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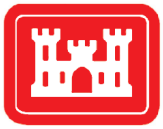

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Levee Setbacks: An Innovative, Cost-Effective, and Sustainable Solution for Improved Flood Risk Management

David L. Smith, Scott P. Miner, Charles H. Theiling,
Randall Behm, and John M. Nestler

June 2017

Environmental Laboratory

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Levee Setbacks: An Innovative, Cost-Effective, and Sustainable Solution for Improved Flood Risk Management

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Final report

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Abstract

This report describes levee setbacks as alternatives to traditional levees for flood risk management and environmental benefits. It is organized into five sections:

1. Information about levees for reducing flood damage, emphasizing environmental considerations
2. Description of the Engineering With Nature (EWN) concept for considering environmental benefits of U.S. Army Corps of Engineers (Corps) actions
3. Explanations of relevant Corps policy (Executive Orders (EOs), Engineer Regulations (ERs), and Memorandums of Understanding (MOUs))
4. Summary of environmental trade-offs between traditional versus levee setbacks
5. Summaries of two Corps levee setbacks in the Sacramento and Omaha Districts that successfully completed the planning process

The summaries describe how hydraulic, flood risk management, and environmental benefits were quantified. The report includes environmental considerations for levee setbacks developed by Rock Island District for the Upper Mississippi River (UMR). Parts of the UMR are not leveed, which provides insight into the ecological response that could be expected from large-scale levee setbacks. Levee setbacks are valuable tools for reducing flood damages and provide environmental benefits consistent with the EWN concept, the Chief's Environmental Operating Principles, and ERs, including the Resilience Initiative Roadmap. The report concludes that levee setbacks should be considered for appropriate sites.

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Preface

This study was conducted for the Headquarters, U.S. Army Corps of Engineers (HQUSACE) under the Dredging Operations and Environmental Research (DOER) program; Project Number 406219, "Engineering With Nature." The program manager was Dr. Todd Bridges (CEERD-EZS).

The work was performed by the Water Quality and Contaminant Modeling Branch (CEERD-EPW) of the Environmental Processes and Engineering Division (CEERD-EP), U.S. Army Engineer Research and Development Center (ERDC), Environmental Laboratory (ERDC-EL). At the time of publication, Mark Noel was Acting Chief, CEERD-EPW; Warren P. Lorentz was Chief, CEERD-EP; and Dr. Al Cofrancesco, CEERD-EZT, was the Technical Director for Civil Works Environmental Engineering and Sciences. The Deputy Director of ERDC-EL was Dr. Jack Davis, and the Director was Dr. Beth Fleming.

The Commander of ERDC was COL Bryan S. Green and the Director was Dr. David W. Pittman.

Unit Conversion Factors

Multiply	By	To Obtain
acres	4,046.873	square meters
acre-feet	1,233.5	cubic meters
cubic feet	0.02831685	cubic meters
feet	0.3048	meters
miles (U.S. statute)	1,609.347	meters
square miles	2.589998 E+06	square meters

1 Introduction

Background

Aging infrastructure, changing climatic conditions, limited resources, and increased environmental awareness have created a conundrum for decision-makers within agencies responsible for water resources management. Many existing, traditional U.S. Army Corps of Engineers "Corps" levees have sustained significant damages through toe erosion, overtopping, and breaching. The repair and rehabilitation costs have been significant and — in some instances — the same levee reach has been damaged multiple times. These damages should be considered as "repetitive loss" infrastructure due to the repetitive damages and rehabilitation costs to make them functional. Agency decision-makers are faced with "doing more with less," considering environmental sustainability in all their actions, and seeking innovative solutions to traditional water resources challenges. These pressures occur across the entire Corps mission portfolio, but are particularly vexing for the flood control mission because there is little margin for error when the protection of property and the preservation of human life is at stake. Extreme floods in many of the Nation's rivers have highlighted the urgency with which the Corps must address the challenge of flood damage reduction as described in the comprehensive "Galloway Report" (Galloway 1994) and subsequent follow-up commentaries (e.g., Snyder and Bruner 1994 and Galloway 2005).

In response to several substantial flood disasters, the federal government established the first Federal Flood Control Acts in 1917 and 1927 and has since played a large role in the Nation's flood damage reduction efforts, and — by extension — the Nation's floodplain management. Most flood damage reduction projects focus on structural measures such as dams, reservoirs, dikes, levees, floodwalls, channel alterations, high-flow diversions, and spillways designed to modify floods. However, increasingly, managers are considering structural measures that reduce the susceptibility and vulnerability to flooding, such as the application of physical techniques applied to individual structures in the form of acquisition, relocation, elevation; wet flood proofing and dry flood proofing; or as nonphysical techniques in the form of land use planning and zoning, building regulations, floodplain management, flood warning systems, evacuation planning, and development of emergency preparedness plans (Galloway

1994). Typically, the environmental impacts of nonstructural methods are reduced compared to structural methods and may even provide environmental benefits.

Importantly, the designation of a levee setback as a nonstructural versus structural alternative is not clear-cut and depends on the selected baseline (or reference condition (Nestler et al. 2012)), degree of setback, authority, and funding source. From an environmental perspective, the confusion occurs because the environmental conditions associated with a setback levee are intermediate between a traditional Corps mainline levee bordering the active river channel and an unleveed river. Using the environmental conditions associated with a traditional Corps levee as a baseline, the construction of a modestly sized levee located near the upland side of the floodplain can be reasonably viewed as a nonstructural alternative because the resulting environmental conditions will be similar to the environmental condition associated with an unleveed river. However, using the unleveed river as a baseline, the same design may be reasonably viewed as a structural alternative because the floodplain is being narrowed and reconfigured by a levee. From an environmental impact perspective, the classification of different levee setback designs as structural or nonstructural is less important than understanding and ranking the environmental impacts and benefits of each design. The same ambiguity of classification affects the Corps planning process. The designation of a levee setback as a nonstructural versus structural alternative is determined by the Corps program through which funds and authority are obtained. Levee setbacks authorized and funded under 33 U.S.C. 701n (commonly referred to as Public Law 84-99, Rehabilitation and Inspection Program (PL 84-99)), as directed by Engineer Regulation (ER) 500-1-1 (entitled "Civil Emergency Management Program,"), are considered nonstructural alternatives. Levee setbacks authorized and funded as Corps civil works projects are considered structural alternatives because levees alter the extent of the flood hazard. The conflicting guidance is the source of active discussion and debate among the Corps and its network of partners and stakeholders on the optimum policy guidance for effectively incorporating levee setbacks into flood risk management approaches. The reader should consult his/her vertical team for the current status of levee setback classification.

Traditional, constructed levees closely bordering river channels are an integral part of most structural flood damage reduction infrastructure. Traditional levees are designed to efficiently convey floodwaters

downstream while protecting farmland, municipalities, and industrial sites from property damages and loss of life caused by high water levels and high water velocities generated by flood flows. Traditional levees functionally converted rivers into efficient "ditch" systems to temporarily (for periods of days to weeks) withstand high water levels until the passage of a flood wave. Levees are not designed to withstand extended periods (months) of high water so that reducing both the height and duration of floodwater level is an important consideration in sustainable flood risk management.

Levees are often sized and located to minimize the width of the flood channel to reduce real estate acquisition costs and shorten the length of energy (power lines) and transportation (vehicle and railway) infrastructure needed to bridge the active river channel with attendant increases in flood risk. For example, the 1944 Flood Control Act specifies conveyance requirements for a reach of the Missouri River at 3,000 ft (Table 1); although the actual levee width can deviate substantially from these specifications. For example, a choke point on Levee System L575 on the Missouri River has a minimum conveyance width of only 1,225 ft and is one of several pinch points on the flood risk management system.

Table 1. Missouri River federal levee design criteria from 1944 Flood Control Act (Sioux City, Iowa to Kansas City, Missouri).

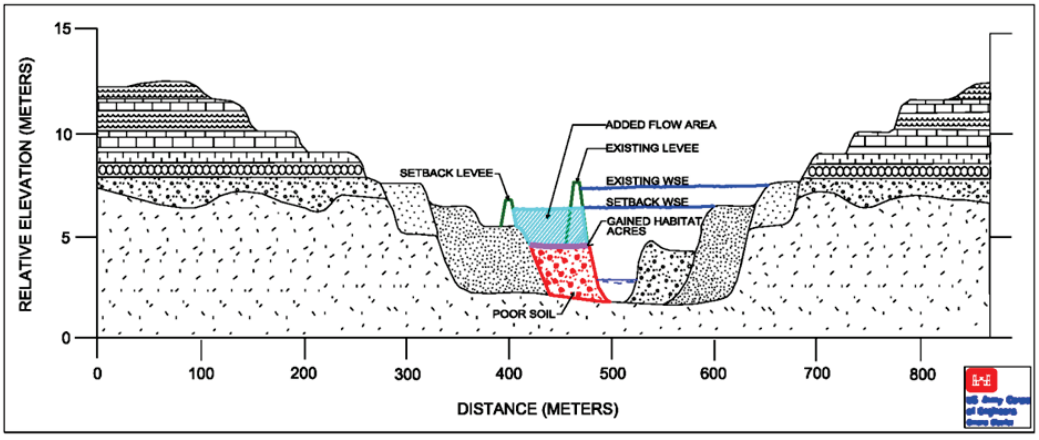
Design Discharge	250,000 cfs at Omaha 295,000 cfs at Nebraska City
Levee Freeboard	3-foot Urban 2-foot Rural
Conveyance Floodway	3,000-foot Sioux City to Kansas City 5,000-foot Kansas City to mouth

The legacy of historical reliance on structural measures can still be seen in the interpretation of the legislation and regulations that govern Corps flood damage reduction actions (Galloway 1994). In addition, flood damage reduction using structural measures is institutionally easier to implement because the Corps mission responsibility is unambiguous, coordination requirements are well-established, and the authorities are clear. In contrast, the mission responsibility for nonstructural flood damage reduction is less clear because it involves multiple agencies and actions that are often outside the floodplain where Corps mission responsibilities are reduced or less clear. However, hydrometeorological alterations caused by land use and climate change, improved understanding of how rivers function, and increased awareness of the importance of healthy, functioning rivers suggest that an alternative view point is necessary.

Levee setbacks are a relatively recent innovation in Corps flood risk management practice to reduce rehabilitation costs and reduce flood stages and velocities (Figure 1). Levee setbacks are constructed at a greater distance from the river channel than traditional levees and they allow a river to occupy a portion of its historic floodplain. Compared to traditional levees, levee setbacks appear to have a number of economic and flood risk management benefits while reducing environmental impacts and, if properly designed, can even achieve environmental benefits. Levee setbacks are of increasing interest to Corps districts as a more sustainable solution to reduce reoccurring flood damages. In a memorandum addressed to the Deputy Commanding General for Civil and Emergency Operations dated May 26, 2016, the Assistant Secretary of the Army for Civil Works makes the following important statements in her policy concurrence with the Director of Civil Works on the Nooksack River Delta Levee setbacks:

1. "It is the policy of the Army to encourage floodplain restoration, as it encourages community resilience and provides benefits to both the ecosystem and human well-being."
2. "If the level of flood risk associated with an ecosystem restoration project is decreased, then the risk reduction increment above the baseline must be cost-effective and incrementally justified."
3. "If the level of flood risk is increased as a result of ecosystem restoration, then the Corps must mitigate any induced damages as part of the restoration project."
4. "This policy shall be added to ER 1105-2-100 during its next update."

Figure 1. Conceptual model of a levee setback considered for Federal Levee System L-575 on the Missouri River. Note that the setback levee reduces flood elevation, increases conveyance area, and results in habitat gains. It is also of lower top elevation and higher foundation elevation (and therefore uses less material) and has better foundation material. Taken from USACE (2012).



Objective

The authors' objective in writing this report is to support the planning of levee setbacks. This report provides general information about levee setbacks to allow district planners and engineers to consider the feasibility of levee setbacks as an alternative to traditional levees for reducing flood damages. Two case histories are then used to demonstrate how levee setbacks have been justified in two completed planning studies in Sacramento District (Hamilton City, CA) and Omaha District (Federal Levee L-575).

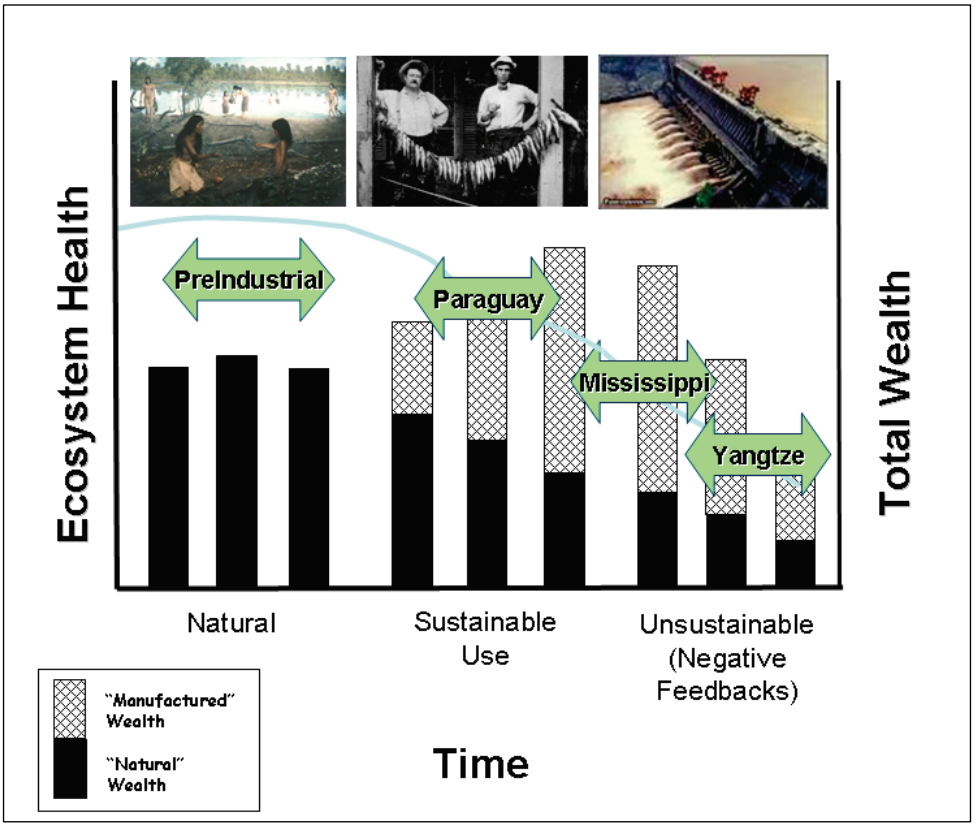
Engineering With Nature

An underlying premise of the National Environmental Protection Act (NEPA) is that water resources development and natural resource conservation (including rehabilitation and restoration) are mutually exclusive. The goal of sustainable water resources development under NEPA is the achievement of economic development goals, but without significant environmental impact. The execution of this logic since the enactment of NEPA for water resources development has produced undeniable increases in economic development, but with a limited improvement in environmental quality conditions in the Nation's large rivers. Evolving thought on water resources infrastructure development, particularly for navigation infrastructure, is moving towards the Engineering With Nature (EWN) concept.

Contrasted against NEPA, the goal of EWN is to achieve water resources development while simultaneously improving environmental quality. In the EWN concept, the underlying premise is that water resources development and natural resource conservation may be complementary. The EWN concept can be illustrated by considering that ecosystems provide "wealth" to humanity. Total wealth is defined as the sum of "manufactured wealth" derived from human exploitation of the system and "natural wealth" defined as ecosystem goods and services (Nestler et al. 2010). Importantly, the maximum in sustainable total wealth occurs at intermediate values of "manufactured" and "natural wealth" (Figure 2). The long-term application of EWN should achieve both water resource development goals and improve environmental quality (Figure 1). The application of EWN is particularly important for the Nation's rivers because almost all of them are already significantly impacted. This degraded ecological condition is particularly acute in rivers constrained by

traditional levees that prevent the river from expanding into its historic floodplain during seasonal high flows (Nestler et al. 2012). Nonstructural flood risk management activities, particularly watershed management, land-use planning, regulation, and floodplain evacuation, meet many underlying principles of EWN such as being holistic, sustainable, science-based, efficient and cost effective, socially responsive, and innovative.

Figure 2. Interplay between natural and manufactured wealth over the history of anthropomorphic effects on rivers. Environmental benefits analysis can be used to explore the tradeoffs between manufactured and natural wealth as part of total wealth (taken from Nestler et al. 2010).



EWN and Ecosystem Services

The currency to describe and implement EWN is ecosystem goods and services (EGSs) (Costanza et al. 1997; Daily et al. 2000). Wainger et al. (in press) reviewed EGS relative to Corps missions, most of which apply to the UMR and probably apply to the many large floodplain rivers in the Nation. Typical EGSs associated with rivers include:

- Ecosystem sustainability
- Water supply and regulation

- Hazard mitigation
- Navigation maintenance
- Recreation opportunities
- Cultural, spiritual and educational support
- Aesthetics
- Food provisioning
- Raw goods and materials provisioning
- Water purification and waste treatment
- Climate regulation, carbon sequestration
- Human health support

Corps projects and operations affect EGS primarily through water management. Natural wealth and manufactured wealth, such as crops, can be better balanced through alternative floodplain management that includes significantly greater managed connectivity. It is even possible to incorporate increased EGS benefits through managed connectivity that fuels alternative land uses alongside crops. Dissolved and particulate materials transported in leveed rivers past floodplains are viewed as pollution by most, but these materials can be nutrients for algal phytoremediation to mitigate upstream nutrient enrichment and grow useful feedstock for enhanced economic benefit (Adey et al. 2011). It is very important to consider alternative economic opportunities, just as it is important to diversify ecosystems.

2 Corps Policy and Guidance for Levee Setback

Executive Orders (EOs)

The EWN approach follows EOs and ERs that govern water resources development and management by the Corps. For example, EO 11198 (May 24 1977 - Floodplain management), a directive to prevent or minimize encroachment of the floodplain, also has provisions that relate to levee setbacks as part of floodplain management. Additional institutional considerations and how they were addressed are described in detail for each case history description presented later in this report. Major critical points in EO 11988 that apply to levee setbacks include:

1. Section 1: "Each agency shall provide leadership and shall take action to reduce the risk of flood loss, to minimize the impact of floods on human safety, health and welfare, and **to restore and preserve the natural and beneficial values served by floodplains** in carrying out its responsibilities…."
2. Section 2: " … each agency has a responsibility to evaluate the potential effects of any actions it may take in a floodplain; to ensure that its planning programs and budget request reflect consideration of flood hazards **and floodplain management**…"
3. Section 2c: "Each agency shall take **floodplain management** into account when formulating or evaluating any water and land-use plans…"
4. Section 2d: "As allowed by law, each agency shall issue or amend existing regulations and procedures within one year to comply with this Order. These procedures shall incorporate the Unified National Program for Floodplain Management of the Water Resources Council, and shall explain the means that the agency will employ to pursue the nonhazardous use of riverine, coastal and other floodplains in connection with the activities under its authority. To the extent possible, existing processes, such as those of the Council on Environmental Quality and the Water Resources Council, shall be utilized to fulfill the requirements of this Order. Agencies shall prepare their procedures in consultation with the Water Resources Council, the Director of the Federal Emergency Management Agency, and the Council on Environmental Quality, and shall update such procedures as necessary."

5. Section 3: "The regulations and procedures established under Section 2(d) of this Order shall, at a minimum, require the construction of Federal structures and facilities to be in accordance with the standards and criteria and to be consistent with the intent of those promulgated under the National Flood Insurance Program."

EO 13690 (January 30, 2015 - Establishing a Federal Flood Risk Management Standard and a Process for Further Soliciting and Considering Stakeholder Input) clarifies and expands on EO 11988 and describes coordination requirements to implement the guidance in EO 11988. Critical points in EO 13690 that apply to levee setbacks include:

1. Section 1. Policy. "The result of these efforts is the Federal Flood Risk Management Standard (Standard), a flexible framework to increase resilience against flooding and **help preserve the natural values of floodplains**."
2. Section 2. Amendments to EO 11988. (c) "Where possible, an agency shall use **natural systems, ecosystem processes, and nature-based approaches** when developing alternatives for consideration."
3. Section 3. Agency Action. This section describes coordination and collaboration requirements to implement EO 11988.
4. Section 4. Three approaches are identified for establishing the Federal Flood Risk Management Standard:
   a. Utilizing the best-available hydrologic and hydraulic data and methods that integrate current and future changes in flooding based on climate science (heretofore referred to as the "climate-informed science approach");
   b. Freeboard (Base Flood Elevation (BFE) + X); and
   c. 500-year flood elevation.

Engineer Regulations and Guidance Documents

There is no specific Headquarters' guidance that applies exclusively to the design or construction of levee setbacks. Levee setbacks must use standard Corps designs for topwidth, slopes, compaction, and other design parameters, but with lower stages and velocities. However, there are a number of ERs and headquarters guidance that could support the study and construction of levee setbacks for environmental benefits in addition to flood damage reduction benefits. These documents establish national policy for the protection, restoration, conservation, and management of environmental resources. They can be used to implement EWN principles

when considering levee setbacks in rivers affected by flood damage reduction measures of the Corps. These documents emphasize environmental goals and declare national policies to conserve living resources and enhance the environment associated with Corps action. They are annotated below to give the reader a comprehensive overview of applicable guidance documents. More detailed applications, plus additional document references, can be found in the case histories described later in this report. Particularly important annotations are emphasized by the authors using bold type.

1. *ER 200-1-5* (dated 30 October 2003) entitled "POLICY FOR IMPLEMENTATION AND INTEGRATED APPLICATION OF THE U.S. ARMY CORPS OF ENGINEERS (CORPS) ENVIRONMENTAL OPERATING PRINCIPLES (EOP) AND DOCTRINE" establishes the policy for implementation and integrated application of the Corps EOPs and Doctrine, to the extent legally and financially practical; guide all appropriate Corps management initiatives and business processes. **This policy encompasses the full spectrum of Corps activities, including operations and maintenance. The EOPs and associated doctrine require a focus on achieving greater synergy between the environmental sustainability and the execution of activities to bring about new and innovative solutions.** The requirements of the Chief's EOP are closely aligned with the principles of EWN.
2. *Reissue of ER 200-1-5* entitled "ENVIRONMENTAL OPERATING PRINCIPLES II" via enclosure to letter from LTG Thomas Bostick, Chief of Engineers, to all subordinate commands (dated August 7, 2012). The goals of the reissuance were to expand and intensify the Corps' environmental commitment by improving the organization's internal management and culture to support the environmental operating principles. The reissue did not create any new or substantive authority or responsibility, nor was it intended to supplant any law, statute, codified regulation or executive order.
3. *ER 1100-2-8154* (dated 31 May 1995) entitled "WATER QUALITY AND ENVIRONMENTAL MANAGEMENT FOR CORPS CIVIL WORKS PROJECTS" states "**It is national policy that the Federal government, in the design, construction, management, operation, and maintenance of its facilities, shall provide leadership in the nationwide effort to protect and enhance the quality of our air, water, and land resources.**" It is unclear if a

traditional flood levee constitutes a Corps "facility" and policy clarification is needed on this point. Historically, this ER was used to adjust the releases from dams, but many of the benefits of changing release patterns from dams also apply to environmental benefits of levee setbacks such as modifying nutrient availability, changing the concentrations of dissolved metals, and changing substrate distributions. This regulation allows alteration of releases to improve downstream habitat quality and quantity to also be considered (e.g., changes in temperature to meet ecological targets, increase dissolved oxygen concentrations, modify nutrient availability, reduce concentrations of dissolved metals, and change substrate distribution). Many improvements in downstream water quality can be attained with minor changes in operations (e.g., using outlet works for selective withdrawal to meet temperature or dissolved oxygen concentration goals). ER 1100-2-8154 further states that **"As stewards of a significant percentage of the nation's aquatic environment, the Corps has a responsibility to preserve, protect, and where necessary, restore the portion of the environment altered by Corps projects. The Corps is fully committed to environmentally sound project management and operation. It is the policy of the Corps that the environment be given equal standing not simply consideration in all aspects of project management and the operational decision-making process."** Note that the previous sentence is closely aligned with EWN principles.

4. *ER 1165-2-26* dated 30 March 1984 entitled "IMPLEMENTATION OF EXECUTIVE ORDER 11988 ON FLOOD PLAIN MANAGEMENT" establishes policy and guidance on implementation of Executive Order 11988 entitled "Floodplain Management." As it pertains to levee setbacks, this regulation covers the planning, design, and construction of Civil Works projects and to activities under the operations and maintenance program that affect floodplain management with increased emphasis on environmental impacts compared to Executive Order 11296 issued 10 August 1966 which it replaced. Two of the four objectives of the new regulation apply directly to design and construction of levee setbacks:
   a. Avoid development in the base floodplain (having a 1% chance of flooding in any year) unless it is the only practicable alternative.
   b. **Restore and preserve the natural and beneficial values of the base flood plain.**

Natural and beneficial values include but are not limited to [*sic*] water resources values (natural moderation of floods, water

quality maintenance, and ground water recharge), living resource values (fish, wildlife and plant resources), cultural resource values (open space, natural beauty, scientific study, outdoor education and recreation) and cultivated resource values (agriculture, aquaculture and forestry). It is important to note that the definition of "base floodplain" as used in this Executive Order is based on a 1% chance of flooding in any year; i.e., the 100-year flood. In river ecology, the floodplain of a river is considered to be fringing land around the river channel that is inundated seasonally. Therefore, the maximum stage of a regulated environmental flow (i.e., seasonal flooding of the floodplain) will be considerably less than the 1% flood stage.

1. *Letter from General Thomas Bostick* dated 16 May 2016, conveying "2016 USACE RESILIENCE INITIATIVE ROADMAP" that describes a holistic approach to addressing threats and uncertainty from acute hazards, such as more frequent and/or stronger natural disasters, man-made threats, changing conditions from population shifts, and climate change. One priority area focuses on providing technical and planning services through the Floodplain Management Services and Planning Assistance to States programs. Specifically, this document directs the Corps to provide expertise in engineering and planning consultation on approaches to manage and reduce flood risk.
2. *Section 206 of the Water Resources Development Act of 1996,* as amended, entitled "The Aquatic Ecosystem Restoration Authority" and often referred to as Section 206. It provides the authority for structural or operational modifications to the existing environment to restore historic habitat conditions of aquatic ecosystems at any location to benefit fish and wildlife resources.
3. *Section 1135 of the Water Resources Development Act of 1986,* as amended, entitled "Project Modifications to Improve the Environment Authority" often referred to as Section 1135. It provides the authority to modify existing Corps projects to restore the environment and construct new projects to restore areas degraded by previously constructed Corps projects.

The Sustainable Rivers Project (SRP)

The Sustainable Rivers Project (SRP) is a cooperative program based on a long-term Memorandum of Understanding agreement between The Nature Conservancy (TNC) and the Corps of Engineers (Hickey and Warner 2006). One of the goals of the SRP is to recreate important

ecological processes associated with seasonal inundation of river floodplains through reservoir regulation (Warner et al. 2014). Similarly, levee setbacks also allow a river to inundate a portion of its original floodplain so that some ecological functions can be recovered, a measure particularly important for rivers with traditional levee systems. The emphasis of both the SRP and levee setbacks on reconnecting a river to its floodplain during high flows allows levee setbacks to be considered within the general framework of the SRP.

The importance of aligning levee setback planning and the SRP is best understood by a brief review of the history of the SRP, which began as a district-level collaboration; however, over time, the importance of environmental flows was raised to the highest leadership levels of the Corps. TNC and the Corps began their collaborative effort to introduce environmental flows to rivers regulated by Corps projects in 2002 with the inauguration of the SRP (see history in Warner et al. 2014). Within the Corps, in a letter addressed to LTG Robert L. Van Antwerp, Chief of Engineers, dated 19 May 2010, Mr. James E. Kundell, Chairman, Chief of Engineers Environmental Advisory Board (EAB), acknowledged the successful partnership of Corps districts with TNC in the SRP. Mr. Kundell recommended steps to institutionalize and expand environmental flows as part of normal water resources planning within the Corps. In his response letter to Mr. Kundell dated 25 Oct 2010, LTG Van Antwerp agreed with the observations and recommendations of the EAB and noted that **the SRP was one of a number of Corps collaborative efforts pursuant to the Corps' Environmental Operating Principles introduced in 2003**. LTG Van Antwerp committed to continuing the successful collaboration of the Corps with TNC by supporting the **SRP and related initiatives**, as permitted by legislation, **to find holistic and sustainable solutions to the Nation's water resources challenges**. It is clear that levee setbacks are a related initiative to the SRP because both emphasize reconnecting a river to its floodplain. The following are some of the advantages of aligning the SRP with levee setbacks:

1. The SRP will bring wider recognition of the importance of connecting a river to its floodplain both by the scientific community and agencies with living resources stewardship responsibilities.
2. The SRP agreement was signed by the Chief of Engineers and is applicable nationwide.

3. The SRP is active in eight river basins involving 36 Corps dams; consequently, there is corporate knowledge and experience within the Corps to implement the SRP.
4. The SRP sites typically involve an existing collaboration of state and federal agencies, NGOs, and stakeholders already conversant with the opportunities and challenges of river management. Therefore, the coordination requirement in EO 13690 can be more easily met with a cadre of willing and informed partners developed through the SRP.
5. TNC has shown to be an active and knowledgeable proponent of increasing ecological benefits through project planning and operation; working with TNC through the SRP would likely result in local and regional support that can be more easily mobilized to support a levee setback project. This last point is important because levee failures are most pressing during extreme floods when the planning horizon is often reduced to an emergency response level. An informed and persistent partner can help the Corps maintain its focus on full and adequate planning during non-emergency periods.

3 Additional Planning Considerations

Potential Conflicts between Navigation, Channel Maintenance, and Levee Setbacks

The potential impacts of levee setbacks on navigation traffic can be best demonstrated in parts of the UMR System in which the river is extensively connected to its floodplain. In these river reaches, navigation continues unabated when the river inundates its floodplain, except under the highest flows. However, each levee setback site has to be considered individually because each river represents a unique set of geomorphic, hydraulic, structural, and barge traffic characteristics, preventing the establishment of general guidelines. The authors recommend consultation with district or ERDC Coastal Hydraulics Laboratory experts for more detailed information. The following issues should be considered for each river reach where levee setbacks are being considered to anticipate impacts to navigation and channel maintenance:

1. Geometry of the channel and overbank areas for the with- and without-setback conditions
2. Distribution of sediment for with- and without-setback conditions
3. Distribution of channel/overbank flows for the with- and without-setback conditions
4. Occurrence of sediment deposition issues within a reach, prior to levee setback assessment
5. Determination of upstream and downstream changes in floodwater surface elevations in response to levee setbacks

The ability of a leveed river, without access to a floodplain, to transport sediment increases with the depth of flow. If access to a floodplain is available — even a small batture between the main channel and a setback levee — this will reduce the overall sediment transport capacity of the river during floods, since additional increases in flow will increase the depth by a smaller amount. The river will also tend to deposit some portion of its sediment, typically smaller particle sizes, on the floodplain. It should be noted, however, that out-of-bank flows will likely only occur once every one to two years, and possibly less often if the river has been fully leveed for a long time. Detailed hydraulic modeling will likely be required to determine the extent of the impact of individual levee setback projects on sedimentation, both in the channel and on the floodplain.

4 Comparison of Levee Setbacks and Traditional Levees

Levee Setbacks - Definition and Planning Considerations

Levee setbacks are a localized realignment of existing levees or construction of a new levee not near the active river channel. Levee setbacks can be of a variety of scales and designs depending upon land use (e.g., urban versus farmland), hydrologic pattern, and local geomorphic conditions (e.g., Figure 3). The basic idea behind a levee setback is to move the location of the levee from its current alignment on the stream banks of the river to an area back away from the stream bank, placing it onto better foundation materials, opening up potential habitat areas, and significantly increasing flood conveyance (see Bozkurt et al. 2000 for a detailed definition and description of levee setbacks). Increased conveyance area decreases the water surface elevation, thereby increasing the level of protection provided by the system. The primary factors that affect the cost, design, and environmental impact of a levee setback are the distance that the levee is set back from its original position, the elevation of the foundation of the levee setback, and the geotechnical attributes of the foundation material. A higher foundation elevation reduces the material needed to construct the levee and also reduces the water pressure on the levee, which reduces the probability of levee failure. Levees that are set back only a modest distance from their original placement will likely have reduced real estate cost, reduced improvement in flood conveyance, and reduced environmental benefit, although other site-specific factors may be important. The hydrologic and geotechnical benefits of a levee setback can include:

- decreased hydrologic loading,
- decreased floodwater velocities,
- groundwater replenishment,
- reduced erosion and scour,
- placement of levee on more suitable geotechnical foundations, and
- increased level of protection if the levee setback is constructed to the same elevation as the original levee.

Figure 3. Typical levee setback alternatives considered for the Missouri River (from MRFTF 2012 presentation).

Some on-going levee repairs at breach areas located along levee systems are often referred to as "setbacks" but do not meet the definition used in this report. These setbacks consist of small changes in the levee alignment associated with the in-place repair of the levee breach that typically provide no flood damage reduction associated with a setback alignment for reducing flood stages or floodwater velocities.

Levee setbacks affect flood stages within and outside of the project footprint. These effects must be understood and considered when levee setbacks are planned. By increasing local conveyance area, levee setbacks affect the stage-discharge relationship in both upstream and downstream directions. Upstream of the levee setbacks, water elevations at high discharges are decreased because energy slope is increased. That is, the increased conveyance area of the levee setbacks increases the upstream energy slope. The increase in energy slope will cause upstream velocities to increase and upstream water surface elevations to decrease. However, the opposite occurs downstream of the levee setbacks where water elevations at high discharge will increase because the energy slope is reduced, channel velocities will decrease, and flood stages will increase. An example of upstream constraints in the operation of a flood risk management system is the unimpounded reach below St. Louis, Missouri. This reach, part of the Mississippi River and Tributaries (MR&T) project, supports a system plan for 500-year flood protection in the Mississippi Delta. The MR&T is beyond the scope of this analysis, except that it exerts a very significant constraint on floodplain management upstream. UMR floodplain management cannot compromise flood profiles at St. Louis.

Changes in regional hydrology or local demographics and patterns of infrastructure development may cause a re-evaluation of the adequacy of existing levee systems to meet their initial design goals. In addition, levees, like all water control infrastructure, have a design life, require maintenance, and are subject to hydraulic and geomorphic processes that can cause them to deteriorate over time or catastrophically fail. Some deterioration and failure mechanisms operate on small-time scales, such as levee breeches caused by overtopping, undermining (often first evidenced as sand boils), or drying and cracking during extended periods of drought. Subsequent rising water enters and expands levee cracks by erosion, eventually leading to levee failure. Other mechanisms operate on longer timescales, such as ground or levee subsidence and vegetation encroachment. Subsidence can occur because of soil drying and compaction or oxidation of soil organic

matter in highly organic soils. For example, some farmland with peat soils protected by levees in the Sacramento-San Joaquin Delta are now 20 feet below sea level. Vegetation encroachment reduces the conveyance capacity of leveed rivers and potentially creates hydraulic piping channels when plant roots pierce the levee and later die and decay. Consequently, there will likely be times in the design life of a levee when its design and placement should be re-evaluated to determine if alternative levee designs or locations may better meet present and future goals. This is particularly true for levee systems that are located in flood-prone settings.

Negative Impacts of Levee Setbacks

Generally, most ecologists consider that the ecological impacts of traditional levee construction on floodplain river ecology are negative so that either removal of traditional levees or construction of levee setbacks should have positive economic and environmental benefits. However, it is important to remember that many floodplain rivers were considered barriers to economic development and detrimental to the health of the early settlers. The Illinois and Iowa tallgrass prairies and Big River Valleys presented significant, but long-forgotten formidable challenges to the settlement of the Mississippi River Valley. The land was seasonally wet, which made farming and transportation difficult. It was also ideal mosquito habitat and a breeding ground for malaria, which was ubiquitous like other water-borne diseases and their vectors in the Mississippi Valley (Petterchak 2000). Ailments like "the shakes," "chills," "Ague," and typho-malaria were common and an impediment to economic development (Ackernecht 1945). Native people avoided traveling through the region in favor of Ozark routes during certain times of year (Petterchak 2000). Concern for public health through malarial mosquito eradication was an additional motivation for the Swamp Land Act of 1850 and other drainage laws, and there is still concern about wetland restoration and mosquito-borne disease (Willott 2004). Warming climates and spread of exotic diseases like the West Nile, Dengue, Chikungunya, and Zika viruses are important risk factors that must be considered in future floodplain management.

Impacts of Traditional Levees

Placement of manmade levees near a river's natural levees using traditional engineering guidelines has a number of significant environment impacts. Levees that border the river channel isolate the floodplain from the river and, as a consequence, the many species of aquatic plants and animals that

require access to seasonally inundated floodplains to complete their life history are heavily impacted or extirpated. The land protected by levees is often drained to become farmland or developed for other economic benefits, which permanently impairs or removes important ecological functions from the river corridor. There are a number of other effects of the seasonal flood pulse, including carbon dynamics, nutrient cycling, sediment transport, and geomorphology that are well summarized in (Nestler et al. 2012, Junk et al. 1989, Junk and Wantzen 2004, Welcomme and Halls 2004) and will not be summarized here.

In their natural state, rivers are dynamic ecosystems that provide a number of critical ecosystem services (Arthington et al. 2010). Rivers transport sediments onto the floodplain to build and reshape riparian habitats important to many species of plants and animals; the sediments provide nutrients at critical times to support ecological productivity of floodplain rivers. Rivers also transport organic material washed in from the watershed to subsidize the organic matter produced within the river corridor. The meandering river and its floodplain temporarily store excess floodwater and can recharge ground water if the necessary geological conditions are present. Traditional levee designs lock the river into a permanent main channel so that it does not meander naturally within its floodplain. The lateral constraints to channel movement imposed by traditional levees eliminate the dynamic spatial complexity upon which biodiversity depends.

The natural hydraulic patterns of a river are also altered when it is leveed. In a leveed system, increases in conveyance area occur primarily through increases in depth. Water velocities in a leveed river will increase substantially with increasing discharge because there is relatively little flow resistance to reduce water velocity. Material washed in from the watershed will be transported through the system with relatively little deposition. The hydraulic environment of a leveed river at high discharges often cannot meet the hydraulic and ecological requirements of many aquatic biota that evolved in a natural river-floodplain complex. In contrast, in an unleveed system, water elevation increases gradually once it escapes its banks — as discharge increases — because conveyance area can increase by lateral expansion of the flood wave onto the floodplain. Natural fringing floodplains are characterized by complex channels, abundant trees and bushes, extensive beds of emergent and submerged wetland plants, and woody material, all of which increase flow resistance

and therefore reduce water velocity. Sediments, organic material of a variety of sizes and oxidation potential, and other material will deposit in the floodplain and participate in a variety of biogeochemical and physical processes that are important to ecological productivity.

5 Levee Setback Examples

Navigation was not considered likely to conflict with levee setback construction in either the Sacramento River or Missouri River case histories that are described later in this report. For the Sacramento River case history, the river is only navigable by small boats in the vicinity of the levee setback, and this area will only be inundated during infrequent high water events. There is no dredging for navigation upstream of West Sacramento (the head of the Sacramento Deep Water Ship Channel), which is located about 80 miles downstream from the levee setback site. The Environmental Impact Statement (EIS) for the levee setback did not address navigation or channel maintenance because there were no significant concerns. Similarly, the Missouri River levee setbacks within the Omaha District have had no foreseeable impacts on navigation. Within this reach of the river, the navigation flows are maintained within the channel. Flows in excess of navigation were the primary focus of the levee setback assessment, as these infrequent, out-of-channel flows have been responsible for significant damages to the federal levees, potential overtopping, and/or potential failure prior to overtopping. Additionally, the Missouri River is a self-maintained navigational channel as dredging does not occur and numerous structural features (revetments, dikes, etc.) have been employed to maintain the navigational channel.

Below the authors describe two completed levee setbacks within the Corps that have successfully completed the Corps planning process: Omaha District's Federal Levee L-575 on the Missouri River and Sacramento District's Hamilton City levee setback on the Sacramento River. The procedures used in these two examples can serve as a template for quantifying benefits that can be used by other districts contemplating construction of levee setbacks.

Omaha District Example - Federal Levee L-575

Background

Excessive rainfall and snowmelt conditions in the upper Missouri River Basin in 2011 led to significant flood damages. This flood was characterized by a long duration; high stages and water velocities; levee breaches and erosion; major repair and maintenance challenges during the flood; and a

continuation of recurring damage at certain locations within the levee system. In immediate response to the flood, the Omaha District repaired numerous downstream federal levee systems, particularly along levee system L-575, located in extreme southwest Iowa and northwest Missouri (Figures 4 and 5). This levee system experienced geotechnical breaches during the flood event and many square miles of land were flooded. Following the Missouri River Flood of 2011, much of the existing flood risk reduction infrastructure located along the Missouri River, from Council Bluffs, Iowa, and Omaha, Nebraska, downstream to Kansas City, Missouri, required significant repairs, rehabilitation, or replacement (R, R, & R).

Figure 4. Damage from Missouri River Levee L-575 lower breach from 2011 flood event.

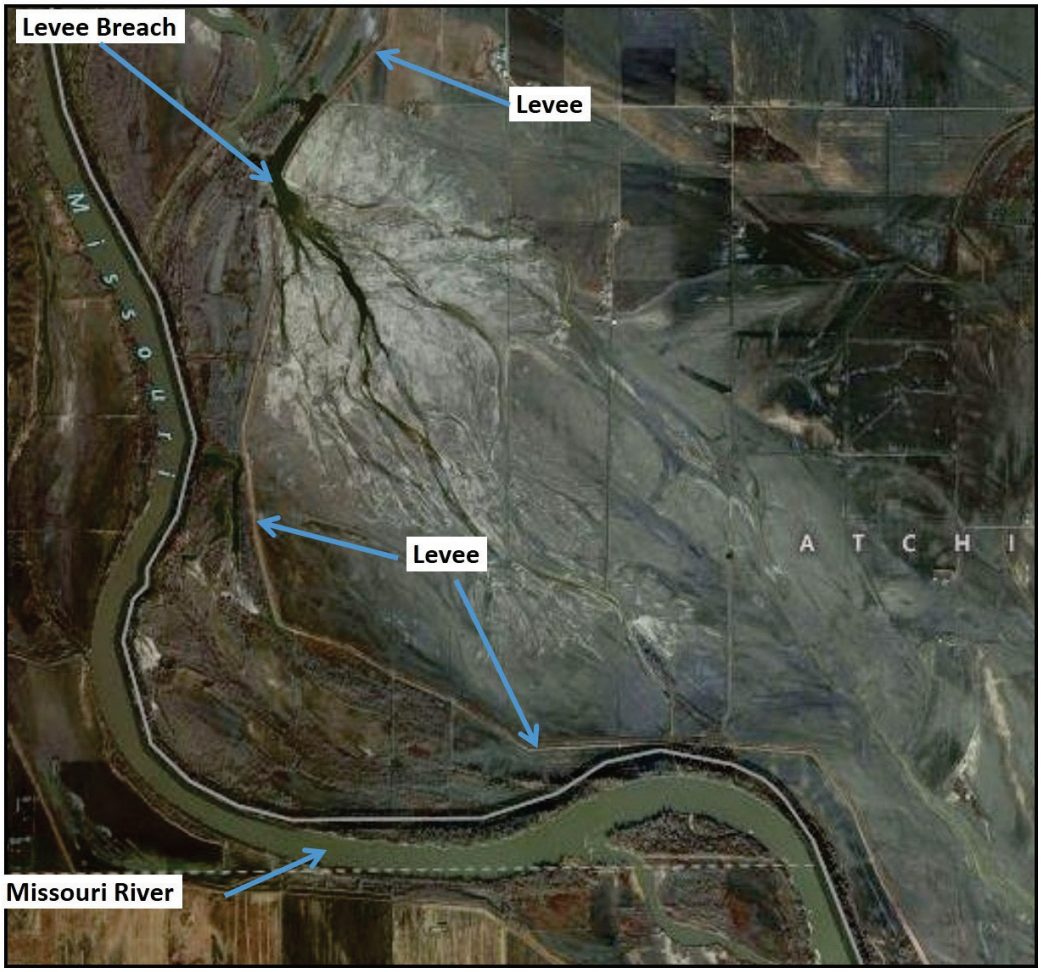
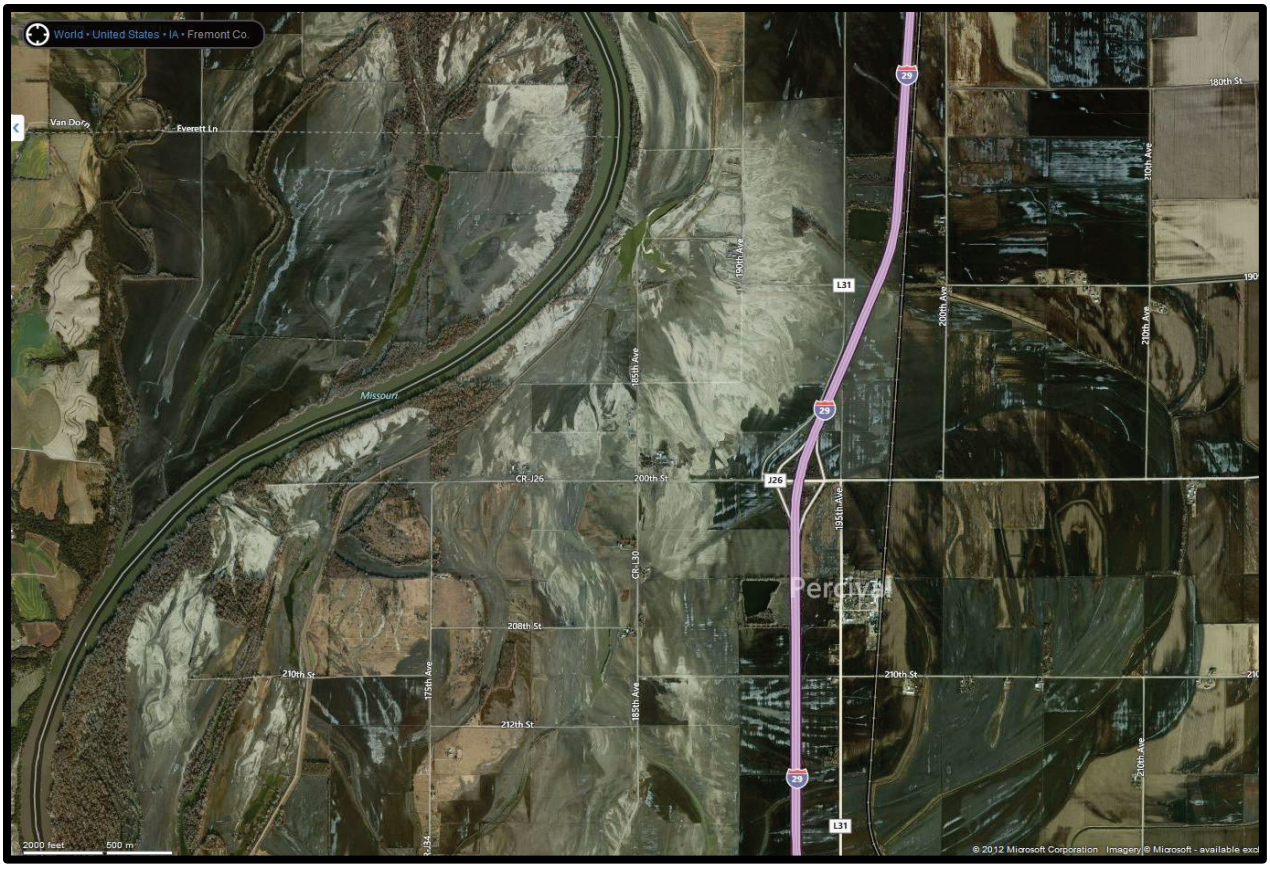


Figure 5. Missouri River Levee L-575 upper breach from 2011 flood event (modified from MRFTF 2012 presentation).



Authorities

Under the authority of PL 84-99, federal funding can be used for rehabilitation of flood risk management systems damaged by floodwaters. ER 500-1-1 gives guidance on the application of PL 84-99. ER 500-1-1 describes the process for the development of nonstructural alternatives including levee setback options. Numerous discussions and debates were conducted regarding application of ER 500-1-1 Section IV – "Nonstructural Alternatives to Structural Levee Rehabilitation," where the option of implementing a nonstructural alternative project could be considered in lieu of a structural repair. According to ER 500-1-1, the principle purposes of a nonstructural action project are floodplain restoration; provision or restoration of floodways; and reduction of future flood damages and associated structural repair costs. In this context, not only would the entire removal of an existing levee be considered a nonstructural alternative, but the restoration of the historic floodplain for reducing future flood damages by setting portions of the existing levee back from the river is an acceptable nonstructural alternative project, if the benefits could be shown to outweigh the costs.

Generally, the urgency to repair levees causes the Corps to automatically default to the repair-in-place option to restore flood risk management capability because fewer steps are involved. However, a review of past flood events along the Missouri River between Iowa, Nebraska, and northwest Missouri uncovered a history of repetitive damages to the existing federal levees dating back to 1952. The continued short-term approach of repairing damaged levee systems in-place following a major flood event imposes a continued cycle of federal and local expenditures without the benefit of additional flood risk reduction. While the data are scarce, there are indications that federal levee L-575 has undergone significant repair and rehabilitation under the PL84-99 program (Figure 5). The local levee sponsor requested that a levee setback be considered in the vicinity of State Highway 2 based on this review and because of significant erosion damages and costly foundation design challenges. The urgency of repairing damaged levees under PL84-99 to protect lives and property from subsequent flooding required an adjustment to customary practice in implementing nonstructural alternatives. The information sharing and vision building that would be necessary to give full consideration of nonstructural alternatives were precluded to expedite the construction of the levee setback alternative.

Hydrology and Hydraulics Considerations

ER 500-1-1 outlines the benefits and allowable expenses for a nonstructural alternative to be economically justified for implementation. These benefits and expenses can be used to justify a variety of nonstructural alternatives, including the construction of levee setbacks. The selected levee was relocated from its original location anywhere from several hundred to several thousand feet. The hydraulic attributes of the setback, shown as stage reduction and frequency of loading reduction, positively impact the levee system, not only near the State Highway 2 Bridge but also at the upstream end of the system (Tables 2 and 3). A stage reduction of 0.4 ft to 1.5 ft for the 100-year flood event along the Missouri River is significant. This amount of stage reduction on the levee system can make the entire system more sustainable over the long term and more resilient to failure during an extreme flood event. The crest of the existing levee would be overtopped with an 80-year flood event. With the setback in place, the levee crest would not be overtopped until the occurrence of a 125-year flood event (Table 2). In addition to a stage reduction averaging between 0.4 and 1.5 ft along the length of the levee, hydraulic modeling indicates that the mean river velocity for the 1% annual chance discharge, was reduced by approximately 2 fps (from 7.6 fps to 5.7 fps)

Table 2. Stage reduction associated with L-575 levee setback for the 100-year flood.

Location	Near Hwy 2	Upstream L-575
Levee Setback	1.5 feet	0.4 feet

Table 3. Frequency of loading L-575 to levee crest.

Location	Percent Exceedance
Prior to L-575 Setback	80-Years
After L-575 Setback	125-Years

Economic Considerations

When a breach in the levee system occurs, hundreds of square miles of productive farmland, rural communities, and farmsteads, along with federal, state, county, and local infrastructure, are placed at risk. Impacts to the federal interstate highway system force traffic — and in particular, semi-trailer trucks — to be detoured to other routes. These routes are often two-lane highways not well maintained for heavy traffic flow and are generally two or more times longer in distance than the original route on the interstate system. Additionally, when a levee breaches, there is a significant amount of erosion that occurs to the landward side of the levee (Figure 3). A breach in the levee system allows a cascade of floodwaters to engulf the formerly protected area, spreading out and ponding to elevations that may be equivalent to the levee itself. These floodwaters can also scour and deposit sediment, changing the localized landscape and damaging infrastructure.

The economic analysis considered traditional and nontraditional benefits and costs (i.e., for R, R, & R, as well as for auxiliary benefits such as reduction in damages to critical facilities, reduced O&M, and increased ecosystem benefits due to additional fish and wildlife habitat) to determine the feasibility of implementing a levee setback in lieu of the repair-in-place option under the PL 84-99 program. According to the National Flood Insurance Program (NFIP), if an insurable structure (residential or commercial) is damaged from flooding twice in a ten-year period, then federal authorities should be utilized to relocate or mitigate the structure so that no future damages occur. If the levee system were insured in the same way as insurable structures, then relocation to a new alignment should be considered to reduce flood risk, increase system resiliency, and improve system sustainability. As described earlier, a

review of the existing levee system shows that L-575 has repeatedly sustained damages since initial construction.

The economic analysis identified nontraditional benefits that apply to the current river system, but that were not considered in the initial benefit-cost analysis for the existing flood risk management system. For example, the Cooper Nuclear Station (CNS), a nuclear power plant located near the levee system, would benefit from a levee setback because CNS would be able to continue operation under higher flows. Costs of shutdown and damage caused by floodwater elevations are estimated at approximately $500,000 per day (according to the Nuclear Regulatory Commission). The station has already encountered significant flood risk issues surrounding their access road and the power transmission area during previous flood events. Additionally, the Nebraska City Coal Power Plant also faces significant flood risk issues, including loss of power production and transmission capability, restricted plant access, and disruptions of coal delivery by rail. Lower flood stages also benefit the region through sustained power generation during flooding. Reduced water velocities will reduce erosion on levees and transportation infrastructure such as railway and highway bridges and transmission line crossings.

The economic analysis is summarized in Table 4. All alternatives are economically feasible, with a benefit cost ratio (BCR) greater than 1. The traditional BCR was completed utilizing the standard project information reports (PIR) approach as directed by ER 500-1-1, where only protection benefits to structure, contents, and cropland are quantified. The BCR reflected the benefit from reduced R, R, & R with a levee setback alternative. However, the benefit of a levee setback is likely conservative and undervalued due to a lack of information for O&M costs for levee setbacks. More accurate R, R, & R would likely cause the BCR for either setback alternative to be greater than shown in Table 4. For this analysis, an O&M cost per mile of levee was used based upon existing levee conditions. Thus, no per-mile O&M cost difference was captured between the levee setback alternative and the repair-in-place alternative. The only difference is the reduced levee length with the levee setback alternatives, although some additional auxiliary benefits may be available due to an old structure versus new structure.

Table 4. Summary for conceptual levee setback alternatives ($ millions) (from USACE 2012).

	Repair-In-Place Alternative (from Project Information Reports)	Setback Alternative with Pre-Flood Level of Protection	Setback Alternative with Pre-Flood Levee Top Elevation
L-550 Level of Protection	20- years	20- years	28- years
L-575 Level of Protection	30- years	30- years	30-yrs upper L-575 56 yrs lower L-575
System Protected Area	72.9 sq miles	64.6 sq miles	64.6 sq miles
Traditional BCR:			
Total Cost	$166.8	$193.8	$212.6
Annual Cost	$10.7	$12.7	$14.0
Annual Benefit	$33.3	$32.1	$32.3
BCR	3.11	2.52	2.30
BCR including R, R, & R:			
Annual Cost	$10.7	$12.7	$14.0
Annual Benefit (including R, R, & R)	$33.3	$32.5	$33.2 to $34.7
Annual R, R, & R Cost Saving	$0.0	$0.4	$1.0 to $1.8
BCR	3.11	2.55	2.37 to 2.48
Other Benefits Associated with Levee Setback Alternatives:			
Reduced damage to critical infrastructure: Cooper Nuclear Power Station, $2.4 million cost savings based on 2011 event Nebraska City Coal Plant, $4.4 million cost savings based on 2011 event Reduced damage to transportation and other infrastructure System benefits: Increased Level of protection behind adjacent and opposing levees Reduced O&M and repair, replace, and rehabilitation costs for adjacent and opposing levees Emergency, evacuation and cleanup cost-savings: Less frequent need for emergency operations and flood-related activities Ecosystem benefits: Increased potential for 6,471 additional acres of fish and wildlife habitat and restoration of important river functions, if both L-550 and L-575 are set back to optimize flood risk management benefits.			

The "Other Benefits Associated with the Levee Setback Alternative" summarized in Table 4, are benefits associated with the levee setback alternatives, but not typically quantified as part of a PIR. These benefits are associated with the hydrologic and geotechnical benefits under a levee setback alternative. It was estimated that the levee setback alternatives through the Missouri River System could provide a total decrease in hydraulic loading of 2 to 4 ft and create hydraulic loading benefit through reduced stages as far as 30 miles upstream. This reduction in hydrologic loading can increase the level of protection provided by the existing

systems by approximately 40 to 50 % for the systems containing the levee setbacks, and by 100% for nearby systems. In addition, decreased flood velocities of between 13 to 44 % would reduce the potential for levee failure, erosion, and scour. As listed in Table 4, the reduced loading on the levee system would lead to reduced damages to critical facilities and infrastructure; system benefits would also be realized, as would cost savings for emergency evacuation and flood clean-up. In addition, there would be increased potential for habitat restoration with a levee setback alignment. Under a levee setback alternative, the river would be better connected with its floodplain, restoring some of the natural riverine processes necessary for creating potential habitat suitable for fish and wildlife species and providing opportunities for alternative farming practices (e.g., biomass production and silviculture).

As shown in Table 4, the levee setback alternatives cost between 16 and 27 % more than the repair-in-place alternative, but over time the repair costs would be less. The cost to construct both levee setback alternatives includes the cost of removing and regrading the existing levees; the existing levees would be used as a source of fill for the levee setbacks. This relatively small difference in cost between constructing new levees and the levee setback alternatives shows how extensive the repairs were for the repair-in-place alternative.

Socio-Economic Considerations

Before the floodwaters had diminished, internal discussions within the Omaha District were concentrating on expedited repairs to L-575 through the PL84-99 program. While this was occurring, a small team of engineers, biologists, and economists were assessing the situation and referring back to the “Galloway Report” (Galloway 1994). This report was the result of studies, assessments, and opinions regarding floodplain management strategies after the Midwest floods of 1993, where over 100,000 homes were destroyed and approximately $15 billion in damages occurred. The question was being asked, “What could we do differently after this 2011 flood event than we did after prior flood events?”

Landowners near L-575 pressed for implementation of a different planning process. Several residents spoke to state and federal officials, regarding the devastating damages resulting from the 2011 flood event, and how these damages were similar to what they had endured after the 1993 and 1952 flood events. Several landowners suggested that the Corps

consider a modified levee alignment rather than repairing-in-place as had been the traditional method of recovery after previous flood events. As a group, local landowners, local and county officials, state officials, and federal agencies advocated a more comprehensive solution to reduce future flood risk.

The expedited planning process for consideration of levee setbacks required extensive coordination in a short amount of time. Fremont County, Iowa, officials hosted monthly coordination meetings with state and federal agencies, as well as with local landowners. These meetings were pivotal in the alignment of different government levels in the pursuit of a levee setback versus simply conducting levee repairs. These meetings also became a forum for discussing levee setback planning progress, real estate needs, utility impacts, and county road modifications. The Iowa Department of Natural Resources (IDNR) discussed, then supported, the proposal for setting back L-575. The IDNR was also consulted on borrow pit wetland grading and seeding. Since IDNR serves as land manager for the Missouri River Recovery Program mitigation sites in Iowa, they could also contribute to wetland construction, conduct disturbance response actions, and plant trees and other native vegetation in the areas to be reconnected to the historic floodplain. The Iowa Department of Transportation (IDOT) assisted with the coordination of levee setback construction in the proximity of Highway 2. This levee setback project has also resulted in IDOT reviewing similar flood risk challenges across the state of Iowa. The Natural Resources Conservation Service (NRCS) was coordinated with prior to and throughout construction of the levee setback to ensure construction activities were compatible with land use requirements on NRCS's wetland easement tracts. The NRCS was also consulted on borrow pit wetland grading and seed mix preparation. The U.S. Fish and Wildlife Service (USFWS) was consulted regarding listed species and migratory bird impacts for project area.

Ecological Considerations

Historically, the Missouri River has been formed and reformed by a constantly shifting channel, comprised of numerous smaller braided channels, chutes, sloughs, islands, sandbars, and backwater areas. These natural features, which supported grassland, river-bottom forest, and wetland habitats, were created and maintained by a pattern of erosion, transport, and deposition that continuously reshaped the channel and adjoining floodplain. These habitats supported at least 160 species of

resident and migrant wildlife and 156 species of native fish in the main-stem river and its tributaries. The river was and continues to be an important migration route for migratory birds.

Although not quantifiable from an economic standpoint, levee setbacks provide an opportunity to restore geomorphic and ecosystem functions in riverine habitats through river-floodplain reconnection. Most river ecologists agree that a combination of habitat formation and natural hydrology are required to sustain aquatic communities and riverine function (USFWS 2003). This combination can be accomplished through implementation of a floodway concept, involving levee setbacks to provide floodway capacity as envisioned in the 1944 Flood Control Act. Rather than mechanically or artificially creating shallow water habitat, a levee setback provides an opportunity to naturally restore the geomorphic and ecosystem functions of the riverine habitat through the river-floodplain reconnection. While it is nearly impossible to place a dollar figure on ecosystem services, it is possible to coarsely estimate the value placed on such services by looking at the investments made as part of Missouri River Recovery Program. Mechanical creation of shallow water habitat and emergent sandbar habitat is an on-going effort by the Corps, with minimum annual expenditures exceeding $50 million. With a levee setback, mechanical creation of habitat would likely not be necessary; instead, natural processes are reestablished through reconnecting the river to its floodplain.

From a national investment standpoint, there is a concern over the high cost of restoration of natural habitats and recovery of threatened and endangered species on the Missouri River. These costs could potentially be off-set to some degree by reconnecting the river with its floodplain, thereby partially mitigating the deleterious effects of mainline levees. Any natural processes that might be restored to the Missouri River via the setting back of levees would have a very high return to the Nation. While those values alone are well worth investment toward restoration of the floodplain, other nonmarket values, such as clean air, water quality, educational opportunities, and aesthetics, would also be gained. Although the economic values of these “products” are difficult to measure in monetary terms, it is clear they are important to sustaining a healthy ecosystem (Millennium Ecosystem Assessment 2005).

Project Summary (Five Years Later)

The L-575 levee setback achieved many of the benefits forecast five years earlier. The levee setback improved hydraulic efficiencies through reduced flood stages and reduced erosive flood velocities within one of the most constricted conveyance reaches located along the Missouri River. The reconnection of 760 acres of historic floodplain, a levee setback of up to approximately 3,000 ft in several locations, and approximately 200 acres of non-typical borrow pits for establishing wetlands, appear to have been successful. Native flora and fauna have responded with increased growth and abundance after implementation of the levee setback, reconnection of the historic floodplain, and introduction of ecologically designed borrow areas, where the overall shape was varied and the side slopes were flattened. Additional fish and wildlife benefits could be realized if L-550 were to be setback an optimal distance from the Missouri River (Behm and Crane 2015).

Setback Levee Project at Hamilton City, California

Background

Hamilton City, California, is an unincorporated town on the west side of the Sacramento River about 80 miles north of the city of Sacramento. It is located about 14 miles upstream from the boundary of the Corps Sacramento River Flood Control Project levee system. The town relies on an uncertified private levee to contain flood flows. Since the construction of Shasta Dam in 1945, a limited portion of Hamilton City has flooded twice, in 1970 and 1974, due to failure of the levee. Evacuation and extensive flood fighting was necessary to prevent levee failure and flooding in 1983, 1986, 1995, 1997, and 1998. Following the 1986 flood, California's Reclamation Board designated a new floodway boundary that runs through Hamilton City.

Based on recent geotechnical and hydraulic analyses, the existing Hamilton City levee has only a 45% chance of safely passing a 10% probability-of-exceedance event. The downstream end of the levee is not tied in to high ground, so backwater flooding of agricultural lands south of Hamilton City occurs fairly frequently.

The Sacramento River is the largest river in California, with an average annual runoff of 22 million acre-ft, which is about one-third of the runoff

for the entire state. In its natural condition, the valley floor was regularly inundated for extended periods by large floods (CDWR 2011). Over the past 160 years, an extensive flood risk management system has been constructed along the Sacramento River and its tributaries that includes dams, levees, and high-flow bypasses. There are more than a thousand miles of levees in the Sacramento Valley (CDWR 2012). The levees are located relatively close to the main river channel, to concentrate flows and help remove excessive channel sediment from earlier hydraulic gold mining in the Sierra Nevada, and work in conjunction with broad bypasses to carry flood flows.

The construction of the Sacramento River levee system isolated the river from most of its natural floodplain. In conjunction with the conversion of land to agricultural and urban uses, the construction of levees has contributed to the loss of about 88% of the watershed's pre-1900 riparian, wetland, and other floodplain habitats (CSUC 2003). The original riparian forest has been reduced to a narrow corridor between levees along most of the river. In 1992, the USFWS estimated that 93% of the original shaded riverine aquatic cover had been removed from 84 miles of channels within the extent of the federal levee system on the lower Sacramento River (USFWS 1992). Control of river flows and armoring of riverbanks to protect levees have also resulted in a loss of naturally dynamic hydrologic and geomorphic processes, including overbank flows and channel meandering. Reductions in the extent and diversity of riparian habitat have caused reductions in fish, wildlife, and native plant populations. As a result, there are numerous special-status plant and animal species associated with the river and its floodplain. Federal special-status fish species in the Sacramento River include three Chinook salmon populations, steelhead, and green sturgeon.

Ecological conditions along the river in the vicinity of Hamilton City are fairly typical for the Sacramento River. Most of the natural floodplain has been converted to agriculture, with small levees that have disconnected much of the floodplain from the river. Remnants of the original riparian forest persist in discontinuous patches in areas that are unsuitable for farming because of frequent flooding or poor soils. Many remaining habitat areas have been protected as state and federal wildlife refuges, including substantial areas along the river to the south of Hamilton City. Along 1.3 miles of river immediately north of Hamilton City, riparian vegetation on both banks has been reduced to a band that is generally less than 100 ft wide. The Sacramento River has been a focus of restoration

efforts in recent decades because of its ecological and economic importance. The Sacramento River National Wildlife Refuge was established in 1989 to protect and restore riparian habitat. TNC, River Partners, and other organizations have also been active in restoring riparian habitats along the river. As restoration activity increased, landowners and other local interests became concerned about potential adverse effects on agricultural land uses, resulting in regional assurances that landowner participation would be voluntary and impacts on agricultural lands would be avoided (SRCAF 2000).

Authorities

Many levees constructed by landowners or local government entities were incorporated into the Corps Sacramento River Flood Control Project when it was authorized in 1917. The Water Resources Development Acts of 1990 (Section 306) and 1996 (Section 210) added environmental protection and restoration as a primary mission of the Corps. That legislation and resulting policy changes allowed the Corps for the first time to combine the seemingly incompatible purposes of flood risk management and ecosystem restoration in planning new projects. In 2004, the Corps completed a feasibility report recommending congressional authorization of a multiple-purpose flood risk management and ecosystem restoration project for Hamilton City, California. The project includes 6.8 miles of levee, with 4.1 miles of new levee setback and restoration of over 1,400 acres of native riparian habitat. The project was authorized by Congress in 2007 and physical construction of the project began in 2016. The Hamilton City project provides an example of the potential advantages of using levee setbacks as a project feature.

Three single-purpose flood risk management studies of Hamilton City were conducted by the Corps prior to the current multiple project. In response to floods in the early 1970s, the Corps produced a 1975 reconnaissance report that recommended further investigation of a levee setback. A levee setback was proposed to avoid induced flooding on the opposite side of the river, particularly in the constricted reach north of Hamilton City. The 1975 study did not progress to a feasibility report due to lack of local support. A reconnaissance report completed in 1991 under the Corps' small flood project authority, Section 205 of the Flood Control Act of 1948, concluded that an economically justified project could not be developed. A third study initiated in 1996 under Section 205 identified a smaller-scale levee setback adjacent to the town as marginally justified.

Hydrology and Hydraulic Considerations

The Hamilton City feasibility study was initiated in 2002 as part of the Corps' Sacramento and San Joaquin River Basins Comprehensive Study. The feasibility study followed the Corps' planning process for multiple-purpose projects, including the use of a trade-off analysis to reasonably maximize the total monetary flood risk management benefits and non-monetary ecosystem restoration benefits relative to total project costs (USACE 2004). Six preliminary alternative plans were developed that combined flood risk management and ecosystem restoration. Each of the six plans included levee setbacks on varying alignments and restoration of riparian habitats on agricultural lands between the new levee setback and the existing levee near the riverbank. Trade-offs between flood risk management benefits and ecosystem restoration benefits resulted from the different levee alignments. Alignments closer to the river provided greater flood risk management benefits because they would reduce flood risk for more agricultural land behind the levee. None of the alignments would significantly affect water surface elevations in the river channel or flooding outside of the immediate project area. Alignments closer to the river had lower ecosystem restoration benefits compared to alignments closer to the urbanized limits of Hamilton City. No single-purpose flood risk management plan was considered because it was unlikely that such a plan would be economically justified.

During the feasibility study, hydraulic modeling was performed to evaluate potential increases in water surface elevations resulting from the alternative plans. The newly constructed levees will be higher and less likely than the existing levees to fail prior to overtopping. Although the levee setbacks will increase the floodplain cross-section available to convey flows, the restored floodplain areas will be heavily vegetated, which will reduce flow velocities and tend to increase stages. The hydraulic study results indicated that most of the existing private levee will need to be removed to avoid increases in water surface elevations along the opposite bank of the river.

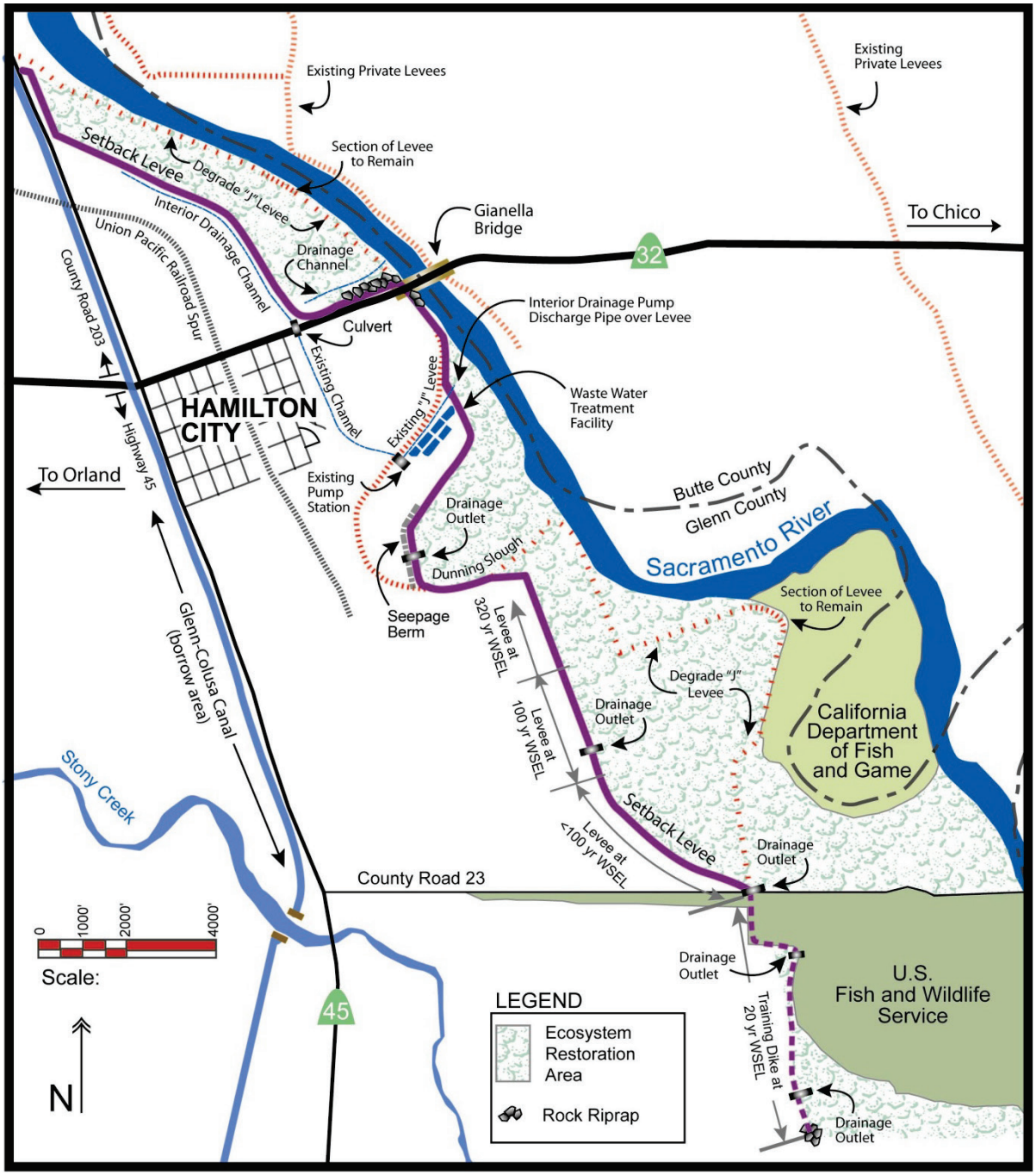
At the request of the California Reclamation Board (now the Central Valley Flood Protection Board), the maximum performance design level for the new Hamilton City levee was set at 90 % confidence of passing a 1 in 75 (1.3%) probability of exceedance event. The design level of performance was limited to avoid additional development in the floodplain that could result if development restrictions under the National Flood Insurance Program were removed, even though a higher level of performance would

have maximized net flood risk management benefits. The design criteria resulted in a levee crest elevation at the 1 in 320 (0.3%) annual chance water surface elevation between the upstream end of the new levee and a point about a mile downstream from Hamilton City. The design level of performance for the new levee setback will then initially decrease to a 90 % confidence of passing a 1 in 35 (2.9%) annual chance event, and then gradually decrease to 90 % confidence of passing a 1 in 11 (9.1%) annual chance event at County Road 23, which is the downstream end of the existing levee (see Figure 6). From that point, the new levee will become a lower elevation training dike that has been designed to be overtopped by high floodwaters while reducing scouring of agricultural lands and backwater flooding in Hamilton City. The training dike will extend 1.2 miles further downstream from County Road 23 and will end without tying into high ground or another levee. Because most of the new levee will be set back from the river channel, rock armoring for erosion protection will be required only at the ends of the levee and at the most exposed angles in the levee alignment. Consistent with the Corps' current design criteria, there will be no designated freeboard. The downstream reduction in the design level of performance for the new levee maximizes the net economic benefit of the project by providing a higher level of performance for Hamilton City than for the downstream agricultural lands that have lower economic damages due to flooding. The downstream reduction in levee height also avoids induced flooding of lands downstream from the project.

Ecosystem evaluation

Over 1,400 acres of agricultural lands on the river side of the new levee setback will be restored to riparian habitats consisting primarily of riparian forest with smaller amounts of oak savannah (mixed trees, shrubs, and grassland), scrub, and grassland. Specific habitat types will be based on the expected frequency of flooding and on soil types. Restoration will be accomplished by removing existing orchards, planting appropriate native species, and implementing irrigation and weed control during a three-year plant establishment period. Planting methods will be based on techniques developed by TNC at previous restoration sites along the river.

Figure 6. Map of Hamilton City levee system.



During the feasibility study, expected restoration benefits were quantified by the USFWS using Habitat Evaluation Procedures (HEP). The Habitat Suitability Index models used in the HEP were a riparian forest cover-type model, a red-tailed hawk model (for oak savannah, grasslands, and agricultural lands), and a scrub shrub cover-type model. HEP analysis was not applied to aquatic species because expected impacts would likely be

immeasurable or nonexistent. The Service's HEP results estimated that the selected plan would more than double the existing habitat values in the project area.

The USFWS's Fish and Wildlife Coordination Act report noted that benefits to restoring floodplain habitat will include habitat complexity, high invertebrate production, and the introduction of nutrients. Floodplain habitat will provide a mosaic of habitat structure and low-velocity habitat for fish. The USFWS also noted that amphibians, reptiles, migratory songbirds, and raptors will benefit from the project. Because the Hamilton City project will result in significant increases in habitat acreages and values, no separate compensatory habitat mitigation is needed. As part of the ecosystem restoration component, existing elderberry bushes, which provide key habitat for threatened Valley elderberry longhorn beetles, will be transplanted from levee work areas into the restoration areas.

Economic Considerations

Hamilton City currently has about 1,800 residents, with a median household income of about $30,000, which is approximately one-half of the median income level for California. Because of Hamilton City's small size, low median household income, minimal commercial development, and generally shallow flood depths, estimated economic damages in the town due to flooding are relatively limited. The town is surrounded by agricultural lands comprised of mostly fruit and nut orchards. An economic analysis estimated average annual economic damages of $768,000 (unadjusted) in the Hamilton City project area (USACE 2004). The largest damage categories were $215,000 in residential damages and $373,000 in crop damages, with the remaining damages spread among the categories of commercial, industrial, public, roads, automobiles, and emergency costs.

During the feasibility study, levee alignments further from the river were generally found to be more cost-efficient because they maximized restoration benefits relative to estimated costs. However, levee alignments closest to the developed area of Hamilton City had relatively high estimated costs because of additional required infrastructure modifications and real estate acquisition. The selected levee alignment (see Figure 6) includes levee setback areas upstream and downstream of Hamilton City that will allow the restoration of riparian habitats on most of the lands in the study area expected to flood at least once every ten years. The middle segment of the levee, closest to Hamilton City, will not be set back from the existing levee

and will include a new levee between the river and the town's wastewater treatment facility.

The Corps' civil works planning process requires that project costs be allocated to specific project purposes to determine economic justification and cost-sharing requirements. The project purposes for Hamilton City are flood risk management and ecosystem restoration. For project features that serve more than one purpose, the Corps uses the SCRB method to allocate a portion of the costs to each purpose. Costs that serve a single purpose are identified as separable costs, while costs that serve more than one purpose are identified as joint costs. In brief, the SCRB method is a mathematical calculation that uses the costs and benefits for each purpose to divide joint costs based upon how much each purpose benefits from being part of a multiple-purpose project rather than a single-purpose project.

For the Hamilton City project, levee setbacks were identified as a joint cost because a levee setback would be required if the project was constructed solely for the purpose of flood risk management or solely for the purpose of ecosystem restoration. Ecosystem restoration will require the removal of the existing levee and a new levee setback will then be required to avoid induced flooding beyond the restoration area. During the feasibility study, based on the SCRB method, joint costs for the portion of the levee setback (including lands and ancillary features) required to replace the existing levee were allocated primarily to ecosystem restoration. Of the nearly $45 million total project first cost (unadjusted), almost 95% was allocated to the ecosystem restoration project purpose in the feasibility report.

Allocation of a portion of the costs of the levee setback to the purpose of ecosystem restoration provided justification for a levee that would not have been economically justified based on flood risk management benefits alone. During the Hamilton City feasibility study, the selected plan was estimated to reduce average annual flood damages by $577,000. The features of the selected plan required for the flood risk management purpose, including levee setbacks, would have had an average annual cost of nearly $1 million (unadjusted). Consequently, the benefit-to-cost ratio for the selected plan, if evaluated as a single-purpose flood risk management project, would have been less than 1:1, and the project would not have met the Corps' requirement for economic justification. However, when the selected plan was evaluated as a multiple-purpose project, the average annual costs allocated

to flood risk management were only $319,000, resulting in a benefit-to-cost ratio of 1.8:1 for the flood risk management purpose.

The total estimated costs allocated to ecosystem restoration in the feasibility study were found to be justified based on the significance of the restoration outputs and other Corps planning criteria. The ecosystem restoration costs, including lands, plantings, and the portion of the levee setback costs allocated to ecosystem restoration, were equivalent to $27,400 (unadjusted) per restored acre, which was considered reasonable in comparison to other restoration projects.

Socio-Economic Considerations

The CALFED Bay-Delta Program began providing significant grants for acquisition and restoration of riparian lands in the Sacramento Valley in 1997 (CBDA 2005). Common interest in a combined levee setback and restoration project in the Hamilton City area was identified through contacts between TNC and agricultural landowners and through other venues. The Corps' *Sacramento and San Joaquin River Basins Comprehensive Study* was initiated in response to widespread flooding in 1997. The *Comprehensive Study* also identified the potential for a multiple-purpose project at Hamilton City that would address both flood risk management and ecosystem restoration.

The Corps' feasibility study was conducted in close coordination with the Hamilton City community and affected landowners. The local community actively participated throughout the study, including holding "levee festivals" beginning in 1998 to help raise funds by selling homemade tamales (SRWP 2015). The community has also formed a new Reclamation District to assess tax funds for operation and maintenance of the project. The study also received state funding through the CALFED Ecosystem Restoration Program (CALFED 2002). Before the feasibility report was completed, TNC had acquired most of the land in the setback area from willing sellers.

Case-History Summary

The inclusion of levee setbacks in the Hamilton City project will provide multiple benefits, resulting in a project that has received strong support across various interest groups and levels of government. Levee setbacks will allow a significant reduction in flood risk to Hamilton City and

contiguous agricultural lands while avoiding increased flooding of lands on the opposite side of the river. Ecosystem restoration in the setback areas will help to offset historic riparian habitat losses and preserve endangered salmon and other native species. The benefits from restoration are the main justification for the overall project and were an important factor in obtaining federal and state construction funding. The combined flood risk reduction and environmental benefits of the project have resulted in an absence of opposition from either environmental or agricultural interests.

6 Discussion

Levee Setbacks and River Geospatial Complexity

Rivers can vary along their length because geologic and hydrologic factors can change significantly. This spatial diversity must be considered in the planning of levee setbacks because the effectiveness of the levee setback may vary by location. For example, the 1,000-mile UMR is typically classified in four hydrogeomorphic reaches, though the boundaries are somewhat variable depending on the purpose of the classification (Theiling and Burant 2012). They generally include an upper reach impacted by impoundment only, a middle reach with impoundments and levees, an open river reach with levees only, and the Illinois River below Peoria Lake with dams and levees. The relatively narrow floodplain upstream of Clinton, Iowa, is inundated as a series of shallow impoundments by low head navigation dams (Theiling and Nestler 2010). There are few levees, and they are located in urban areas. Consequently, levee setbacks would have limited environmental and flood risk management benefits in the upper reach and likely substantial benefits in the reach that possesses only levees. The environmental benefits of levee setbacks in reaches having impoundments and levees is determined by the exact location of the levee setbacks relative to the effects of impoundment.

Levee Setbacks and Water Resources Planning

Using the EWN Concept for Corps Water Resources Planning

The EWN concept offers a powerful approach to increase the Nation's wealth in a way that is consistent with NEPA and more accurately accounts for the costs and benefits of Corps actions (both monetary and non-monetary). The EWN provides an effective way of implementing NEPA that should be further explored as projects and issues allow so that institutional procedures can be fully established. Planning coordination and collaboration, design, construction, and monitoring of ecological benefit (if possible) of new levee setbacks provides an excellent opportunity because both ecological benefits and flood damage reduction benefits are aligned and not in opposition. Based on the authors' analysis, there is already sufficient authorization in existing EOs and ERs to implement the EWN concept in NEPA compliance, particularly in the case of the levee setbacks.

The case histories presented in the report are of rather small scale (restoration of over 1,400 acres of native riparian habitat for the Sacramento River example and 760 acres of floodplain reconnected in the Missouri River example). To be ecologically effective at a river reach scale, tens of thousands or hundreds of thousands of floodplain acres would have to be reconnected to the river. While this may seem unrealistic, climate change may significantly reduce the level of protection afforded by existing levee systems. Raising the levee may be impractical because failure rate of the levee may increase with increased height. The only effective and sustainable solution may involve large-scale levee setbacks.

New Factors in Flood Damage Reduction Planning

The development of flood risk management infrastructure is generally an institutional response to large-scale damage that occurs from relatively infrequent flooding events. As such, it is usually a very deliberate process that includes a sequence of authorizing legislations to protect the built environment, a detailed scenario-based planning process, and selection and construction of a preferred flood risk management alternative. However, large rivers can cross climatologic zones and climatologic zones can change over time. For example, in the UMR, flooding occurs in early spring in response to snowmelt and rain on snow (USACE 2008). The flood of record was in 1965, with significant flooding in 1993, 2001, and 2014. There is a climatological transition through Iowa from Clinton, Iowa, to Keokuk, Iowa, where rain on snow or extreme rain in Iowa tributaries may drive significant floods. Rainfall is the major hydrologic driver below Keokuk, Iowa, and on the Illinois River. There is strong evidence that regional precipitation patterns are changing, with up to 20 % more precipitation in some areas of the UMR Basin during the last century and more intense storms throughout the UMR Basin (National Climate Assessment 2014). Increased streamflow has increased streambed and bank erosion (Lenhart et al. 2012), which delivers more sediment to large rivers, factors that must be considered in levee setback planning.

Floods of unanticipated severity have occurred that exceed the worst-case scenarios used in the Corps' planning process. Emergency response to severe flooding is restricted to "repair-in-place" reactionary options because there is no time to conduct the extensive planning required to design and construct more sustainable solutions. During or immediately after a flood event is a poor time to consider alternative levee designs because the urgency to immediately restore the flood risk management system

precludes careful planning to avoid reoccurring cycles of flood damage and emergency in-place levee repair. The repetitive cycle of repairing levees in-place after each major flood event has resulted in increased O&M and R, R, & R costs; increased flood risk; and general concern over the effective level of protection. Levee repairs in-place do not reduce flood risk. Long-term, sustainable solutions to reoccurring floods should be developed using careful, coordinated, and collaborative planning of flood risk management alternatives prior to the occurrence of a major flood.

Deliberative Planning of Levee Setbacks

Levee setback planning often succumbs to the "leaky roof" principle. No one thinks to repair the roof when it is not raining, but it is also impossible to fix the roof while it is raining. It is important for Corps staff to begin planning levee setbacks when there is time for the necessary deliberative process, including all of the collaboration and coordination, as well as re-evaluation of flood risk maps and other preliminary evaluations**.** These preliminary steps can be expedited by taking advantage of the process already established for the SRP.

State of Data used for Flood Risk Management Studies

Current input data used for flood risk management studies often require modernization because of outdated input data, changes to the conveyance channel geometry, and upland land use patterns. Compiling and maintaining information on the Nation's levee systems are extremely complicated tasks. The structures were frequently started by others and then improved by the Corps, so design documentation quality varies and records have been lost. Modern survey and inspection data have been managed on a per-project basis, so comprehensive databases need to be built. Data standards were established for a National Levee Database (NLD), but some parameters may not exist for all projects and raw data require interpretation. Ongoing levee inspections do not include elevation surveys, so changes since the design drawings may not be reflected. Levee subsidence does not seem to be a significant issue, but unauthorized levee height raises have occurred where flood-fighting berms were not completely removed. Unauthorized levee raises and flood fighting change floodplain geometry such that existing hydrologic model predictions do not apply during the most critical emergency response periods. Fortunately, flood area engineers and levee operators cope with uncertainty well, but a system plan will help reduce uncertainty.

7 Conclusions

The post-1993 flood "Galloway Report" recommended many changes in its review of floodplain management following the record-setting flood (Galloway 1994) that should be included in the consideration and planning of levee setbacks. In a contemporary review of the response, Galloway (2005) recommends an evolution toward the recommendations rather than an urgent response. In addition to the recommendations of the Galloway reports (1994, 2005) that pertain to levee setbacks, the authors offer the following conclusions from this report:

- Both environmental benefits and flood damage reduction benefits can be obtained from levee setback projects.
- Levee setback projects are excellent opportunities for demonstrating and implementing EWN concepts within existing laws, policies, and regulations.
- Levee setback projects are supported by a number of EOs and ERs.
- Levee setbacks must be planned during non-crisis periods to avoid repair-in-place.
- Coordination and collaboration requirements for levee setbacks can be developed from precedents established by the SRP.

Levee setbacks are often an economical, environmentally beneficial, and effective nonstructural alternative for achieving reduction in flood damages. Planning for levee setbacks should be completed and implemented before a significant flood event that overwhelms or damages existing flood risk management systems. Without preplanning, funds for levee repair must be expended on a variance of the repair-in-place option to provide for immediate restoration of flood protection. This approach will perpetuate reoccurring cycles of flood damage and prevent development of sustainable flood risk management.

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Levee Setbacks: An Innovative, Cost-Effective, and Sustainable Solution for Improved Flood Risk management

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14. ABSTRACT
This report describes levee setbacks as alternatives to traditional levees for flood risk management and environmental benefits. It is organized into five sections:

Information about levees for reducing flood damage, emphasizing environmental considerations
Description of the Engineering With Nature (EWN) concept for considering environmental benefits of U.S. Army Corps of Engineers (Corps) actions
Explanations of relevant Corps policy (Executive Orders (EOs), Engineer Regulations (ERs), and Memorandums of Understanding (MOUs))
Summary of environmental trade-offs between traditional versus levee setbacks
Summaries of two Corps levee setbacks in Sacramento and Omaha Districts that successfully completed the planning process

The summaries describe how hydraulic, flood risk management, and environmental benefits were quantified. The report includes environmental considerations for levee setbacks developed by Rock Island District for the Upper Mississippi River (UMR). Parts of the UMR are not leveed, which provides insight into the ecological response that could be expected from large-scale levee setbacks. Levee setbacks are a valuable tool to reduce flood damages and provide environmental benefits consistent with the EWN concept, the Chief's Environmental Operating Principles, and ERs, including the Resilience Initiative Roadmap. The report concludes that levee setbacks should be considered for appropriate sites.

15. SUBJECT TERMS
Levee Setback, Flood Control, River Restoration, Floodplain Restoration, Engineering With Nature, Floodplain Management, River Management, Missouri River, Ecosystem Services, Sustainable Rivers, Sacramento River, Levees, Environmental management

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