Session No. 6

Course Title: Breaking the Disaster Cycle: Future Directions in Natural Hazard Mitigation

Session Title: Structural Approaches to Flood and Coastal Hazard Mitigation; Assessing Structural Approaches

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Time: 150 minutes + 15 minute break

Objectives:

6.1 Understand the use of structural approaches to hazard mitigation and their alternatives
6.2 Identify types of structural approaches used for mitigating different types of hazards
6.3 Review the history and context of structural mitigation approaches
6.4 Describe procedures for analyzing costs and benefits of structural projects
6.5 Discuss case studies of structural projects initiated by the Corps of Engineers and FEMA
6.6 Discuss opportunities and problems with structural approaches from the point of view of community stakeholders during a structured discussion session

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Scope:

The first part of the session describes the uses of structural approaches to hazard mitigation. It provides examples of communities that rely on structural measures and discusses some of the strengths and weaknesses of these measures. This is followed by a description of some of the key types of structures used, e.g., seawalls and levees, as well as a review of the history of such structures. In addition, the session describes the procedures used to analyze the costs and benefits of structural approaches and some of the shortcomings of these procedures.

The second part of the session provides case studies of three communities that adopted different approaches, including the implementation of hardened structures, to mitigate natural hazards. Finally, the session ends with a role-playing exercise that will provide students with an opportunity to examine the pros and cons of structural approaches to mitigating natural hazards.

Reading:

Instructor and student reading:

Interagency Floodplain Management Review Committee. 1994. Ch. 1, The Flood of 1993, pp. 3-35; Ch. 2, Impacts of Human Intervention, pp. 37-58; Ch. 10, A New Approach for the Upper Mississippi River Basin, pp. 141-152. *Sharing the Challenge: Floodplain Management into the Twenty-first Century*. (Galloway Report) Washington, D.C.: U.S. Government Printing Office.

Troubled Waters: Congress, the Corps of Engineers, and Wasteful Water Projects. A report by Taxpayers for Common Sense and National Wildlife Federation. March 2000. (http://www.taxpayer.net/corpswatch/troubledwaters/troubledwaters.pdf)

Schwab, James, et al. 1998. *Planning for Post-Disaster Recovery and Reconstruction*. PAS Report 483/484. Chicago: American Planning Association.

McPhee, John. 1989. *The Control of Nature*. "Atchafalaya," pp. 3-92..New York: Farrar, Straus and Giroux.

Additional instructor reading:

Pilkey, Orrin and Katharine Dixon. 1996. *The Corps and the Shore*. Island Press. Washington, DC.

Handouts: none

Overheads:

- 6.1 Structural Approaches to Hazard Mitigation
- 6.2 Nonstructural Approaches to Hazard Mitigation
- 6.3 The Saga of Seawalls
- 6.4 Impact of Groins
- 6.5 Flood Region: 1993 Midwest Flood
- 6.6 Levee Failure
- 6.7 Pros and Cons of Structural Approach
- 6.8 Charles River, Massachusetts
- 6.9 Grand Forks Greenway
- 6.10 Soldiers Grove, Wisconsin, Before-After

General Requirements:

The instructor presents a lecture during the first part of the session. The lecture includes numerous examples of structural approaches to hazard mitigation. In the second part, students engage in a role-playing exercise that is designed to explore some of the key questions about the appropriate use of structural measures.

Remarks:

During previous sessions, students examined nonstructural approaches to hazard mitigation, including the use of buyouts to move people out of harm's way. In this session, in contrast, we will explore the use of structural measures. Students should be able to consider the pros and cons of different approaches to mitigating natural hazards: structural and nonstructural. Historically, our nation has favored structural approaches. Perhaps nowhere has this been more evident than in the proposals and projects of the Corps of Engineers. Gradually, however, our nation has been moving toward more nonstructural measures, in large part because of the enormous costs, both economic and environmental, of engineering works such as dams, levees and seawalls. Nonstructural measures, however, aren't cheap. Buyouts can be very expensive, yet they are often cheaper than dams or levees in the long run.

Course Introduction

6.1 Understand the use of structural approaches to hazard mitigation and their alternatives

In contrast to nonstructural approaches to mitigating natural hazards, such as regulating land use or purchasing homes in hazard-prone areas, structural approaches seek to hold back or control the forces of nature with man-made devices such as dams, weirs, jetties and levees. While nonstructural approaches seek to keep people out of harm's way, structural approaches seek to keep natural hazards at bay. Thus, rather than move people or buildings, we can move or tame rivers and hold back coastal waters that put us at risk.

<u>Early Uses of Structural Measures</u>
Since ancient times, humans have strived to subdue nature and bend its will to suit our needs, with mixed results. Early civilizations sprouted along rivers to be close to water supplies, transportation routes and fertile farmland. Eventually, people sought ways of controlling the natural flows of the river to protect their livelihood. Ancient Persians built levees along the Tigris and Euphrates Rivers and farmed the fertile soils of the floodplain. Egyptians dug an elaborate web of irrigation canals along the Nile River and later built one of the world's largest dams to store water and control the natural fluctuations of the river. Today, the vast majority of people in Egypt live in a relatively narrow sliver of land along the Nile River: 97% of the population of Egypt lives on 2.5 percent of the land.

In the United States, many of our largest cities are located along rivers, lakes or coastal harbors: Chicago, St. Louis, Washington, D.C., New Orleans, Charleston, Miami and Portland, Oregon, to name a few. Most of these cities would not be what they are today if not for the presence of structural flood control measures such as dams, floodwalls or levees. New Orleans would cease to exist if it weren't for the extensive flood control works built and maintained by the Corps of Engineers. Galveston, Texas would have succumbed long ago to the rising waters of Gulf if not for the massive seawall built decades ago. In 1900, Galveston was struck by a devastating hurricane that leveled much of the city and claimed the lives of over 6,000 residents. The 1900 storm remains as the deadliest natural disaster in U.S. history. In response, the city pumped in several million cubic yards of sand and raised the elevation of the island by about 17 feet. In addition, it built an enormous seawall that stands nearly 16 feet tall and stretches for 10 miles along the shore.

<u>Adverse Consequences</u>
Despite their benefits, structural measures are extremely costly and can wreak havoc on the natural environment.

- *Levees* destroy floodplains and wetlands and can exacerbate flooding downstream.

- *Seawalls* and *jetties*, (discussed below) can lead to severe coastal erosion and even a loss of the beach. In addition, structural measures can create a false sense of security, increasing the amount of property at risk of flooding as people and businesses locate behind levees and floodwalls.

Examples

- Levees constructed in the 1960s by the Corps of Engineers to protect Jackson, Mississippi from flooding by the Pearl River were overtopped in the 1979 flood. An estimated 40 percent of the damage was inflicted on construction that had occurred since the levee was built.
- Numerous other communities, (e.g., Grand Forks, North Dakota, Princeville, North Carolina) have suffered a similar fate, as levees built to protect the community encouraged construction of homes in the floodplain, many of which were destroyed by subsequent flooding.
- Following the 1993 Midwest flood, the Interagency Floodplain Management Review Committee concluded that "while human activities [in the upper Mississippi river Basin] have produced significant economic and social benefits, some of these activities have placed both humans and nature at risk," (Interagency Floodplain Management Review Committee, 1994).

Since the late 1960s, there has been a gradual realization that often the most cost-effective hazard mitigation strategy is to protect the natural mitigative features of the environment—wetlands, floodplains, dune systems and natural vegetation (Godschalk, et al., 1999). All across the country, communities have adopted measures that work with, rather than against, the forces of nature and that recognize the importance of protecting and maintaining healthy, functioning natural ecosystems (*Figure 6.2: Non-Structural Approaches*).

6.2 Identify types of structural approaches used for mitigating different types of hazards

Structural approaches can be divided simply into two categories, (1) those designed to protect buildings and property along the shoreline from the erosive forces of the sea, and (2) those built to prevent flooding along rivers by restricting the spread of water into floodplains. These approaches are described below.

<u>Shoreline protection works</u>

Along the coast, early attempts to protect the coastline relied on hardened structures such as seawalls, breakwaters, groins and jetties to either block and dissipate wave energy or trap sand to widen the beach (*Figure 6.1: Structural Approaches*). Seawalls and breakwaters are built parallel to the beach. Groins and jetties are built perpendicular to the beach (Godschalk, Beatley and Brower, 1989).

- *Seawalls*, as their name suggests, are vertical walls built on land and parallel to the beach to absorb wave energy. They are the most common type of hardened shoreline protection measure and are typically constructed from heavy concrete steel or rocks. Seawalls typically function to halt the retreat of the shoreline into adjacent buildings but are not designed to block storm waves(*Figure 6.3: Saga of a Seawall*).
- *Bulkheads* are similar to seawalls, but are generally smaller than seawalls. They are usually used to protect headland areas and inlet channels.
- *Breakwaters* are fixed or floating structures that parallel the coast but are built just offshore. They serve to reduce the energy of waves before they hit the shoreline.
- *Revetments* have a similar purpose, but may be angled and typically use riprap or interconnecting concrete blocks to protect dunes and beaches from erosion (Bush, et al.,1996).
- *Jetties* and *groins* are rock walls or piles built perpendicular to the beach. Jetties typically serve to interrupt the flow of sand along shore and prevent ship channels from filling in, while groins usually are built to capture migrating sand and increase the width of beaches.

Example: Sea Bright, NJ

In Sea Bright, New Jersey, a massive, 17-foot tall seawall protects an area of less than one-square mile and a population of fewer than 2,000 year-round residents. The wall has protected the city from coastal storms, but at the cost of its beach. By the mid-1990s, the beach, robbed of its local sand supply by the seawall and probably impacted by redistributed wave energy (off the wall) had all but disappeared (Bush, et al., (1996). In addition, the wall blocks the views of the sea. In 1995, however, the Corps of Engineers embarked on a massive effort to replenish the disappearing beaches along all 127 miles of New Jersey's coastline by pumping sand onto the beaches, a process known as beach nourishment. The project is estimated to cost about $60 million a mile, most of which is paid for by U.S. taxpayers. Sea Bright was one of the first recipients of sand--the Corps pumped half a million dump trucks worth of sand onto the beach at Sea Bright (Grunwald, 1999). Today, the town enjoys a relatively wide, albeit private, beach, although no one knows how long it will last.

Jetties and groins usually lead to erosion of beaches "downdrift" by starving such beaches of sand. A classic case is the New Jersey coast, where hundreds of groins jut out from the beach. Once a groin is built, it robs sand from adjacent, downdrift beaches, which must then build their own groin to capture whatever sand floats by or risk watching their beach erode. Eventually, every downdrift community along the coast must build a groin or lose their beach. The net effect is that every few hundred yards or so, a line of boulders extends from the beach virtually the entire length of the New Jersey shore. This is often referred to derisively as the "New Jerseyization" of the coast. To prevent this from happening, some states, such as North and South Carolina, prohibit the use of hardened structures such as groins or seawalls along the beach, with few exceptions (*Figure 6.4: Impact of Groins*).

Folly Beach and nearby Morris Island in South Carolina illustrate how jetties can cause beach erosion. In the late 1890s, the Corps of Engineers built jetties to stabilize the entrance to Charleston Harbor, eight miles to the north of Folly Beach. Since then, the beach has retreated some 800 feet landward. Before the jetties were constructed, sand moved naturally from north to south and from island to island, across the tidal delta at the entrance to the harbor. The jetties blocked the migration of sand and have led to the steady erosion of Folly Beach and Morris Island immediately to the north of Folly Island. The Morris Island lighthouse, built in the mid-1800s, once stood on Morris Island some 1,200 feet from the sea. It now sits stranded 400 feet out to shore, completely surrounded by water. The island literally migrated out from under the lighthouse (Pilkey and Dixon, 1996).

Flood control works

Designed to manage or reduce the damaging effects of flooding, structural flood control devices vary from relatively small projects such as the construction of retaining ponds to hold excess stormwater to the construction of large dams. *Dikes* and *levees* are elevated earthen works, often topped with concrete, that are used to protect against rising floodwaters. For example, a series of levees and locks has been constructed on Lake Pontchartrain in New Orleans to protect against hurricane flooding. Similarly, severe flooding caused by a hurricane in 1947 prompted the construction of enormous levees along Lake Okeechobee in Florida. Much of the Mississippi River is lined with earthen dikes to prevent flooding. Elsewhere, hundreds of miles of dikes line the banks of rivers and lakes throughout the United States. Generally, we never hear about them until they fail to hold back rising floodwaters. The examples described in Objective 6.5 below illustrate some of the key issues and limitations of dikes and levees.

Structural flood control works have long been a favorite of the Corps in addressing the risks posed by hurricane and coastal storms, as discussed in the next section.

6.3 Review the history and context of structural mitigation approaches

Through most of the last two centuries, the nation's approach to floodplain management focused on reducing flood impacts through structural means. Floodplain management meant flood control. The Mississippi basin in particular relied heavily on the construction of levees for flood control. Floodplains along the Mississippi River and its tributaries contain some of the most productive farmland in the country, and by the late 1800s, settlers had cleared and drained many wetlands within the Mississippi River Basin for agriculture.

<u>Federal Flood Control Efforts</u>

Federal involvement in flood control evolved incrementally, dating back to the mid-1800s, when Congress authorized the Corps of Engineers to study flood control alternatives for the lower Mississippi (Godschalk, et al., 1999). Established in 1779, the Corps focused initially on fortifying the coast against attack from the British. Its role gradually expanded to facilitating navigation on the nation's waterways, controlling floods and protecting wetlands. The Corps spent much of the 19th and 20th centuries building and deepening more than 140 ports and harbors, constructing the nation's 11,000-mile network of inland waterway navigation channels, 8,500 miles of levees and floodwalls, and more than 500 flood control dams (Stein, et al., 2000).

In the western part of the country, the Bureau of Reclamation, established in 1902, constructed dams on most major rivers—over 450 dams in all—for flood control and water supply. Included in its inventory are some of the largest dams in the country: Grand Coulee on the Columbia River and the Hoover Dam on the Colorado River. Federal involvement expanded following a series of flood control acts beginning in 1917 and expanded considerably in the 1930s, with some $11 billion expended for flood control works (Godschalk, et al., 1999), mostly in the Mississippi basin. In the southeast, the Tennessee Valley Authority built a system of 34 flood control dams plus another 29 for hydroelectric power. Florida criss-crossed the state with a series of flood control canals and dams that succeeded in reducing the incidence of flooding but knocked the entire Everglades ecosystem off balance.

Increasing costs, environmental opposition plus the spectacular failure of Teton Dam in 1976 brought the era of dam construction to a virtual halt. Today, although it continues to pursue flood control projects, often over opposition of fiscal conservatives and environmentalists, the Corps of Engineers is working to undue some of the damage wrought by earlier flood control projects. Most notably, the Corps is working to restore a segment of the Kissimmee River in Florida. In the 1960s, the Corps transformed a lazy, 98-mile river, which ran from Lake Kissimmee to Lake Okeechobee, into an efficient, 56-mile canal. As a result, the river no longer overran its banks and the adjacent marshes dried up. Wildlife disappeared. In 1992, Congress directed the Corps to restore a segment of the Kissimmee and its parched wetlands by diverting water back into the original river channel. The Corps spent over $30 million to take the meanders out of the river and it will cost over $400 million to put them back (Salvesen, 1994).

Midwest Flood of 1993
The shortcomings of a hazard mitigation strategy that relies on structural measures alone was made painfully obvious during the Midwest flood of 1993 (*Figure 6.5: Flood Region: 1992 Midwest Flood*). The flood burst through levees along many parts of the Mississippi and its tributaries, inundating farms, small towns and cities. Over 100,000 homes were damaged or destroyed by flooding. The flood caused an estimated $12 - $18 billion in damages, with agriculture accounting for over half of the losses. Flood response and recovery cost taxpayers an estimated $6 billion (Interagency Floodplain Management Review Committee. 1994). Flood control projects, however, helped spare large areas of St. Louis and Kansas City from the ravages of the flood. In St. Louis, the Mississippi River crested at 49.6 feet, almost 20 feet above flood state, yet that portion of the city protected by the large floodwall escaped inundation. The Corps estimated that flood control structures in place during the 1993 Midwest flood prevented $19.1 billion in damages. Of course, much of the development protected from flooding may never have been built if not for the Corps flood control projects *(Figure 6.6: Levee Failure)*.

In the aftermath of the 1993 Midwest flood, federal policy began to shift toward nonstructural measures, such as land use controls, buyouts and relocation. Congress enacted the *Hazard Mitigation and Relocation Assistance Act*, which set aside 15 percent of all disaster relief for relocation and other forms of mitigation. In addition, Congress set aside $375 million in relocation block grants. For the first time in the nation's history, most flood victims had a financially affordable choice between rebuilding and relocating to higher ground (Faber, 1996). Congress also created a *Mitigation Directorate* within FEMA. This marked a turning point in our nation's attitude toward natural hazards and signaled a commitment at the federal level to relying on mitigation as a means of reducing vulnerability. The Directorate initiates programs and studies to lessen the effects of natural and man-made disasters upon life and property. It also assists in the recovery from declared disasters by providing technical and financial assistance to State and local governments, small business and individual property owners (*Figure 6.7: Pros & Cons of Structural Approaches*).

An unprecedented number of people whose homes were flooded in 1993 chose to relocate rather than rebuild. The choice reflected both a change in local attitudes toward the river and changes in federal policy intended to minimize future losses. For many, the financial and emotional cost of rebuilding was too great. In Missouri alone, over 2,000 homes and businesses were relocated or acquired. More than half were in St. Charles County, one of the nation's most flood-prone communities (Faber, 1996).

6.4 Describe procedures for analyzing costs and benefits of structural projects

Throughout its long history of developing flood control projects, the federal government has sought, ostensibly, to ensure that the benefits of such projects outweigh the costs. For example, the *1936 Flood Control Act* declared that

> The Federal Government should improve or participate in the improvement of navigable waters or their tributaries, including watersheds thereof, for flood

> control purposes if the benefits to whomsoever they may accrue are in excess of the estimated costs, and if the lives and social security of people are otherwise adversely affected.

But what constitutes a benefit or a cost is subject to debate. Critics have called upon the Corps of Engineers, the federal agency primarily responsible for "improving" navigable waters and for flood control, to include cultural, historic, aesthetic and environmental values of floodplains in its cost-benefit analysis.

The Corps is responsible for the construction and maintenance of over 1,500 federal water resources projects in the United States. When considering proposed federal flood control projects, the Corps evaluates alternative approaches and recommends the one that will yield the greatest *net economic development*, consistent with protecting the Nation's environment. To measure a project's contribution to net economic development, the agency compares the net benefit of a proposed project with its likely costs.

Benefits include increased income of existing floodplain activities and the reduction or avoidance of flood damage due to a proposed flood control structure, including physical damage, income loss and emergency costs. That is, the Corps estimates the amount of flood damage that would occur with and without the proposed structure. This so-called "without-structure" condition is the baseline upon which the benefits of proposed alternatives are measured (Mays, 1996).

Costs include the cost of implementing, operating, maintaining, repairing, replacing and rehabilitating the proposed structure. In addition to meeting cost benefit analysis criteria, a proposed project must be consistent with protecting the nation's environment.

The random nature of flooding complicates the calculation of the estimated benefits of flood reduction. For example, a flood-control project that prevents flood damage one year may be insufficient to prevent flood damage in an extremely wet year and much larger than required in an extremely dry year. In calculating the annual expected flood damage, the Corps weighs the expected damage caused by each flood by the probability of occurrence to come up with an expected value of annual damage.

<u>Uncertainty</u>
Not surprisingly, there is a good deal of uncertainty in the calculations, including uncertainty about the extent, frequency and duration of future flooding, the cost of a project, and the expected benefits. In fact, some critics have charged that the Corps often presents overly rosy forecasts of economic benefits while underestimating expected costs. For example, a 2000 report prepared jointly by the National Wildlife Federation and Taxpayers for Common Sense claimed that guidelines used by the Corps are heavily biased toward large-scale construction solutions at the expense of smaller, less intrusive approaches. Other guidelines that mandate fiscal and environmental considerations are sometimes ignored by the Corps or overruled by Congress. Members of Congress often place pressure on the Corps to approve pet projects, even if the project does not meet the Corps cost/benefit criteria. "The extreme political pressure placed on the Corps to carry

out construction without sufficient scrutiny has led to the authorization of large number of marginal or unjustified projects" (Stein, et al., 2000).

Intrinsic Value of Floodplains

The assumption behind flood control works is that development in floodplains is in society's best interest. But floodplains can have environmental values that are incompatible with development (Burby, 2001). In the 1970s, environmentalists and fiscal conservatives began questioning the wisdom of flood control projects such as dams and levees that inundated wetlands and floodplains and impeded the flow of rivers, at great cost to the environment. Many urged Congress and the Corps to consider rivers as part of a larger watershed that includes forests, wetlands and floodplains. At the same time, the nation was beginning to rethink its historic disregard for wetlands as nuisances and discovered that wetlands and floodplains serve a number of vital functions, such as attenuating floods and providing areas for recreation or wildlife habitat.

Example: The Charles River Natural Valley Storage Project

The Charles River winds 80 miles from central Massachusetts to Boston Harbor. When Hurricane Diane struck in 1955, the existing dam at the mouth of the harbor proved inadequate to handle the volume of water generated by the storm. In its initial report in 1968, the Corps recommended construction of a new dam, which was completed in 1977, plus additional structural controls in the upper basin. In its 1972 final report, however, the Corps uncharacteristically recommended a strategy of relying on the extensive system of wetlands along the river as a means of reducing downstream flooding. The proposed flood control works would have cost an estimated $100 million. In comparison, the cost of acquiring 3,250 acres outright plus easements on an additional 4,680 acres was only about $10 million (Faber, 1996). In addition to flood control, the project, completed in 1984, provides much-needed open space and wildlife habitat adjacent to a major metropolitan area (*Figure 6.8: Charles River, Massachusetts*).

6.5 Discuss case studies of structural projects initiated by the Corps of Engineers and FEMA

The three cases below illustrate some of the key issues involved in the development of structural flood control devices such as dikes and levees. Grand Forks, North Dakota and Princeville, North Carolina both suffered heavy damage when rising floodwaters spilled over their levees, which for years had protected the towns. After heated debate, both towns decided to put their faith once again in levees, this time bigger and more expensive ones, as the primary means of protection against future flooding. In contrast, Soldiers Grove, Wisconsin took what was considered a radical approach three decades ago in opting to relocate its downtown to higher ground, rather than build a levee.

Grand Forks, North Dakota

The winter of 1997 was one of the worst in North Dakota's history. The state had endured eight blizzards that dumped a total of nearly 100 inches of snow. When spring finally arrived, melting snow swelled rivers throughout the state. By mid-April, melting snow had pushed the Red River over the levees in Grand Forks, North Dakota and East

Grand Forks, Minnesota, causing the worst flooding in decades. The water crested at 54.35 feet, heights not seen since 1895. Normal water flow rates are 780 cubic feet per second; floodwaters increased the flow to 140,000 cubic feet per second.

The flood damaged over 8,600 homes in Grand Forks. Ninety percent of all buildings were damaged. Adding insult to injury, 11 buildings in downtown Grand Forks were gutted by fire that broke out after the city had been evacuated. Flood damage was estimated at nearly $2 billion. In addition, over 5.4 million acres of farmland were flooded in North Dakota and Minnesota and over 123,000 cattle died as a result of the flood. Miraculously, no human lives were lost directly due to the flooding, in large part because most people were evacuated in advance of the flood.

In the aftermath of the flood, Grand Forks adopted a strategy that involved removing many of the homes along the river and building a larger, stronger dike. The city acquired and demolished or relocated over 400 homes damaged or destroyed by flooding. In addition, Grand Forks retreated a few blocks from the river by removing permanently downtown streets that stood closest to river. North Dakota and Minnesota are collaborating on a plan to build a greenway on both sides of the Red River in the areas that once contained houses or commercial buildings (*Figure 6.9: Grand Forks Greenway*).

Grand Forks considered several options for reducing its vulnerability to flooding, including building a new levee and the construction of a split flow-western diversion system for the river. After much discussion, the city selected to follow a levee-only option for flood protection. The diversion project had an extremely low cost-benefit ratio, which raised concerns that the federal government would not fund the project. But the issue was far from over. The Corps' plan called for building a new dike further back from the river from the location of the previous dike in order to anchor the new dike in more stable soils. The new alignment would have required the demolition of numerous homes. Heated debate ensued between the Corps and residents whose houses would be demolished to make way for the new dike. Ultimately, a compromise alignment for the dike was reached, one that would spare some homes, but still provide the stable foundation needed to anchor the dike.

<u>Princeville, NC</u>

On September 4, 1999, Hurricane Dennis swept through the Eastern North Carolina, dropping seven inches of rain. On September 16,th just twelve days later, Hurricane Floyd struck and brought another 20 inches of rain to the already saturated landscape. The Tar River flows through the small town of Princeville, which had been settled by freed slaves. Since the mid-1960s, the town had been protected from flooding by a dike along the river. But the heavy rains from Dennis and Floyd pushed the river to historic heights. The swollen river broke through the dike and swamped the entire town. The flooding moved houses and mobile homes off their foundations and into the middle of the streets. Many homes and other buildings in Princeville were completely submerged under the floodwaters.

All 2,100 residents of Princeville were evacuated. Floyd destroyed over half of Princeville's 800 homes, 33 businesses, and 3 churches. Many homes and apartments remained submerged under 12 to 15 feet of water for over a week. One year after the flood, less than half of Princeville's residents had been able to return to their homes.

Following Hurricane Floyd, the federal government declared 66 of North Carolina's 100 counties "major disaster" areas. Damage totals exceeded the $6 billion cost incurred by Hurricane Fran only 3 years before. In Eastern North Carolina, over 30,000 homes were damaged. Of those, 17,000 homes were considered uninhabitable and 8,000 were declared destroyed. Housing damage alone amounted to over $70 million. North Carolina farm and agricultural losses rose over $1 billion, with massive losses in livestock and crops.

As the waters receded, Princeville contemplated its future. The Corps proposed to buy out virtually all of Princeville's land and buildings—simply move residents to higher ground. In a controversial and emotional decision, city officials rejected the offer. Though some residents supported the buyout, city officials cited the importance of maintaining the heritage that Princeville represents as reason to stay in the threatened floodplain. To mitigate future floods, the city decided instead to ask the Corps to rebuild the dike rather than relocate residents. Princeville, a historic town settled by freed slaves, would not be moved.

In both Grand Forks and Princeville, the new dikes will provide greater protection against flooding than the previous dikes. Critics, however, assert that the cities may be setting themselves up for an even greater disaster in the future. The new dikes will facilitate development in the floodplain, which could lead to even greater damages when the next record-breaking flood strikes.

<u>Soldiers Grove, Wisconsin</u>
Located along the Kickapoo River between the Mississippi and Wisconsin Rivers in southwest Wisconsin, Soldiers Grove is a small village that had endured decades of repeated flooding. In the late 1960s, the Corps proposed to build a levee to protect the town from future flooding. The proposed levee would have cost an estimated $3.5 million, which was considerably more than the total assessed value (about $1 million) of all of the property in the floodplain. The town rejected the proposal.

In the mid-1970s, the town proposed an alternative plan: relocate the entire business district to higher ground. In 1978, the town was struck by the worst flood in its history. Following the flood, the town took the unusual step of refusing federal disaster assistance, which would have been used for reconstruction, and suggested that the money be used instead to move the town out of the floodplain. In short, the town wanted to work with the river rather than attempt to control it. The Corps eventually agreed and the entire business district was moved. The old business district had been in decline anyway since a highway bypass was built in the 1950s. The new business district was located along the bypass, which improved visibility for merchants. The entire district was built as a solar village: all of the buildings are heated by solar energy (*Figure 6.10: Soldiers Grove, Wisconsin, Before and After*).

In addition, several homes in flood-prone areas were raised above the 100-year floodplain, and the floodway was converted to a riverside park and recreation area. The relocation cost about $7 million dollars, compared to about $8 million for the proposed levee.

6.6 Discuss opportunities and problems with structural approaches from the point of view of community stakeholders during a structured discussion session

The instructor leads the class in a discussion about a town's proposal to build a levee to protect the town from flooding. The purpose of the discussion is to provide an opportunity for students to examine, from different viewpoints, the pros and cons of structural flood control measures and to develop alternatives, including nonstructural approaches, that may be more cost-effective.

Students will be asked to play the role of one of the stakeholders summarized below. The instructor may choose to assign more than one student to each role (e.g., three representatives from the environmental group or homeowners association). Following the discussion, the instructor will review some of the key factors that should be considered when developing a flood control strategy, such as economic and environmental impacts, cost, equity, and overall effectiveness—that is, whether the chosen approach will reduce the town's vulnerability to flooding over the long run.

The scenario

Riverside, a riverine community of 15,000 residents is considering applying to the Corps of Engineers for a levee to protect the downtown area. Concerns have been raised about the impact of a levee on riverfront neighborhoods and on downstream communities. The town is holding a public hearing on the issue. What arguments would you expect to hear from various stakeholders, including: downtown business interests, Chamber of Commerce, tax watch association, environmental organization, homeowners association, and mayor of downstream community. How would you advise the community to analyze the economic, social, and environmental costs and benefits of building a levee? If a levee was politically or economically infeasible, the town would likely apply to join the National Flood Insurance Program.

Stakeholders and their positions

<u>Downtown business owner</u> – The owner of a locally-owned camera shop would like the town to build the levees to protect against future flooding. If the downtown isn't protected, building owners will not invest in maintenance and restoration of their buildings and the area will slowly deteriorate. In fact, the camera shop owner has considered moving to a location on higher ground in the suburbs to avoid the risk of flooding.

<u>Chamber of Commerce</u> – The Chamber supports efforts to protect downtown businesses from flooding. A few years ago, a record-breaking flood inundated the downtown with nearly five feet of muddy water. Several businesses went bankrupt not only because of the extensive flood damage they suffered, but because they remained closed for at least a month while their buildings were cleaned and repaired. The levee, which benefits the entire community, would ensure that the town retains a strong downtown business district.

<u>Tax watch association</u> - A conservative group, the association's main objectives are to control government spending and reduce taxes. It is concerned about the cost to build and maintain the levee and whether the town would have to increase taxes to pay for it. The association questions whether it is the government's responsibility to protect against flooding and has argued that there are probably less expensive ways to protect the town.

<u>Environmental organization</u> – The organization, People Against Levees or PAL, is against the levee on the grounds that it will destroy what little remains of the wetlands along the stream. These wetlands provide wildlife habitat and are used extensively by birdwatchers. The members also claim that the wetlands provide natural flood control and would provide more effective, long-term protection against flooding than a levee. A more effective flood control strategy would be to move people away from the river. The group suggests that the city acquire or relocate the homes that are most vulnerable to flooding.

<u>Homeowners association</u> - Willow Run is a close-knit neighborhood of modest homes adjacent to the river. The neighborhood homeowners association is overwhelmingly in favor of the proposed levee. Residents have suffered through three floods in the last 10 years alone and probably could not afford to live through another. They claim that without a levee, their community would be extremely vulnerable to another flood. Unless the levee is built, the city risks losing one of the few areas where housing is still affordable. They do not want to move to another part of the city.

<u>Mayor of downstream community</u> – The mayor of Baytown, which lies downstream of Riverside, opposes the proposed levee on the grounds that it may exacerbate flooding in his town. By narrowing the river channel and cutting off the river from its floodplain, more water will be shunted downstream. As a result, even relatively small rain events could lead to flooding downstream. If Riverside builds a levee, Baytown would have to follow suit. The mayor has threatened to sue Riverside if the levee exacerbates flooding in Baytown.

<u>Local planner</u> – Favors strategy of strategic retreat from the river. The town could seek state and federal hazard mitigation funds to cover the cost of acquiring or relocating homes from the floodplain. In the meantime, the town could search for a nearby site (on higher ground) in which to locate new or relocated homes and it could give Willow Run residents first choice at purchasing the homes, thus allowing some residents to stay together. Eventually, the area along the river could be used to provide much-needed open space for the town.

Farmers/agricultural association – Favors construction of a levee to protect farmland from flooding. Opposes nonstructural measures that threaten continued farming of low-lying (flood-prone) lands. Also want to protect farmland so that it could be sold, sometime in the future, for development. They would only back nonstructural measures if farmers were bought out at market rate. Represented by agricultural extension agent.

State NFIP coordinator – Advocates that the town join the NFIP and qualify for reduced flood insurance rates by participating in the Community Rating System. The town could adopt floodplain zoning, designate a green space corridor along the river in its land use plan and use its capital improvement plan to steer growth away from the floodplain (e.g., by not providing or improving infrastructure to flood-prone areas).

Figure 6.1. Structural Approaches

Coastal

Parallel to Shore:

- ➢ Seawalls
- ➢ Bulkheads
- ➢ Revetments
- ➢ Breakwaters

Perpendicular to Shore

- ➢ Groins
- ➢ Jetties

Riverine

- ➢ Levees
- ➢ Dams
- ➢ Weirs

Figure 6.2. NonStructural Approaches

- Acquisition and Relocation

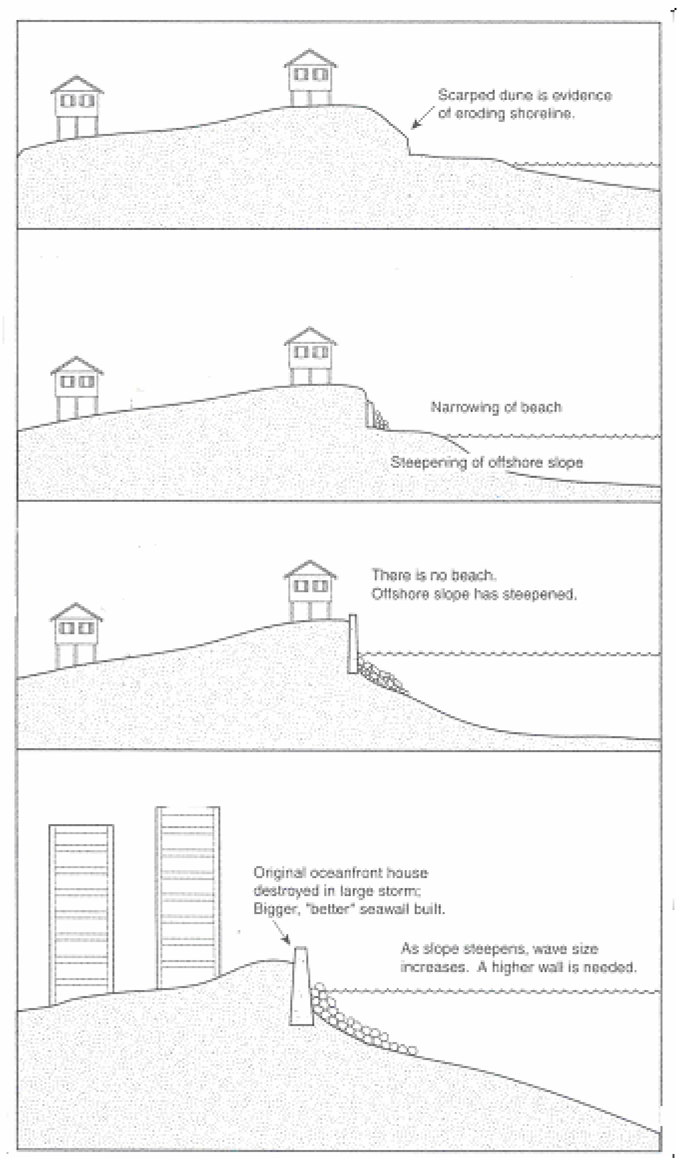
- Land Use Regulations
  - Zoning
  - Subdivision ordinances

- Building codes and construction standards (including elevation of homes)

- Insurance

- Beach nourishment

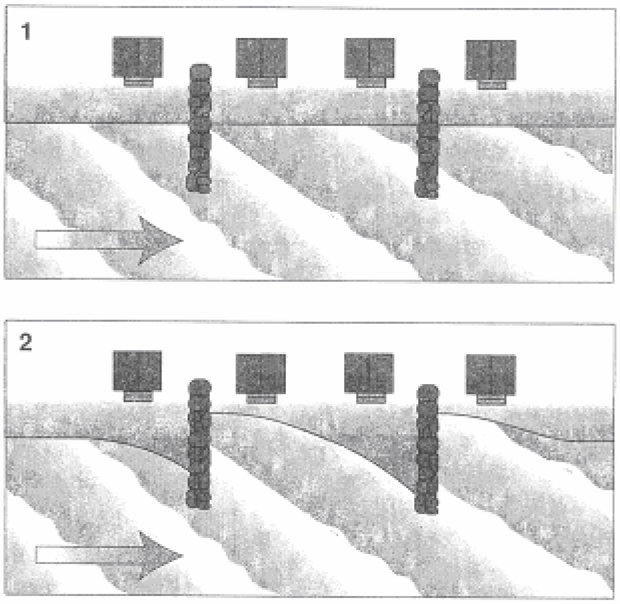
Figure 6.3: Saga of a Seawall



1) An eroding shoreline threatens buildings. 2) In response, homeowners build seawall. 3) Overtime, the wall's size is increased, and the beach has disappeared. 4) Fifty years later, the seawall is huge, the beach is gone, the shoreface has steepened, and the house is gone. Condominiums replace beach cottages, but no beach remains for visitors to enjoy.

Source: Adapted from Pilkey and Dixon, 1996:42

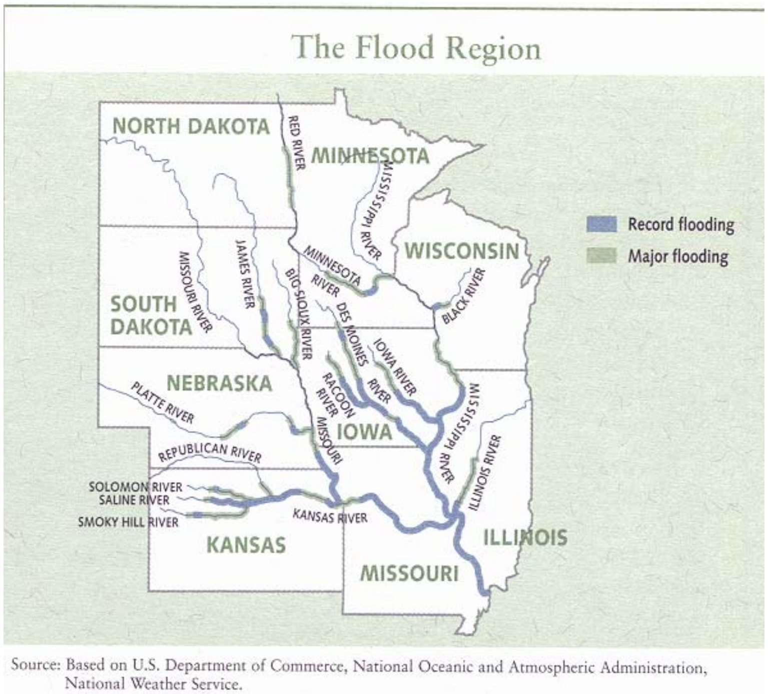
Figure 6.4. Impact of Groins



Groins trap sand moving in the littoral drift along the shore, helping some beachfront property owners, but robbing others of sand.

Source: adapted from Dean, 1999

Figure 6.5. Flood Region - 1993 Midwest Flood



Source: Faber, 1996, p.3

Figure 6.6. Levee Failure

Source: adapted from Faber, 1996, p. 6.

Figure 6.7.   Pros and Cons of Structural Approach

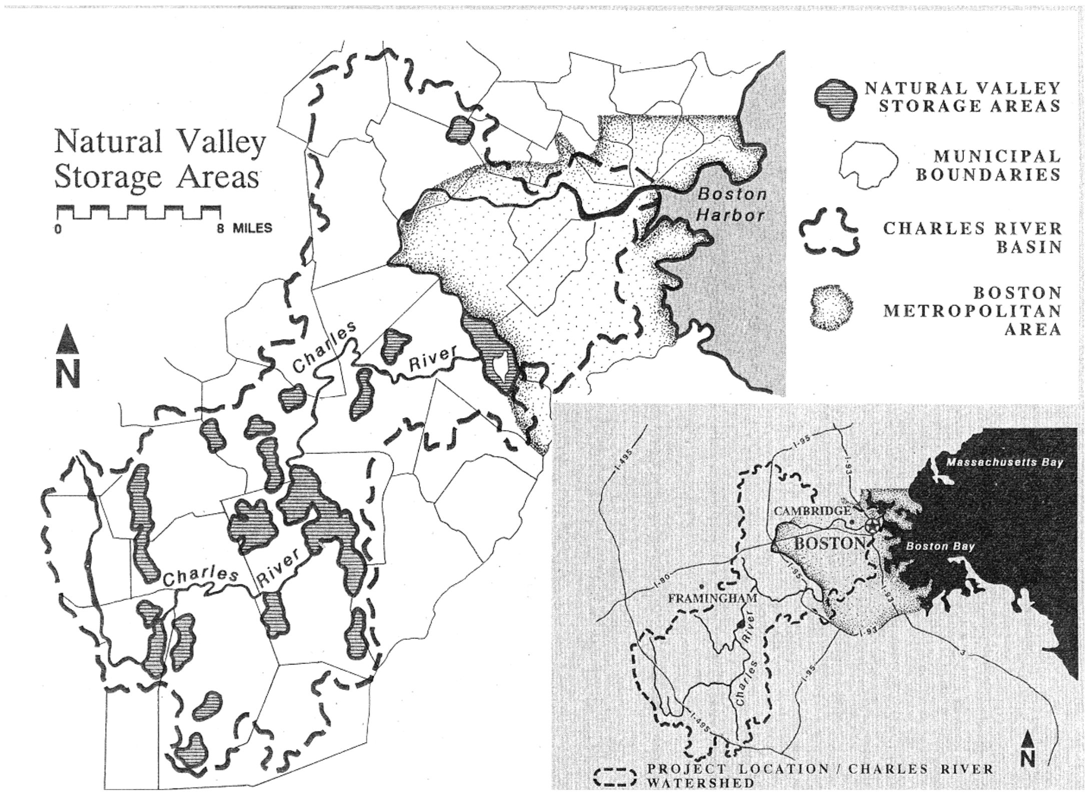
Pros

- Protects property
- Allows development of hazard areas (e.g., floodplain)
- Provides sense of security

Cons

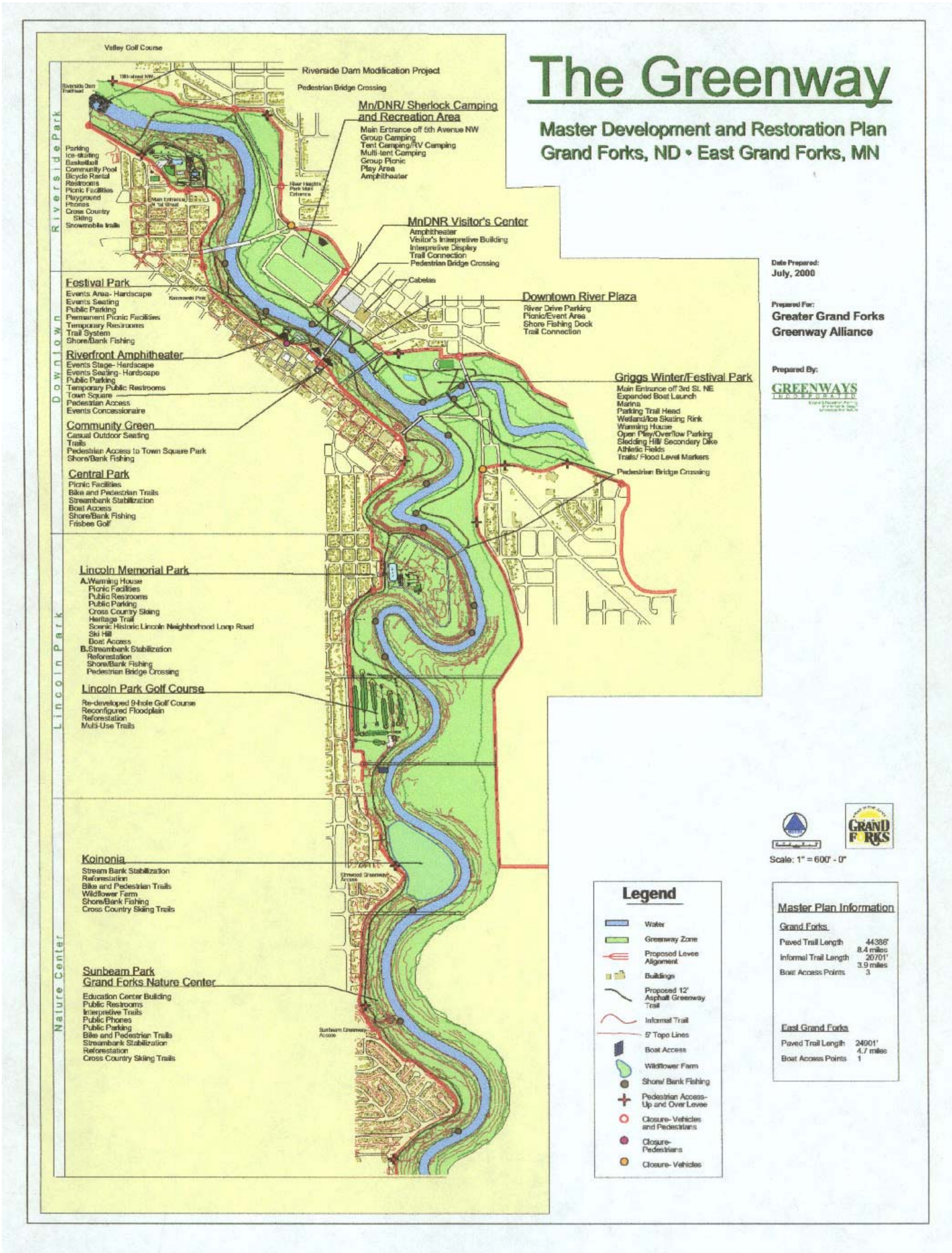
- Environmental impacts (loss of wetlands & floodplains)
- Costly
- Creates false sense of security, which may lead to greater damages in future
- Coastal: Accelerates erosion and may result in loss of beach
- Riverine: Exacerbates flooding downstream

Figure 6.8. Charles River, Massachusetts



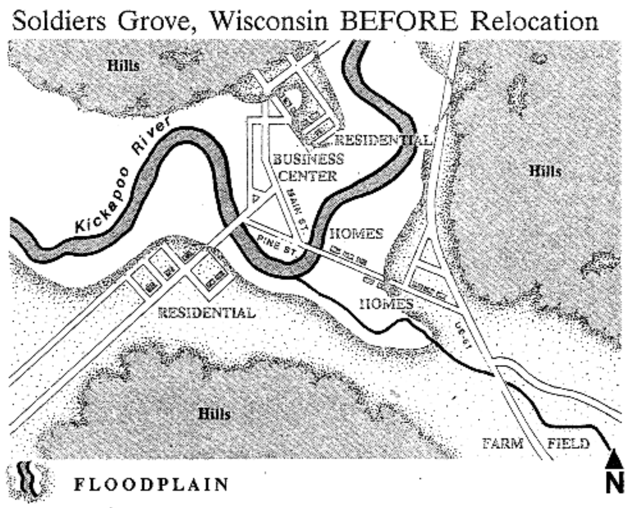
Source: U.S. Department of the Interior, 1991, p. 4.

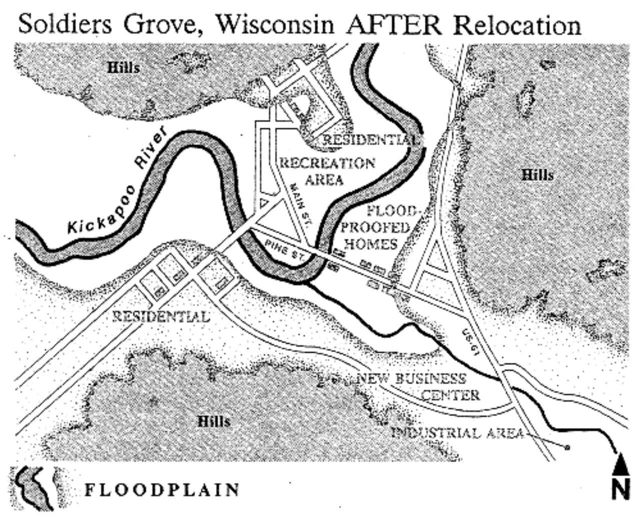
Figure 6.9 Grand Forks Greenway



Source: City of Grand Forks, ND

Figure 6.10. Soldiers Grove, Wisconsin, Before-After





Source: U.S. Department of the Interior, 1991 p. 28.

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