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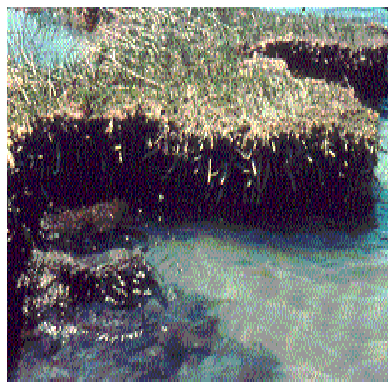
WETLANDS AND NATURAL HAZARDS



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FOREWORD

The following paper examines the relationship between wetlands and natural hazards. It suggests measures for simultaneously reducing flood losses and protecting the natural and beneficial functions of wetlands and floodplains. It builds upon with greater specificity the discussion and recommendations of a 2002 Report for Congress by the federal Task Force On the Natural and Beneficial Functions of the Floodplain, The Natural and Beneficial Functions of Floodplains, Reducing Flood Losses by Protecting and Restoring the Floodplain Environment. In the last decade, the attention of the press, the public, and the scientific community has been drawn to the relationship of wetlands to natural hazards by a number of severe flood events. These include the Great Flood along the Mississippi River and its tributaries in 1993, the powerful 2004 Asian tsunami, and Hurricane Katrina in 2005. The following paper explores this relationship.

The paper is based upon a review of scientific literature, a web search, and an examination of federal, state, and local regulatory policies and court cases.

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ABSTRACT AND SUMMARY:
WETLANDS AND NATURAL HAZARDS

Wetlands and the uses and activities placed in them are often subject to severe natural hazards. These include flood, wave action, erosion, soil instability, liquefaction, subsidence, and earthquake wave propagation hazards. Many wetlands are subject to one or more hazard such as flooding and erosion or flooding and subsidence which make them poor sites for development apart from their ecological functions and values. Even highly degraded wetlands in urban settings with limited ecological functions and values may be serious flood hazard areas and also important for flood and storm water storage and conveyance.

Over the last two decades, federal, state, and local wetland regulatory and management programs have focused primarily upon the protection and restoration of wetland ecological “functions” and values. These functions are of great importance. But natural hazards provide an additional and independent basis for regulation of wetlands at federal, state, and local levels and for “sequencing” in regulation and management. This may be true even where wetlands are characterized by limited or degraded natural functions (e.g., habitat) such as urban wetlands. Natural hazards also need to be considered where proposals are made to use mitigation banks to compensate for impacts to wetlands because hazards are typically site-specific and cannot be mitigated by going offsite. For example, restoring a wetland or participating in a mitigation bank several miles from a wetland with severe flood and erosion hazards will not reduce the hazards at the original wetland site or the impacts on adjacent properties due to fill, dredging, or channelization of the original site. Some combination of onsite and offsite mitigation may be appropriate.

Flooding is the most pervasive hazard. Many wetlands lie within the 100-year floodplain. Coastal and estuarine wetlands are often subject to 9-15 feet of inundation and high energy waves during a 100-year hurricane or coastal storm. Similarly, wetlands adjacent to major rivers are often subject to 8-10 or more feet of flooding during a 100-year flood event. Lake fringe wetlands like those adjacent to the Great Lakes and depressional wetlands are often subject to long term fluctuations of 6 or more feet due to fluctuations in precipitation in the watershed. Many coastal and some riverine wetlands are high risk erosion areas. Organic, saturated wetland soils in all locations are often subject to structural bearing capacity problems for houses and roads. Use of onsite liquid waste disposal systems (septic tank/soil absorption fields) is severely limited in wetland soils. Many filled wetlands including the waterfronts of coastal cities such as San Francisco, Oakland, Charleston, and Boston are also subject to liquefaction and special earthquake wave propagation hazards.

Houses and other structures constructed in wetlands not only suffer natural hazard damages but increase flood and erosion hazards on other lands by blocking flood flows or increasing runoff. Landowners have, in some instances, successfully sued other landowners for filling or altering wetlands with resulting increases in natural hazards on adjacent lands. Buyers have also successfully sued sellers for constructing residences in flood hazard areas including wetlands under theories of “implied warranty of suitability” or “implied warranty of habitability” because the residences have been subject to flood, subsidence, erosion or other natural hazards.

Efforts to drain and fill wetlands often only partially reduce hazards and may, in some instances, increase hazards on adjacent lands. For example, drainage does not, typically, reduce flooding by large scale, infrequent flood events although it does reduce water levels and flooding from seasonal events. Filling wetlands may reduce the depth of flood inundation on the filled area but may also increase flood heights, duration, and velocities on other lands by destroying flood storage and conveyance. Filling wetlands may increase the potential for liquefaction and special earthquake wave propagation in saturated soils.

Federal agencies, states, and local governments have adopted a number of policies and programs to reduce natural hazard losses from flooding in wetlands and to protect wetland functions and values. At the federal level, President Carter adopted Floodplain Management and Wetland Protection Executive Orders which apply to federal activities. Regulations adopted by the U.S. Army Corps of Engineers (Corps) pursuant to section 404 of the Clean Water Act require the Corps personnel to consider natural hazards in evaluating permit applications for activities in wetlands. The Water Resources Development Act of 2007 requires the Corps to develop updated "principles and guidelines" for water projects to protect the "natural and beneficial functions of floodplains" and sets forth standards for mitigation plans if water projects impact wetlands. Wetland protection and restoration have been incorporated into an increasing number of federal water projects. State wetland statutes often list flood hazard reduction goals among the major goals for regulation of wetlands. At the local level, many towns, cities, villages and counties have adopted wetland regulations with reduction in flood losses as one goal. Wetland protection and restoration may also be a part of "greenway", storm water management, recreation and open space, and other community programs.

Federal agencies, states, and local governments have protected specific wetlands subject to natural hazards through acquisition, conservation easements, public land management, integration of wetlands into flood control works, wetland and stream restoration and other activities. The Corps, National Oceanic Atmospheric Administration (NOAA), USDA Natural Resources Conservation Service (NRCS), U.S. Environmental Protection Agency (EPA) and other agencies have restored some coastal and freshwater wetlands with the goal, in some instances, of reducing flood and erosion losses. Massive restoration efforts are proposed for the Mississippi Delta.

The courts have strongly endorsed floodplain, wetland, and other natural hazard-related regulations designed to prevent landowners from increasing natural hazards on other lands and increasing natural hazard losses.

Despite federal, state, and local flood loss-related policies, many activities in wetlands subject to natural hazards continue to be unregulated or only partially regulated. Some wetlands are isolated and not regulated by the Clean Water Act. Fills, drainage of wetlands, and other activities take place in some wetlands without consideration of natural hazards even where hazard-related provisions have been adopted because regulators do not understand how to evaluate flood and other hazards, inadequate hazard maps are available or regulators are unfamiliar with hazard loss reduction techniques.

Measures for simultaneously better protecting wetland natural functions and values include the following (see Part 5 for more detailed discussion of each recommendation):

1. **Recognize** (All levels of government) **that wetlands are often subject to natural hazards and that keeping development out of wetlands will often both reduce flood losses and maintain wetland natural and beneficial functions.**

2. **Revise the federal principles and guidelines (**Corps, EPA, U.S. Fish and Wildlife Service (FWS), Federal Emergency Management Agency (FEMA), other federal agencies) **for water projects to better protect and restore the functions of natural systems and to mitigate any unavoidable damage to natural systems.** (Revised guidelines should require more detailed analysis of floodplain and wetland functions and values including flood storage, flood conveyance, wave attenuation, and erosion control.

3. **Presume** (All levels of government) **that wetlands are hazard areas.** Not all wetlands are hazard areas. Nevertheless, the high incidence of flood, erosion, subsidence, unstable soil, earthquake hazards justifies an overall "hazard" presumption at all levels of government. Such a presumption may be rebutted in a particular instance through the use of flood maps, soils maps, flood records, topographic maps or onsite information.

4. Prepare and adopt (Local governments) **community comprehensive planning including "smart growth" efforts.** Such efforts should concentrate development on uplands and keep it out of floodplain, riparian, and wetland areas to reduce flood losses, protect natural and beneficial functions, and achieve infrastructure and other transportation efficiencies.

5. **Prepare** (Corps, EPA, FWS, NRCS, NOAA) **"how to manuals"** for wetland managers concerning the assessment and mitigation of natural hazards. Prepare similar "how to" manuals for floodplain managers concerning the assessment, protection and restoration of wetland functions and values.

6. **Undertake** (FEMA, USFWS, USGS, States, Tribes) **additional and more detailed mapping** of flood, erosion, liquefaction, and other hazards for wetland areas (particularly those under development pressures). Similarly, undertake additional wetland mapping for flood and other hazard areas.

7. **Improve** (FEMA, U.S. Geological Survey (USGS), FWS, States, Tribes) **dissemination or natural hazard and wetland maps and/or digital imagery** via the Internet to wetland and floodplain managers.

8. **Train** (Corps, EPA, FEMA, FWS, NOAA, NRCS) wetland managers concerning natural hazards; **train** floodplain and other natural hazard managers concerning the protection and restoration of wetland functions and values.

9. **Provide** (Corps and EPA) more explicit guidance concerning the consideration of natural hazards in Section 404 and Section 10 permitting for wetlands and other waters. Similarly, FEMA should provide more explicit guidance to states and local governments adopting floodplain regulations with regard to protection and restoration of wetlands.

10. **Broadly incorporate** (FEMA, FWS, States, Tribes, Local Governments) wetland protection provisions into floodplain regulations; similarly incorporate natural hazard provisions into wetland regulations.

11. **Recognize at all levels of government** that wetlands and floodplains with limited ecological functions (e.g. urban, degraded wetlands) may nevertheless be subject to severe natural hazards and **"sequencing**" (avoidance, impact reduction, and compensatory mitigation) makes sense for such wetlands and floodplains even if they have limited ecological functions.

12. **Make broader use** (Federal agencies, States, Tribes, Local Governments) in planning, regulatory permitting, and other management programs **of hydraulic and hydrologic models** which allow consideration of wetlands and floodplains flood storage in calculating flood flows and elevations.

13. **Apply** (State, Tribal, Local Government) **in community and state floodplain programs a "no adverse impact"** standard to flood hazards and wetland ecological functions.

14. **Continue and enhance** (FEMA) the Flood Insurance Community Rating System to provide additional incentives for community protection of wetland and floodplain areas and for habitat planning.

15. **Undertake** (All levels of government) **additional restoration** of wetlands and floodplains in both pre and post disaster contexts.

16. **More broadly incorporate wetlands into water projects** (All levels of government but particularly the Corps) including storm water and flood control projects to provide flood storage and conveyance, reduce erosion, protect and restore water quality, and achieve other objectives.

17. **Make greater use** (All levels of government) **of bioengineering for stream bank stabilization** (rather than concrete) to help protect and restore riverine wetlands and riparian areas while reducing flood and erosion losses.

18. **Relocate repetitively flood-damaged structures** (All levels of government,) out of wetlands and floodplains.

19. **Undertake** (Federal government agencies, States, Tribes, Academic institutions) **priority research** concerning measures and strategies to simultaneously reduce natural hazard losses and better protect wetland functions and values. (See discussion below of more specific research needs.)

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PART 1: INTRODUCTION

Wetlands have been defined by the scientific community and by state, federal, and local management agencies in a variety of ways. The most commonly used definitions are those adopted by the U.S. Army Corps of Engineers (Corps) for the purposes of its Clean Water Act Section 404 program and the U.S. Fish and Wildlife Service (FWS) for its National Wetland Inventory efforts.[1] The Corps's wetland definition provides: [2]

> *Those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.*

Saturation of the ground by surface or ground water produces hydric soils.[3] Saturation also results in the growth of "hydrophytic"[4] rather than upland vegetation. Providing adequate nutrients are available and temperatures are not too low, saturation results in high primary productivity. The combination of saturation, hydric soils, hydrophytic vegetation, and high productivity make wetlands valuable as habitat for fish, waterfowl, other birds, amphibians, reptiles and a broad range of other wildlife. These features also give rise to a broad range of other wetland ecological and societal services such as food chain support, pollution control, and flood storage.

Table 1 **WETLANDS:** **COMMON NATURAL HAZARDS**
• **Storm Surge (Coastal and Estuarine)** • **Inland Flooding Due to Runoff** • **Inland Flooding Due to Long Term Fluctuation in Ground Water Levels** • **Coastal/Estuarine/Inland Wave Action** • **Eroision** • **Liquefaction** • **Subsidence** • **Earthquake Wave Propagation** • **Inadequate Septic Tank/Soil Absorption Capability and Resulting Pollution**

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1 The Fish and Wildlife Service definition is: *"WETLANDS are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. For purposes of this classification wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soil; and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of the year."* See http://www.fws.gov/nwi/definition.htm.

2 See 33 CFR Part 328 at http://www.sac.usace.army.mil/assets/html/regulatory/wetlands/33cfr328.html

3 See NRCS, Field Indicators of Hydric Soils in the U.S. at http://www.itc.nl/~rossiter/Docs/NRCS/FieldIndicators_v5_01.pdf

4 See U.S. Army Corps of Engineers Wetland Delineation Manual at http://www.wetlands.com/regs/tlpge03d.htm

Table 2

Floodplain, Wetland, Riparian Area Natural and Beneficial Functions

- **Groundwater recharge**
- **Groundwater discharge**
- **Flood storage and desynchronization**
- **Flood conveyance**
- **Wave attenuation and water velocity reduction (hurricanes, coastal storms, thunderstorms)**
- **Shoreline erosion control**
- **Sediment trapping**
- **Nutrient retention and removal**
- **Food chain support**
- **Habitat for fisheries**
- **Habitat for wildlife**
- **Active recreation such as canoeing**
- **Passive recreation such as bird watching**
- **Reduce the build-up of heat (heat islands) in urban areas**
- **Wild crops (e.g., blueberries, cranberries, salt marsh hay)**
- **Timber**
- **Historical, heritage value such as shell mounds**

PART 2. WETLANDS AS HAZARD AREAS

Overview

Most wetlands are subject to natural hazards. Virtually all are subject to periodic flooding. Many are subject to erosion and subsidence. Some are subject to liquefaction and special earthquake hazards. Wetland plants and animals often depend, in part, upon such flooding and saturation although they may also be damaged in the short term by flooding, erosion and other hazards.

The discussion which follows first considers several types of flood hazards. It then considers erosion, saturated and unstable soils, subsidence, liquefaction, earthquake wave propagation hazards, sulfate soils, and water pollution due to septic tank failure.

Flooding

Virtually all wetlands are subject to some measure of flooding although the frequency, depth, and velocity of flooding differ greatly.

Flooding of Coastal and Estuarine Wetlands by Coastal Storm Surge and Waves

Coastal and estuarine wetlands are typically subject to storm surge flooding[5] to a depth of 8-15 feet during a 100-year hurricane/storm.[6] Waves and wave run-up may add 6 to 8 or more feet to this depth.

Wetlands like these can reduce storm surge and wave height elevations.
Source: S.C.DNR

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[5] For discussion of storm surge, see generally Storm Processes at Coastal Hazards, Coastal Information Clearing House, Western Carolina University at www.wcu.edu/coastalhazards/Libros/libroschapter3.htm

[6] Coastal and estuarine wetland plants such as mangroves and *Spartina Alternaflora* and *Spartina Patens* typically grow within the intertidal zone to an elevation of meter or so above mean sea level although maximum and minimum elevations are somewhat variable. See K. McKee & W. Patrick, 1988. The Relationship of Smooth Cordgrass (Spartina alterniflora) to Tidal Datums. Estuaries, Vol. 11, No. 3 (Sep. 1988) pp. 143-151 A Review. Salt marshes and mangroves are, therefore, typically flooded by a 100 year hurricane or Northeaster storm surge to within a meter of the full depth of the surge. Substantial wave heights may be added. For examples of 100 year storm elevations see Flor. Dept. of Environmental Protection, One Hundred-Year Storm Elevation Requirements for Habitable Structures Located Seaward of a Coastal Construction Line. http://www.dep.state.fl.us/beaches/publications/pdf/100ystrm.pdf.

The storm surge is the "water pushed toward the shore by the force of winds swirling around the storm."[7] The surge from a hurricane or winter storm combines with a normal tide to create a hurricane or storm tide. Wind driven waves add to the height and velocity of the surge. Combined storm tide and wave elevations in Hurricane Katrina exceeded 30 feet in some instances.[8] Typical storm tide and wave elevations in Florida communities for a 100-year storm range from a low of 16 feet to more 21 feet[9]. Surge elevations alone (without waves) from a Category 3-4 Hurricane like Katrina are more than 20 feet in locations such as Tampa (25 feet)[10] and Long Island (29 feet).[11]

The heights of both the storm surge and waves depend upon a variety of factors including wind velocity, wind direction in relationship to the shore, and duration of the wind. Higher wind velocities, winds blowing onshore, and long duration winds (e.g., large, slow moving storms) produce higher surges and waves. Surge and wave elevations also depend upon the depth of the offshore water, the below water and beach contours, and the shoreline configuration. They depend upon the presence or absence of barrier islands and wetlands.

A storm surge often begins with the slow rise of water pushed toward the shore by a hurricane/storm many hours before arrival of the eye of the storm. The water rises more quickly as wind velocities increase and as water is both pushed more strongly shoreward and prevented from flowing back. As surge depths increase, wave heights also increase since waves are dependent upon water depth, wind velocities and fetch (distance).

Coastal and estuarine wetlands may both reduce surge elevations and wave heights in a number of ways. First, they may slow the shoreward advance of the storm surge due to the friction of the vegetation on the surge and waves. Coastal and estuarine wetlands are typically located behind barrier islands, in estuaries, and along some low energy open coasts (e.g. Gulf of Mexico). Consequently, storm surges and waves flow through and over such wetlands to reach back-lying areas including coastal cities. Such wetlands include salt marshes, brackish marshes, intermediate marshes and freshwater marshes some distance back from the water.

It has been empirically estimated that each 1.0 to 2.7 mile of wetland may reduce the storm surge by 1 foot.[12] Reductions may be particularly significant for a quickly moving hurricane. However, reduction depends upon the type, density, and height of vegetation and the speed and duration of the surge. Particularly great reductions may occur for wide expanses of mangroves and other forested wetlands with high friction coefficients.

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[7]National Hurricane Center. 2005. Hurricane Preparedness, Storm Surge. http://www.nhc.noaa.gov/HAW2/english/storm-surge.shtml

[8]See FEMA http://www.fema.gov/hazard/flood/recoverydata/katrina/katrina_la_index.shtm FEMA estimated storm surge flooding alone of 20-30 feet above normal tide levels.

[9]See Flor. Dept. of Environmental Protection, One Hundred-Year Storm Elevation Requirements for Habitable Structures Located Seaward of a Coastal Construction Line. http://www.dep.state.fl.us/beaches/publications/pdf/100ystrm.pdf

[10]See http://news.mongabay.com/2005/0916-ucf.html

[11]See, Long Island Express, 2005. http://www2.sunysuffolk.edu/mandias/38hurricane/storm_surge_map;

[12]See Jeffery Zinn, 2006, Coastal Louisiana Ecosystem Restoration After Hurricanes Katrina and Rita, Congressional Research Service, Order Code RS22276 at http://www.ncseonline.org/nle/crsreports/06apr/RS22276.pdf

Second, wetlands may cause storm waves to "break" and dissipate their energy at some distance from dikes, levees, or other sensitive structures as the water depth becomes less than 1.3 of the height. Waves begin to "break" when they begin to "touch bottom". The bottom of a wave is slowed and the upper portion "breaks" over the lower, more slowly moving section. Wetlands elevate the substrate (in comparison with open water, beaches, and flats) by trapping sediments and organic matter. Waves break on this elevated substrate. Wetland grasses, sedges, and trees (e.g., mangroves) may further reduce the "effective" depth of the water. Compressible wetland soils may absorb wave energy. Roots and other organic matter reduce erosion.

The effectiveness of wetlands in reducing storm surge, wave heights, and erosion depends upon a number of additional factors. The width of the wetland is one. Wider wetlands (distance from open water to upland), in general, provide greater reductions. The height and density of the vegetation is another. In general, taller and denser trees and other vegetation provide more reduction in surge and wave elevations. For example, mangroves which are relatively tall and have many limbs as well as "knees" are more effective than lower marshes in reducing surge and wave heights. The resilience of the wetland is a fourth factor. For example, mangroves are resistant to hurricane force winds and waves and do not, therefore, quickly erode during a long duration storm. Other types of coastal wetlands with limited vegetation may be quickly eroded and have less influence on storm surge and wave elevations.

Internationally, wetlands have been recognized as important in reducing storm surge, wave elevations, and erosion. In Bangladesh in 1985 40,000 people drowned in one storm surge.[13] Since then, the government of Bangladesh has spent large sums of money in replanting mangroves to reduce storm surges. The Philippine Government passed a 1986 law requiring a 50-100 meter protection width for mangroves along shorelines.[14] The Dutch have restored and created wetlands in front of levees to reduce the height and velocity of storm waves. So have the English, Danes, and Germans.[15]

A massive restoration effort is proposed for the Mississippi Delta where hurricanes and marsh loss threaten the lower delta and New Orleans. In the last 60 years over a million acres of wetlands have disappeared, primarily due to subsidence, sediment deprivation, and dredging.[16] A 14 billion dollar, 30-year restoration project has been proposed to restore these wetlands.[17]

The waterfronts of coastal cities have often been placed on fill to a depth of several to 10 or more feet. Development placed on this fill is, nevertheless, often subject to flooding by storm surge, waves, and wave run-up during a major flood event (combined surge and wave elevations of 15 to 25 feet or more). Ditches have been placed in many salt marshes to drain them. Canals are also common in Gulf coast wetlands. However, ditches and canals provide no protection from storm surge and may accelerate the rate at which surge and waves enter wetlands and back-lying areas.

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[13] Ramsar. 2005. Wetland Values and Functions: Shoreline Stabilization and Storm Protection http://www.ramsar.org/info/values_shoreline_e.pdf
[14] Id.
[15] Waddensea, 2005. Section 2.1 of a Report, Wadden Sea Ecosystem No. 19—2005. http://www.waddensea-secretariat.org/
[16] See Louisiana's Coastal Wetland Restoration Plan at http://www.lacoast.gov/reports/cwcrp/1993/index.htm
[17] Id.

Coastal/Estuarine Wetland Flooding by Tsunamis

Coastal and estuarine wetlands are also subject to deep inundation by tsunamis like the South Asian tsunami of December 2004. Studies suggest that hurricane and tsunamis waves bring similar forces to bear.[18] Satellite photos after the South Asian tsunami in December 2004 showed that areas with coastal mangroves were relatively intact after the tsunami but those without were often devastated. Mangroves helped reduce the impact of the waves by absorbing some of the wave energy[19] and causing the waves to break. The condition of the mangroves was also important.[20]

Mangroves like these can reduce storm surge and wave heights (including tsunamis) and reduce erosion. *Source:Tsunamis and Mangroves: The Shrimp Connection* *http://scienceblogs.com/grrlscientist/2006/02/ tsunamis_and_mangroves_the_shr.php*

Flooding of Inland Wetlands by Runoff, Waves

Freshwater wetlands are also often subject to deep and, in some instances, high velocity flooding although the flood characteristics for inland wetlands vary greatly. Freshwater wetlands are flooded by runoff from rainfall and snowmelt rather than storm surge. Riverine wetlands along major rivers and streams are often subject to flooding to a depth of 10 or more feet during a 100-year flood event.[21] Waves may add 4 to 8 feet (for large rivers with considerable flood depths and fetch). Water velocities may be high, particularly near a river channel and in mountainous or

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[18]See http://www.eurekalert.org/pub_releases/2007-04/pues-soc041107.php
[19]See Danielsen et. al., The Asian Tsunamie: A Protective Role for Coastal Vegetation, Science, 28 Oct. 2005, Vol. 310, no. 5738, p. 643. See Evironmental Justice Foundation, (undated) Mangroves, Nature's Defense Against Tsuamis, UK, 2006. See http://www.ejfoundation.org/pdf/tsunami_report.pdf; See also http://www.sciencedaily.com/releases/2005/10/051028141252.htm; Dahdouh-Guebas et. al., How Effective Were Mangroves as a Defense Against the Recent Tsunami? Current Biology, Vol 15, No 12, R444; http://www.vub.ac.be/APNA/staff/FDG/pub/Dahdouh-Guebasetal_2005b_CurrBiol.pdf http://edcintl.cr.usgs.gov/mangrove/; http://girlscientist.blogspot.com/2005/01/tsunamis-and-mangroves-shrimp.html; http://www.worldchanging.com/archives/001898.html; http://www.fao.org/newsroom/en/news/2005/89119/index.html; http://www.csmonitor.com/2005/0110/p07s01-wosc.html http://www.ecoworld.com/home/articles2.cfm?tid=359
[20]Dahdouh-Guebas et. al., How Effective Were Mangroves as a Defense Against the Recent Tsunami? Current Biology, Vol 15, No 12, R444; http://www.vub.ac.be/APNA/staff/FDG/pub/Dahdouh-Guebasetal_2005b_CurrBiol.pdf
http://edcintl.cr.usgs.gov/mangrove/;
[21]Many riverine wetlands lie in and immediately adjacent to rivers and streams, particularly in low gradient landscapes. These are typically flooded to the full depth of a 100-year flood which varies greatly but is often 10 or more feet.

other high gradient areas. Severe erosion is also common in high velocity areas including many urban, small high gradient creeks and streams. In some instances, particularly mountainous areas, "flash" flooding occurs with rapid rise of high velocity waters.

Freshwater wetlands may affect the depth and velocity of downstream flooding and erosion in a number of ways. First, they temporarily store flood waters, reducing the height and velocity of flooding at downstream locations. Second, they help convey flood waters from upstream to downstream points, reducing water velocities. Third, they trap sediment and bind the soil, reducing erosion. These roles are discussed in greater depth below.

Development has been commonly placed on filled inland riverine wetlands with fill depths from a few feet to 10 or more feet. Such development may, nevertheless, be subject to severe damages during a 100-year flood event with flood heights which exceed fill elevations.

Wetlands along rivers and streams are often subject to deep, high velocity flooding.
Source*: Unknown.*

Lake and Reservoir Fringe Wetland Flooding by Long Term Fluctuations In Surface Water Levels

Wetlands adjacent to the Great Lakes, major reservoirs, and many smaller lakes and ponds are flooded by long-term fluctuations in precipitation and resulting fluctuations in ground water levels. For example the levels of the Great Lakes and associated wetlands fluctuate seasonally and longer term 3.5 to 6 feet.[22] in 29-38 and 120-200 year cycles. Wetlands fringing the Great Lakes shift in position and elevation in response to such fluctuations. The rise and fall of surface water elevations in large reservoirs and associated wetlands is even greater. Houses built in wetlands near such water bodies during low level periods are often flooded for years or months and become uninhabitable even if elevated on pilings. An example is Lake Elsinor in California. Another example is the flooding of Devil's Lake Basin in North Dakota. This interior drainage basin has experienced flood conditions since 1993 as the result of high precipitation. Devils Lake has risen more than 20 feet and the lake has tripled in area. This has resulted in widespread and long duration flooding of residences. It has resulted in a 426% increase in the area of rural wetland ponds.[23] Still another example of a lake (and associated wetlands) with long term flooding is the Great Salt Lake in Utah.

[22] See C. Grubb and W. Cwikiel, (2004) Fluctuations of Great Lakes Water Levels and Their Importance to Shoreline Ecosystems, Tipp of the Mitt Watershed Council at http://www.watershedcouncil.org/GLwaterlevels.pdf
[23]See Paul Todhunter & Bradley C. Rundquist, 2004. al Lake Flooding and Wetland Expansion in Nelson County, North Dakota in Physical Geography, Volume 25, Number 1.

Because of the severity of flooding from closed basin lakes, the Federal Emergency Management Agency (FEMA) in a rule adopted August 2, 1999 established a procedure for honoring in advance flood insurance claims for buildings subject to continuous lake flooding or under imminent threat of flood damages from closed basin lakes.[24] This policy requires local governments or tribes to tightly regulate any new development adjacent to closed basin lakes subject to flooding.

Wetlands along the great lakes are subject to six feet or more of long term cyclic Water level fluctuations.
Source: Great Lakes Coastal Wetlands, www.geology.wisc.edu/.../wetlandfeatures.htm

Depressional and "Pothole" Wetland Flooding Due to Long Term Fluctuations in Ground Water Levels

Some depressional wetlands such as Prairie Potholes are subject to long-term fluctuations in ground water levels.[25] These fluctuations reflect precipitation cycles. Long-term fluctuations may exceed 7 feet. Development, roads, and other structures constructed during low water level periods near or adjacent to in such wetlands are often subject to long duration flooding.

Erosion

Coastal and estuarine wetlands and the activities and structures placed in such wetlands are often subject to severe erosion due to the powerful waves or hurricanes and major coastal storms. Erosion may also occur during the outflow of coastal storm surges. This is how many of the "cuts" in barrier islands are formed. Wetlands along the Great Lakes are subject to erosion due to long term fluctuations in water levels and storm waves.

Wetlands in and adjacent to the channels of high velocity rivers and streams are also subject to erosion.[26] Erosion, including head-cutting in riverine wetlands is a particular problem with sediment-deficient streams which have been dammed in the West. As will be discussed below, wetlands reduce erosion by reducing the velocity of waves and waters. The roots of wetland plants also bind the soil.

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[24]See CFR, Part 61 for FEMA policy guidance for Closed Basin Lakes. See http://www.fema.gov/business/nfip/closedbasin.shtm.
[25]See generally Harold Kantrud et. al, 1989. Prairie Basin Wetlands of the Dakotas: A Community Profile at http://www.npwrc.usgs.gov/resource/wetlands/basinwet/index.htm
[26]See Understanding Soil Risks and Hazards, p. 43 at ftp://ftp-fc.sc.egov.usda.gov/NSSC/Soil_Risks/risk_low_res.pdf

Saturated, Unstable Soils and Hydrostatic Pressures

Decomposition is slow in saturated soils, leading to the build up of organic material.
Source:
http://www.michigan.gov/deq/0,1607,7-135-3313_3687-10408--,00.html

Gasoline storage tank which "floated" to the surface due to saturated soils and flooding*.*
Source: Patricia Bloomgren

As described above, wetland soils are typically saturated all or much of the year. Many also have a high organic content. Such soils pose hazards for construction of residences and other buildings.[27] Basements placed in such soils may crack or collapse due to the high hydrostatic pressures of the adjacent saturated soils. If drained or buried under fill, high organic content soils often compress, resulting in cracked foundations. In northern climates, "ice heaves" often develop in secondary roads constructed over saturated soils. It is often possible to identify while driving former wetland areas on rural blacktop roads by noting the areas where bumps are most common.

Saturated, organic soils pose problems for not only construction but for agriculture and forestry. Most plants and trees will not grow and die in saturated soils.[28] Saturated and organic soils are also susceptible to compaction by machinery, cattle and other activities.[29] Once compacted, such soils are severely limited for agriculture and forestry.[30]

Establishment of lawns is difficult in saturated soils. Many lawn grasses will also not grow with the result that lawns will be dominated by mosses.

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[27]See Understanding Soil Risks and Hazards, p. 90 at ftp://ftp-fc.sc.egov.usda.gov/NSSC/Soil_Risks/risk_low_res.pdf
[28]See, e.g, Moss and Algae Control in Lawns at http://www.aces.edu/pubs/docs/A/ANR-0908/ANR-0908.pdf.
[29]See, e.g., Managing Stock on Wet Soils at http://www.trc.govt.nz/environment/land/pdfs/52_managing_stock_wets.pdf
[30]Id.

Subsidence

Subsidence is another common hazard for wetland areas.[31] Wetland soils (commonly histosols) contain a great deal of water and organic matter. Histosols are commonly called peat or muck and, by definition, contain more than 30 percent organic matter.[32] Subsidence occurs when such soils are drained or exposed to air which causes oxidation of the organic material. Houses, roads, fills, and other materials placed on wetland soils also compact the underlying materials, causing it to differentially settle or sink. Foundations crack and water enters. Roads constructed in wetlands are often subject to differential settling.

Particularly large amounts of subsidence have occurred in some areas of the Nation. For example, subsidence of over 12 feet has occurred in the Sacramento Delta due to agricultural drainage and oxidation. Many levees along the Sacramento River are constructed on such subsided soils. Other examples include the Everglades and the Mississippi Delta.[33]

In Amherst, New York more than 1000 houses are sinking and cracking due to construction on hydric and easily compressible soils.[34] Since 1996 there have been more than 501 reports of foundation problems.

Cracked basement wall in Amherst, New York area.
Source: Amherst Soils Study, U.S. Army Corps of Engineers, Buffalo District

[31]See Devin Galloway, David Jones, and S. Ingebritsen, 2000. Land Subsidence in the U.S. at http://pubs.usgs.gov/circ/circ1182/pdf/circ1182_intro.pdf; See also Understanding Soil Risks and Hazards, p. 87 ftp://ftp-fc.sc.egov.usda.gov/NSSC/Soil_Risks/risk_low_res.pdf
[32]Id.
[33]Understanding Soil Risks and Hazards, p. 71 at ftp://ftp-fc.sc.egov.usda.gov/NSSC/Soil_Risks/risk_low_res.pdf
[34]See Costs Associated With Structural Damage to Homes on Unstable Soils, www.geocities.com/ntgreencitizen/amherst5.html?200716 and http://www.riverkeeper.org/document.php/%20125/NY_Atty_Gen_Com.doc

Liquefaction

Some wetland soils, particularly saturated soils in filled wetlands, become unstable during earthquakes and flow. Such "liquefaction" can greatly contribute to earthquake losses, particularly for waterfront facilities, structures and buried pipelines.[35] Soils subject to liquefaction are typically young, loose, well-sorted and water saturated sands or silts. Widespread liquefaction occurred in the San Francisco Bay area in the 1989 Loma Pieta earthquake and in Alaska in the 1964 Earthquake.

Liquefaction is particularly a problem in the San Francisco Bay area due to prevalence of well sorted and saturated soils, extensive areas of fill, and high earthquake risks. In the 1989 Loma Pieta earthquake about $100 million in losses were due to liquefaction.[36] Many areas of man-made landfill liquefied in this earthquake. The Marina district which was a shallow bay filled in after the 1906 earthquake suffered serious damage. Approximately one quarter of the San Francisco Bay region is subject to liquefaction.[37]

But liquefaction affects other areas as well including but not limited to Washington, Oregon, and many other states. Observers of the 1812 New Madrid earthquake with an epicenter in Missouri observed widespread liquefaction along the Mississippi. Many coastal cities with moderate earthquake threat such as Boston[38] and Charleston[39] have extensively filled wetlands in their waterfront areas. These filled wetlands are potentially subject to liquefaction. Other coastal cities subject to earthquake/liquefaction hazards include Anchorage, New York, Portland, San Diego, Santa Barbara, and Seattle.

Both liquefaction hazard and shaking amplification maps have been prepared by the U.S. Geological Survey (USGS) for the San Francisco Bay area.[40] Depth to saturation is a critical factor.[41] Mapping of potential liquefaction areas has also been undertaken for Salt Lake,[42] Seattle, St. Louis,[43] and Albuquerque.[44]

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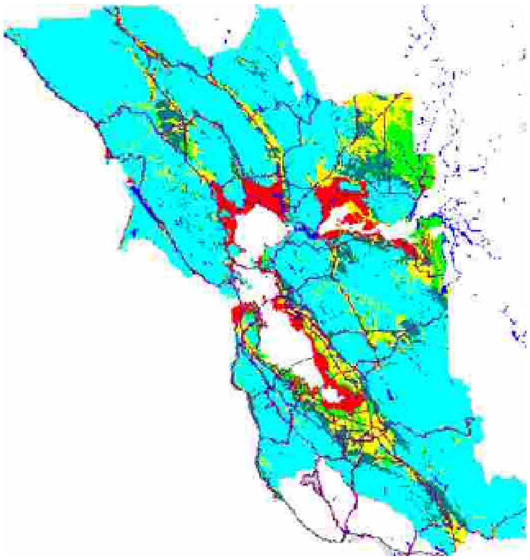
[35](Stewart, 2005). See also Understanding Soil Risks and Hazards, p. 71 at ftp://ftp-fc.sc.egov.usda.gov/NSSC/Soil_Risks/risk_low_res.pdf
[36]See www.abag.ca.gov/bayarea/eqmaps/liquefac/introduc.html
[37]See http://geomaps.wr.usgs.gov/sfgeo/liquefaction/susceptibility.html
[38]The "Cape Ann" earthquake with an estimated magnitude of 6.2 on the Ricter scale head Boston and New England in 1755.
[39]A severe earthquake occurred in Charleston in 1886.
[40]See http://geomaps.wr.usgs.gov/sfgeo/liquefaction/about.html#compilation
[41]See http://geology.utah.gov/online/pi/pi-80.pdf
[42]See http://geology.utah.gov/online/pi/pi-80.pdf
[43]See http://gsa.confex.com/gsa/2006AM/finalprogram/abstract_113435.htm
[44]See http://gsa.confex.com/gsa/2001RM/finalprogram/abstract_5783.htm



Earthquake liquefaction map for San Francisco Bay area.
Source: www.co.marin.ca.us/.../part1pg3.cfm?print=yes&

Special Earthquake Wave Propagation Hazards

Earthquake waves are amplified in some “soft” soils and sediments such as filled wetlands resulting in increased damage to structures, roads, and pipelines. This also results in liquefaction although earthquake damage also occurs without liquefaction. Much of the earthquake damage in the Loma Pieta Earthquake in San Francisco in 1989 and in the Mexico City Earthquake in 1985 was in filled wetland areas.[45]

Loss of life was particularly great for the Mexico earthquake of 1985. At least 9,000 people were killed and 30,000 injured. It has been estimated in the Mexico City Earthquake in 1985 that earthquake shaking for saturated soil areas was amplified 5-20 times.[46]

Earthquake damage from the Loma Pieta earthquake of 1989 for an area of saturated fill in the Marina District of San Francisco*.*
Source: New Geologic Maps
Highlight Bay Area Earthquake Hazards;
http://earthquake.usgs.gov/regional/nca/qmap/

[45]Stewart, J. 2005. Key Geotechnical Aspects of the 1989 Loma Prieta Earthquake. http://nisee.berkeley.edu/loma_prieta/stewart.html
[46]See www.riskinc.com/Catastrophe/Models/Mexico.asp

Acid Sulfate Soils

Some salt marshes are underlain by acid sulfate soils.[47] Such soils contain iron sulfides. If drained, mined, excavated, or dredged and exposed to aerobic conditions, they release sulfuric acid. Concrete and other building materials placed in such soils quickly erode.[48]

Water Pollution Due to Failure of Septic Tanks/Soil Absorption Fields[49]

Septic tank and soil absorption fields placed in saturated soils often quickly fail to absorb domestic liquid wastes due to the build-up of organic matter.[50] Untreated wastes are then discharged onto the land surface.

The Association of State and Territorial Health Officials[51] pointed out the health concerns from septic tank/soil absorption systems which fail:

> Onsite systems are increasingly a concern for state health agencies. Wastewater treated by onsite systems contain various pathogens that pose serious health risks to humans, including salmonella, shigella, enterovirus, heptatitis, rotaviruses, caliciviruses, such as Norwalks, Vibrio cholera, and E. cole. All of these pathogens can cause severe gastrointestinal illness. Many other pathogens may also be present that can lead to pneumonias, toxicity, ulcers, and other major health concerns. Failing systems pose risks to the general public and particularly to sensitive populations such as children and those with compromised immune systems."

The U.S. Environmental Protection Agency (EPA) notes the problem with saturated or flooded soils:[52]

> Since the soil absorption area must remain unsaturated for proper system functioning, it may not be feasible to install septic systems in regions prone to frequent heavy rains and flooding or in topographical depressions where surface waters accumulate.

The EPA further noted (citing a study concerning the performance of soil absorption systems) that "the depth of unsaturated soil beneath the system was determined to be a more decisive factor in system performance than hydraulic loading."[53]

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[47]See Gary Muckel (ed.) Understanding Soil Risks and Hazards ftp://ftp-fc.sc.egov.usda.gov/NSSC/Soil_Risks/risk_low_res.pdf
[48]Id.
[49]Saturated soils are not a hazard per se but placement of septic tank/soil absorption fields in such soils commonly results in pollution.
[50]See generally Benjamin Kaplan, 1994. Septic Systems Handbook, Second Edition. CRC Press; Larry Cantor and Robert Knox. 1985. Septic Tank Systems System Effects on Ground Water Quality, Lewis Publishers. See generally NRCS, Soil Survey Manual, table 6-1 at http://soils.usda.gov/technical/manual/contents/chapter6c.html#fig6-6
[51]See Issue Brief: Onsite Wastewater Systems at http://health.jfcountyks.com/pdf/CH2ESCodes.pdf
[52]See E.P.A., Decentralized Systems Technology Fact Sheet, Septic Tank-Soil Absorption Systems (E.P.A. 1999) http://www.epa.gov/owm/mtb/septicfc.pdf
[53]C. Cogger, L. Hajjar, C. Moe, and M. Sobsey, M.D., 1988. Septic System Performance on a Coastal Barrier Island. Journal of Environmental Quality. 17: 401

State and local sanitary codes typically prohibit the use of septic tank soil absorption fields in areas of high ground water or tight, organic soils. For example, New York State requires a minimum setback of 100 feet for soil absorption fields from wetlands or watercourses.[54] New York regulations further provide that:[55]

> (1) Areas lower than the 10-year flood level are unacceptable for on-site systems. Slopes greater than 15% are also unacceptable.
>
> (2) There must be at least four feet of useable soil available above rock, unsuitable soil, and high seasonal groundwater for the installation of a conventional absorption field system (75-A.8(b)).

Local governments also typically prohibit the use of septic tank/soil absorption systems in areas of high ground water or flooding. For example, a Jefferson County Kansas wastewater disposal ordinance provides in part:[56]

> No portion of a domestic onsite wastewater system or privy shall be located below the full flood elevation of any federal reservoir or full flood pool elevations of any pond, lake, stream, water supply reservoir, or within a regulatory floodway.

[54] Title: Appendix 75-A.4 - Soil and site appraisal

[55] Id.

[56] See http://health.jfcountyks.com/pdf/CH2ESCodes.pdf

PART 3. THE IMPACT OF NATURAL HAZARDS ON WETLANDS

Wetland animal species may be killed or injured by coastal storm surges and inland flooding. Wetland trees and other vegetation may be damaged by in-line winds and wave action. Wetlands may be filled by sediment deposition.[57]

Coastal and estuarine wetlands are particularly vulnerable. Coastal hurricanes and other coastal storms may severely erode coastal and estuarine wetlands due to wind and wave action and rapid return flows of the storm surge.[58] For example, Hurricane Betsy in 1965 killed many mangroves in Everglades National Park and damaged Delta wetlands south of New Orleans. Hurricane Frederick in 1993 also tore also away pieces of the salt marshes in the Park and in the Delta. Some wetlands were buried by sediment.[59] Inland wetlands in the Park and along the Gulf coast (later hit by both Betsy and Frederic) were killed by salty Gulf waters. Hurricane Katrina converted many Delta wetlands to open water.[60] For example, it converted more than 30 square miles of marsh in Breton Sound to open water, about 20-26% of the 133-square mile area. Other wetlands were covered with sediment. Sea grass beds were damaged. How quickly they will recover remains to be seen.[61]

Ironically, sediment which is needed for recovery of wetlands may also bury and destroy wetlands during flood events[62] or diminish flood storage and conveyance, habitat, pollution control and other functions. Wetlands usually recover from coastal hurricane/storm and freshwater flooding quite quickly, providing there is sufficient sediment supply. Dams and other structures in rivers may interrupt the sediment supply. Coastal sea level rise may also prevent or slow recovery.

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[57] See, e.g., Pervaze Sheikh, 2005, The Impact of Hurricane Katrina on Biological Resources, CRS Report for Congress available at http://opencrs.cdt.org/rpts/RL33117_20051018.pdf; James Kolva, 1997. Effects of the Great Midwest Flood of 1993 on Wetlands" in U.S. Geological Survey, National Water Summary on Wetland Resources, United states Geological Survey Water Supply Paper 2425

[58] See, e.g., Pervaze Sheikh, 2005, The Impact of Hurricane Katrina on Biological Resources, CRS Report for Congress available at http://opencrs.cdt.org/rpts/RL33117_20051018.pdf; See D. Cahoon et. al., 2002. Hurricane Mitch, Impacts on Mangrove Sediment Dynamics and Long-Term Mangrove Sustainability. U.S.G.S. at http://www.nwrc.usgs.gov/hurricane/mitch/Cahoon%20Mangrove%20Sediment%20Final%20Revised.pdf

[59] See, e.g., Pervaze Sheikh, 2005, The Impact of Hurricane Katrina on Biological Resources, CRS Report for Congress available at http://opencrs.cdt.org/rpts/RL33117_20051018.pdf

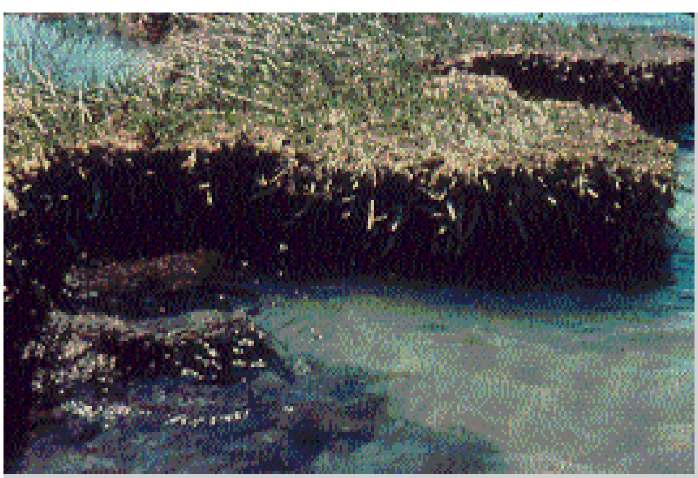
[60] Pervaze Sheikh, 2005, The Impact of Hurricane Katrina on Biological Resources, CRS Report for Congress available at http://opencrs.cdt.org/rpts/RL33117_20051018.pdf

[61] For photos showing the impact of Katrina on wetlands, sandflats, beaches, dunes, and channels see "USGS releases Katrina impact studies" at http://www.nola.com/katrinaphotos/nola/gallery.ssf?cgi-bin/view_gallery.cgi/nola/view_gallery.ata?g_id=6921

[62] See Goodbred and Hine, 1995. Coastal Storm Deposition; Salt Marsh Response to a Severe Extratropical Storm, Geology, 1995: 23:679-682; John Lovelace & Benjamin McPherson, 1997. Effects of Hurricane Andrew (1992) on Wetlands in Southern Florida and Louisiana in National Water Summary on Water Resources, United States Geological Survey Water Supply paper 2425; van de Plassche et al. (2006). Salt-marsh erosion associated with hurricane landfall in southern New England in Geology. 2006; 34: 829-832; D. Cahoon et. al., 2002. Hurricane Mitch, Impacts on Mangrove Sediment Dynamics and Long-Term Mangrove Sustainability. U.S.G.S. (Open Filed Report) 03-184 at http://www.nwrc.usgs.gov/hurricane/mitch/Cahoon%20Mangrove%20Sediment%20Final%20Revised.pdf

Mangroves damaged by Hurricane Mitch.
Source: USGS Hurricane Mitch Program Projects.
mitchnts1.cr.usgs.gov/projects/coastal.html

Sediment deposited at a levee breach by the Great Flood of 1993 along the Missouri river.
Source: Unknown



Coastal storms and winter ice action erode coastal wetlands like these on Cape Cod.
Source: Jon Kusler, ASWM

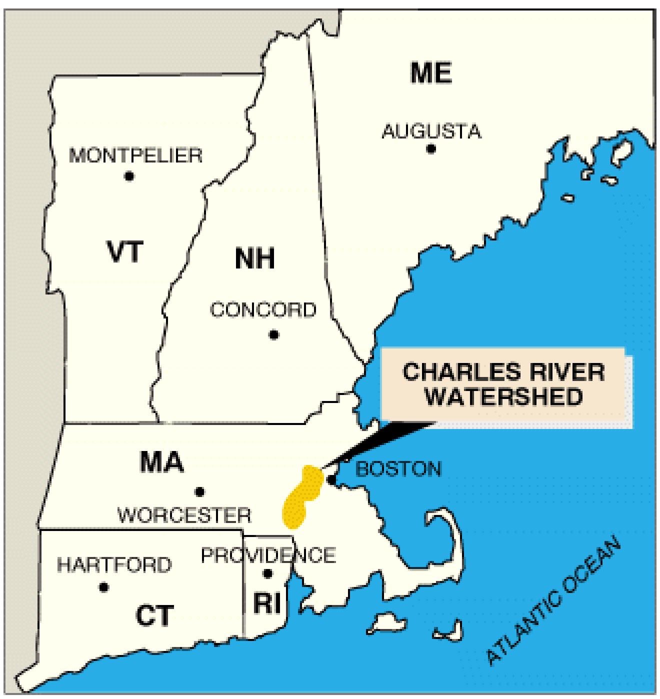
PART 4. THE ROLE OF WETLANDS IN REDUCING NATURAL HAZARDS ON OTHER LANDS

Wetlands are not only subject to natural hazards but may reduce natural hazards on other lands. Conversely, destruction of wetlands often increases hazards on other lands.

Wetlands may reduce hazards on other lands by:

- Storage of flood waters,
- Conveyance of flood waters,
- Attenuation of coastal storm surges, waves and tsunamis, and
- Reducing erosion and sedimentation.

Each of these roles will be briefly discussed in the materials which follow:



Location of the Charles River Project.
Source: U.S. Army Corps of Engineers

Flood storage wetlands along the Charles.
Source: U.S. Army Corps of Engineers

Storage of Flood Waters

Inland wetlands reduce flooding along rivers, streams, and lakes by both storing and conveying flood waters (see discussion below).[63] Wetlands can reduce flood heights and velocities. Virginia Carter in the National Water Summary on Wetland Resources[64] in 1996 observed that:

> *A strong correlation exists between the size of flood peaks and basin storage (percentage of basin area occupied by lakes and wetlands) in many drainage basins throughout the United States (Tice, 1968; Hains, 1973; Novitzki, 1979, 1989; Leibowitz and others, 1992). Novitzki (1979, 1989) found that basins with 30 percent or more areal coverage by lakes and wetlands have flood peaks that are 60 to 80 percent lower than the peaks in basins with no lake or wetland area. Wetlands can provide cost-effective flood control, and in some instances their protection has been recognized as less costly than flood-control measures such as reservoirs or dikes (Carter and others, 1979). Loss of wetlands can result in severe and costly flood damage in low-lying areas of a basin.*

Wetlands store water during floods although the magnitude of this storage role depends upon "antecedent" condition of the wetlands prior to a flood event including water surface elevations and moisture content of soils. A wetland already filled with water at the time of a flood will provide no or little flood storage. The role of a specific wetland in storing flood waters and reducing downstream flood heights also depends upon the size of the wetland, its depth, the

[63]See Tsihrintzis et. al., 1998. Hydrodynamic Modeling of Wetlands for Flood Detention, Vol. 12, Number 4, Water Resources Management.; Thongchai Roachanakanan, Wetlands Creation for Flood Control. (Use of swamps for flood detention in Thailand) Paper prepared for the Tropical Wetlands Management Training Programme, held at Mahidol University, Thailand, 1-26 May 2006 at http://www.dpt.go.th/Sub-web/web_stbd/web-stbd/article/Wetlandl.doc; Gleason, R. et al. 2007. Estimating Water Storage Capacity of Existing and Potentially Restorable Wetland Depressions in a Subbasin of the Red River of the North. U.S. Geological Survey, Open File Report 2007-1159 at http://pubs.usgs.gov/of/2007/1159/pdf/ofr2007-1159.pdf. See also other papers cited below.
[64]Carter, V. 1996. Wetland Hydrology, Water Quality and Associated Functions. United States Geological Survey Water Supply Paper 2425

vegetation, and the extent to which it is connected to other wetlands and waters. It depends upon the broader flood regime including the timing of various inputs of flood waters.[65]

Wetlands are typically located in depressions in the landscape (e.g., Prairie Potholes,). Depressions fill with water during periods of high rainfall and snowmelt. It has been estimated that a one acre wetland flooded to the depth of one foot can hold up to 1.5 million gallons of water.[66] It has also been estimated that bottomland hardwoods along the Mississippi River once stored about 60 days of floodwater along the Mississippi but now have only 12 days of storage due to filling and drainage.[67] Don Hey from the Wetlands Initiative in Illinois has estimated that all of the water flowing by St. Louis in the 1993 Great Flood along the Mississippi could have been stored on about 13 million acres of land at a depth of three feet.[68] This compares with the 20 million acres of wetlands which have been lost along the upper Mississippi basin since 1780.

Mitch and Gosslink and other scientists have suggested that at least 3-7% of a temperate zone watershed should be wetland to optimize the landscape for ecosystem values including flood control and water quality enhancement.[69]

Wetlands important in providing flood storage include not only wetlands adjacent to water bodies but millions of partially "isolated" wetlands in upland locations such as the Prairie Pothole region. These headwater wetlands store and slowly release flood waters although they may have little connection with other waters during normal flows. Although each wetland may store relatively little water, millions may store large quantities of water.

Prairie Pothole wetlands like these in the Cottonwood Lakes Area are subject to large, long term fluctuations in water levels.
Source: U.S. Geological Survey.
http://www.npwrc.usgs.gov/projects/clsa/

On the international scene, a 2003 joint report by English Nature, the Environment Agency, the Department for Environment, Food and Rural Affairs and the Forestry Commission examined the relationship between wetlands, land use change and flood management and recommended

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[65]Bullock, A. and M. Acreman. 2003. The Role of Wetlands in the Hydrologic Cycle. Hydrology and Earth Systems Sciences 7(3), 358-389 2003 (GU) at
http://www.iucn.org/themes/wetlands/pdf/RoleWetlandsHydrologicalCycle.pdf
[66]Ducks Unlimited. http://www.ducks.org/Conservation/Habitat/1542/IncreasedFloodStorage.html
[67]Id.
[68]Hey et. al. 2004. Flood Loss Reduction in the Upper Mississippi: An Ecological Alternative.
http://www.wetlands-initiative.org/images/UMRBFinalReport.pdf
[69]Mitch, W & J. Gosselink, 2000. Wetlands (3rd ed.) John Wiley & Sons, New York, N.Y.

wetland creation to increase flood storage. Case study examples were provided.[70] The Thai government has also protected a number of wetlands for flood storage.[71]

In some instances wetlands have been protected and restored specifically to provide flood storage although storage is typically one goal among many. The Corps in 1976 in a study of flood reduction options for the Charles River concluded that it would be much less expensive to acquire the wetlands along the Charles rather than construct a dam to reduce downstream flooding. The Corps then acquired 8,500 acres of wetland for $7,300,000 in lieu of building a $30,000,000 flood control structure.[72]

There have been relatively few large projects like the Charles to provide wetland flood storage. However, the Corps is acquiring 5,350 acres along the Passaic River in New Jersey to protect flood storage.[73] The state of New Jersey will continue to protect 6,300 acres. This adds to 9,500 acres in the central Passaic basin already protected.

Many federal agencies contributed to efforts to acquire wetlands along the Mississippi after the Great Flood of 1993. One of the goals was protection of flood storage. The efforts included the "buy-out" of Louisa 8 Levee District and the return of the 2006-acre area to wetlands to provide storage and wildlife.[74] The USDA Natural Resources Conservation Service (NRCS), FWS, and other agencies are continuing to acquire and protect wetlands through the Wetland Reserve and other programs along the Missouri River, in part to protect flood storage. Since 1992 NRCS has enrolled approximately 65,000 acres in the Wetland Reserve Program in Missouri alone.[75] Many of these acres have been in floodplain locations such as the Marion Bottoms (3,000 acre tract).

An EPA publication[76] describes other efforts to protect or restore wetlands to provide flood storage including Horseshoe Park, Colorado; Grand Kankakee Marsh, Indiana; Mayview Wetland Project, Pennsylvania; Prairie Wolf Slough, Illinois; and the Vermillion River, South Dakota. An American Rivers publication[77] describes other efforts including the St. Johns River, Florida (large scale wetland and floodplain restoration); Tulsa Oklahoma (removal and relocation, greenway), Grand Forks, North Dakota; East Grand Forks, Minnesota (greenway); and Napa, California ("living river plan"-- reconnecting river to floodplain).

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[70] English Nature et. al, 2003, 2005. http://www.defra.gov.uk/environ/fcd/policy/Wetlands/Wetlands3.pdf
[71] See T. Roachanakannan 2006 Wetlands Creation for Flood Control. Paper prepared for the Tropical Wetlands Management Training Programme, Mahidol University, Thailand, May 2006 at http://www.dpt.go.th/Sub-web/web_stbd/web-stbd/article/Wetlandl.doc
[72] Corps, 2004. U.S. Army Corps of Engineers. 2005. Charles River Natural Valley Storage Area. http://www.nae.usace.army.mil/recreati/crn/crnhome.htm
[73] U.S. Army Corps of Engineers. 2004. Preservation of Natural Flood Storage Areas: the Passaic River http://www.nan.usace.army.mil/project/newjers/factsh/pdf/pasres.pdf
[74] USFWS, 2004 Horseshoe Bend Division. http://www.fws.gov/midwest/PortLouisa/horseshoe_bend.html
[75] Natural Resources Conservation Service, 1999. Missouri Wetlands Reserve Program
[76] EPA, 2006.Wetlands: Protecting Life and Property from Flooding. EPA843-F-06-001 at http://www.epa.gov/owow/wetlands/pdf/Flooding.pdf
[77] American Rivers. 2006. Unnatural Disasters, Natural Solutions, Lessons from the Flooding of New Orleans. American Rivers. Washington, D.C. at http://www.americanrivers.org/site/DocServer/Katrina_Publication-take2.pdf?docID=4481

Although the large wetland restoration projects to provide flood storage are modest in number, municipal engineers now routinely create and restore wetlands in designing and retrofitting stormwater systems to simultaneously store flood/stormwaters and reduce water quality problems.

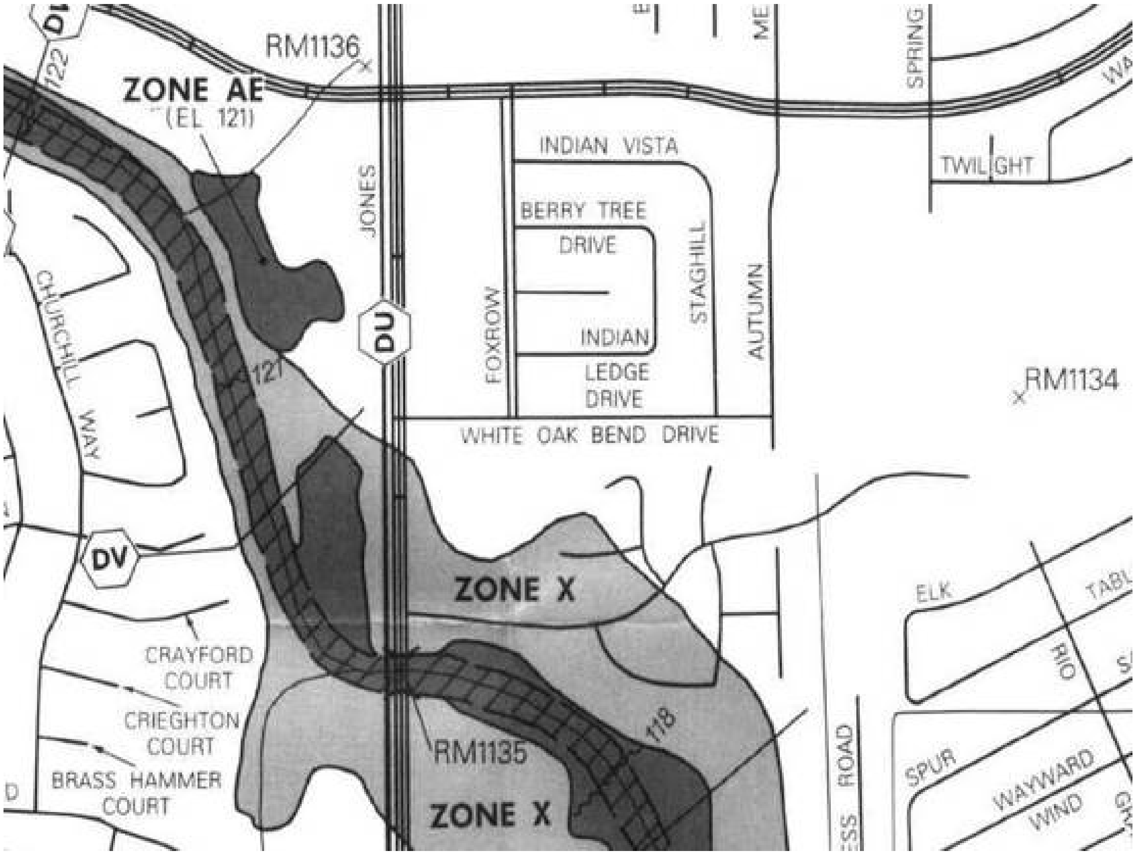
Restoration of wetlands to restore flood storage and meet broader environmental objectives may be accomplished by removing fill, filling drainage ditches, collapsing drain tiles, removing fills, and constructing water control structures.

Wetlands adjacent to the Colorado River near Grand Lake convey flood waters.
Source: Jon Kusler, ASWM

Conveyance of Flood Waters

Wetlands not only store flood waters but reduce upstream flood heights by conveying flood waters from upstream to downstream locations. Riverine wetlands are often located within "floodway" areas identified on floodway maps prepared by the National Flood Insurance Program. These maps have been widely used by communities to adopt floodplain regulations. The "floodways" identified on these maps are typically defined as areas near a river or stream channel which convey waters from upstream to downstream locations without raising flood heights more than a specified amount (e.g., 1 foot, zero rise, etc.) for a specified flood (e.g., a 100 year flood).[78]

[78] See http://www.fema.gov/plan/prevent/fhm/fq_term.shtm#6



FEMA Flood Map. *Source: Federal Emergency Management Agency.*

The flood conveyance role of wetlands may appear contradictory with the flood storage, but it is not. Flood storage areas are needed in headwater and broad near channel areas of a floodplain to reduce downstream flood heights. But, flood conveyance is also needed, particularly along narrow portions of a valley or in developed areas. Here even small increases in flood heights may overtop levees or increase flood damages to residential, commercial, or other areas. The flood conveyance versus storage roles of wetlands depend upon the location of the wetland in relationship to a river or stream, its depth, width and length, and its vegetation. They are both important.

Restoration of wetlands by removing fill, structures, and levees can increase the flood conveyance capacity of the wetlands. For example, FEMA through its "buyout" program helped Pierce County, Wisconsin remove 70 structures from Trenton Island in the floodway of the Mississippi River after the Great Flood of 1993. This $6 million buyout resulted in reduced flood damages for later floods in 1997 and 2001.[79]

[79]FEMA, 2004. Region V. Floodways and Wetlands of the Mighty Mississippi: Trenton Island, Wisconsin. http://www.fema.gov/regions/v/ss/r5_n21.shtm

Attenuation of Storm Surge, Waves, and Tsunamis

As discussed above, wetlands may reduce storm surge and tsunamis damage to back-lying lands and structures by slowing the inland flow of a surge or tsunamis. Wetlands may also reduce wave and erosion damage and by dissipating wave energy and causing waves to "break" some distance from vulnerable structures. It has been broadly suggested the damage from Hurricane Katrina was more serious along the Louisiana and Mississippi coasts due to destruction of wetlands.

Reducing Erosion and Sedimentation

Wetlands and riparian vegetation reduce erosion and sedimentation of adjacent lands by lowering flood velocities and wave heights. Root structures bind the soil. However, wetlands may also be eroded by high velocity flows.

Trees and root structures like these lower water velocities and reduce erosion.
Source: www.sturgeoncity.org/wetlands.html

PART 5: EXISTING POLICIES AND LAWS

Part 5 provides a brief description of private law suits and government programs relevant to wetlands and natural hazards. Private landowners have sued other landowners and individuals for increasing flood, erosion and other hazards on their lands by draining wetlands or for failing to take into account or divulge flooding in the construction and sale of residences. The federal government, states, and local governments have adopted a variety of policies and regulations intended to reduce natural hazard losses in wetland areas (and other hazard areas as well).

Private Law Suits

Landowners have in some instances sued other landowners for draining or filling wetlands which increased the amount or location of water discharged onto other lands. Courts in a number of cases have held that filling or drainage of a wetland with resulting increase in flooding on other lands constitutes a trespass, nuisance, or negligence.[80]

The buyers of subdivision lots or new houses have also, in some instances, sued sellers or builders for locating structures in high ground water or flood areas with subsequent flood or drainage problems.[81] Examples include:

- A Nevada court[82] held that the developer of lots in the Lake Tahoe basin had failed to warn buyers of the risk of being located in the floodplain of a mountain stream although they knew buyers planned to build there. The developer was negligent when the home that was built was destroyed by a flow of water carrying trees, mud, and other debris.

- A Colorado court[83] held a seller or a residence liable for water damages and problems due to wetness and swelling soils under a theory of implied warranty of suitability.

- A Washington court[84] awarded damages against both a real estate broker and seller for failure to exercise due care and misrepresentation with regard to inadequate onsite septic tank/soil absorption capability for a residence.

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[80]See, e.g., Hendrickson v. Wagners, Inc. 598 N.W.2d 507 (S.D., 1999) (Injunction granted by the court to require landowner who drained wetlands with resulting flooding of servient estate to fill in drainage ditches.); Boren v. City of Olympia, 112 Wash. App. 359, 53 P.3d 1020 (Wash. 2002) (City was possibly negligent for increasing discharge of water to a wetland which damaged a landowner.); Snohomish County v. Postema, 978 P.2d 1101 (Wash. 1998) Lower landowner had potential trespass action against upper landowner who cleared and drained wetland.); Lang et al v. Wonnenberg et al, 455 N.W.2d 832 (N.D., 1990) (Court upheld award of damages when one landowner drained a wetland resulting in periodic flooding of neighboring property.); Janice J. Cook &a. v. John D. Sullivan &a, 829 A.2d 1059 (N.H., 2003). (Landowner successfully sued adjacent landowner for filling a wetland and building a house in a jurisdictional wetland without a permit which resulted in flood damages. Court found that the house and fill were a nuisance and ordered removal of the fill and house.)
[81]See Annot., 12 ALR 4th 866 (1982) Statutes of Limitation: Actions by Purchasers or Contractors Against Vendors or Contractors Involving Defects in Houses or Other Buildings Caused by Soil Instability; Annot., 80 ALR2d 1453 (1961) Liability of Vendor of Structure for Failure to Disclose That It Was Built on Filled Ground
[82]Village Development Co. v. Filice, 526 P.2d 83 (Nev., 1974).
[83]Mulhern v. Henderich, 430 P.2d 469 (Colo. 1967).
[84]See Tennant v. Lawton, 615 P.2d 1305 (Wash., 1989).

Contractors have also sued landowners for failing to divulge soil wetness and organic matter problems in negotiating construction contracts.[85]

Government Policies and Regulations

Federal

Congress has adopted a broad range of hazard-related programs, some of which apply to wetland hazard areas although they are not designed specifically for wetlands. These include the flood control programs of the Corps, Bureau of Reclamation, Tennessee Valley Authority, and other agencies. They include FEMA's National Flood Insurance Program and Disaster Assistance Programs. They include FEMA's, the Corps, USGS, National Oceanic Atmospheric Administration (NOAA), and NRCS hazard mapping programs.

The federal government has also adopted a number of initiatives to simultaneously both protect wetland and floodplain functions and reduce flood losses. These efforts include:

> **Wetland Executive Order.** In 1977 President Carter adopted Wetland and Floodplain Executive Orders. The Protection of Wetlands Executive order No. 11990 May 24, l977, 42 F.R. 26961 provides in part:
>
> Section 1. (a} Each agency shall provide leadership and shall take action to minimize the destruction, loss or degradation of wetlands, and to preserve and enhance the natural and beneficial values of wetlands in carrying out the agency's responsibilities for (1) acquiring, managing, and disposing of Federal lands and facilities; and (2) providing Federally undertaken, financed, or assisted construction and improvements; and (3) conducting Federal activities and programs affecting land use, including but not limited to water and related land resources planning, regulating, and licensing activities.
>
> Section 5. In carrying out the activities described in Section I of this Order, each agency shall consider factors relevant to a proposal's effect on the survival and quality of the wetlands. Among these factors are:
>
> > *(a) public health, safety, and welfare, including water supply, quality, recharge and discharge; pollution; flood and storm hazards; and sediment and erosion;* (emphasis added).
>
> **Clean Water Act, Section 404 program.** The Corps and EPA have adopted regulations for the Clean Water Act Section 404 permitting program which require the Corps permits for most activities in wetlands. These regulations require the consideration of natural hazards in the processing of permits:
>
> Section 320.4 - General policies for evaluating permit applications.

[85] See, e.g., Pinkerton & Laws Co. v. Roadway Express, Inc., 650 F.Supp. 1138 (N.D., Ga., 1982)

The following policies shall be applicable to the review of all applications for DA permits.

(a) Public Interest Review.

(1) The decision whether to issue a permit will be based on an evaluation of the probable impacts, including cumulative impacts, of the proposed activity and its intended use on the public interest. Evaluation of the probable impact which the proposed activity may have on the public interest requires a careful weighing of all those factors which become relevant in each particular case. The benefits which reasonably may be expected to accrue from the proposal must be balanced against its reasonably foreseeable detriments. The decision whether to authorize a proposal, and if so, the conditions under which it will be allowed to occur, are therefore determined by the outcome of this general balancing process. That decision should reflect the national concern for both protection and utilization of important resources. All factors which may be relevant to the proposal must be considered including the cumulative effects thereof: *among those are…, flood hazards, floodplain values, …shore erosion and accretion….*(emphasis added).

33 CFR Part 320 Section 320.4 further provides, in part:

"*Wetlands considered to perform functions important to the public interest include:*

(iii) *Wetlands the destruction or alteration of which would affect detrimentally natural drainage characteristics, sedimentation patterns, salinity distribution, flushing characteristics, current patterns, or other environmental characteristics;*

(iv) *Wetlands which are significant in shielding other areas from wave action, erosion, or storm damage. Such wetlands are often associated with barrier beaches, islands, reefs and bars;*

(v) *Wetlands which serve as valuable storage areas for storm and flood waters;"* (emphasis added)

Louisa 8 Levee District agricultural lands, acquired after the great flood of 1993 and restored to wetland.
Source: Iowa Natural Heritage Foundation.
http://www.inhf.org/25event25.htm

National Flood Insurance Reform Act of 1994. Congress in Section 562 of the National Flood Insurance Reform Act of 1994 directed a Federal Task Force on Natural and Beneficial Functions of the Floodplain to

- "identify the natural and beneficial functions of floodplains that reduce flood losses; and
- recommend how the nation can further reduce flood losses through the protection and restoration of natural and beneficial functions of the floodplain."

The Task Force published a report for Congress in 2002 entitled The Natural and Beneficial Functions of Floodplains, Reducing Flood Losses by Protecting and Restoring the Floodplain Environment. This report made a series of recommendations for simultaneously reducing flood losses and protecting natural and beneficial functions. The first and broadest of these recommendations included:

> "Develop an updated and expanded national policy on the protection and restoration of the natural and beneficial functions of floodplains as an integral part of all Federal, state, tribal, and local government programs, actions, planning, policies, regulations, and grants."

Water Resources Development Act. The Water Resources Development Act of 2007 (HR 1495) provides, with regard to water resources Principles and Guidelines (Sec. 2031), that (a) ….It is the policy of the United States that all water resources projects should reflect national priorities, encourage economic development, and protect the environment by—

(1) seeking to maximize sustainable economic development;

(2) seeking to avoid the unwise use of floodplains and flood-prone areas and minimizing the adverse impacts and vulnerabilities in any case in which a floodplain or flood-prone area must be used; and

(3) protecting and restoring the functions of natural systems and mitigating any unavoidable damage to natural systems (emphasis added*.)"*

The Act also (Section 2036) sets forth requirements for "mitigation" plans for mitigation of fish and wildlife and wetlands losses from water projects. It provides, in part, that a mitigation plan for a water resources project shall include, at a minimum—"the criteria for ecological success by which the mitigation will be evaluated and determined to be successful based on replacement of lost functions and values of the habitat, including hydrologic and vegetative characteristics…."

National Flood Insurance Act of 1968 With Amendments. In the National Flood Insurance Act, Congress authorized FEMA to establish a community flood insurance rating system to achieve a number of goals stated in the National Flood Insurance Act, Section 4012 which include:

(A) to provide incentives for measures that reduce the risk of flood or erosion damage….
(B*) to encourage adoption of more effective measures that protect natural and beneficial floodplain functions;*

(C) to encourage floodplain and erosion management; and
(D) to promote the reduction of Federal flood insurance losses." (emphasis added)

Pursuant to this Act, FEMA has establish a Community Rating system which reduces flood insurance rates for communities which adopt wetland, floodplain and other open space and hazard reduction programs. The federal courts have held that FEMA must consider rare and endangered species in implementing these provisions. In Deer v. Paulson, 522 F.3d 1133 (11th Cir. 2008) the 11th Circuit Court of Appeals sustained an injunction prohibiting FEMA from issuing flood insurance for new development in endangered species listed habitats (here Key Deer) in Monroe County, Florida. The Court held that FEMA had not, pursuant to these broad criteria for community programs and the Endangered Species Act, undertaken an adequate program to conserve endangered or threatened species.

State

States, like the federal governments, have adopted a variety of statute and regulations which apply at least in part to wetland hazards (along with other hazard areas).

All coastal states have adopted some measure of regulatory protection for coastal and estuarine wetlands although the scope of these regulations differs greatly. Some states have adopted wetland protection regulations as part of broader coastal zone management or shoreland regulations like those in California, Oregon, and Washington State. Other states like Georgia and Rhode Island have adopted specific coastal and estuarine wetland protection statutes.

Most state coastal and estuarine wetland protection regulations set forth reduction in flood and erosion losses as one goal. However, it would appear that analysis of hazards[86] is often not a consideration in state evaluation of permit applications due to lack of expertise and maps.

Approximately one half of the states have adopted wetland protection regulations for freshwater wetlands. Most states like Michigan, Wisconsin, and New York have adopted specific wetland protection statutes. A small number of states regulate freshwater wetlands as part of shoreline zoning regulations (Washington), public water statutes (Pennsylvania), or pollution control statutes (North Carolina, California).

State freshwater wetland statutes and regulations also generally contain hazard loss reduction goals. Massachusetts regulates the 100-year floodplain as part of its wetland protection program. Connecticut regulates hydric soils as part of its program and requires local communities to regulate wetlands and watercourse.

However, state wetland regulators apparently spend little time evaluating natural hazards on permit applications for reasons similar to those for coastal wetland statutes and regulations.

[86]This observation is based upon the author's conversations with state wetland and floodplain managers.

States apply a variety of additional regulations to public waters which may include wetlands. For example, many states regulate or require local regulation of major floodways and, in some instances, floodplain areas. Most states have adopted state sanitary codes which prohibit septic tank/soil absorption fields in areas with saturated soils.

Most States like New York prohibit installation of septic tank systems in wet soils.
Source: http://www.inspect-ny.com/septic/fieldfail.htm

Local

An estimated 5,000 local governments have adopted wetland protection ordinances. Many of these ordinances set forth flood storage, erosion control, and other public health and safety goals. For example, the Falmouth, Massachusetts wetland ordinance states that it has been adopted to promote the following resource "values" including but not limited to "flood control", "erosion and sedimentation control", "storm damage prevention".[87]

More than 20,100 local governments have adopted floodplain regulations for mapped flood plains. A smaller number also regulate floodway areas. Most local floodplain regulations do not specifically address wetland areas although these ordinances (particularly floodway regulations) do provide some indirect protection for wetlands by prohibiting fills within floodway areas.

Local governments have adopted a variety of watershed and comprehensive plans and implementing regulations which provide some measure of protection for wetlands by tightly controlling certain types or aspects of development. Such regulations include stream protection regulations, fill and grading regulations, sediment controls, stormwater ordinances, shoreland and coastal ordinances, and local sanitary codes.

It would appear that wetland and floodplain programs are independently implemented with often limited communication between the wetland and floodplain regulations and regulators.[88] It has also been suggested that the National Flood Insurance program encourages development in wetland areas by providing subsidized flood insurance for such areas. Floodplain regulations typically make no mention of wetlands and may encourage the use of fill in outer "flood fringe" areas.

[87]Falmouth Wetland Regulations. http://www.buzzardsbay.org/sect1.htm. See also Association of State Floodplain Managers, and U.S. Federal Emergency Management Agency. Reducing Losses in High Risk Flood Hazard Areas: a Guidebook for Local Officials. FEMA 116, February 1987.
[88]This is, again, an observation based upon discussions with many wetland and floodplain managers over a period of years.

Wetlands Regulations and the Courts

The U.S. Supreme Court and lower courts have broadly upheld wetland regulations. Courts have been particularly receptive to regulations designed to protect public health and safety although the courts have endorsed broader objectives as well. As stated by the U.S. Supreme Court,[89] when threats to human life are involved, a legislature may adopt "the most conservative course which science and engineering offer."[90] Regulations to protect health and safety are sustained even where they regulate existing uses or prevent new ones.[91]

Courts in many cases have endorsed floodplain regulations prohibiting structures and fills in coastal and inland areas that would be subject to flood damage or would block flood flows, thereby increasing flood damages on other lands.[92]

Courts have also, more specifically, upheld wetland regulations designed to reduce flood losses.[93] For example, a Massachusetts Court of Appeals upheld the denial of a permit to fill a wetland area where there was testimony that filling would deprive the town of 23.8 acre feet of water storage or 7.77 million gallons.[94] Although there was testimony that this loss would have resulted in a small increase in flood heights (perhaps ½ of an inch) the court held that seriousness of the problem was for the local regulatory board not the court to determine. Similarly a Connecticut court [95] sustained a conservation commission's denial of an application to build a home within 200 feet of a wetland at a site which was subject to flooding and with possible adverse affect on the floodplain.

Courts have often supported stringent regulation of the use of septic tanks and soil absorption fields in and near wetlands including large setbacks.[96]

In supporting hazard-related regulations, courts have reasoned that landowners have no right to threaten public safety or create nuisances. Courts have strongly endorsed regulations to prevent

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[89]See Queenside Hills Realty Co. v. Saxl, 328 U.S. 80, 83 (1946).
[90]Id.
[91] See, e.g., Cleaners Guild v. City of Chicago, 37 N.E.2d 857 (Ill. 1941); Denver & Rio Grande R.R. Co. v. City and County of Denver, 250 U.S. 241 (1919).
[92]See Responsible Citizens in Opposition to Flood Plain Ordinance v. City of Ashville, 302 S.E.2d 204 (N.C. 1983) upheld flood loss reduction regulations against takings and equal protection challenges. A California court in Turner v. County of Del Norte, 24 Cal. App. 3d 311 (Calif. 1972) endorsed a county zoning ordinance that limited an area of extreme flooding to parks, recreation, and agricultural uses. Similarly, the Massachusetts Supreme Court in Turnpike Realty Co. v. Town of Dedham, 284 N.E.2d 891 (Mass. 1972), cert. denied, 409 U.S. 1108 (1973 endorsed local floodplain zoning and observed, that the "general necessity of floodplain zoning to reduce the damage to life and property caused by flooding is unquestionable."
[93]See, e.g., Moskow v. Comm'r of Dept. of Envtl. Mgmt., 427 N.E.2d 750 (Mass. 1981).
[94]See Subaru of New England, Inc. v. Board of Appeals of Canton, 395 N.E.2d 880 (Mass. 1979).
[95]Kaeser v. Conservation Com. Of Easton, 567 A.2d 383 (Conn. 1989) a court
[96]See also Tortorella v. Board of Health of Bourne, 655 N.E.2d 633 (Mass, 1995); Biggs v. Town of Sandwich, 470 A.2d 928 (N.H. 1984) in which the Supreme Court of New Hampshire upheld zoning board of adjustment's denial of a variance for a septic tank permit because the proposed septic tank would have been within a 125 foot setback area from a wetland. See also Claridge v. New Hampshire Wetlands Bd., 485 A.2d 287 (N.H. 1984); Saturley v. Hollis Zoning Bd. of Adjustment, 533 A.2d 29 (N.H. 1987).

nuisances or control uses with nuisance characteristics.[97] Courts have sustained prohibition of nuisance-like activities against takings challenges even where such prohibition denies all economic use of lands.[98] For example, a Connecticut court[99] upheld a conservation commission's decision denying a permit to deposit fill and build a house near a wetland and river due in part because the fill could exacerbate flooding. Efforts to prevent flood damage and prevent changes significant changes in hydrology have also been broadly endorsed.[100]

Evidence of inadequate soils for septic tanks/soil absorption fields and possible resulting pollution has also been given great weight by courts.[101]

Courts have endorsed protection of ecological values but have traditionally afforded such values somewhat less weight than protection of safety and prevention of nuisances. Courts have, in a number of cases, held that severe restrictions which deny all economic use of lands based primarily upon ecological considerations are a taking.[102]

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[97]See, e.g., Hadacheck v. City of Los Angeles, 239 U.S. 394 (1915); Reinman v. City of Little Rock, 237 U.S. 171 (1915): Pierce Oil Corp. v. City of Hope, 248 U.S. 498 (1919).

[98] For example, the California Supreme Court in Consolidated Rock Products Company v. City of Los Angeles, 370 P.2d 342 (Cal. 1962), appeal dismissed, 371 U.S. 36 (1962) sustained an ordinance prohibiting sand and gravel operations in a dry stream bed where no other economic use could be made of the land because nearby residential areas would be affected by the dust and noise of the mining operation. The court observed that the primary purpose of zoning was to prevent land uses that would threaten other landowners or the public. See also Filister v. City of Minneapolis, 133 N.W. 2d 500 (1964), cert. denied, 382 U.S. 14 (1965) in which the court sustained a single family residential classification for a swampy area surrounded by residences in part because proposed apartments would have been nuisance-like in the low density surroundings.

[99]See Kaeser v. Conservation Com. of Easton, 567 A.2d 838 (Conn. 1989).

[100]See, e.g., Michelson v. Warshavsky, 653 N.Y.S.2d 622 (A.D. 1997) (Denial of permit to subdivide valid based upon threat of flooding.)

[101]See, e.g., Saturley v. Town of Hollis, 533 A.2d 29 (N.H. 1987), in which the New Hampshire Supreme Court held that denial of a variance for a septic tank in a wetland was reasonable based upon pollution concerns; Santini v. Lyons, 448 A.2d 124 (R.I. 1982) (Denial of permit for fill and septic tank in salt marsh upheld, in part, due to pollution concerns); Milardo v. Coastal Resources Mgmt. Council, 434 A.2d 266 (R.I. 1981) (Denial of a permit for construction of sewage disposal system in a marsh upheld). English Nature et. al, 2003, 2005. http://www.defra.gov.uk/environ/fcd/policy/Wetlands/Wetlands3.pdf

[102]See Annicelli v. Town of South Kingston, 463 A.2d 133 (R.I. 1983) (Court held regulations which prevented building on barrier island were a taking); Morris County Land Improvement Co. v. Parsipanny Troy Hills Township, 193 A.2d 232 (N.J. 1963) (Court invalidated in total a wetland conservancy district which permitted no economic uses where the district was primarily designed to preserve wildlife and flood storage). However see also Just v. Marinette County, 201 N.W.2d 761 (Wis. 1972).

PART 6: CONCLUSIONS AND RECOMMENDATIONS

How can all levels of government reduce flood losses while better protecting floodplain and wetland functions and values? Recommendations include:

1**. Recognize that wetlands are subject to a variety of natural hazards.** All levels of government need to recognize wetlands are often subject to natural hazards and that keeping development out of wetlands will often both reduce flood losses and maintain wetland natural and beneficial functions. Coastal and estuarine wetlands and wetlands along major rivers are often subject to severe flooding and erosion. Many wetlands are also subject to subsidence, liquefaction, and earthquake wave propagation problems. This makes them poor sites for development apart from their ecological functions and values. Even highly degraded wetlands in urban settings with limited ecological functions and values may be subject to severe natural hazards and provide important flood storage, flood conveyance, pollution control and other functions. These hazards will become more severe (in some instances) with climate change, rising sea levels, and increased severe meteorological events.

2. **Revise** (Corps, EPA, FWS, FEMA, other federal agencies) **the federal "principles and guidelines" for water projects to better protect and restore the functions of natural systems and to mitigate any unavoidable damage to natural systems.** Revised guidelines should require more detailed analysis of floodplain and wetland functions and values including but not limited to flood storage, flood conveyance, wave attenuation, and erosion control in water project planning and assessment.

3. **Presume** (All levels of government) **that wetlands are hazard areas.** Not all wetlands are hazard areas. Nevertheless, the high incidence of flood, erosion, subsidence, unstable soil, earthquake hazards justifies an overall "hazard" presumption at all levels of government. This is particularly true for coastal and estuarine wetlands and wetlands along major rivers, streams and lakes. Such a presumption may be rebutted in a particular instance through the use of flood maps, soils maps, flood records, topographic maps or onsite information.

4. **Prepare and adopt** (Local governments) **community comprehensive planning including "smart growth" efforts.** Such efforts should concentrate development on uplands and keep it out of floodplain, riparian, and wetland areas to reduce flood losses, protect natural and beneficial functions, and achieve infrastructure and other transportation efficiencies.

5. **Prepare "how to manuals".** "How to" guidebooks could be written for federal, state, and local wetland managers by the Corps, FEMA, EPA, NOAA, USGS, NRCS or other agencies concerning the assessment and mitigation of natural hazards. "How to" guidebooks could also be written for floodplain managers concerning wetland functions and values and measures to reduce the impacts of floodplain projects on wetlands.

6. **Undertake additional and more detailed mapping of wetland, flood, erosion, liquefaction and other hazard areas.** Such mapping should be undertaken by FEMA, FWS, USGS, States, Tribes, and Local Governments where maps do not exist or more detailed and accurate maps are needed. This is particularly needed for areas under development pressures. Existing floodplain

and wetlands maps also often need to be updated to take into account changes in watershed hydrology, land and water uses, and vegetation. More detailed and accurate mapping is also needed for urban areas to aid comprehensive land and water planning, floodplain management, greenway and open space acquisition, and other management efforts.

7. **Improve dissemination of hazard and wetland maps or digital imagery other data via the Internet.** FEMA, USGS, FWS, States and Tribes should better disseminate flood, earthquake, wave action, liquefaction and other hazard maps to wetland managers to help them take into account natural hazards. Similarly, these agencies should better disseminate wetland maps to floodplain managers could help them take into account wetland functions and values. Ideally, such data should be in digital form and easily accessed over the Internet. Federal floodplain, wetland, and other mapping efforts are moving in this direction and this direction should be continued.

8. **Train wetland and hazard managers.** The Corps, EPA, USGS, NOAA, NRCS and other agencies should provide training to wetland managers at all levels of government concerning the identification of natural hazards in wetlands and techniques to reduce and avoid natural hazard losses. Hazard managers should be trained in protecting and restoring wetlands.

9. **Provide more explicit guidance to wetland regulators concerning the identification of hazards and the reflection of hazards in wetland permitting; similarly provide more explicit guidance to floodplain regulators with regard to mitigation of impacts of development in floodplains upon wetlands.** The Corps and EPA should provide more specific Section 10 and Section 404 guidance for Corps and EPA regulators to help them more carefully consider natural hazards in Section 404 and Section 10 permitting. Similarly, FEMA should provide more explicit guidance to state and local regulators with regard to mitigation of impacts on wetlands. State and local agencies should provide similar guidance for their wetland and floodplain regulators.

10. **Incorporate wetland protection provisions into floodplain regulations and hazard provisions into wetland regulations.** Local governments and states need to more fully incorporate wetland protection provisions into floodplain ordinances and regulations and flood hazard provisions into wetland ordinances. For example, floodplain regulations should prohibit fill in wetlands.

11. **Recognize at all levels of government that wetlands with limited ecological functions (e.g., urban, degraded wetlands) may, nevertheless, be subject to severe natural hazards and that "sequencing" (avoidance, impact reduction, and compensatory mitigation) makes sense for these wetland as well.** Recognition is needed at all levels of government that multiple severe hazards such as flooding, erosion, and subsidence often make wetlands poor sites for development apart from their ecological functions and values. Avoidance, impact reduction and compensatory mitigation make sense even if wetlands have limited ecological functions and values. Even highly degraded wetlands from a habitat perspective may also be important flood storage, flood conveyance, and stormwater storage and purification areas, particularly in urban settings.

12. **Make broader use in planning, regulatory permitting, and other management programs of updated hydraulic and hydrologic models which permit consideration of flood storage and conveyance.** All levels of government should make use of computerized models to consider flood storage in calculating flood heights and velocities.

Houses in the 100-year floodplain are often constructed on fill.
Source of photo of a house on fill in floodplain:
www.tunicacounty.com/.../comprehensiveplan2.html

13. **Adopt a "no adverse impact" standard for floodplains and wetlands.** Local, State, Tribal, and Federal agencies could strengthen their hazard reduction programs and reduce flood losses by adopting a "no adverse impact" standard for floodplains and wetlands of the sort suggested by the Association of State Floodplain Managers. This would include a "zero" rise floodway and prohibition of fill in the floodplain.[103]

14. **Continue and enhance the Community Rating System.** FEMA should continue and enhance its "Community Rating System" which provides communities with reduced flood insurance rates if they tightly regulate hazard area and protect open space including wetland areas.[104]

15. **Undertake additional restoration of wetlands and floodplains in both pre and post disaster contexts.** Federal agencies, States, and Local governments should more aggressively restore wetlands and floodplains in both pre and post disaster contexts to reduce future flood losses and restore wetland and floodplain functions and values. These functions include but are not limited to flood and stormwater storage, flood conveyance, wave reduction, pollution control, habitat and other functions and values. Several types of wetland restoration and creation projects which could both reduce flood losses and restore wetland and floodplain functions and values include:

- **Restore or create** wetlands and vegetated floodplains **in front of seawalls and levees** to reduce the impact of storm surge, waves, erosion and consequential land loss. Restoration may involve re-grading of shoreline areas to create a substrate for wetlands or other floodplain vegetation, use of dredge spoil to create a substrate, replanting of wetland vegetation, control of exotic species, and other techniques.

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[103]See http://www.floods.org/NoAdverseImpact/NAIjournal.pdf
[104]See http://www.fema.gov/business/nfip/crs.shtm and http://www.fema.gov/pdf/nfip/manual200605/19crs.pdf
Over 1049 communities participate in FEMA's Community Rating program. Preferential flood insurance rates are given to communities which adopt regulations which exceed minimum FEMA (FIA) standards or otherwise restrict development through open space or other programs.

- **Restore broader wetlands** and barrier islands (e.g. the lower Mississippi Delta) to reduce storm surge and waves. Restoration techniques may include sediment diversions, re-grading, use of dredge spoil, replanting, filling canals, and other approaches.
- **Reconnect** wetlands and floodplains to broader aquatic ecosystems after flood disasters by not repairing selected breached levees (e.g., Louisa 8), breaching existing levees, or creating "setback" levees. Replanting of wetland vegetation or natural revegetation may also be needed. Such an approach was, to some extent, applied after the Great Flood of 1993.
- Create or restore wetlands as part of **community stormwater management.** Created and restored wetlands can be used to reduce and treat pollution as well as reduce future flood losses. Rebuilding and repair may involve redesign and retrofitting of existing stormwater systems and creating new wetland/detention areas.
- Restore wetlands and floodplains as part of **comprehensive land use, watershed, or disaster mitigation planning.** Such planning efforts, including "green infrastructure" and "smart growth" efforts, can include relocation of infrastructure, homes, businesses and regrading and replanting of open areas. Restored or created wetlands may be part of greenways, parks, recreation areas, open spaces in subdivisions, and stormwater systems.
- Restore wetlands and floodplains as part of **greenway** efforts.

Restored wetland on the Cornell University Campus designed to reduce sediment loading in stormwater runoff to Cascadilla Creek and peak flows.
Source: Cornell University web site.

- Restore wetlands as part of **"mitigation"** projects required by Clean Water Act Section 404 or state or local regulatory authorities. For example, water quality standards in Wisconsin requires that projects in wetlands protect "(s)torm and flood water storage and retention and the moderation of water level fluctuation extremes".[105]

16. **More broadly incorporate wetland and floodplain ecosystem protection and restoration measures into water projects.** The incorporation of wetland protection measures into additional water projects (e.g. the Charles River Project) could better both protect wetland and floodplain functions and reduce flood losses at all levels of government.

[105] Wisconsin, 1991. Water Quality Standards for Wetlands.
http://www.aqua.wisc.edu/waterpolicy/record.cfm?RecordID=3&Ca

17. **Make greater use of bioengineering.** All levels of government should make broader utilization of bioengineering techniques to stabilize river banks rather than “rip rap”, concrete channels, or culverts. Bioengineering can both reduce flood and erosion hazards and losses and protect and restore wetland and riparian area functions and values.

18. **Relocate development out of floodplains and wetlands**. All levels of government should help relocate development out of floodplains and wetlands. Hurricanes like Katrina destroy and damage homes, business, industries and infrastructure (roads, bridges, sewer and water lines, electrical lines), particularly along the immediate coastal shoreline and in inland floodways where the deepest surge flooding and highest velocity flood waters occur. This destruction and the influx of recovery funds after a disaster often creates opportunities to relocate structures and other activities outside of wetlands and other hazard areas. Such efforts could target repetitively damaged structures.[106] For example, tens of thousands of flood-damaged structures were relocated out of the floodplain as part of recovery efforts from the Great Flood of 1993 along the Mississippi and tributary rivers.[107]

Relocation of house from wetland/floodplain areas can reduce flood losses and help restore wetland functions and values.
Source: U.S. Water Resources Council

Placement of brush in stream bank bioengineering.
Source: Ann Riley

[106]See Conrad, D. Higher Ground: A Report on Voluntary Property Buyouts in the Nation’s Floodplains, National Wildlife Federation (To receive a copy of this publication, contact the National Wildlife Federation at 1-800-822-9919)
[107]Id.

19. **Undertake priority research.** Federal government agencies, States, Tribes, and Academic Institutions should undertake research into techniques for simultaneously better reducing natural hazard losses and better protecting and restoring wetland and broader floodplain functions and values. Priority research topics may include:

- The role of mangroves and other wetland and floodplain vegetation in reducing storm surge and wave heights and in reducing erosion.
- The spatial relationships between floodways (including zero rise floodways), wetlands, and broader floodplain areas.
- The role of wetlands in conveying flood flows comparing floodway and riverine wetland maps.
- The role of wetlands in storing flood flows in various landscapes through the gathering of empirical data and watershed modeling.
- Understanding, expertise, and practices of wetland and floodplain managers. Wetland managers should be surveyed to determine their understanding of natural hazards, how hazards are to be assessed, their use of hazard loss reduction techniques, and what is needed to help them better reflect natural hazards in wetland permitting. Similar surveys should be carried out for floodplain managers to determine their level of understand concerning wetlands, wetland assessment, and wetland protection and restoration measures.
- The short-term and long-term impact of coastal storms and inland floods on wetlands in light of projected sea level rise and more severe hurricanes, winter storms, and summer thunderstorms.

PART 7: SELECTED PUBLICATIONS AND WEB REFERENCES

(Note, we have found the following particularly helpful. Other publications and web references are cited in the footnotes to this paper.)

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