fill	30,000 cu yd	295,000 cu yd
Topsoil	70,000 cu yd	115,400 cu yd
Levee Surfacing	5,000 tons	6,100 tons
Seeding	83 acres	117 acres
Rehabilitation of Existing Wells	40	0
Abandon Existing Wells	0	40
Sheet Pile	170,000 sq ft	0
Permanent erosion control mat (armor max)	200,000 sq ft	0
New Relief Wells	128	40
North of HWY 2 Cost	$14,220,644	$10,884,244
South of HWY 2		
Stripping	15,000 cu yd	31,900 cu yd
Sand Fill	85,185 cu yd	324,000 cu yd
Cohesive Fill	0	98,300 cu yd
Topsoil	14,056 cu yd	38,500 cu yd
Levee Surfacing (Restore Berm Road)	3,825 tons	1,370 tons
Seeding	18 acres	39 acres
Rehabilitation of Existing Wells	40	0
Abandon Existing Wells	0	0
New Relief Wells	102	0
South of HWY 2 Cost	$4,657,657	$2,910,382
Total Cost	**$18,878,301**	**$13,794,626**

Ecosystem Evaluation This ACNALS habitat assessment described conceptual biotic responses that would occur in relation to various flood frequencies and depths. The review identified that the reconnected lands have the capability of boosting primary and secondary productivity and provide increased fish access to floodplain habitat for rearing, foraging, and cover. Floodplain areas that have not been converted to cropland or other uses typically contain open water and some remnant areas of mature cottonwood and willow stands, shrub understory, green ash, American elm, and herbaceous wetland vegetation. These vegetative communities are indicative of the plant species and distribution that would most likely become established and successfully colonize the newly reconnected floodplain.

Construction of the two levee setbacks provided 1,740 acres (2.7 sq mi) of floodplain connectivity. Since establishing this connectivity, the general responses anticipated in the ACNALS report have started to occur in the reconnected floodplain. Over 320 acres of borrow pits used to obtain material for the setback construction were treated to encourage wetland establishment. Treatment of the pits involved shaping to incorporate depth diversity, irregular bank lines, gentle side slopes, and seeding.

In 2013, the USACE and the Iowa Department of Natural Resources (IDNR) engaged in monitoring the setbacks and borrow pit wetlands. The USACE evaluated vegetative composition of the wetlands while IDNR conducted a multi-taxon survey. While detailed quantitative data about wetland establishment and other biotic responses will require more years of surveying to obtain, the treated borrow pits are exhibiting wetland characteristics within one to two growing seasons. All borrow pits have some degree of hydrological connectivity with the Missouri River water table, allowing for development of hydric soils over time. Hydrophytic vegetation emerged from the soil's seed bank at all surveyed borrow pits. During certain times of the year, large open water areas contained upwards of tens of thousands of water fowl.

IMPLEMENTATION AND CHALLENGES

There are a number of programs which provide authority to support the implementation of a levee setback. Notably Section 205 and Section 1135 authorities address flood risk reduction and ecosystem benefits at constructed projects respectively. Additionally, post flood repairs can be an opportunity to implement a levee setback; as part of the PL 84-99 program, the levee sponsors have the option to implement a Nonstructural Alternative (NSA). ER 500-1-1 (5-17 c (6)) identifies acceptable costs for a NSA as "construction to promote, enhance, control, or modify water flows into, out of, through, or around the nonstructural project area". While this definition seems sufficiently broad as to incorporate a levee setback, there remain concerns if levee setbacks are an appropriate NSA.

Challenges preventing the implementation of levee setbacks include the requirement in ER 500-1-1 to use the least-cost alternative instead of the most beneficial alternative. ER 500-1-1 (5-11 e (3)) identifies that

> *If the public sponsor prefers an alternative method of repair that is not the least cost to the Federal government alternative, the public sponsor shall pay 100 percent of the additional costs above the least cost alternative.*

Most levee sponsors have established operating budgets consistent with the routine O&M costs and rely on the assistance and/or bonding activities for larger costs. Accordingly, large-scale costs such as levee setbacks are not likely economically feasible without assistance and/or sufficient lead time to establish financial capability.

In comparison with the in-place repair option, levee setbacks present unique challenges in locating real estate and borrow material sources. Typically, the non-federal levee sponsor would supply the real estate and borrow material for a new levee alignment to be constructed under the PL 84-99 program. The constructed levee setbacks are located primarily on land either owned by the USACE for MRRP habitat restoration purposes, or on land encumbered by Natural Resources Conservation Service (NRCS) easements for habitat purposes. This alleviated the need for the sponsors to provide the borrow material. While USACE real estate outgrant policies and procedures are being reviewed and clarified to avoid lapses in PL 84-99 role accountability, borrow sourced from federally owned land intended for habitat restoration for future levee rehab efforts remains a solution worth considering.

Post flood timing is a major challenge for implementation. The desire to rapidly reestablish protection requires careful attention to construction phasing. With regard to the implemented levee setbacks, material from the damaged original levee alignment could not be accessed or used for the setback construction until the setback was built to a 25-year level of protection. This requirement led to uncertainties that all old levee material could be incorporated into constructing the completed setbacks. In constructing future levee setbacks, timing of original levee degradation would be considered on a case by case basis with consideration for time of the year and other factors contributing to potential flood risk.

A systems approach to riverine management identifies the "triple bottom line" interconnectivity of flood risk, economics, and ecosystem impacts. Many of the authorities for implementation identified above have restrictions on the purposes of the efforts. For example, MRRP funds are primarily for projects benefiting habitat restoration, while PL 84-99 funds are for restoration of levee systems. Disconnects between the systems approach necessary for sustainable solutions and nonsystematic focused funding mechanisms is an impediment for implementation. Similarly interaction of various agency programs provides a challenge. During implementation of levee setbacks on L-575 concerns about programmatic conflicts of the NRCS was common.

CONCLUSIONS

In conclusion, the use of levee setbacks provides a sustainable strategy to modify existing levee systems to meet the triple bottom line benefits to flood risk, economics, and ecosystems. Conceptual analysis in the ACNALS report and the implementation and monitoring of levee setbacks in two locations as part of the 2011 Missouri River Flood recovery have shown levee setbacks to be an implementable and beneficial strategy. The ACNALS report identifies that significant flood risk reduction can be achieved by locating setbacks at hydraulic constrictions. The constructed levee setbacks on L-575 show that benefits can be achieved with modest-sized setbacks. The economic analysis in the ANCNALS and financial data from the constructed setbacks show economic viability of the concept as well economic benefits that may not be fully accounted for in traditional economic analysis. Ecosystem assessments and monitoring of the constructed levee setbacks have shown benefits in the reconnectivity of the floodplain including conditions encouraging hydric soil development and immediate biotic response. While there are a number of benefits of levee setbacks, challenges to implementation exist. These challenges include programmatic authorities as well as real estate and funding. In a post-flood situation, the desire to re-establish the protection in a short time may amplify these challenges

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