# Why We Continue to Develop Floodplains:
Examining the Disincentives for Conservation in Federal Policy

EARTH ECONOMICS

# WHY WE CONTINUE TO DEVELOP FLOODPLAINS: EXAMINING THE DISINCENTIVES FOR CONSERVATION IN FEDERAL POLICY


## AUTHORS

Zachary Christin, Earth Economics, Project Director
Michael Kline, Vermont Rivers Program Manager, VT Department of Environmental Conservation



## RECOMMENDED CITATION

Christin, Z., Kline, M. 2017. Why we continue to develop floodplains: Examining the disincentives for conservation in federal policy. White paper. Earth Economics, Tacoma, WA.

## ACKNOWLEDGEMENTS

This work is supported by the Kresge Foundation.

This document is owed to the extensive review and insight of David Fowler, John McShane, David Carlton, Eileen Shader, Jonathan Loos, Jessica Hanson, and Matt Chadsey. We would like to gratefully acknowledge the contributions of David Conrad to national flood policy which helped guide this research. We finally want to thank contributing organizations for their devotion to sound floodplain policy research and their assistance providing content in this document, including Earth Economics, National Wildlife Federation, and American Rivers.

We would also like to thank Earth Economics' Board of Directors for their continued guidance and support: Alex Bernhardt, David Cosman, Elizabeth Hendrix, Greg Forge, Ingrid Rasch, Molly Seaverns, and Sherry Richardson.

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# Executive Summary

This report explores the value of floodplains and attempts to explain how the nation's rivers and floodplains have become physically disconnected, leading to loss of floodplain functions. With federal agencies now incorporating the value of natural infrastructure, or ecosystem services, into federal planning and decision-making, there are opportunities as never before to examine and change the disincentives for floodplain conservation.

Floods are perceived as destructive forces of nature. However, the damage and suffering associated with floods are directly attributable to our decisions about where to live, work, and play. Flood risk management, too, seeks to enable communities to live nearby by controlling rivers with levee systems and other structures. This false sense of protection places families and infrastructure at risk in a climate that is changing beyond our capacity to maintain protections against its effects. Rather than attempting to control our country's powerful rivers, we should instead control how and where we allow human activities.

Policy makers must restructure floodplain regulations to incentivize resilient, nature-based solutions to risk reduction. We need investment to protect and restore our floodplains, including buyouts and relocations. There are cost-effective approaches that provide a host of benefits to residents in addition to flood protection, including clean water, habitat for fish and wildlife, and increased opportunities for recreation and tourism. They also produce taxpayer savings nationwide.

This report argues that current federal guidelines and standards may create perverse outcomes and vary widely between federal agencies. In some cases, guidelines and standards may not be enforced at all. With the effects of climate change on human development becoming increasingly evident with each passing year, the cost of floodplain loss is gaining national recognition. Although climate scenarios show little change in annual precipitation, they nevertheless create a sense of urgency for a new floodplain management paradigm as heavy rainfall events are expected to become more prevalent throughout the country, leading to higher peak streamflows and flood risk.[1] Nationwide, the average likelihood of a 100-yr flood is expected to increase by 45 percent in riverine areas and 55 percent in coastal areas by 2100.[2]

Agencies have taken steps towards supporting nonstructural mitigation projects and higher regulatory standards, but this support is not uniformly reflected in federal regulatory policy. This report investigates whether current federal policy is structured to prevent future flood damage or if incentives are leading to further floodplain development.

# Current State of Affairs: Flooding in the 21st Century

In the last decade, public policy has gradually shifted from a focus on mitigating the economic damage of floods to an acceptance of a resilience approach that integrates loss of life, human suffering, environmental damages, and community engagement.[3] In spite of this shift, the U.S. still inherits nearly a century of manmade structures that attempt to control and restrict our major river systems.

Over the last century, the typical floodplain strategy has been to alter or confine a stream or river to a predefined size or shape that maximizes the extent of developable or agricultural land while preventing floodwater from damaging property. Likewise, low-lying valleys have been viewed as places to flatten and fill to facilitate urbanization. To ensure "safety," residences and other structures built in flood-prone places are elevated above the minimal flood level, which also allows for insurance policies to cover potential damage.

In the early 20th century, multiple devastating floods led the U.S. Congress to pass the Flood Control Act of 1917,[4] which resulted in the construction of levee systems along the Ohio, Mississippi, and Sacramento Rivers.

Major flooding in 1936 prompted a federal response to public demands for aid for flood-prone areas of the country during the Great Depression, resulting in the Flood Control Act of 1936. In the decades following, the Army Corps of Engineers constructed thousands of levees, covering nearly 100,000 miles total.[5]

Although the levees were intended to protect people and structures from flood damage, their construction slowly crippled the natural capacity to convey floodwaters and regulate flood stage. The floodplains surrounding each river were cut off from their source of water and nutrients, causing them to slowly diminish. Today, continued population growth, uncontrolled urban sprawl, and the channelization used to protect development all contribute to further diminishing the functions of our nation's floodplains.

In the remainder of this document, we explore the benefits and the natural protective qualities of healthy, functional floodplains. We then discuss the causes of floodplain destruction and investigate the policies that further incentivize their development. Finally, we outline paths forward to create new floodplain policy.

# What is a Functioning Floodplain?

The relatively flat areas adjacent to a river are "functioning" floodplains if the river can inundate these lands during periods of high flow, or flood.[6] Highly functioning floodplains are those inundated at a flood stage that occurs every one to two years. Periodic floods and meander migration (sediment erosion and deposition) form floodplains over thousands of years, shaping them with specific ecological features that influence wildlife and plant communities, river dynamics, and ecosystem processes. Features associated with floodplains include oxbows, side channels, logjams, meander bends, and wetlands. As the source of a vast share of biodiversity and ecological services, floodplains are one of the planet's most valuable ecosystems.[7]

Floods are natural and can be beneficial by recharging water supply sources, carrying nutrients to enrich soils, and creating regular disturbances on which some ecosystems depend. Flood events are also quite common. In flood-prone regions of Washington State's Puget Sound, for example, rivers have exceeded the flood stage more than 1,400 times since 1900, damaging structures in only a subset of cases.[1]

"Floodplains by Design" is a partnership of federal, state, and local partners in Washington State. The ambitious effort is intended to integrate and accelerate floodplain restoration throughout the state with locally driven solutions and support from local business partners and farmers. In the Puyallup River Watershed alone, the program has accomplished the following:

- Reconnection of over 1,100 acres of floodplain
- Preservation of 600 acres of prime farmland through conservation easements
- Establishment of side-channel habitat for key species
- Significantly reduced flood risk along the watershed's three river systems[8]

## Measuring the Benefits of Natural Floodplain Function

Federal, state, and local benefit-cost analyses (BCA) often do not account for the environmental benefits of naturally functioning floodplains, and thus these benefits play no role in decision making. However, floodplains, which are a type of natural capital system, provide a suite of highly valuable ecosystem services that provide benefits to people. The benefits of ecosystem services are seldom considered in development scenarios. For example, natural capital assets within a floodplain (e.g. forests, wetlands, and rivers) perform critical functions such as capturing, storing, conveying, and filtering rainfall destined for the water supply that humans need to survive (see Figure 1). Yet, these functions are too often forgotten.

The following sections highlight several of the services most commonly provided by natural floodplains.

### Benefit 1: Hazard Avoidance – Peak Flow and Velocity Reductions

The increasing intensity of storms and flooding puts aging infrastructure such as roads, bridges, utilities, and levees at great risk and demands billions in maintenance and reconstruction costs. Alternatively, if the hydrological connection between rivers, adjacent wetlands, and floodplains were to be restored, then the resulting lower gradient, overbank flows, and increased surface roughness of the natural riverine system could result in flood conditions that are lower in both stage and velocity.[9]

Channelized rivers, commonly associated with disconnected or dysfunctional floodplains, are major contributors to erosion, sedimentation, and quicker degradation of built infrastructure such as adjacent roadways or levee walls. Climate change projections indicate an increase in the frequency and magnitude of flooding, with the size of floodplains, flood depths, and flood damages likely to increase.[10] This suggests that, in order to lower flood damages, communities may need to abandon channel works and invest in infrastructural changes.

**Figure 1. Natural Capital Functional Flow**

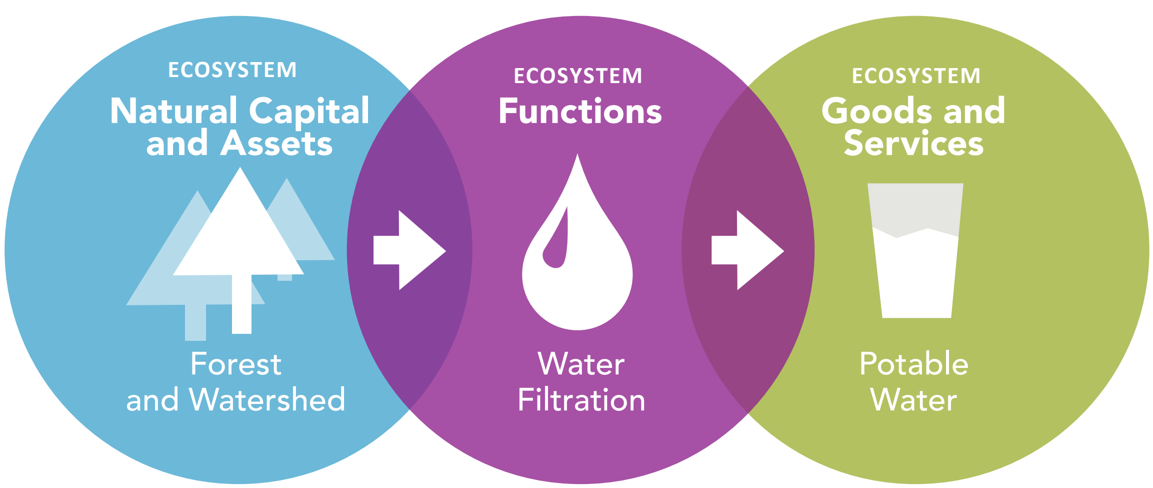
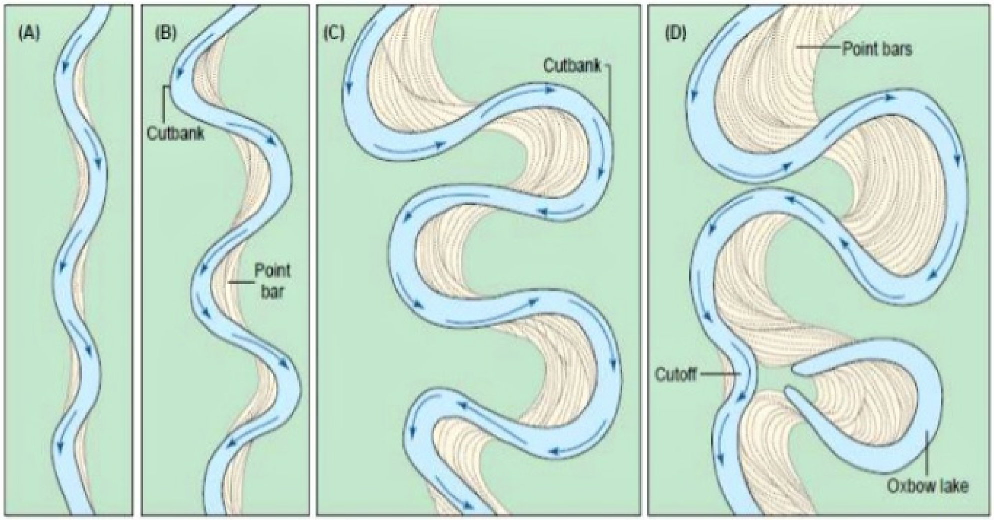


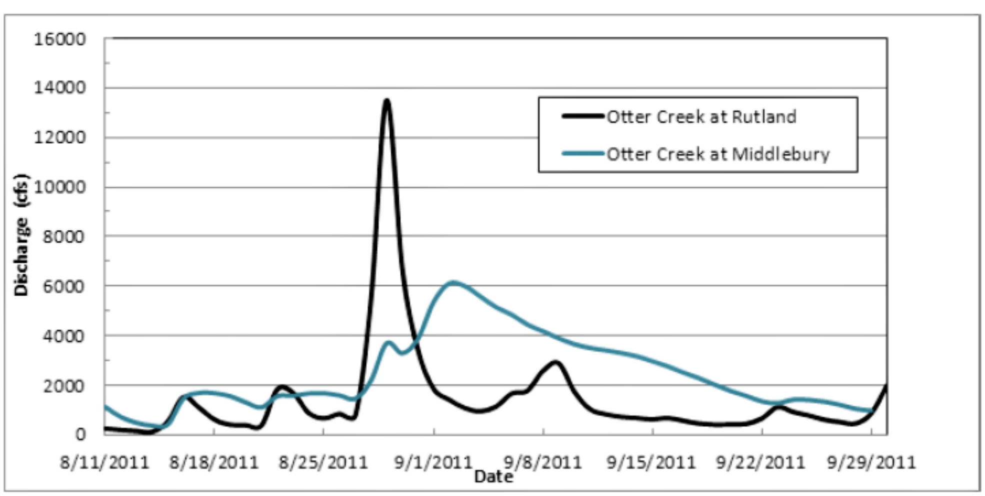
**Figure 2. Stream Sinusoidal Types**[11]




Flood velocity is affected by the paths and gradients of streams. Natural meandering streams are often situated in wider valleys with lower gradients and smaller sediment sizes typical of the streams depicted in panels C and D in Figure 2. If these same streams are managed and constrained into straighter paths, with higher gradients, as in panels A and B, they will flood with higher velocities and become highly erodible.

Meandering rivers with naturally functioning floodplains can also have a profound effect on flood stage. One example is the Otter Creek case in Vermont. Otter Creek flows north into Lake Champlain, with a drainage area that doubles in size from Rutland to Middlebury. Yet during Tropical Storm Irene (2011), the peak discharge that moved through Middlebury was less than half that experienced upstream in Rutland (Figure 3). Modelling to demonstrate the effect of the large functioning wetland-floodplain complex between the two towns showed that flood heights might have been 3.2 meters higher in Middlebury Village during Irene without the natural flood storage upstream. Over time, this reduced flood height saves the town up to 78 percent of potential damages.[12]

**Figure 3: USGS Flow Gage Data for Otter Creek at Rutland and at Middlebury, VT during and after T.S. Irene**[13]



## Benefit 2: Sediment Retention and Water Quality

Natural erosion and deposition, particularly during flood events, is beneficial as floods provide streams with sand, gravel, and woody debris. When floodplains are functioning, these materials are retained, sorted, and distributed into habitat features essential for fish and other species. When they are dysfunctional, streams become unstable and erosive, and the habitats associated with the bed and banks of the stream are scoured away. Additionally, detrimental rill and gully type soil erosion is minimized in forested floodplains with healthy root systems and soil crusts. Forested and vegetated areas provide natural stability and erosion control, while impervious surfaces and deforested areas cannot retain soil very well without stormwater treatment systems. Many large receiving waters in the U.S. suffer from severe sediment and nutrient loading as a result of floodplain soil and channel erosion (e.g., Lake Champlain and Chesapeake Bay). Thus, erosion and deposition are beneficial under healthy conditions, while in altered floodplain-river systems, increased erosion can do great damage.

Floodplains that experience detrimental erosion have drastically altered hydrology and geomorphology due to human development activities, such as mechanical tillage, dam construction, river channelization, and deforestation.[14] Restorative land use and best practices for river management can reverse this process (see case study #1 at the end of this document) and return floodplains to naturally functioning states that provide water quality and soil retention benefits.[15]

## Benefit 3: Habitat

An unaltered, naturally functioning river and floodplain system contains native riparian vegetation, sinuous curves, both deep and shallow bed forms, and woody debris, all of which support unique habitat conditions. Floodplain species benefit from nutrients mobilized by naturally occurring floods, while riverine species benefit from access to the floodplain for foraging, spawning, and refuge from high velocities in the river during high flow events.[16]

Endangered fish species rely on riparian conditions to spawn or migrate to saltwater after hatching and growing in healthy freshwater and floodplain systems. The Pallid Sturgeon, found in the Missouri and Mississippi Rivers, has experienced dramatic decline as nearly all of its habitat has been modified through channelization or other changes to river conditions.[17]

Endangered salmon entering estuaries are very dependent on functioning riverine systems and estuarine environments. Juvenile emigration through the transition zones and into estuaries is critical to survival.[18] Salmon rearing habitat is also important to supporting salmon populations. Sufficient saltwater acclimation areas are needed for smolt survival in their journey from their river habitat to the sea.[19] Coastal and estuarine restoration would support survival by creating the saline wetlands conditions needed for anadromous species' acclimation to saltwater. One case in urban south Seattle demonstrated this need with a restoration of 5.5 acres along the Green-Duwamish River that allowed salmon to travel successfully to Puget Sound (see case study #2).[20]

The Key deer, a subspecies of the white-tailed deer, once ranged throughout the lower Florida Keys, but now lives primarily in one area called Big Pine Key. In 1994, a U.S. District Court found that federal flood insurance in the Florida Keys was fueling development in the endangered Key deer's habitat. The judge ruled that under the Endangered Species Act, the Federal Emergency Management Agency (FEMA) was required to consult with the U.S. Fish and Wildlife Service to develop a plan to prevent the flood insurance program from jeopardizing the species. An injunction barring FEMA from issuing flood insurance for new development in the habitats was issued in 2005, and reaffirmed in 2008.[21]

## Benefit 4: Social and Cultural Values

Restoring natural river flows and reconnecting old floodplains to the river enhances people's quality of life within the watershed: community safety improves, the perceived environmental amenities can increase property values, the natural surroundings and views improve, and recreational opportunities are enhanced. Functioning floodplains provide reliable fishing opportunities, scenic hiking trails, abundant gaming habitat, and access to other recreational activities. One community in Wisconsin established the "Milwaukee River Floodplain Forest," a forest preserved for its recreation and habitat benefits.[22] This small eight-acre plot gained community and state support for investment in invasive species control to preserve the area into perpetuity.

Indigenous cultures rely on functioning ecosystems to forage for resources, provide shelter, and retain cultural activities and traditions. Native American Tribes gave up thousands of square miles of land in exchange for a small amount of money and permanent protection from the United States government. These treaties specified that the Tribes retained rights to fish. Yet some species have declined precipitously and are threatened with extinction. For example, the declining stocks and reduction in fishing opportunities are direct threats to the provisions guaranteed by the Treaty of Point Elliott, the lands settlement treaty between the United States government and the nominal Native American tribes of the greater Puget Sound region. It is widely accepted by fish experts that increasing salmon populations require more habitat, restoration of hydrology that is compatible with salmon biology, and a climate that is compatible with healthy salmon abundance.[23] Prioritizing floodplain restoration and conservation will reestablish and retain the social and societal benefits of floodplains as society begins to cope with climate change.

A recent study demonstrated how upstream development near Sebring, Florida nearly compromised Lake Iskokpoga's $49 million recreation economy.[24] Floodplain restoration, including invasive species removal and hydrologic reconnections, were estimated to cost approximately $992,000 over a six-year period.

# How Did We Lose the Benefits of Natural Floodplains?

The last four decades have shown an increasing rate and extent of flood-related damages.[2,25] Floodplains' flat topography and proximity to waterways attracts new roads and industry, leading to construction of large flood control structures and eventually homes. Following development, floodplain functions such as water storage, flood depth, and velocity attenuation diminish and become disconnected from broader watershed functions.

## Disconnected and Dysfunctional Floodplains

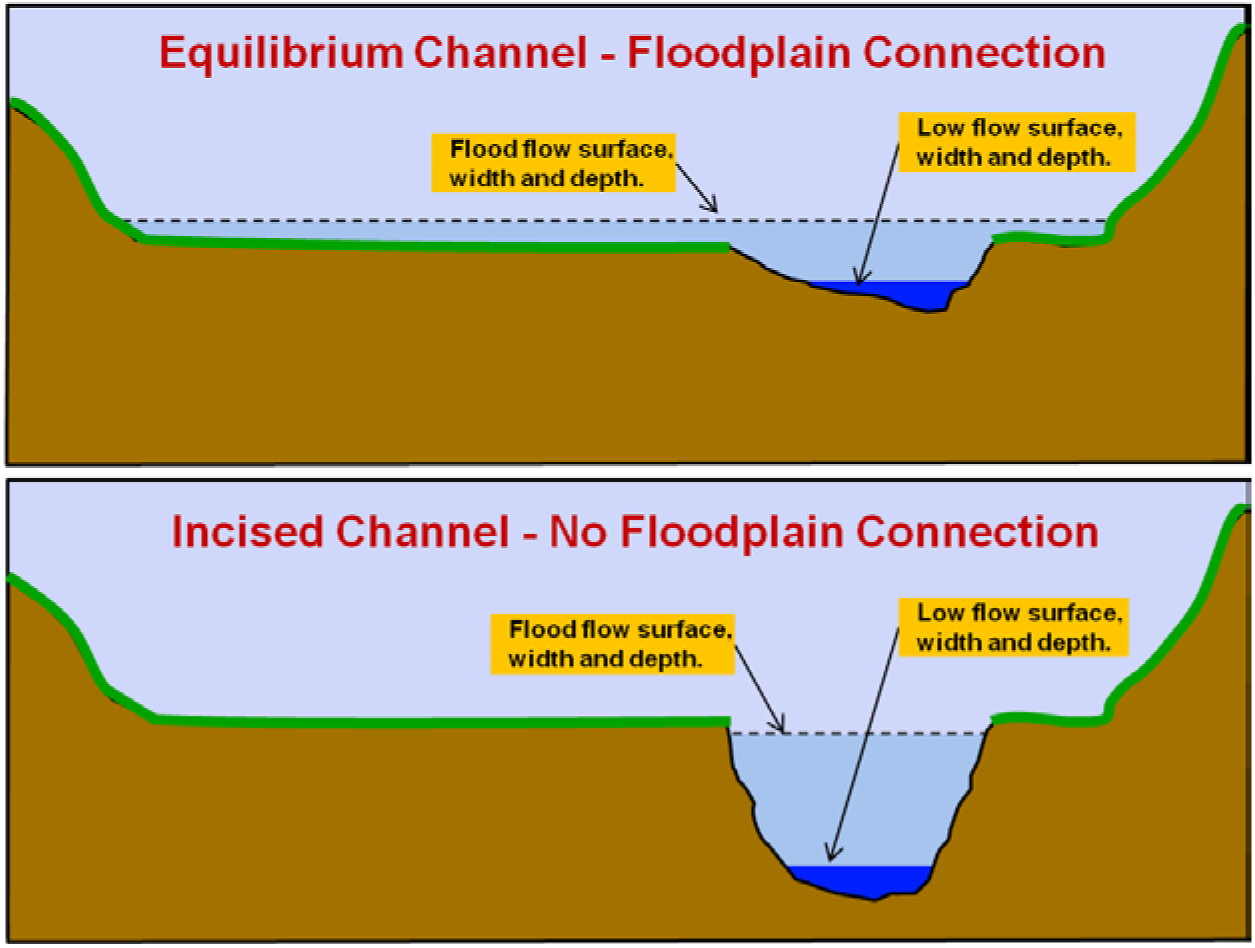
Floodplain functions are lost or greatly diminished when floodwaters are disconnected or diverted from the floodplain by levees, dikes, railroads, or the fill associated with roads, homes, and buildings. Dysfunction also results from changes to the shape of river channels or changes in the inputs of water and sediment that have led to imbalance (disequilibrium) and vertical disconnection of the river from the floodplain (referred to as channel degradation or incision, when erosion of river bed sediments increases the depth of the channel—see Figure 4). Since European settlement, repeated watershed and stream channel modification (i.e., deforestation, ditching, dredging, damming, straightening, and armoring) have led to a widespread loss of floodplain functions. Stream channel modifications have largely been pursued to protect adjacent land uses that may be threatened by flooding or fluvial erosion. Note: The most common causes of floodplain disconnection are construction of levees or berms at the top of streambanks and channelization that leads to incision. Both practices lead to flood flows becoming contained within the channel, rather than spreading across the floodplain.

## What Dysfunction Looks Like

Nationwide, cities and states find themselves in an escalating cycle of spending millions of dollars to maintain river channels, repair and rebuild flood-damaged roads and bridges, and protect adjacent structures from destruction. Unfortunately, these river management investments often either fail during the next flood, or contribute to increased damages elsewhere. For example, California's Feather River West Levee near Sacramento has continuously been under construction after a series of levee failures in 1955, 1986, and 1997 within a stretch of only 44 levee miles.[26]

Riparian landowners are increasingly vocal about the failures of channelization. While decreased property value is the face of risk, stream channel erosion is increasingly cited as one of the most significant water resource concerns. Typically,

**Figure 4. Hydrologically Functioning Floodplain**[27]




*Note: The most common causes of floodplain disconnection are construction of levees or berms at the top of streambanks and channelization that leads to incision. Both practices lead to flood flows becoming contained within the channel, rather than spreading across the floodplain.*

channelized streams are straighter, steeper, wider, and largely devoid of the instream and riparian features that maintain natural channel stability and provide a diversity of aquatic and riparian habitats. Channelization results in the following:

1. Streams that are eroding downward, incising, and losing access to floodplains, which are essential to maintaining natural channel stability over time.

2. Rivers and streams that have lost access to their floodplains during frequent runoff events (1- to 10-year floods) or large discharges (50- to 100-year floods).

3. Lands previously used by river meanders and floodwater are deemed safe to use for riverside agriculture, residential and commercial development, and transportation infrastructure.

4. An acceleration of fluvial erosion and deposition processes as major storm events widen and energize channelized stream systems with inputs of water and sediment.

## The Cost of Floodplain Development

The full cost of floodplain development is not accounted for in many areas, including the cost of undoing the damage from past actions. From stormwater management and floodplain restoration to post-disaster cleanup and mandated aquatic recovery, taxpayers are paying a hefty bill to fix our past mistakes. In the winter of 2015, more than $90 million was spent on projects to reduce flood risk in Santa Clara County alone.[28] Elsewhere around the state of California, preparations for El Niño storms attempt to mitigate the risk of damage to powerlines and riverside infrastructure.

The downstream cost of channel works such as levees is reflected in the destruction of habitat and increased risk of downstream flooding. Channelization typically pinches the river and severs connections to the floodplain, funneling the water downstream faster, and causes flooding upstream as water backs up behind the pinch point. As a result, the river and floodplain processes no longer create critical habitats such as side-channels and off-channel areas that are essential shelter and forage areas for juvenile fish.[29] Channels and levees are often lined with rocks (riprap), which creates an inhospitable habitat, often devoid of trees and vegetation that cool the water through shade.

More than 90 percent of Puget Sound's floodplains and wetlands have been lost to development, agriculture, and other human activities.[31] Most of the remaining floodplains are in poor condition, especially in urban and agriculturally dominated areas.[32] According to Washington State county assessor data, an estimated 105,332 structures are located on parcels within FEMA's regulatory floodplain boundary. These structures at high risk of flood damage are valued at more than $28.7 billion.[7]

Floodplain function has been lost along 75 percent of Vermont stream miles where channels have become moderately to severely incised.[30] EPA Region 1 issued a Total Maximum Daily Load (TMDL) for impaired sections of Lake Champlain (June, 2016), estimating that 22.3 percent of the total phosphorus load was coming from unstable incised streams. EPA Region 1 has also approved Vermont's Phase 1 Plan to reduce this load through passive and active restoration of floodplain function that has been lost due to channel incision.

If this cycle is not broken, land-based enterprises will suffer economically because, in addition to erosion hazards, channelization leads to a loss of sediment storage and a net export of life-giving soil and nutrient from a watershed. Alluvial rivers that have down cut and lost access to their floodplains will erode their banks until new floodplains are formed. During the early stages of this channel evolution process, floods remain within deepened channels and have much more power to erode and carry away anything that enters them. Without floodplains and meanders, lakes and reservoirs are often the first quiet waters in which rivers deposit the eroded soil and nutrients.

***CALL TO ACTION***

*Levee walls and channelization alter flood heights, increase floodwater velocities, and result in more powerful flood surges downstream, all of which increase channel erosion and downstream deposition, risking homes and commercial property. Urban communities are currently required to build structures that address only one piece of the puzzle: flood risk. Many of these built solutions, however, result in negative impacts up and downstream and still contribute to flooding. How can we address this problem? At a national scale, it is important to identify and understand the factors that cause continued social, economic, and ecological costs, while providing opportunities for decision making that results in net-beneficial projects. In the following sections, we break down policies that provide perverse incentives for floodplain development, then follow with an outlook for change that improves our current regulatory conditions.*

# Breaking Down Perverse Incentives for Floodplain Development

As far back as 1945, the "father of floodplain management" Gilbert White called for the examination of measures used to justify floodplain encroachment.[33] White correctly asserted that some floodplain development in the U.S. increased the exposure of communities living in low-lying areas and exacerbated flood risk. As the U.S. transitioned away from an agriculturally dominant economy in the 1980s, the country ushered in hard-engineered measures designed to enable economic growth while preventing inundation. This shift prevented local flood damages, but did not consider the watershed and floodplain-scale changes that also influence flood risk.

Today, we continue to experience the symptoms of this development paradigm, where built infrastructure solutions for flood control dominate land-use changes across the country. Current federal, state, and local floodplain management policies subsidize the costs of living in floodplains. Federal funds artificially increase floodplain land values by providing or improving nearby infrastructure, repairing such infrastructure after floods, building structural flood barriers to reduce flood risks, and reallocating risks of flood damages from floodplain property owners to taxpayers in general. In this section, we discuss the reasons why this development has persisted.

## Lack of Enforcement

President Carter's 1977 Executive Order (EO) 11988 required all federal agencies to avoid direct or indirect support of floodplain development.[34] In February 1978, the Water Resources Council published "broad guidance" to assist agencies in developing regulations to comply with EO 11988. However, there has been a clear lack of enforcement throughout the federal government concerning federal actions to curtail the development of floodplains. For example, EO 11988 was not consistently considered in appropriations for Hurricane Katrina, Hurricane Sandy, or other major disasters.[35]

There is also a disconnect between federal requirements and state-level applications. In April 1979, the Department of Transportation (DOT) issued Order 5650.2 "Floodplain Management and Protection." The DOT Floodplain Order prescribes policies and procedures to ensure that DOT agencies work to avoid and mitigate impacts on 100-year floodplains. The Order directs DOT agencies to identify 100-year floodplains encroachments under planning phases of projects, consider reasonable alternative actions using flood maps, and consult FEMA flood maps or flood insurance studies. Although

DOT consistently considers comprehensive floodplain regulations, federally funded state transportation activities often do not comply with DOT regulations. Some state departments of transportation routinely claim that they are exempt from state and local regulation of floodplains and stormwater discharges.[36]

In January of 2015, EO 13690 amended EO 11988 and called for the establishment of a Federal Flood Risk Management Standard (herein the Standard) to improve the nation's resilience to flooding and better prepare the nation for the impacts of climate change. The Standard specifically requires agencies to consider current and future risk when taxpayer dollars are used to build or rebuild floodplains and provides flexibility in selecting approaches for establishing the flood elevation and hazard area federal agencies use in siting, design, and construction.[37] One option is to utilize best-available, actionable data and methods that integrate current and future changes in flooding based on science. This provision is a significant opportunity to work with federal partners and consider the alternatives for establishing federally funded structures in a manner that both protects and restores natural floodplain functions, given their importance in mitigating the impacts of climate change. However, guidance on implementation of the standard has not been established. Since this white paper was published, public comment has been collected and the final draft of EO 13690 is soon to be released.

The EPA has worked with several rural towns to help them achieve development goals while preventing development in floodplains. For example, in Sussex County, Delaware, the EPA and NOAA are helping identify methods to protect water quality under "Smart Growth Strategies." These strategies would prevent urban sprawl and riparian development in accordance with restrictions enforced by Special Flood Hazard Area designations.[38] However, local officials have experienced difficulty enforcing ordinances, particularly within riparian corridors, and the EPA lacks the authority to regulate activities outside of water quality violations. At all levels of government, flood risk reduction mandates have simply not been enforced, even if the regulatory structure to do so exists.

## Moving the Problem Downstream

Construction of flood mitigation structures can shift flood risk from one community to another, which is unregulated and often unforeseen. Levees, just like other channel works, diminish floodplain storage during floods and confine the river within the channel, pushing the flooding and erosion damage farther downstream and adding pressure to extend the levee. In other words, levees move floodwaters instead of mitigating risk. Upstream communities have the incentive to build in the former floodplain and take little interest in alternative investments that would capture floodwaters, such as setback levees or riparian restoration. In cases like this, reducing risk in one area can simply shift it downstream to another location.

The National Marine Fisheries Service found that this phenomenon was present throughout the State of Oregon. Their study found that the National Flood Insurance Program (NFIP)) promotes floodplain destruction by encouraging developers to map parcels outside of the regulatory floodplain using levees and landfill-based property elevations. Once outside the regulatory floodplain, property owners avoid floodplain regulations and flood insurance purchase requirements. This practice, however, leads to constricted river channels, concentrated runoff, increased bank erosion, decreased water quality, disruption of essential ecological processes, loss or inaccessibility of habitat and more intense flooding.[39]

## Repetitive Flooding

The Repetitive Flood Claims (RFC) program is authorized by Section 1323 of the National Flood Insurance Act, (42U.S.C.4030). The stated goal of the RFC program is to reduce flood damages to individual properties for which one or more claim payments have been made for losses under the National Flood Insurance Program (NFIP) and that will lead to savings to the National Insurance Fund. Barriers to the implementation of sound floodplain management within this law include insufficient funding, improper implementation of mitigation projects, and the need for education and outreach related to best practices. Additionally, smaller communities are under constant pressure to allow development that preserves the community's tax base and economic stability, perpetuating the existence of repetitively flooded communities.

Additionally, the NFIP has further incentivized floodplain development by providing flood insurance below-cost while encouraging the channelization activity described above. Many properties are flooded, sometimes repeatedly, and then rebuilt with NFIP funds. Repeatedly flooded properties represent a disproportionate share of NFIP claims—about 40 percent in one study.[40] Efforts to curb further development in floodplains, such as the prevention of development in Special Flood Hazard Areas (SFHA), have not been enforced. In order for community members to buy federal flood insurance, their jurisdiction must qualify for the program by adopting floodplain management regulations that meet FEMA's minimum requirements. However, FEMA rarely penalizes communities that fail to enforce floodplain development restrictions. In fact, in some regions, such as the Puget Sound, no community has ever been suspended from the program.[1] The lack of enforcement becomes an incentive to floodplain development.

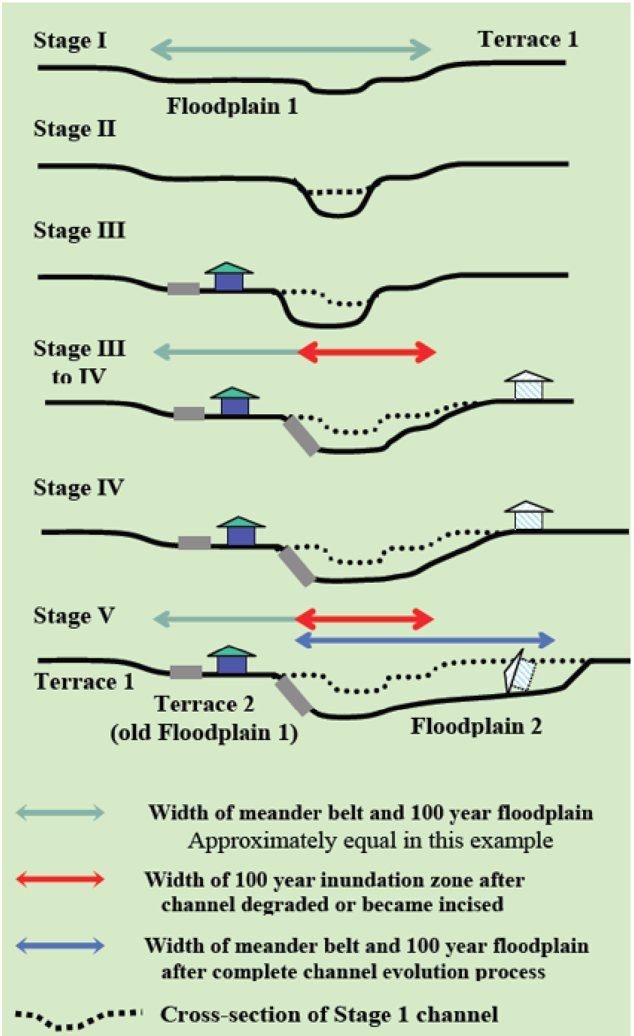
Residents of Iowa's' Middle Cedar Watershed, a natural floodplain, are no strangers to floods. Major flood events along the Cedar River occurred in 1929, 1950, 1951, 1952, 1961, 1962, 1965, 1978, 1993, 1999, 2000, 2004, 2008, as well as 2016.[41, 42] A report for the City of Cedar Rapids on flood recovery states that the city's location within the watershed, changes in land use, and sloping topography all make the city "increasingly susceptible" to future flooding.[43]

## Outdated Risk Assessments and the Lack of Investment in Flood Hazard Mapping

A second major factor that affects floodplain development is the state of risk assessments and flood maps. In many parts of the country, river channels were moderately to severely incised during the 1970s and 80s when FEMA flood insurance rate maps were first created. Consequently, the depicted flood hazard areas were much narrower than they would have been if the channels and floodplains were not vertically disconnected. Channel incision during the development of NFIP maps (i.e., at stages II, III, and IV of the channel evolution process depicted in Figure 5) created a misleading snapshot of the lateral extent of floods, including the 100-year flood. For over 30 years, these maps have been a perverse incentive to develop in areas the rivers were working to recapture.[30]

Another vexing issue with NFIP mapping is the limited geographic extent of mapping in some parts of the country. In Vermont, only 20 percent of the streams and rivers have mapped FEMA floodplains. In the absence of mapped floodplains across the rest of the state, the implication is that development along the other 80 percent of the state's rivers and streams is safe.

**Figure 5. Flood Stage Mapping as Affected by Channel Incision[28]**




Relative to the need for updated and extended flood hazard mapping, FEMA has been allocated only a fraction of the funds that would be needed to inform communities about inundation and fluvial erosion hazards.[44]

## Competing Federal Laws

Competing federal laws are another area affecting floodplain development. FEMA has the authority to take steps to protect endangered species, such as salmon, as governed by the terms of the statute delegating FEMA's authority to implement the NFIP. It does not matter that protection of the environment or endangered species is not one of the stated purposes of the statute. However, under administration of the insurance program, endangered species are often not considered. In April 2016, the National Marine Fisheries Service (NMFS) released an important new assessment for the State of Oregon that concluded FEMA's implementation of the NFIP has led to unsafe floodplain development that harms 17 of the state's endangered species.[45]

Many scientific assessments suggest that protecting and restoring floodplains is one of the most cost-effective actions for reducing the risks of devastating floods and recovering riparian habitat.[1] In 2008, the National Marine Fisheries Service (NMFS) came to a similar conclusion in its Biological Opinion (BiOp). BiOps are prepared when federal government agencies consult with other federal agencies in a process detailed in Section 7 of the Endangered Species Act. In Puget Sound, NMFS assessed the impacts of FEMA's NFIP on sensitive species in decline, such as salmon and orca whales. The study concluded that the NFIP is "likely to jeopardize the continued existence" of these species.[39]

### Agriculture

Farmers also find that their activities are subject to sometimes contradictory federal law. State and federal policy regarding agriculture in floodplains has evolved under a common perception that fields should be kept dry and protected from flooding, as in residential areas or town centers. As a result, little distinction has been made between agricultural practice and the structures regulated as development in Special Flood Hazard Areas (SFHA). Now, as Flood Insurance Rate Maps are revised and levees are deemed deficient, i.e., not meeting FEMA's 100-year requirement, agricultural areas thought to be protected by levees, and therefore mapped outside the SFHA, may now be bound by the requirements of the NFIP floodplain development regulations. Many rural agricultural communities will likely find themselves mapped into the SFHA. While farm structures should meet the standard floodplain regulations, it remains unclear whether NFIP standards, river management regulations (i.e., those administered by the USACE under Clean Water Act, Section 404), or Farm Bill programs have the flexibility needed to ensure the viability of crop and pasture land use coexisting with non-channelized rivers and functioning floodplains. Agriculture is a vital component of our nation's economy, and long-term implications of current floodplain policies may threaten vibrant agricultural communities unless we implement programs to support the compatibility of flooding and farming.

## Levees and False Sense of Security

Policies regarding levees are yet another issue in floodplain development. The federal government lacks a comprehensive national levee safety policy, program, and engineering standards for levees, floodwalls, and structures along canals. Currently, there are no national engineering or planning standards for levees or levee systems. As part of its response to the 2005 Katrina catastrophe, the USACE established a Levee Safety Program to assess the integrity and viability of these levee systems and recommend measures to ensure that levee systems do not present undue risks to the public, property, and the environment. However, this program is administered for USACE levees systems only, leaving much of the country's levee inventory at risk.

The country has many aging levee systems that fail to protect against the 100-year storm. While FEMA has taken action to address failing levees, a long history of neglect has left many cities at risk. Many levees were originally built to protect agricultural land, but now have homes and businesses located behind them.

The city of Dallas has one of the country's largest levee systems, covering a majority of the 710 miles along the Trinity River from the Oklahoma border through Texas to Lake Livingston near Galveston. In March 2009, FEMA de-accredited the city's entire floodway system, suggesting the structure was not sufficient to protect against a 100-year flood.[46] Other areas of the country face similar problems. In Washington State, a recent levee inventory found that 91 percent of levee miles in the state (627 miles) did not meet the federal requirements for FEMA accreditation, which suggests they do not protect against the 100-year flood.[47]

FEMA and USACE are working within current authorities to provide as much support and technical assistance as possible to nonfederal partners struggling with levee challenges. The most visible examples of this successful collaboration include the work associated with the National Levee Database and Inventory, the Silver Jackets Program, and innovative applications of the "Flood Plain Management Services Program" and "Planning Assistance to States" programs. To their credit, FEMA and USACE have worked to leverage as much existing data as possible to inventory every federal levee and as many nonfederal levees as possible to populate the National Levee Database. The NFIP, USACE levee programs, and the interplay among all federal programs have a role in flood risk, floodplains, and levees, but this system is highly complex and often opaque to many communities, stakeholders, and property owners.

The significant costs of floodplain development are borne by communities, businesses, individuals, farmers, and wildlife. Insurance "protection", however, covers only a small part of the financial toll, and thus taxpayers, individuals, and businesses shoulder much of the financial burden of post-flood cleanup and rebuilding. Those who live far from flood-prone areas pay taxes that support structural protection and rebuilding in flood risk locations. Federal and state disaster funds often function as a subsidy that reduces financial risk, shielding people, communities, and businesses from the true risks and costs of locating in flood-prone areas.

## Other Public Works and Other Government Subsidies

Despite multiple decades and billions of dollars spent to control floods by managing floodplains, flood damage has continued to increase for three reasons:

1. Communities, state and federal agencies, and property owners continue to build or subsidize building in high-risk areas;
2. When structures are built in high-risk areas, construction is often done with inadequate flood-proofing or design considerations for both current and future flood hazards; and
3. Damaged facilities are often rebuilt to the same failed standard.

A federal provision of the disaster recovery public assistance law (Stafford Disaster Act) provides mitigation funding, but critical facilities such as government complexes, transportation systems, and utility systems continue to be constructed in floodplains. Additionally, public structures that once were built outside the flood zone are now under threat as development in the upstream floodplain channels more floodwater downstream that otherwise would have been stored during storms. Municipalities and federal agencies have experienced a shift in the type of construction that would mitigate flood damages because of the perceived protection from levee systems, dams, and other channel works. This is evident in New Orleans, where residential construction in lowlands was once avoided, and elevated buildings were more common.[3] The following sections explore the extent of public infrastructure construction in floodplains.

### Roads and Culverts

The Federal Highway Administration requires state transportation departments to comply with NFIP requirements when building and replacing roads and bridges as a condition for receiving federal funds.[48] Many local roads and bridges are built in Special Flood Hazard Areas (SFHA) without due consideration of performance during flood events. The same is true for railroad embankments, which were built years ago and exacerbate drainage and flooding problems. A common case of failure to prevent future damage is during post-disaster conditions when replacing county and local roads and bridges. Very few standards are applied to the repairs, including any consideration of reducing the flood damage caused by the road or bridge.

Following Hurricane Isaac in 2011, the entire community of Laplace, Louisiana was without electricity for five to ten days due to flooding of local power stations. As a result, the pump and lift stations that power sewage and other water utilities went completely offline. This resulted in raw sewage flooding the streets in a multi-block radius and contaminating nearby Lake Pontchartrain. Following the flood, the power stations and lift stations were reconstructed in nearly the exact same manner. These stations will remain at risk of overflowing during storm events if major reinvestment is not prioritized.

At river crossings, many roads throughout the U.S. use embedded or open-bottom culverts tend to be more economical than alternatives, such as bridges. These culverts were built by the thousands, and the technique is often applied on streams where traditional hydraulic criteria for fish passage cannot be met.[49] By creating backwater and upstream sediment deposition during floods, culvert designs are often too small, leading to clogs and fails. Decades of decay and poor maintenance have degraded the original culverts, many of which were installed without consideration of their impacts on salmon population or their potential to impact flooding. Replacing poorly designed or damaged stream crossings will provide multiple benefits from improved stormwater mitigation to increased salmon habitat.

In 2016, the U.S. Fish & Wildlife Service completed a study of culverts on roads and railways in the Mat-Su Basin of Alaska.[50] Of 573 sites, 476 (83 percent) were on salmon-bearing streams, 287 of which (60 percent of all salmon streams) were considered barriers to salmon migration, blocking access to 455 miles of habitat. During major flooding in 2012, the railroad line and 40 roads throughout the region became impassable, many after culverts were washed out or clogged. Since the 2012 flood, many of the remaining culverts have been marginally repaired or left in dysfunctional conditions.

## Dams

Dams exist on a substantial number of U.S. riverine systems. Of the approximately 3.5 million miles of river in the U.S., nearly 600,000 river miles are impounded behind dams.[51] They alter the hydrologic and sediment regimes and present barriers to fish, as they block the downstream movement of juvenile fish to the ocean waters where they will spend their adult lives.

Like many levees in the U.S., dams are also aging and in need of repair. According to a 2013 report by the American Society of Civil Engineers, over 4,000 dams require repair, half of which protect residents directly downstream.[52]

Approximately 66 percent of U.S. dams were built before 1970, long before the negative environmental effects on floodplains were well recognized and implemented in federal policy.[53] As a result, over 57,000 dams are located within a floodplain and continue to disrupt riverine functionality today. Additionally, dams are often built for a single purpose, such as flood protection or navigation. For example, dams on the Mississippi River have the sole purpose of maintaining water levels high enough for navigation. While some dams continue to be used for this purpose, many no longer serve these same purposes.

On the Lower Snake River in Eastern Washington, freight volumes passing through the harbor locks have declined more than 20 percent since 2002.[54] Barges on the river reservoirs are used to transport wood chips, wheat and barley, pulses (e.g. garbanzo beans), and rapeseed (canola). The volume decline is especially true for wood chips, which declined 63 percent (by volume) from 1992 to 1997.Grains (chiefly wheat and barley) have been somewhat more stable, having declined by 8 percent.[55]

# Creating Positive Incentives: Starting with a Better Understanding of Risk

There is a clear need for a nationwide approach to floodplain definitions and mapping as well as effective floodplain protection and restoration. A "portfolio approach" that incentivizes multiple built and natural solutions will be most effective. Although floodplain destruction has been over a hundred years in the making, the trend can still be reversed.

Successful floodplain management, in the long-term, will be measured by our ability to solve problems at the watershed and river corridor scale. For example, how do we resolve conflicts at individual erosion sites? From a fluvial geomorphic standpoint, this means recognizing that rivers transport and deposit sediment and therefore cannot be managed as static channels without consequence. Natural stability and balance in riverine systems will depend on the river's opportunity to build, create, and access a floodplain, creating depositional features to distribute energy and sediment load in a sustainable manner.

## Better Understanding of Risk

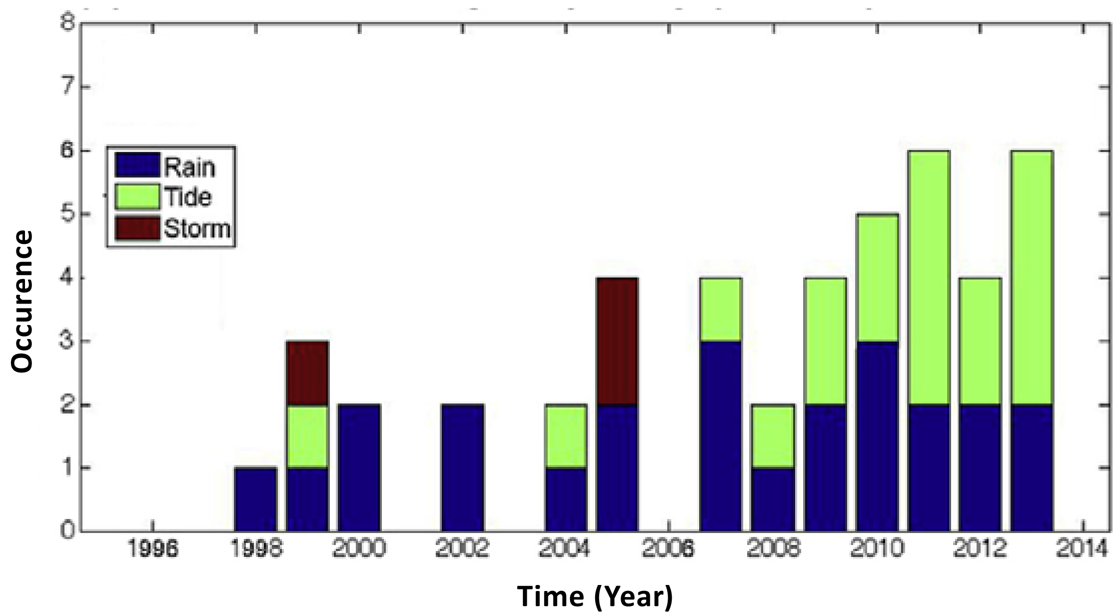
Flooding occurs throughout the U.S., but certain areas are especially prone to serious flooding. To help communities understand their risk, FEMA created flood maps (called Flood Insurance Rate Maps FIRMs) under the NFIP program to show the locations of high-risk, moderate- to low-risk and undetermined-risk areas. Because of the deficiencies of the NFIP mapping described earlier in this paper, there remains a disconnect between real and perceived flood risk from both the public and regulatory perspectives.

The average person lacks an understanding of how rivers meander and expand during floods. There is a need and an opportunity to educate the general public, particularly families that might be ready to purchase or build homes in the floodplain, putting themselves in harm's way.

Risk is not being communicated when FEMA provides flood insurance below its actual cost through the NFIP, thereby subsidizing the true price of living in a floodplain. Opportunities to communicate risk through insurance pricing is currently being debated in Congress and across the nation.

FEMA, NOAA, and other state and federal agencies are working on new mapping and risk communication tools that go beyond the traditional NFIP mapping of the area subject to a one percent annual chance of flooding, often called the "100-year flood." While this may seem like a rare event, it actually has a one in four chance of occurring during the life of a 30-year mortgage.[56] Figure 6 shows the occurrence rate of flooding on Miami Beach between 1998 and 2013, with a significant increase in tidal flooding.[57]

**Figure 6. Flood Frequency**[58]

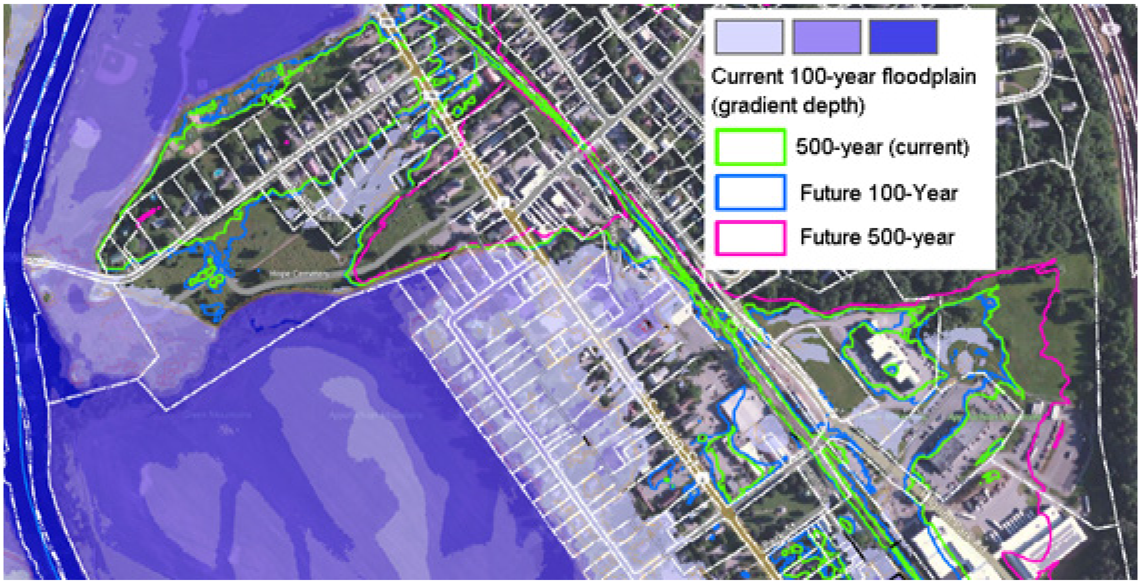



One emerging trend is to communicate the risks associated with encroaching on moving and evolving river channels (both natural and manmade), and future flood risk due to fluvial erosion, climate change, and increased stormwater flows. Case Study #1 (page 25) explains how Vermont has been integrating fluvial process-based performance standards (i.e., departures in hydrologic and sediment regimes) to communicate environmental impacts and flood risks. In its Riverine Erosion White Paper, the Association of State Floodplain Managers explains how many states, counties, and municipalities have begun mapping programs to address the risks associated with erosion, which may exceed those associated with inundation in some regions.[59] The paper explains the relationship between the assessment of floodplain function and the identification of riverine erosion hazard areas. Many experts agree that limiting regulations to the 100-year flood area is inadequate and that a higher level of protection is preferable, especially as climate change exacerbates flooding due to increasingly severe storms.[60]

Recently, multiple efforts have been made to better understand, map, and communicate changes in the FEMA 100-year floodplain. In one study, scientists and planning commissioners in Vermont and New York's Lake Champlain Valley wanted to understand changing floodplain delineations following Hurricane Irene (also see Case Study #4).[9] The results showed that, under climate change projections, the future 100-year floodplain equals or exceeds the current 500-year floodplain extent. Figure 7 below shows this difference in Waterbury, Vermont. The study predicted that, by 2065, the projected 100-year flood would be 29 percent higher than the FEMA effective flow.[9]

The work of state agencies and local entities is also important for the NFIP to function efficiently and effectively. Thousands of communities participate in the NFIP, far too many for FEMA to advise and supervise. State floodplain management offices, established to coordinate NFIP activities, perform multiple functions that fulfill, supplement, and complement federal activities.

**Figure 7. Change in 100- and 500-year Floodplain over 50 Years in Waterbury, VT**[9]




However, despite the federal mandate for states to designate a coordinating agency, the legislation that created the NFIP is largely silent about the states' potential contribution to floodplain management. This leaves each state to determine how large a role to play in floodplain management. In particular, states may be in the best position to help communities understand the importance of floodplains and assist in the adoption and administration of regulations that go beyond the NFIP's minimum requirements to better minimize risks due to flood and fluvial erosion.

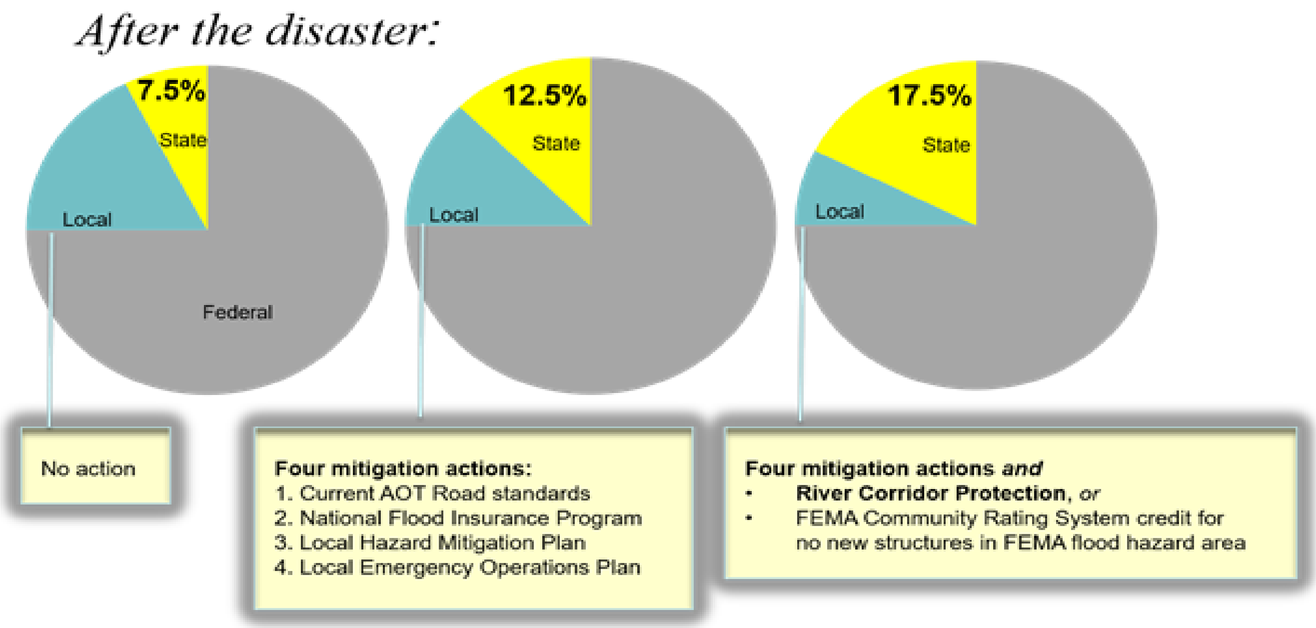
## Economic, Regulatory, and Funding Incentives

To achieve successful floodplain management, advocates for floodplain protection and restoration must work together to appeal to our government agencies for a coordinated set of incentives (e.g., see example in Figure 8). However, the roles and responsibilities of some programs, along with those of private, historic preservation, and environmental interests, often conflict. This tension impedes effective flood risk management and, in some cases, leads to narrow outcomes that reduce one stakeholder's risk by shifting it to another.

Solutions such as relocation or removal of built structures may be the most effective strategy, but they are often excluded from consideration due to perceived regulatory barriers. This includes federal and state agencies, and the local government that has responsibility for land use. Another barrier to such measures is the anticipated loss of economic development, which often provides incentives for a structural approach. To counter these issues, local, city, and state governments have collaborated with NGOs to purchase areas of high flood risk. This solution, along with the negotiation of land easements, has proven to be successful, but without far greater incentives for buyouts and conservation, there will be too few cases to make a national impact.[62]

In urban areas, California now requires protection against the "200-year flood", or that with a 0.5 percent annual probability of occurrence. The State Department of Water Resources is required to release informational 200-year floodplain maps for urban areas protected by the State Plan of Flood Control.[61] Case study #3 below demonstrates other approaches to understanding risk in levee structure assessments.

**Figure 8. Vermont State Cost Share Percentages Based on Municipal Mitigation Actions as Adopted in its Emergency Relief and Assistance Fund Rule[27]**




## Moving in the Right Direction

A handful of federal agencies have begun changing internal policy, leading the way for other agencies to create incentives to protect floodplains nationally. FEMA became the first federal agency to adopt ecosystem services valuation in their formal Benefit-Cost Analysis (BCA). Faced with rising natural disaster costs and climate uncertainty, FEMA approved Mitigation Policy FP-108-024-01 in June of 2013[63], allowing the inclusion of ecosystem services in BCA for acquisition projects. This policy is being applied to all flood and hurricane disaster mitigation in all 50 states, for all private residential, business, public utility, city, county, and state impacted infrastructure. On May 13, 2016, FEMA expanded the application of ecosystem services to all FEMA project types, including fire and drought.[64]

FEMA is authorized to acquire properties within system units and otherwise protected areas[65] using hazard mitigation grant funding. FEMA's Pre-Disaster Mitigation Program is also an incentive to avoid the cost and misery at repetitive damage sites. However, FEMA's hazard mitigation grant programs have historically been underfunded and oversubscribed.

The Federal Interagency Floodplain Management Task Force, originally established in 1975, has reengaged in recent years. By adopting a new vision and goals that include the protection of beneficial floodplain functions, the Task Force is perhaps the most promising arena from which a coordinated set of floodplain protection incentives might emerge. If federal and state agencies were to audit their funding, technical assistance, and regulatory programs for consistency with this vision and goals, there might be a dramatic decrease in the encroachment and channelization that diminish floodplain function.

In response to two United States Supreme Court rulings, the EPA and the USACE released a joint proposed rule in 2014 clarifying which waters are protected by the Clean Water Act.[i] The rule proposes to restore protection to all tributaries that flow to traditionally navigable and interstate waters and all of the wetlands, lakes, or other waters within the floodplains of these tributaries. This proposal is one of the most important policy measures in recent history for protecting wetlands, headwaters, and other natural infrastructure, which will in turn safeguard people and property from floods and hurricanes. However, it still leaves many important waters at risk. The EPA and the USACE have an opportunity to issue a final "waters of the United States" rule that clearly restores Clean Water Act safeguards to all tributaries, all water bodies located within the floodplains of tributaries, and all other wetlands and water bodies important to the health of downstream rivers and bays.

[i] Department of Defense, Department of the Army, Corps of Engineers and Environmental Protection Agency. 2014. Definition of "Waters of the United States" Under the Clean Water Act. Proposed Rule. Federal Register 79: 22188-22274.

**Vision and Goals of the Federal Interagency Floodplain Management Task Force**[66]

The Task Force is renewing its efforts to develop and implement unified floodplain management throughout the 12 member agencies by finalizing a Work Plan following the Task Force Vision of:

> *The economic, environmental, and societal values of floodplains are protected and flood-prone communities are resilient and sustainable.*

To meet this Vision, the Task Force established three overaching goals of:

***Goal 1 - Public Safety:*** Protect lives, property, and cultural assets through effective implementation of sound floodplain management programs and policies by all federal agencies.

***Goal 2 - Sustain the Nation's Floodplain Resources, Functions, and Services:*** Protect and restore the natural resources and beneficial functions of floodplains, and the services they provide.

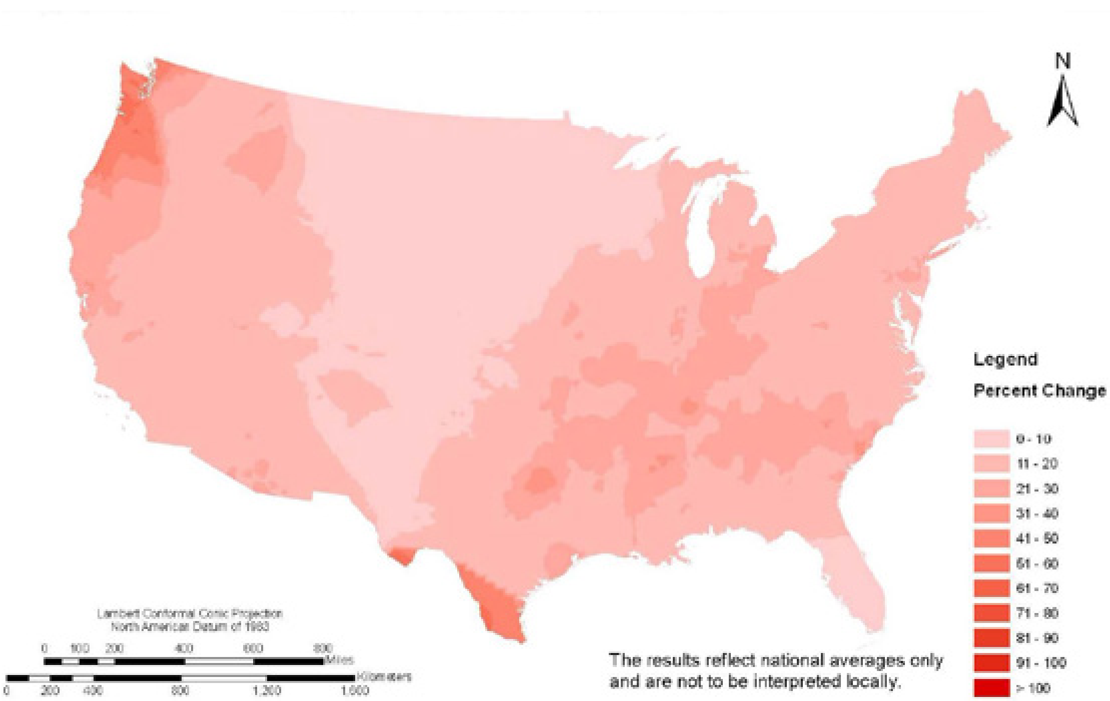
***Goal 3 - Economic Vitality:*** Promote and sustain economic benefits of floodplains with minimal degradation to the natural environment while limiting flood risk.

# Planning for the Future

Improving the resilience of communities to these natural hazards must become a paramount principle of public policy, recognizing that the risks will increase as the climate changes and that many more people will move into or find themselves in hazard-prone areas in the future. Climate change is predicted to increase the frequency and intensity of storm events, making flood-prone areas even more dangerous and costly to inhabit. The amount of land that floods in much of the coastal waters of the U.S. is also expected to increase with climate change. FEMA projects a 45 percent increase in the land designated as Special Flood Hazard Areas (SFHA) across the country. Figure 10 shows the distribution of change across the country.

Safeguarding U.S. citizens from the mounting risks from floods and hurricanes requires being proactive: Implementing strategies to reduce exposure and vulnerability to such events before they occur, not just responding to the aftermath. Resilience also requires working with nature, rather than against it.

**Figure 10. Median Projected Percent Change for 2100 over Current Conditions**[66]



# Conclusion

This paper is a call to action for placing greater value in natural floodplain functions and for federal incentives, including regulatory, technical assistance, and funding incentives, to protect and restore natural floodplains in what promises to be an increasing conflict between U.S. economic expansion and the greater frequency and magnitude of floods. Studies in different parts of the country show how human and natural communities have or would have suffered without the functions associated with fully-connected river-floodplain systems. We have not only come to understand the value of natural floodplains in avoiding flood damage, but also for their water quality, habitat, and other cultural values, and the extent to which these functions and values are being lost.

We have disconnected rivers and floodplains with levees, and disrupted river hydrologic and sediment regimes with dams and channelization practices to protect lands for development and agriculture. Many types of structures used to control and contain floods have not only failed over time, requiring large outlays for maintenance, they have increased the erosive power of floods. The degree of erosion and channel incision documented in the U.S. reveals the immense challenge we now face with reconnecting rivers and floodplains.

An argument for floodplain protection is not new, but we now have a clearer accounting of how policy and practice have diminished the natural functions of floodplains that might have served us. Our greater understanding of natural fluvial processes, together with a set of integrated state and federal floodplain policies may redirect development and remove encroachments to allow many of our floodplains to reform.

This report urges the continued work of a Federal Interagency Floodplain Management Task Force to audit federal agencies and help rework or replace the incentives for floodplain development that have contributed to a loss of floodplain function in the United States. Federal agencies might then incentivize the same policy and practice within their state and local agency counterparts. A set of Federal Flood Risk Management Standards should be established that utilize best-available, climate-informed and fluvial process data and methods in siting federally funded structures in a manner that both protects and restores natural floodplain functions.

# Case studies

National policy, regulations, and agreements are currently not enough to protect at-risk communities from increased flood risk over the next several decades. Some communities must rely on lower level governments to implement policy to protect structures from flooding, while enhancing the quality of floodplain function. To conclude this document, we provide five case studies on state approaches to sound floodplain management. These cases may provide insight as to the approach to federal policy amid the pressures of climate change, continued flood risk, and changing administrations.

## Case #1: Vermont – Avoiding New Channelization and the Loss of Floodplain Function

Vermont's avoidance-based strategies at the state level of jurisdiction are now beginning to reverse decades, if not centuries, of river and floodplain alterations. The following performance standards are embedded in precedent-setting regulations[68] that recognize: 1) that natural floodplain function depends on sound river management to ensure stable vertical connectivity of the river and its floodplain, and 2) that geomorphically stable and ecologically functioning rivers depend on the erosion and deposition processes that occur in unconstrained, functioning river meander belts and riparian buffer systems.

Stream Alterations: To avoid adverse effects to public safety and significant damage to fish, wildlife, and riparian owners, the Vermont Agency of Natural Resources applies the following performance standards in reviewing activities that alter the course, current, or cross-section of a perennial stream (other than those practices that address existing threats to public safety):

- Equilibrium Standard - An activity shall not change the physical integrity of the stream in a manner that causes it to depart from, further depart from, or impede the attainment of the channel width, depth, meander pattern, and slope associated with the stream processes and the equilibrium conditions of a given reach of stream, resulting in no unnatural aggrading (raising) or degrading (lowering) of the channel bed elevation along the longitudinal stream bed profile.

- Connectivity Standard- An activity shall not alter local channel hydraulics, natural streambank stability, or floodplain connectivity in a manner such that changes in the erosion or deposition of instream materials a) results in localized, abrupt changes to the horizontal alignment of streambanks or vertical profile of the stream bed, or b) creates a physical obstruction or velocity barrier to the movement of aquatic organisms. A person shall not establish, construct, or maintain a berm in a flood hazard area or river corridor unless authorized temporarily as an emergency protective measure.

River Corridor Encroachment: To avoid adverse impacts to public safety from fluvial erosion hazards, the Vermont Agency of Natural Resources applies the following performance standard in reviewing land uses under state jurisdiction:

River Corridor Standard: A proposed development shall provide for a meander belt and riparian buffer that ensure no increase in fluvial erosion hazards by causing the river reach to depart from or further depart from the channel width, depth, meander pattern, and slope associated with natural stream processes and equilibrium conditions. Proposed development shall not be approved, if, as a result of the development, there is an immediate need or anticipated future need for stream channelization that would increase flood elevations and velocities or alter the sediment regime triggering channel adjustments and erosion in adjacent and downstream locations.

These fluvial process-based performance standards are also embodied in Vermont Water Quality Standards (2016) for protecting aquatic habitat (as a designated use) and will support the evaluation of the cumulative impacts of instream and floodplain activities on stream equilibrium and connectivity when implementing anti-degradation policy during CWA Section 404/401 reviews.

In November, 2016, FEMA Region 1 approved specific codes and standards for the replacement of damaged bridges and culverts after a declared disaster under the Public Assistance (PA) Program. Design requirements for new or replacement bridges and culverts, in the Vermont Stream Alteration General Permit, have been developed to ensure compliance with the equilibrium and connectivity performance standards. FEMA's notification to Vermont that its codes and standards are PA eligible, will allow Vermont communities to replace undersized stream crossings with larger, more flood resilient crossings that adhere to the GP design requirements, without having to apply and compete for FEMA hazard mitigation funds. This partnership is a case study in how climate-informed and fluvial process data and methods may contribute to the restoration of natural floodplain function.

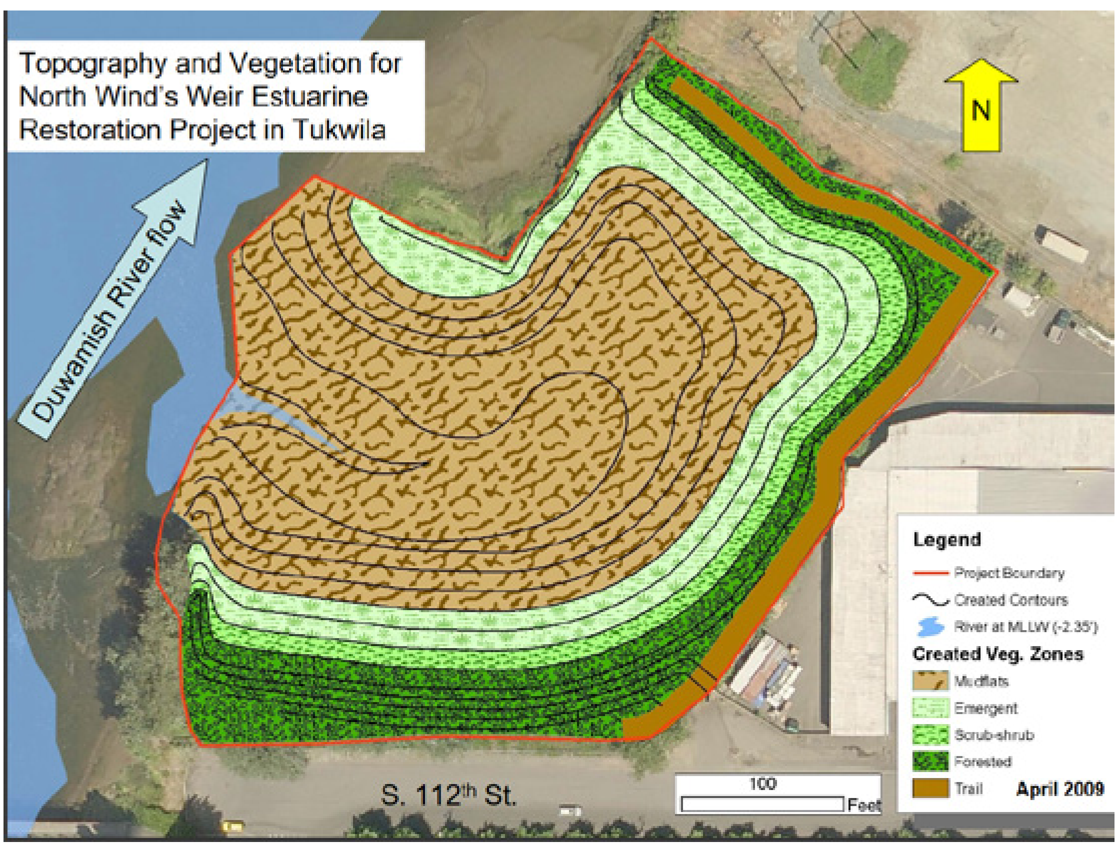
## Case #2: Washington – Restoration of Dysfunctional Floodplain: North Wind's Weir[20]

The North Wind's Weir (NWW) estuary habitat restoration project is located in the lower reaches of the Duwamish River, a critical zone for salmon. The project was created to help alleviate the shortage of juvenile salmon by providing them with a feeding area and a "transition zone" in brackish estuarine water from the freshwater river to saltwater to continue their migration into Puget Sound.

Without off channel areas, salmon smolts may be flushed directly from freshwater into saltwater without time to adjust or grow to a healthy size. This results in high mortality rates. Upstream salmon restoration without restoration of transition zone sites may be largely ineffective.

In 2001, King County purchased this property (2.5 acres) along the Duwamish River in an industrial region. Ten years later, the restoration was completed after contaminated soils were removed and native upland and emergent vegetation was planted. Over the process, $5.6 million was spent to acquire the property, remove toxins, and restore the property.

Restoration of NWW removed hazardous material in the soils which, over time, move downstream and into the Puget Sound. The project also resulted in the installation of native vegetation that, once fully established, provides a suite of ecosystem service benefits, including flood protection, stormwater mitigation, water quality enhancements, recreation, air purification, and carbon sequestration. A fully restored NWW property provides a key transitional habitat in the Duwamish River. Investment in NWW restoration also provides jobs and economic contributions to local economies.

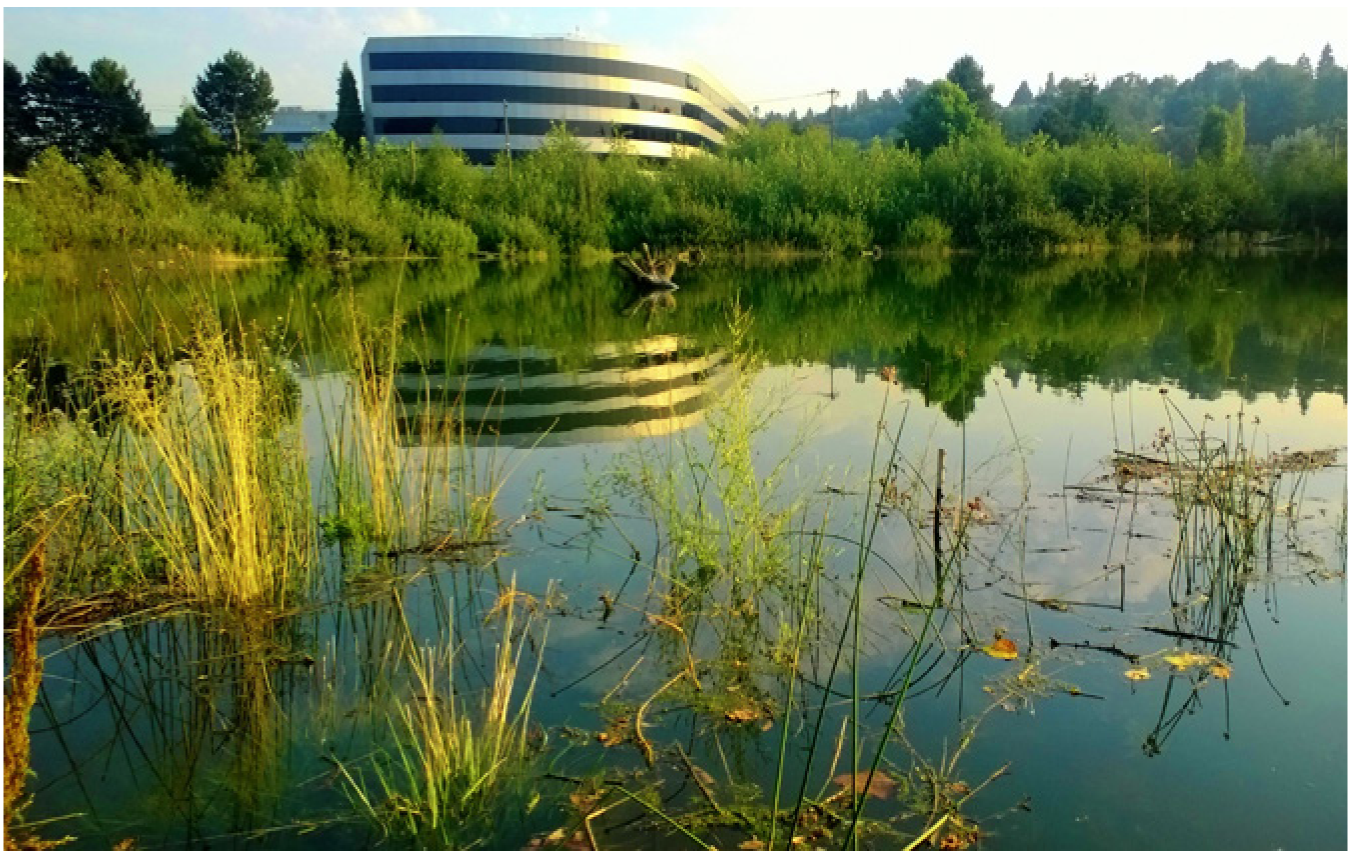



Source: North Wind's Weir Duwamish Salmon Habitat Acquisition and Restoration Project[69]

| ESTIMATED ROI OF THE NWW RESTORATION PROJECT | | | | |
|---|---|---|---|---|
| TIMEFRAME | 0%, LOW | 0%, HIGH | 2%, LOW | 2%, HIGH |
| 10 Years | -0.13 | -0.09 | -0.13 | -0.09 |
| 25 Years | -0.03 | 0.08 | -0.07 | 0.02 |
| 50 Years | 0.14 | 0.37 | 0.02 | 0.16 |

The results show that, after 25 years, the benefits provided by NWW's ecosystem services, their economic contribution, and volunteer activities in the area outweigh the initial investment cost of acquisition and restoration activities, under sum total high estimates. Additionally, both low and high estimates were shown to outweigh initial costs after 50 years under both discount rates. Benefits were valued using zero and two percent discount rates.

Some ecosystem goods and services, such as recreation activities and pollination, were not included in the calculations above. This was due to a lack of data and information on these services, despite their existence on this stretch of the river.



## Case #3: California – A Change of Course after Levee Failures[69]

California has had a long history of building and maintaining levees to protect its expansive cropland and growing communities against flood risks. In Yuba County, three major rivers, the Yuba, Bear, and Feather, have brought critical water resources – and devastating floods – to the region since the early 1800s.

Since then, the area has become a patchwork of levees surrounding farms and towns. Unfortunately, the aging infrastructure has not prevented major flood events. In 1986, a levee break on the Yuba River led to floods that damaged or destroyed nearly 4,000 homes and caused $22 million in losses.[70] In the wake of this disaster, the USACE spent millions of dollars to improve levees throughout the region, yet the flood risks remained. In 1997, levee failures along the Bear and Feather Rivers flooded 1,000 acres of residential, 15,500 acres of agricultural, and 1,700 acres of industrial land, causing damages estimated at more than $300 million.

These events have led several communities to rethink flood management. While considerable investments continue to be made in shoring up levee infrastructure, there have been several notable projects to develop setback levees, which allow "room for the river" by incorporating natural floodplain lands and habitat restoration into the project design. Not only do such projects take advantage of natural floodplain functions, but the levees themselves often can be built and maintained at a lower cost because they do not have to accommodate as much flood velocity as if they were directly along the river.

In one such project that was built by Three Rivers Levee Improvement Authority (TRLIA) and coordinated with the USACE, 9,600 feet of levees were set back along the confluence of the Bear and Feather Rivers, reconnecting 600 acres of flood-prone agricultural land to the floodplain.[71] This land has since been restored into riparian and grassland habitat that supports numerous species of fish and wildlife, provides a variety of recreational opportunities, and helps buffer the release of pollutants from nearby agricultural operations into the rivers. The new setback levee and restoration area are excellent examples of blending flood control with ecological habitat while maintaining all the necessary flood flow requirements. Although isolated cases of progress on levee setbacks exist, more specific information is needed about how these projects came about and which factors made them successful to facilitate the widespread use of this practice. A promising start, the Engineering with Nature initiative within the USACE has begun to identify opportunities for levee setbacks and document case studies of successful levee setback projects to advance the understanding and implementation of such projects.[72]

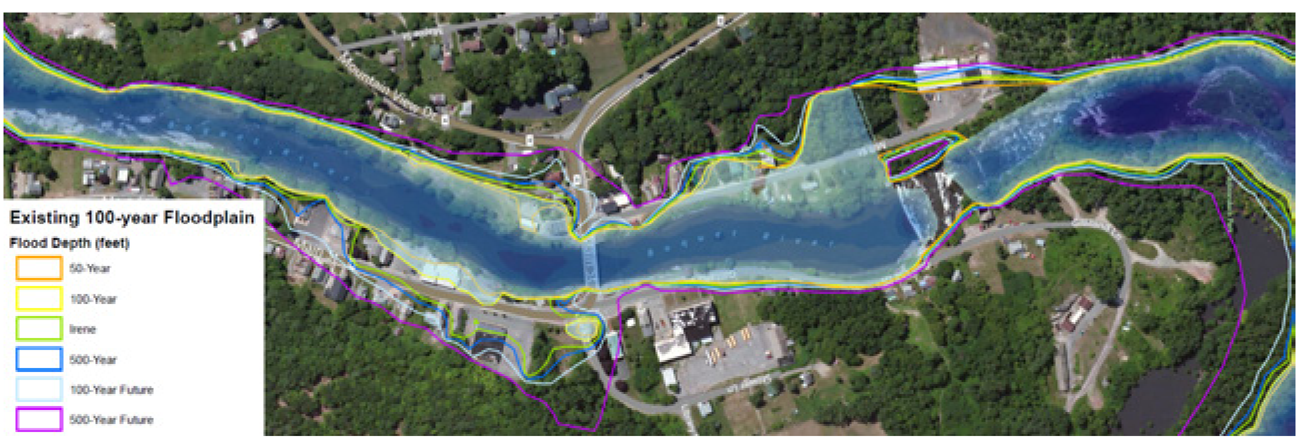
## Case #4: Upstate New York – Return on Investment of Willsboro Flood Protection

Willsboro, New York, located just west of Lake Champlain, has endured damaging floods due to its riverine and lakeshore settings. Flood damages and cleanup costs around Lake Champlain have amounted to $1.75 million from a single storm.[73] To improve economic opportunities while increasing flood resilience, Willsboro officials sought local NGOs and scientists to conduct a study to help towns make sensible floodplain management decisions. The town officials were interested in mitigating future damages while balancing economic, social, and environmental vitality with potential climate change impacts to local precipitation patterns.

The subsequent study, which was completed in 2015, modeled future flood threats under multiple scenarios.[9] The baseline scenario included a maximum possible build-out within a 500-year floodplain. This entails clearing the land of all current development and rebuilding at the maximum allowable density by-right, based on current local zoning regulations. This scenario was created in anticipation of future regional population growth in the region. A build-out by-right could yield millions of dollars of increases in residential and commercial buildings in the floodplains. However, this scenario would exacerbate flood damages by increasing the number of structures in harm's way.

A second scenario modeled the removal of current development followed by riparian restoration, returning the section of highest-risk floodplain to a state as close to natural function as possible. The study found that, while the political feasibility of this second scenario was low, it also demonstrated economic feasibility over time. This option represents the best way to limit future building damages while also avoiding loss of tax revenue through building relocation.

Using historic rainfall data for future projects, hydraulic modeling of floodplains demonstrated the widening or growth of 100- and 500-year floodplains over a 50-year timeline. The figure below shows this growth in the community of Willsboro, comparing flood depths from 2011's Hurricane Irene to current and future flood extents. Flood scenarios showed widespread



damages along the Winooski and Boquet Rivers, which both feed into Lake Champlain. If predicted flood flows increase, the floodplain will widen and flood depths will increase. Floodplain restoration was shown to lower flood depths in multiple areas.

Damage modeling for buildings, content loss, and inventory loss shows that the Willsboro residents “pay” thousands of dollars annually for continued residence in the floodplain. Even with only 21 buildings in the 500-year floodplain, Willsboro residents incur an average of $1,600 dollars in damages annually, which could increase to $5,800 by 2065 if floods increase. While simulated damages increase as more buildings are added to the floodplain, they decrease as aggressive mitigation strategies like elevating or removing buildings are adopted. Avoidance is the best strategy for minimizing future damages. Some projected losses in tax revenue can be addressed by moving or building structures into town and out of the floodplain.

Floodplains store floodwaters and lower flood depths, thereby reducing damages. The proposed Willsboro floodplain restoration would decrease existing annual building damages from $51,000 to $41,000 and further reduce damages in the event of a future tropical storm event by $2.6 million. Both the current and future cost of living in the floodplain lowers with floodplain restoration. Additionally, restoration scenarios showed an increase in ecosystem services, or environmental benefits, over a 50-year timeframe - $4.5 million to $37.0 million in Willsboro. These ecosystem services, which include erosion control, flood mitigation, and recreation and tourism, should be protected and expanded where possible.

## Case #5: Louisiana – Enhancing Multiple Lines of Defense in Louisiana

Although Louisiana has long had "multiple lines of defense" against hurricanes, from the region's barrier islands and wetlands to the extensive system of dikes and levees, the state's heavy reliance on built infrastructure and the loss of coastal wetlands due largely to anthropogenic factors have significantly decreased the coastline's resilience in the face of extreme events.

The value of natural wetlands for storm and flood protection services is quite evident in the Mississippi River Delta region, particularly in the wake of Hurricane Katrina. The 2005 storm was one of the deadliest, costliest storms in U.S. history. Historic losses of more than 1.2 million acres of coastal lands over the last 80 years have greatly increased storm and flood vulnerability in the region.[74] The trend of ecosystem deterioration in the Mississippi River Delta is amplified over time due to a positive feedback effect: As storm and flood damages increase after protective natural ecosystems are lost, land loss also accelerates. Losses from hurricanes in 2005 alone represent 42 percent of the land loss that was previously predicted to occur over a 50-year period.[75]

Economic analysis of future storm and flood risk reveals that without a change in course, the continued trend of wetland loss in this area will result in more than $41 billion in economic losses.[76] This estimate includes only direct economic loss, without consideration of further losses from damage to the natural infrastructure that provides a range of ecosystem services. Given this, the USACE adopted a strategy to "hold the line" by taking measures to avoid further wetland loss in the 2008 Louisiana Coastal Protection Technical Report (LACPTR). While this would be better than no action, it would not secure significantly greater natural hurricane buffering or even achieve the level of buffering available before Hurricane Katrina hit. The more effective option would be to work with the dynamic nature of the Delta and work to achieve sustainable restoration of wetlands through large-scale, controlled diversions of water and sediment from the Mississippi River to the Delta. In addition to avoiding the $41 billion in losses, it would add an estimated $21 billion in economic benefits.[76]

In the years since Hurricane Katrina, the USACE has invested heavily in a new flood protection system for New Orleans. One project, a new 1.4-mile long seawall in New Orleans, cost $1.1 billion. It is the largest design-build project in the history of the USACE. While the seawall is designed to withstand a 100-year flood event, the continuing decline in wetlands and rising sea levels means that the seawall and other armoring will face the brunt of any storm surges. Accordingly, the region has been exploring the use of wetland restoration to reduce the risk to coastal communities. In 2012, Louisiana released its Coastal Master Plan (CMP), which identifies 109 projects that will deliver measurable benefits to coastal ecosystems and communities.[77] If fully implemented, restoration projects in the CMP could cost up to $25 billion, and non-structural flood control efforts would cost an additional $12 billion. Compare that to the $108 billion in damages caused by Hurricane Katrina alone, and there is clear long-term value in investing in healthy coastal forests and marshes that reduce storm surge and protect communities through hurricane after hurricane.

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