The Value of Floodplain Reconnection as a Nature-Based Solution

A Case Study of the L-550 levee on the Missouri River

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Highlights

- Floodplain reconnection improves the flood protection services provided by levees and reduces flood risk in neighboring communities
- The valuation of ecosystem services can make nature-based alternatives more competitive in flood risk mitigation planning studies
- Every $1 spent on floodplain reconnection results in a return of over $3 in benefits

INTRODUCTION

Large-scale floodplain restoration is a vital for ensuring the resilience of communities within the Mississippi River Basin, USA — with high-impact benefits including reducing flood risk, increasing habitat, storing carbon, providing space for recreation, and improving water quality.

The Institute for Resilient Infrastructure Systems (IRIS) at the University of Georgia completed a detailed assessment of a large-scale floodplain reconnection with a levee setback along the Missouri River near Brownville, Nebraska. This assessment used a series of novel methods developed by IRIS that include non-traditional metrics such as expected reductions in repair and maintenance costs as well as ecosystem services. These methods were combined with traditional benefit-cost analyses following the U.S. Army Corps of Engineers (USACE) guidance to estimate the ratio of benefits to costs (BCR) for different scales of levee setbacks. The results may be used as evidence for legislators and decision-makers to make informed decisions for funding large-scale floodplain reconnection projects.

The study found that the benefits of reconnecting approximately 18% of the levee-protected floodplain (+1000-m setback, 29.8 sq-km or 7,364 acres) outweighed the costs (BCR>1) even when only considering traditional metrics and increased when accounting for other benefits. A +1000-m setback could avert $9.96 million[1] in flood losses and provide an additional $3.84 million in ecosystem services annually. These annualized values translate to $268 million and $100 million over 50 years at a 2.75% discount rate, respectively, for a total benefit value **over $360 million**. Smaller scale setbacks have low BCRs due to the initial capital costs of building a setback levee but also have BCRs>1.0 when considering non-traditional metrics. The inclusion of such benefits and costs results in setbacks as small as +500m (15.69 sq-km or 3877 acres) having BCRs greater than 1.0.

Finally, the inclusion of ecosystem services in this assessment highlights the immense benefits of levee setbacks. Levee setbacks and the restoration of floodplains along major river corridors are essential for the long-term viability and resilience of the Mississippi River Basin. The hypothetical levee setback in this assessment represents less than 20 miles of the more than 2,000 miles of existing levees (<1%) in the Mississippi River Basin. Extending levee setbacks to 25% of the basin would translate into more than $10 billion in benefits for the Mississippi River Basin.

[1] All values reported in 2024 U.S. Dollars

WALTON FAMILY FOUNDATION

Prepared by the Institute for Resilient Infrastructure Systems at the University of Georgia. The IRIS mission is to advance the integration of natural and conventional infrastructure systems to strengthen long term resilience to natural hazards; enable communities, businesses and institutions to deliver infrastructure strategies for enhanced social, economic and environmental benefits; and support informed decision making through interdisciplinary expertise, cutting edge tools and techniques, holistic education and collaborative partnerships.

WHAT IS A LEVEE SETBACK?

A levee setback is a floodplain reconnection strategy where a levee, a human-made embankment, is moved further away from a riverbank or coastline, creating a buffer zone or restored floodplain between the levee and water source. This allows for floodwaters to spread out, reducing pressure on the levee and potentially enhancing the natural ecosystem.

Why setback? Traditional levees, built close to the riverbank, can inadvertently exacerbate flooding by forcing water to concentrate and potentially overwhelm the levee itself. Setbacks address this by moving people and property further away from the river and allowing floodwaters to spread out, reducing pressure on the structure and potentially preventing overtopping or breaching during major floods. Levee setbacks provide a range of benefits including:

- **Improved Flood Protection:** By providing a buffer for floodwaters, setbacks can reduce the risk of levee failure and damage to surrounding infrastructure, reduce flooding up and downstream.
- **Improved Fish and Wildlife Habitat:** By restoring the floodplain, setbacks can enhance habitat for fish wildlife and provide recreational opportunities including boating, hunting, and fishing.
- **Enhanced Water Quality:** By restoring the floodplain vegetation, setbacks can enhance water quality through removal of nitrogen and phosphorous.
- **Reduced Maintenance and Repair:** By moving a levee away from the main channel, setbacks reduce stress on the levee and can reduce reduce maintenance and repair costs.

Challenges to setbacks:

- **Land Use:** Setbacks may require cost-prohibitive land acquisition or easements.
- **Planning and Engineering:** Careful planning and engineering are necessary to ensure the effectiveness of a setback project and minimize potential risks.
- **Cost and Financing:** Traditional benefit-cost analyses do not account for the affected area of a levee setback, the reduced repair costs, and ecosystem service benefits. These analyses restrict financing options.
- **Community Engagement:** Public engagement and collaboration are crucial for successful implementation of setback projects.

In essence, levee setbacks represent a nature-based approach to flood management that can improve both flood protection and environmental health while minimizing the drawbacks associated with more restricted floodplains.

WHAT ARE ECOSYSTEM SERVICES?

Ecosystem services are the many benefits that humans receive from the natural world, including various goods and services provided by ecosystems. These benefits range from essential needs like clean water and air to less tangible yet also crucial aspects like mental well-being.

Levee setbacks reconnect floodplains and in doing so provide a variety of ecosystem services. Among these are:

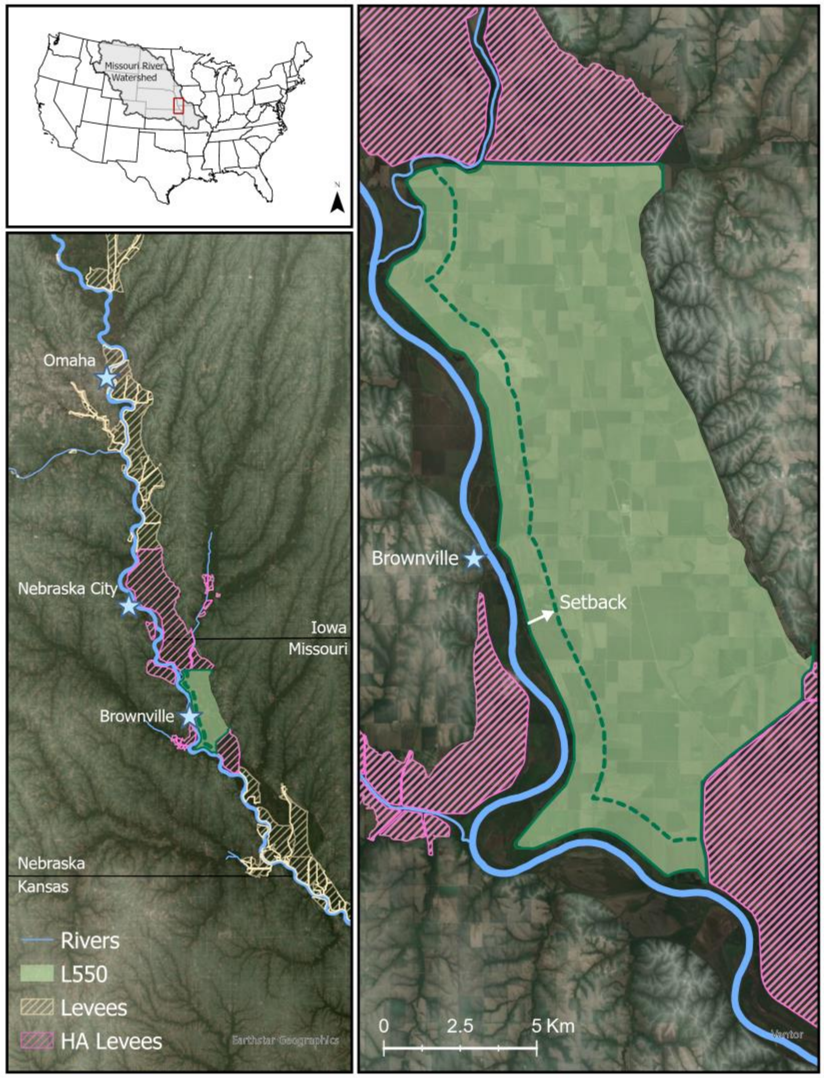
- **Increased floodplain storage:** Levee setbacks increase the storage of flood waters that can reduce water levels both up and downstream from the actual setback area. Lower water levels reduce the risk of damage and therefore repair costs.
- **Biodiversity and Conservation:** Reconnected floodplains offer habitat for waterfowl and other wetland species that were lost during levee construction.
- **Carbon Storage:** Wetland ecosystems have much greater carbon storage potential than agricultural lands or even forests. Restored floodplains provide a significant source of carbon storage and sequestration.
- **Recreational Opportunities:** Increased habitat creates space for outdoor recreation including hiking, boating, bird watching, fishing, and hunting.
- **Water Quality:** Restored floodplains offer increased water filtration and reduce agricultural runoff. Uptake of phosphorous by wetlands is higher than cultivated lands. Since these lands are no longer fertilized there is also reduced input into the system.

In this case study, these ecosystem services are valued and combined with a traditional benefit-cost analysis following USACE guidance that does not account for the above levee setback benefits.

L-550 SETBACK CONDITIONS

The L-550 levee is located along the southern end of the Missouri River watershed in a predominantly rural area near Brownville, NE. The levee protects approximately 161 sq-km (~40k acres) of floodplain that is predominantly developed for row crop agricultural (corn and soybeans). This case study evaluates the benefits of multiple levee setback sizes ranging from +250m to +2000m that reconnect ~5-35% of the total levee-protected floodplain area. It is assumed that land in the setback area is converted to conservation while farming will continue landward of the setback levee.

For each setback, we modeled the reduction in flood risk for a range of flood events ranging from the 2-yr to the 500-yr floods. Flooding was simulated in HEC-RAS with 1D/2D features (2D floodplains) and unsteady flow conditions. The model was calibrated with mean daily flows within a 10-year period of record (2010-2020). We then calculated the averted flood damages to roads, structures, and crops as the difference in damages between each levee setback and the existing levee condition. Consequences were estimated using an economic model built in the software LifeSim. Uncertainty was assessed by varying inputs, such as flood depths and structure depth-damage curves, in Monte-Carlo simulations.



Alternative	Leveed area (sq.km)	Setback area (sq.km)	Area fraction (%)	Frontage length (km)	Length fraction (%)
No levee	0.00	0.00	0.00	0.00	0.00
Existing levee	160.97	0.00	0.00	32.14	100.00
+250m setback	152.71	8.26	5.13	31.44	97.84
+500m setback	145.28	15.69	9.75	30.08	93.60
+750m setback	137.75	23.22	14.43	28.14	87.57
+1000m setback	131.18	29.80	18.51	26.96	83.91
+1500m setback	118.13	42.84	26.61	25.37	78.93
+2000m setback	105.86	55.12	34.24	23.88	74.32

HOW WERE BENEFITS VALUATED?

The benefits and costs calculated here are specific to the river reach in question. Source data was collected from the field, modeled using locally specific datasets, sourced from local communities, or sourced from the broader literature. The estimated ecosystem services are therefore dependent on the expected local ecosystem response to reconnection as well as the spatial scale of hydraulic effects along the river corridor.

Many traditional assessments do not capture expected reductions in repair and maintenance costs for hybrid projects that marry nature-based design elements with gray infrastructure (e.g. a levee). Such repair and maintenance costs are expected to decrease for setback levees and consideration for how these costs decrease may be consequential to decision-making processes in real world civil works actions. For example, their inclusion in this assessment challenges the economic defensibility of maintaining the status quo levee by lowering the BCR of a "do nothing" alternative below 1.0.

These same traditional assessments do not typically capture ecosystem service benefits such as improved habitat, increased opportunities for tourism and recreation, carbon storage, and water quality. For ecosystem services, we use a Price x Quantity model. The quantity of ecosystem services (e.g., how much nitrogen was removed through uptake in vegetation or denitrification from infiltration) was estimated with numerical modeling and local data. Whereas the prices or dollar value of a unit change in the accrual of ecosystem services were estimated with benefits transfer from studies in the Missouri River watershed or Midwestern region as well as a meta-analytic value transfer model with local constraints (depending on the ecosystem service and data availability). Benefits from ecosystem services were assumed to be delayed due to construction and regrowth and increase over time eventually reaching a peak value at 50 years. Details on the estimates of different benefits are below.

- **Averted Damages:** Averted damages includes both unrealized losses and reductions in repair and maintenance costs (repairs counted as costs that decrease with setback distance). To estimate averted damages, the study modeled a range of levee setback sizes using standard unsteady flow 1D/2D flood modeling techniques in the software program HEC-RAS (USACE) and geotechnical estimates of levee failure risk. Modeled flooding was then used to estimate the dollar value of damages to roads, crops, and structures in the software program LifeSim (USACE).

- **Habitat and Biodiversity:** Habitat and biodiversity were valued using a meta-analytic value transfer function that included ecosystem services reported in the broader literature.

- **Tourism and Recreation:** Tourism and recreation benefits were estimated using a meta-analytic value transfer function. Similar assumptions about ecosystem response were made as those for habit and biodiversity benefits.

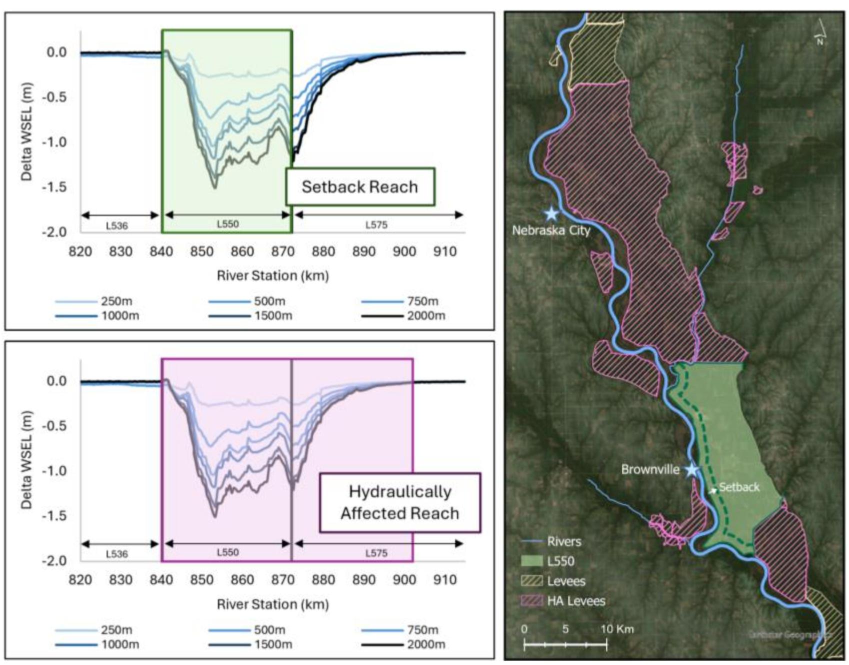
- **Carbon Storage:** Net change in carbon storage capacity was estimated using the InVest model and changing land use of the setback from current land use to common land cover types in the existing connected floodplain areas, such as wetlands and bottomland forests. The net change in land cover was then combined with a social cost of carbon.

- **Water Quality:** Water quality improvements were estimated using numerical flood modeling, field data, and nutrient removal models from the literature. Estimates focused on nutrient management such as nitrogen and phosphorus loading to the Missouri River from local agricultural production. The economic valuation of their management was sourced from the social cost of their presence in the environment and sourced from the literature.

BENEFIT VALUATION

The total benefits for a +1000-m setback totaled over $268M. For ecosystem services, we use a Price x Quantity model. The quantity of ecosystem services (e.g., how much nitrogen was removed through uptake in vegetation or denitrification from infiltration) was estimated with numerical modeling and local data. Whereas the prices or dollar value of a unit change in the accrual of ecosystem services were estimated with benefits transfer from studies in the Missouri River watershed or Midwestern region as well as a meta-analytic value transfer model with local constraints. Benefits from ecosystem services were assumed to be delayed due to construction and regrowth. Values in parentheses are the total value over a 50-year time horizon with a 2.75% discount rate using the example of a +1000-m setback (29.8 sq-km or 7,663 acres). The overall BCR for the +1000-m setback is 2.97 and varies from 2.6 – 3.2 over discount rates from 2-10%.

- **Averted Damages ($268.9 million):** Model results show an increase in the area benefited within a hydraulically affected reach (figure below) of averted damages was estimated at $9.96 million annually.
- **Habitat and Biodiversity ($15.12 million):** Habitat and biodiversity were valued using a meta-analytic value transfer function that depends on anticipated changes in the ecosystem after floodplain reconnection using ecosystem services reported in the literature. The analysis suggests an annual value of $0.56 million.
- **Tourism and Recreation ($11.06 million):** Tourism and recreation benefits were estimated using a meta-analytic value transfer function for habitat. Similar assumptions about ecosystem response were made as those for habit and biodiversity benefits. The model provides an annual value of $0.41 million.
- **Carbon Storage ($43.19 million):** Net change in carbon storage capacity was estimated using the InVest model and changing land use within the setback from current land use to common land cover types in the existing floodplain areas, such as wetlands and bottomland forests and combined with a social cost of carbon ($51/t$CO_2$e and $190/t CO_2e). The analysis provides an annual carbon storage value of $1.6 million.
- **Water Quality ($31.05 million):** Water quality improvements were estimated using numerical flood model and field data focusing on nitrogen and phosphorus loading to the Missouri River from local agricultural production. The economic valuation of their management was sourced from the social cost of their presence in the environment and sourced from the literature. The analysis provides an annual N and P removal value of $1.15 million.



Reduction in floodwater levels (change in water surface elevation) along the Missouri river affected by a levee setback along L-550. Benefit using only setback reach (green), and benefits to hydraulically affected reach (purple), and map of region showing the scale of both.

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