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LEARNING FROM THE MISSISSIPPI FLOOD OF 1993: IMPACTS, MANAGEMENT ISSUES, AND AREAS FOR RESEARCH

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Abstract. Throughout the Summer and Fall of 1993, the people throughout the world with access to the Cable News [television] Network (CNN) were shown scenes of the devastation brought on the Midwestern part of the United States by what became known as the "Great Mississippi Flood of 1993. Since the early days of the 20th century, the United States had labored to reduce the vulnerability of its people to flood damages and yet this flood had destroyed tens of thousands of homes, flooded hundreds of thousands of acres of prime farmland and had disrupted the economic and social fabric of several million people. National leaders as well as private citizens not only raised questions about how such flood damages occurred, but demanded to know what should be done to prevent recurrences of these damages. This paper discusses the 1993 flood in terms of its extent and its impacts on the region and its populace and describes and extracts from the conclusions reached by a White House based Interagency Floodplain Management Review Committee as to the causes of the flood, and management of the floodplain both in the Mississippi basin and nationwide. It concludes with a discussion of the Review Committee's recommendations (Appendix A) concerning research that should be conducted to reduce the potential for repetition of similar natural disasters.

1. THE FLOOD OF 1993

1.1 THE UPPER MISSISSIPPI RIVER BASIN

The Mississippi River and its tributaries have played a major role in the United States history. Their existence was critical to the growth of the Midwest region and fostered the development of major cities and a transportation network linking the region to the rest of the world. The floodplains of these rivers provided some of the most productive farmland in the country. They today offer diverse recreational opportunities and contain important ecological systems.

The Mississippi River basin stretches from the eastern slopes of the Rocky Mountains in Montana to the western reaches of New York State (Figure 1). It drains all or parts of 32 states and 2 Canadian provinces covering 1.25 million square miles or 41 percent of the contiguous

land area of the United States. The upper Mississippi River Basin begins at the confluence of the Ohio and Mississippi rivers and encompasses 714,00 square miles, over 57 percent of the total basin. From its source at Lake Itasca, Minnesota, the Mississippi River courses a distance of 1366 miles. Its principal tributary, the Missouri River runs for over 2466 miles and drains 529,00 square miles above its mouth near St. Louis, Missouri. While the upper Mississippi flow is essentially unregulated except for the minimal controls need to operate locks and dams for navigation, flow on the Missouri is controlled by six large dams on the upper section of the river.

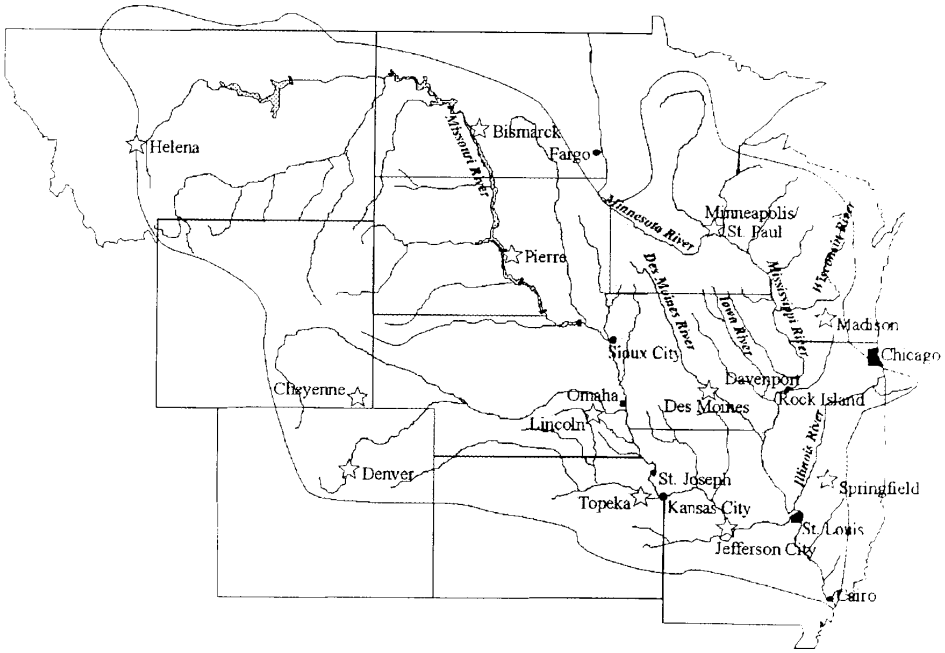

Figure 1. Upper Mississippi River Basin (source U.S. Department of Commerce, NOAA, National Weather Service)

Land use in the region is predominantly for agriculture although there are clusters of industry in and near major cities and adjacent to many smaller communities. The area's 208 million cropland acres represent nearly 32 percent of United States farm acreage. In the floodplain of the upper Mississippi and Missouri, the same development patterns prevail with over 60 percent of the land (7 million acres) devoted to agriculture. Most major population centers in the region (except for Chicago) are located along the Mississippi and Missouri Rivers and their tributaries. Flood vulnerable sections of major urban areas, for the most part, have been protected by levees and/or reductions in flood stages brought about by upstream impoundments.

1.2 A SIGNIFICANT HYDROMETEOROLOGICAL EVENT

The flood of 1993 was a hydrometeorological event without precedent in modern US history. The late summer and fall of 1992 were wetter than normal for the Midwest and coupled with cooler temperatures produced wet soil conditions. A normal winter rainfall was followed

by increasingly heavy precipitation throughout the spring, summer and into the early fall. Seasonal rainfall records were shattered in all nine states impacted by the flood. Summer rainfall amounts equaled those computed for storm frequencies having 75 to 300 year recurrence intervals. During the 14 month period from July 1992 to September 1993, rainfall amounts were significantly above average in all but 3 of the 14 months. In Iowa, the rainfall from January through September was the greatest amount, 44.5 inches, in 121 years of record. Evaporation was the lowest on record and cloud cover and soil moisture readings were the greatest in history.

Early in the summer, this intense and continuous rainfall, coupled with the wet soil conditions, began to fill every ditch and channel, and every stream and provided record flows on many reaches of the Missouri and Mississippi and their tributaries (Figure 2). By mid-July, river stages exceeded the 100-year discharge at 45 of nearly 500 gauging stations in the region and near 500 year elevations were seen along the Missouri from southeastern Nebraska to near St. Louis and from southern Iowa to above St. Louis on the Mississippi (the accuracy of the "assigned" flood recurrence interval remains in question. St. Louis has experienced floods similar to the 1993 event in 1900, 1909, 1927, and 1973. The need for better methods of computing the recurrence interval is addressed in the section on research.) The duration of the flood added to its impact. The high stages in July were followed in many reaches by late August and early September rises that approached the mid-summer levels. Considerable acreage was underwater for several months as continuing high stages prevented the drainage of floodplains.

2. FLOOD IMPACTS

2.1 GENERAL

The costs to the nation from the flood were extensive. Thirty-eight deaths were attributed directly to the flood and estimates of fiscal damages ranged from $12 billion to $16 billion. Agriculture accounted for over half of these damages. More than 100,000 homes were damaged. Flood response and recovery operations cost more than $6 billion. Many costs could not be quantified as impacts on businesses in and out of the basin were difficult to calculate and there was no accurate way to assess tax losses to governments. There also were impacts of the flood on the population's physical and mental well being, but these too were difficult to sum.

The Midwest Flood of 1993, one of the most costly flood events in US history, flooded over 6.6 million acres in the 419 counties in the upper Mississippi Basin. The damages experienced reflected the land-use and settlement patterns within and adjacent to the floodplain. The floodplains along the main stem Mississippi and Missouri rivers and the major tributaries that were inundated generally are used for agriculture and most areas are sparsely populated. Throughout most of the area, river towns are protected by urban levees, or they are located primarily on a bluff. Floodwaters thus inundated neighborhoods rather than entire communities. Residences, businesses, and industries did receive extensive damages in bottomland areas and along tributaries near Kansas City and St. Louis. Development in these urban areas, however, is largely in the uplands or protected by urban levees that provided flood protection. As a point of comparison, the Midwest Flood of 1993 impacted significantly fewer people than were impacted by the 1927 flood on the lower Mississippi River.

Over half of the damages sustained were agricultural damages to crops, livestock, fields, levees, farm buildings, and equipment. The remaining damages were primarily to residences,

businesses, public facilities, and transportation. Much of the agricultural damage occurred in upland areas as the result of wet fields and a short growing season rather than inundation by floodwaters. Similarly a portion of residential and business damages was caused by basement flooding due to high groundwater and sewer back-up in areas outside the floodplain.

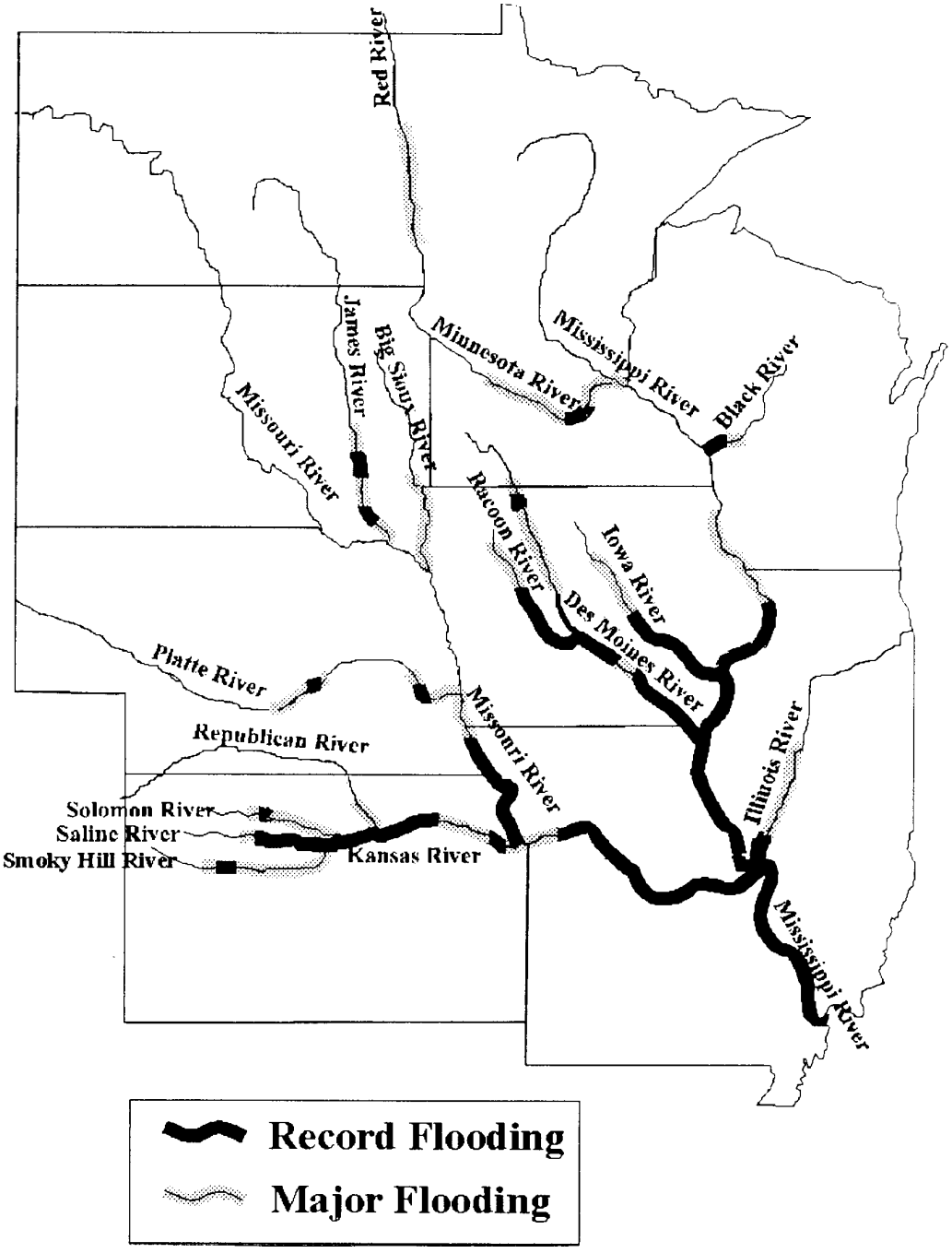

Figure 2. River Flood Levels (source U.S. Department of Commerce, NOAA, National Weather Service)

The National Weather Service (NWS) estimated damages for the Midwest flood at $15.7 billion based on information provided by its field offices. This estimate was based on totals by state, but did not include breakdowns of damage by type. In August 1993, *The New York Times* published an estimate of nearly $12 billion in damages based on information it obtained from state and federal officials. State and federal officials could not assess all damages until floodwaters receded, and the full extent of agricultural damages was not known until after the end of the growing season. Most of the affected states updated their damage estimates, and the total ranges from $12 to $13 billion.

The Interagency Floodplain Management Review Committee (hereafter referred to as the Review Committee) developed an estimate of flood damages using federal payments and making assumptions as to what percentage of damages those payments represent. This information indicates that total damages were more than $12 billion with as much as $4 to $5 billion of that total being agricultural damages in upland areas.

Damage estimates for the Midwest flood show marked inconsistencies. No federal agency was responsible for developing accurate assessments of flood damages, nor was funded to do so. The affected states and the Federal Emergency Management Agency (FEMA) conduct preliminary damage assessments to determine if a Presidential disaster declaration is warranted and to estimate the resources necessary for response and recovery. Once sufficient damage has been identified to justify a declaration and once FEMA has a general idea of how resources should be allocated, federal agencies have little incentive to expend resources updating preliminary assessments. Resources are instead focused on tracking and projecting expenditures. The NWS is not funded to estimate total damages but does so to support other missions. The US Army Corps of Engineers (USACE), which in the past estimated flood damages, is no longer funded to do so. (The Review Committee was concerned that decisions involving hundreds of millions of dollars often were made without systematic assessments of flood damages and without a clear understanding by decision makers of the nature and extent of the damages incurred).

2.2 AGRICULTURE

Agricultural damages from the Flood of 1993 had two primary causes: excessive moisture that prevented planting and reduced yields in upland and floodplain areas and actual flooding that destroyed crops and severely damaged many acres of fertile floodplain cropland. It is difficult to separate the factors that influenced crop production during the 1993 growing season in the 9-state region. They included rain, low temperatures, early frost, and floods. More than 70 percent of the crop disaster assistance payments, however, were made to counties in upland areas -- not in main stem river floodplains.

Agricultural damages directly attributed to actual flooding totaled more than $2.5 billion, with an estimated $1.4 billion in lost corn and soybean sales. Most of these losses were restricted to 1993 as the productive capacity of the land was unchanged. There were, however, damages to field fertility and farm infrastructure of at least $100 million.

Each state suffered different types of losses. For example, Missouri with 34 percent of its cropland (5.1 million acres) in the floodplain, had crop damages from flooding on 3.1 million acres causing $247 million in lost sales (Cassidy and Rickert, 1994). In Illinois, only 3 percent of the state's corn and soybean acreage (312,000 and 276,000 acres, respectively) were lost to flooding with a loss in sales of $153.4 million (Bhowmik, 1993). Minnesota farmers lost $500

million in crop sales, but most of the damage was caused by wet conditions rather than riverine flooding (Taff and Maki, 1993). Damage from scour and deposition affected 455,000 acres on the Missouri River floodplain representing 20 percent of the flooded cropland along the Missouri and Mississippi rivers. Drainage ditches were filled with sediments, and other agricultural infrastructure was destroyed. Almost 60,000 acres had sand deposition more than 24 inches thick and reclamation costs to restore fertility to damaged cropland were estimated at $190/acre. If cropland restoration required removal of sand, it cost approximately $3,200 to remove each acre-foot of sand. Over $10 million was required to remove sediment and debris from ditches (US Department of Agriculture, 1993).

Secondary impacts of agricultural losses to a local economy vary substantially with the dependence of that economy on the agricultural sector. Immediate losses are due to lost sales and unemployment. In the long run, the assessed value of land that sustained long-term damage may be reduced which will affect the property tax base of affected communities.

Another secondary effect was a reduction in crop-support payments since crop prices adjusted to the reduced production caused by wet weather in the Midwest and drought in the Southeast in 1993. This loss to farmers was a gain for taxpayers since subsidies represent transfer payments. For corn, these deficiency payments were reduced by more than $2.6 billion (US Department of Agriculture, 1993). These price effects and subsequent reduction in deficiency payments were temporary, as the 1994 crop supply returned to past levels.

Wet soil conditions and inundation in upland areas caused the majority of 1993 agricultural damages in the Midwest. Damage to inundated cropland in the floodplain was significant with almost complete crop losses behind failed levees. Areas affected by severe erosion and deposition may suffer long-term loss of productivity**.**

2.3 RESIDENCES AND BUSINESSES

Estimates vary on the number of homes flooded and families impacted by the Midwest flood. Surveys made by Red Cross workers immediately after the floods identified more than 55,000 flooded residences (American Red Cross 1993). FEMA subsequently verified these damages with Red Cross chapters and developed an updated estimate of 70,545 residences (Shepard, 1994). The *New York Times* (August 10, 1993), estimated that more than 84,000 residences were damaged. By April 1994, the federal government had received 167,224 registrations for individual assistance and 112,042 applications for the Disaster Housing Program. Within this latter group, over 90,000 applications were approved. The Disaster Housing Program data indicated that more than 100,000 residences were flooded (US FEMA, 1994).

Businesses sustained significant physical damages particularly in urban areas such as St. Louis County and the Kansas City areas of Missouri. Much of this damage occurred behind levees that failed or were overtopped. The 996 National Flood Insurance Program (NFIP) claims payments made to small businesses and the 4,667 Small Business Administration (SBA) loans for damages to businesses indicated that in excess of 5,000 individual businesses were damaged (US FEMA, FIA, 1994). No overall damage estimates for businesses were available, but as a measure of this damage, SBA loans to businesses, exceeded $334 million for physical damage and economic injury (Kulik, 1994). Add to these loans NFIP flood insurance payments for small businesses and other non-residential buildings that exceeded $94 million, and the total exceeds $431 million (US FEMA, 1994). In addition to physical damage to buildings and their contents,

lost profits and wages from businesses closed by the flood had local and regional impacts. For example, an American Cyanamid Plant near Hannibal, Missouri was protected by its own levee and not damaged by floodwaters, but the plant was shut down for nearly three months because its access road was inundated when an agricultural levee failed.

2.4 TRANSPORTATION SYSTEMS

Rivers and river valleys historically have been major transportation routes, particularly in the area impacted by the 1993 flood. In the Midwest, transcontinental railroads, interstate highways, and other road systems either follow river valleys or cross them. As a result, physical damages to transportation systems created a significant percentage of total flood damages. In addition to direct damages, indirect costs accrued when transportation routes were inundated by floodwaters, and traffic was halted or detoured.

A major portion of flood damages to public facilities in 1993 involved roads and bridges. These damages ranged from blown culverts and wash-outs on rural roads and city streets to loss of bridges and damages to interstate highways inundated by floodwaters. The repair of flood-damaged roads and bridges generally is funded through the FEMA Public Assistance Program or the Department of Transportation. Funds expended by those agencies when added to the state/local cost share for public assistance indicated that total physical damages to roads and bridges exceeded $250 million (US FEMA, 1994).

Road and bridge flooding caused indirect losses related to increased transportation costs. In extreme cases, detours of 100 miles were required to travel between adjoining communities that had been connected by a bridge. Often bridges were elevated high above the river to allow for navigation or to minimize hydraulic impacts of floods, but bridge approaches built at or near the natural elevation of the floodplain were inundated by floodwaters. Even though the bridge was undamaged and the approach damage was minimal, the economic impacts on the communities served by the bridge could be extreme, particularly for a long duration flood such as occurred in 1993. For example, Keokuk, Iowa, was cut off from market areas in Illinois and Missouri for several weeks when the approaches to bridges over the Mississippi and Des Moines rivers were inundated. This resulted in serious economic impacts on local businesses. Flooding of the approaches to the bridge over the Mississippi River at Quincy, Illinois for 73 days resulted in an estimated $30 million in lost business to Quincy merchants (Bhowmik, 1993). In addition, many people who lived in Missouri and could not commute to work in Illinois were temporarily unemployed. Ferries were eventually established to address part of this problem. The full magnitude of these losses was reflected in over 36,000 claims approved for a total of $92 million in Disaster Unemployment Assistance.

Historically railroads were built in floodplains and river valleys to minimize construction and fuel costs. Main lines continue to parallel both the Missouri and Mississippi rivers. Although generally tracks are elevated on embankments above the elevation of most floods or are located behind levees, they remain subject to major flood events. In 1993 over 800 miles of track were flooded and several main lines were inundated for varying periods of time, but most trains were routed around flooded areas. The Association of American Railroads estimated that railroad damages totaled $182 million, including $131 million in physical damages to tracks, bridges, signals, communication lines, switches, locomotives, rolling stock, and buildings. Additional costs of $51 million resulted from detouring trains around sections of flooded track (Harper, 1993). Repair costs were generally borne by the railroads themselves although $21

million was distributed to railroads through a supplemental congressional appropriation, 'Local Rail Freight Assistance.'

Airports often are located in floodplains because of the flat terrain and close proximity to urban areas. The Federal Aviation Administration (FAA) identified 33 airports with varying degrees of flood damage and repair costs exceeded $5.4 million. The airports ranged in size from the Spirit of St. Louis Airport in St. Louis County, Missouri, to airports that were little more than grass landing strips with a few hangars for private aviation. Most of the flooded airports were in Missouri (16) and Iowa (12). The Spirit of St. Louis Airport, an alternate for Lambert-St. Louis Airport, sustained $1.7 million in damages when a 100-year local levee failed. Other major airports that were flooded include those at Creve Couer and Jefferson City and the Kansas City Downtown Airport. Several smaller airports went out of business (Trilling, 1994).

2.5 NAVIGATION

Most of the main stem rivers were closed to barge traffic from July 11 until August 15, 1993, and severe limitations on barge traffic continued through September, October, and November. The Maritime Administration estimated that losses of revenue to the navigation industry were $300 million per month. More than $165 million were lost in Illinois alone. Regional impacts on jobs from barge and port disruptions were not quantified but were estimated to be greatest in Illinois (US Department of Transportation, 1993).

2.6 PUBLIC FACILITIES

The Midwest flood caused extensive damages to water and wastewater treatment plants and other public facilities. Damages to utilities, including water and wastewater treatment facilities and stormsewer systems, exceeded $85 million. Water treatment plants often are located in floodplains to be near well fields or the surface water that supplies the system. In addition, water supply lines must cross floodplains to serve floodplain residents. The EPA identified 200 municipal water systems impacted to some degree by the flood. The most prominent example was the Des Moines Water Works that serves the City of Des Moines and adjoining communities. The plant was flooded and remained out of operation for 12 days and water from it was not safe to drink for another seven days. In addition to physical damages of $12 million, significant impacts were felt in the service area. Businesses and government offices closed because of lack of fire protection, and bottled water and portable toilets had to be provided for residents. The economic impact of the shutdown exceeded the cost of repair of the physical damage.

Wastewater treatment plants also tend to be located in floodplains, which are generally the lowest point in a community and offer the advantage of gravity flow. Furthermore the effluent from these plants is discharged into major rivers or streams. The impact of flooding ranges from temporary plant shutdown and the discharge of raw sewage into the river during the flood to physical damage that results in extended plant shutdowns and continued discharges of raw sewage or partially treated effluent until such time as the plant can be repaired. A total of 388 wastewater facilities were impacted by the flood (Knight, 1993).

Damages to public buildings exceeded $27 million. Water control facilities had more than $20 million in damages, and facilities such as parks and other recreation facilities recorded

more than $22 million. These estimates were based on FEMA projections of infrastructure spending that included a 10-percent local cost share.

2.7 NON-QUANTIFIABLE COSTS

The EPA determined that 59 Superfund sites experienced flooding; however, impacts to the sites were minimal and corrective measures were completed on sites requiring them. In addition, 73 solid waste treatment, storage, and disposal sites were flooded. Large propane tanks that were dislodged floated downriver and created the potential for massive explosions. Besides the large propane tanks, states collected over 18,000 orphaned drums -- each with a potential hazardous or toxic substance -- and a large amount of household hazardous wastes (US EPA, 1994). Daily loads of agricultural chemicals (herbicides and nitrates) transported by the Mississippi River were large relative to previous years; record flooding did not dilute the concentrations of herbicides. Concentrations of two herbicides (atrazine and cyanazine) in some samples from the Mississippi River exceeded health-based limits for drinking water. (Goolsby and Battaglin, 1993). The cumulative impact of any flood-related releases of hazardous materials, including pesticides, herbicides, and other toxic materials has not been yet established.

The effects of flooding on groundwater hydrology and groundwater quality also have yet to be determined. In response to concerns regarding the safety of private wells, the Administration established a well-water contamination survey in coordination with the nine flood states (Young, 1994). The EPA conducted floodwater quality sampling around major metropolitan areas on the Missouri River. In some cases, drinking water standards were exceeded, but the majority of the readings posed no health risk. Results from sampling of treated drinking water revealed three locations where maximum contaminant levels were exceeded although results from a single sample did not indicate a problem (US EPA, 1993). The US Geological Survey (USGS) and the National Oceanic and Atmospheric Administration (NOAA) did not find significant changes in water chemistry since the 1993 flood (Goolsby and Battaglin, 1993).

Impacts of the flooding on the distribution of contaminated river sediments are also unknown. Studies are underway to determine sediment chemistry and characterize sediment deposition patterns in rivers and streams (US EPA, 1993).

Effects of the flood on public and mental health are largely anecdotal. Some communities noted increases in spousal and child abuse and numbers of calls for police response. Mental health effects of community and individual buyout/relocation are poorly understood. Several studies are underway to assess the human response to the 1993 flood and to evaluate the factors that strain the ability of families to function adaptively to the event. Experience with other floods indicates that outbreaks of Equine, Western, and St. Louis encephalitis can be expected two years after a flooding event (due to the lag time in amplification of disease vectors). The length of time between the flood event and the appearance of disease adds to the problem of attributing costs (Young, 1994).

The flood took its toll on historic and cultural resources in the area. Historic homes in Grafton, Illinois and Ste. Genevieve, Missouri and a church in Portage des Sioux were damaged. A cemetery in Hardin, Missouri was inundated which disinterred over 500 bodies. There were several American Indian tribes effected by the Flood of 1993. The SAC and Fox of the Mississippi in Iowa (Mesquakie) lost 10 homes and the ceremonial area of their Pow-wow grounds. The Kickapoo Tribe in Kansas had damages to their crops, bridges, roads, and water

system (Wilson, 1994). Frequent rains saturated Indian lands in the prairie pothole area. Local lakes flooded homes on the shore and contaminated drinking water wells. Well and lake water continue to be monitored for pesticides, animal wastes, and other pollutants potentially carried by runoff to the upland lakes (Oliver, 1994).

Field investigations by state and federal forestry staff in Mississippi River navigation pools 25 and 26 revealed that all hackberry and sugarberry and a large percentage of sycamore were dead or dying. Similar effects occurred elsewhere in the Basin's floodplain where flood duration coincided with the entire growing season. Hackberry and sugarberry are important mast-producing trees, and mature sycamore is frequently selected by species of colonial nesting birds (US Army Corps of Engineers (1994). The full effects on forest canopy and subcanopy structure will not be known for many years to come.

3. MANAGEMENT OF THE FLOODPLAIN

3.1 BACKGROUND

Since passage of the Flood Control Act of 1936, the US federal government has dominated the nation's flood damage reduction efforts and, as a result, the nation's floodplain management activity. Structural programs were deemed important and were also the principal sources of funds for any efforts to stem the rising tide of flood losses. In recent years, the federal government has begun to support nonstructural approaches. Many states, tribes, and local governments developed and carried out floodplain management efforts that both reduced flood damages and enhanced the natural functions of floodplains. There are more than 8,000 miles of levees in the Upper Mississippi Basin. Approximately half were constructed by the federal government or were locally constructed using federal standards. The levee system in the Upper Mississippi Basin is a loose amalgam of federal store and locally constructed levees. In carrying out these programs, however, they were hampered by uncoordinated and conflicting federal programs, policies, regulations and guidelines that have hindered efficient floodplain management. Some state and local governments have not been as active in floodplain management. With the federal government assuming the dominant role and funding most ecosystem restoration, flood damage reduction, and flood recovery activities, the incentive has been limited for many state, tribal and local governments, businesses, and private citizens to share responsibility for making wise decisions concerning floodplain activity.

3.2 EXISTING SYSTEMS

Federal Flood damage reduction projects and floodplain management programs, where implemented, worked essentially as designed and significantly reduced the damages to population centers, agriculture, and industry. Reservoirs and levees built by the US Army Corps of Engineers (USACE), prevented more than $19 billion in potential damages. Large areas of Kansas City and St. Louis were spared the ravages of the flood, although several suburbs suffered heavy damages. Watershed projects built by the Soil Conservation Service saved an estimated additional $400 million. Land use controls, required by the National Flood Insurance Program (NFIP) and state floodplain management programs, also reduced the number of structures at risk throughout the basin.

3.3 PROBLEM AREAS

3.3.1 Division of Responsibilities. The division of responsibilities for floodplain management activities among and between federal, state, tribal, and local governments is not clearly defined. Within the federal system, water resources activities in general and floodplain management in particular lacks coordination. Management of the nation's water resources is provided by several federal agencies. Yet water resource issues are inextricably linked and accomplishment of agency mandates requires coordination and collaboration among agencies. The National Flood Insurance Act of 1968 required reports to Congress analyzing the implementation of current programs and recommending actions needed to achieve a unified program of planning and action at all levels of government to reduce flood losses and losses of floodplain natural values. Despite these *Unified National Program for Floodplain Management* reports, the United States, in practice, has no unified national program for floodplain management.

State and local governments have little fiscal stake in floodplain management; without this stake, few incentives exist for them to be fully involved in floodplain management. State governments must assist local governments in dealing with federal programs but, in many cases, do not become involved in federal-local activities.

In 1977 with issuance of Executive Order (EO) 11988, Floodplain Management, President Carter raised federal agency attention to issues of floodplain use. It was apparent following the 1993 flood that some federal agencies either were unaware of or misunderstood the requirements of the EO and either built or supported building in floodplains. Under the EO, federal agencies must demonstrate that no practicable alternative site exists outside of the floodplain, and if no alternative exists, take steps to minimize direct and indirect impacts of the proposed action and to restore and preserve the floodplain.

During Review Committee visits to the Midwest and discussions with the FEMA, USACE, and state floodplain managers revealed several examples of apparent non-compliance by federal agencies with the EO. While the responsible agencies no doubt believed they had complied with the EO, these developments point out some of the deficiencies with the EO. Among the most notable examples were a low-income housing project funded by HUD and a federally funded state prison within floodplains, and a proposed construction of a federal weather station behind an uncertified levee.

3.3.2 Levees. Levees serve as a means of minimizing flood vulnerability. Of the approximately 8,000 miles of levees in the upper Mississippi River Basin, roughly half were constructed by the federal government or meet federal standards and thus received support from the federal government following the flood. The other half were locally constructed with little control over their location or construction standards. Many locally constructed levees breached and/or overtopped and frequently, these events resulted in considerable damage to the land behind the levees through scour and deposition.

Following the flood, five different federal agencies engaged in the repair of federal and non-federal levees damaged by the 1993 flood. These agencies were involved in funding, design, construction, or a combination of the three. The water resources design and construction agencies, the USACE and the Soil Conservation Service (SCS) were joined in the levee repair and construction business by the FEMA, The Economic development Administration (EDA), and the Department of Housing and Urban Development (HUD), through their public assistance and grant programs. Normally only the USACE and the SCS construct levees as part of projects

authorized by Congress, although in recent years, SCS levee construction has significantly declined.

These agencies did not use the same engineering standards or methods of economic analysis in carrying out their programs. Some of the differences rest with the purposes of the programs and the varying nature of the levees. Nevertheless these differences cause confusion among those dealing with the multiple programs. The cost to the nation of this multi-agency approach, measured in dollars or social and environmental impacts was and remains large.

Federal and state oversight over non-federally constructed levees was and remains diffuse. Several states regulated construction in floodplains, but many did not. The situation was further exacerbated by the potential for future flow increases that could occur if development continued upstream and by the uncertainty about changes that may occur in long term weather patterns. Few states controlled either the decision about where levees are placed relative to the river channel or whether a particular levee should be protected from overtopping (floodfought) during a flood, although such actions can have hydraulic and environmental consequences elsewhere. Some states had little or no involvement in the processes associated with federal levee programs since federal agencies generally dealt directly with the local organizations responsible for levee operation and maintenance.

3.3.3 Flood Insurance. The National Flood Insurance Program (NFIP) was created by Congress in 1968 in response to mounting flood losses and escalating costs to the general taxpayer for disaster relief in the belief that flood insurance is preferable to disaster assistance. To encourage participation in the NFIP by communities and purchase of flood insurance by individuals, the federal government subsidizes the premiums for buildings constructed prior to the issuance of a FEMA Flood Insurance Rate Map (FIRM). This subsidy also recognizes that many floodplain buildings were built or purchased without knowledge of the flood risk. New construction (post-FIRM) is charged an actuarial premium that reflects the property's risk of flooding. Currently 59 percent of NFIP policyholders pay a full actuarial rate and 41 percent are subsidized. If the NFIP is to be successful in indemnifying property owners from flood losses and reducing federal expenditures for disaster assistance, a high percentage of property owners must purchase and maintain flood insurance coverage. The program depends on the mandatory flood insurance purchase requirement contained in the Flood Disaster Protection Act of 1973 and voluntary purchase by other property owners at risk. The 1973 Act requires the purchase of flood insurance by property owners who receive federal grants or loans, or loans from a federally supervised, regulated, or insured lender for the acquisition, construction, or improvement of structures located in identified special flood hazard areas (the 100-year floodplain). In the 9-state region affected by the 1993 flood, only about 20 percent of structures in the floodplain carried flood insurance, a rate well below optimal levels.

The NFIP has not achieved the public participation needed to reach its objectives. This situation is evidenced by the assistance provided to individuals and businesses during the Midwest flood. Although policyholders filed 16,167 flood insurance claims, the FEMA approved 89,734 applications for the Disaster Housing Program and 38,423 applications for Individual and Family Grants. In addition, the Small Business Administration (SBA) approved 20,285 loans for individuals and businesses. Many of these applications or loan approvals were for persons outside of identified flood hazard areas or from renters who do not normally purchase flood insurance. Others, including many of those who obtained SBA loans, should have had flood insurance either because it was required or because they were at risk. Some of

those who obtained SBA loans may have had flood insurance, but their coverage may not have been sufficient to cover their losses.

Estimates of those covered by flood insurance nationwide range from 20 to 30 percent of the insurable buildings in identified flood hazard areas. Initial estimates in the Midwest flood area ranged from below 10 percent up to 20 percent. None of the estimates are authoritative, since no nationwide inventory of floodprone structures exists. The Review Committee obtained reliable structure counts for a number of Midwest communities. Sources of these data included inventories conducted by state and federal agencies, data from community geographic information systems, data submitted by communities participating in the NFIP Community Rating System, and counts obtained by Review Committee members on visits to Midwest communities. Market penetration (percentage of those eligible who actually purchased insurance) in these communities ranged from less than 5 percent to more than 50 percent. The Review Committee believed that market penetration in small rural communities was probably less than 10 percent. For most medium to large communities, market penetration appeared to be in the 20 to 30 percent range. For a few large communities with middle-income floodplain populations and a high degree of flood hazard awareness among community officials, lenders, and property owners, market penetration exceeded 30 percent and, in one instance, 50 percent.

A perception persists that disaster assistance compensates homeowners as fully as flood insurance coverage. This may or may not be true depending on the value of the property affected and the income of the owner. A particular concern expressed by communities and others after the Midwest flood was that disaster victims, particularly those with lower incomes, who obtained disaster assistance from the Individual and Family Grant Program, the Disaster Housing Program, the Red Cross, and other programs ended up as well off as those who purchased flood insurance and received payment for claims. Generous disaster assistance creates negative incentives for the purchase of flood insurance.

3.3.4 Planning Tools. The principal federal water resources planning document, *Principles and Guidelines* (US Water Resources Council), is outdated and does not reflect a balance among the economic, social, and environmental goals of the nation. This lack of balance is exacerbated by a present inability to quantify, in monetary terms, some environmental and social impacts. As a result, these impacts are frequently understated or omitted. Many critics of *Principles and Guidelines* see it as biased against nonstructural approaches and the reason the federal government supports more structural than non-structural projects.

3.3.5 Environmental Programs. During the 1993 flood, environmental easement and land acquisition programs were tools in assisting recovery and in removing people from long-term flood vulnerability. In addition to meeting the needs of disaster relief victims, these programs were effective in achieving the nation's environmental goals. Environmental enhancement and mitigation programs essential to ecosystem management are often part of federal development projects. In the past, though, such programs were delayed, underfunded, or not funded at all. Had they been implemented before the 1993 flood, these programs would have restored natural lands and provided a measure of flood protection through reduced runoff and increased floodwater storage. Environmental mitigation programs also have tended to be site-specific rather than focusing on broader ecosystem goals. Federal programs designed to protect and enhance the floodplain and watershed environment are not as effective as they should be. They

are competitive, lack support, flexibility and funding, and are not well coordinated. As a result, progress in improving the quality of riverine environment is slow.

3.3.6 Disaster Preparedness and Response. At the time of the 1993 flood federal pre-disaster, response, recovery and mitigation programs needed streamlining. The nation clearly recognized the aggressive and caring response of the government to the needs of flood victims, but coordination problems developed among federal and state agencies. A new program supporting buyouts of floodprone homes and damaged lands was very successful and by mid-1995, over 8200 families had been relocated from floodplain areas and over 100,000 acres of marginal farm land acquired.

3.3.7 Upper Mississippi Basin System. Up to the present, there has been no coordinated strategy for effective management of the water resources of the upper Mississippi River Basin. Responsibility for integrated navigation, flood damage reduction and ecosystem management has been and remains divided among several federal programs.

The current flood damage reduction system in the upper Mississippi River Basin represents a loose aggregation of federal, local, and individual levees and reservoirs. This aggregation does not ensure the desired reduction in the vulnerability of floodplain activities to damages. Many levees are poorly sited and likely will fail again in the future. Without change in current federal programs, some of these levees will remain eligible for post-disaster support and will be repaired again after the next flood. Current federal rules essentially require, the federal government to repair these levees each time they fail.

3.3.8 Science and Technology. At the time of the 1993 flood, the nation was not using science and technology to full advantage in gathering and disseminating critical water resources management information. Opportunities exist to provide information needed to better plan the use of the floodplain and to operate during crisis conditions.

3.4 RECOMMENDATIONS

The recommendations of the Review Committee to the White House are summarized in Appendix A.

4. AREAS FOR RESEARCH

The 1993 flood not only presented the United States with a significant hydrometeorological event and the disastrous consequences of the flood waters, but it was also sounded a clarion call for more attention to research in areas affecting floodplain and river management and the impacts of flooding. The following paragraphs highlight areas where the Review Committee determined that research is needed.

- DATA COLLECTION. The United States Government's National Performance Review (NPR) contains recommendations regarding the use of information technology to create a government that works better and costs less. The NPR advocates creation of a national spatial data infrastructure that would establish standards for data collection and cataloging

and create a clearinghouse for finding, accessing, and sharing spatial data, in addition to addressing related issues. As indicated in the NPR report, "Data collection is duplicated at the federal, state, local, and private levels for different purposes. Moreover different entities are often unaware that another party have already acquired much needed data. Even when specific spatial data are known to exist, non-standardized collection procedures and lack of easy access often restrict their use (US National Performance Review, 1993).

The most difficult task for the Review Committee was compiling useful data regarding the upper Mississippi River Basin. Basic information such as the amount of damages from the 1993 floods and the amount of expenditures related to disaster response and recovery were not readily available, nor easily obtainable. Data assembled from a variety of sources were difficult to use because they were neither spatially referenced nor were they in compatible formats or structures. Precise answers to many questions were difficult, if not impossible, to obtain. For example: How many structures are in 100-year floodplains along the Mississippi and Missouri rivers? How many structures did the flood affect? Where were levees located and what level of protection did they provide? How many people applied for assistance in a given county or community? Where is critical infrastructure located with respect to the floodplains? What is the expected flood crest and when will it occur, given a certain flow in the river? During a floodfight, the availability of such information is key to decision making. Other data, such as the boundaries of the 100-year floodplain, were not in digital format and had to be digitized. Neither the public nor the nonprofit sectors uniformly apply Federal Information Processing Standards (FIPS) in collecting pre-disaster, response, or recovery data.

Research Topic: Based on the experience of those involved in developing a spatial data infrastructure for analysis of the 1993 flood, develop updated national standards for the collection, storage, retrieval, and display of spatial data.

- NATIONAL INVENTORY OF STRUCTURES. The Review Committee was unable to obtain definitive numbers on how many structures were impacted in the Midwest Flood of 1993. Estimates ranged from 55,000 to 100,000 structures. It was also difficult to estimate the level of National Flood Insurance Program market penetration without time and labor-intensive studies. These are two tasks that could easily be accomplished if a national inventory of structures existed. Nationwide there is no authoritative estimate of the number of structures exposed to floods and other natural hazards. As a result floodplain and emergency management decisions are often made based on inadequate information. This results in inappropriate allocation of resources.

  Research Topic: What methods would be most feasible to conduct and maintain a national inventory of floodprone structures. Such an inventory is needed to determine the number, location, building type, and functional uses of structures in floodplains. Technology certainly makes such an inventory feasible. These data and the risk analysis that would become possible for the first time could allow the nation to focus mitigation and pre-disaster planning at specific areas of high risk. At the same time, funding for these activities could be targeted and adjusted in relation to the degree of exposure to the relative risk. In the event of a disaster, an immediate assessment of response needs would be available in summary format. This information would also enable targeting specific addresses to inform residents of the flood risk and the availability of insurance. Other potential users of such a database

are communities, lenders, planners, citizen groups, and underwriters. An accurate database would serve as a cornerstone in the national spatial data.

- HYDROLOGIC, HYDRAULIC, AND HYDROMETEOROLOGIC ANALYSIS. To carry out its mission, the Review Committee needed to answer questions about flow characteristics for the entire reach of the Mississippi River from Cairo, Illinois, to St. Paul, Minnesota and for the Missouri River from its mouth to Gavins Point, the site of the first dam on the Missouri. A model to accomplish this task did not exist at the time of the review. Five US Army Corps of Engineer districts are involved in managing these river reaches, and the models used by each differed. Additionally, the availability of the high resolution topographic data needed to operate the available models was limited to only certain river reaches.

  Current one-dimensional models are unable to satisfactorily model the complex condition of flow in large rivers where water moves into large storage areas in the overbank floodplain and where land cover varies both in the cross section and along the length of the river. The most widely used model for flood elevation determination is HEC-2, a steady-state, one-dimensional, rigid-boundary model that cannot simulate levee breaches or take storage effects into account. UNET, a one-dimensional unsteady-flow model used by the Review Committee to model a portion of the basin, has the capability to assess impacts of levee breaches and associated storage effects. A system-wide, unsteady-flow model of the main stem rivers in the upper Mississippi River Basin would help evaluate the impacts of proposed structures and floodfighting, and could be used for coordinated ecosystem modeling, and for floodplain management decisions. Further, advanced hydrologic and hydraulic models can be combined with meteorologic observations and forecasts to provide information to enable better floodplain and water resources management. Since the flood of 1993, the Corps of Engineers has extended the UNET model to include the mainstem of the upper Mississippi from Cairo to St. Paul, Minnesota and the Missouri from its mouth to Omaha, Nebraska. Considerable work remains to be done to incorporate tributary flows and to model tributaries in basin wide system models.

  Federal, state, tribal, and local agencies need to coordinate estimates of floodflow frequency curves, flood elevation profiles, and floodplain maps. Overall improvement in the modeling of complex river systems is needed to advance in hydrologic prediction capabilities for both real-time forecasts of flood events and for water-resources planning.

  Research Topic: What unsteady state tools are available and satisfactory for modeling of large river systems? How can hydrologic/hydraulic models be linked to meteorological models for better operation of river systems. While the UNET model offers promise for better analysis of complex conditions of flow in large rivers, there has been little validation of UNET and consideration of other models that might be available for use.

- FLOOD RISK ASSESSMENT**.** Models used for determining flood heights require current estimates of flood discharges. Maintaining up-to-date estimates of discharge-frequency curves requires that they be reviewed as the period of hydrologic record increases and whenever new peak flowrates are recorded. By doing so, the representative sample of the parent population of hydrologic event data is enlarged and the estimate of the frequency of occurrence associated with a given discharge is improved. In 1979 the USACE estimated flood discharges for the upper Mississippi River corresponding to the 5-, 10-, 50-, 100-, and

500-year frequency floods. Water surface profiles for the Mississippi River, developed from these discharge frequency curves, form the basis for FEMA's flood insurance rate maps for the areas along the Mississippi River. The 1993 flood established new peak discharges on many tributaries and on major reaches of the main stem rivers.

Currently the method of computing the relationship between annual flood peak discharge and frequency of occurrence on large river systems is standardized among federal agencies. Frequency curves are developed using the current federal standard distribution function (log-Pearson Type III) for annual peak discharges. Though the federal method was reviewed in the early 1980's, the magnitude of the 1993 flood and its possible effects on discharge-frequency curves for stations in the upper Mississippi River Basin provide the opportunity to ascertain the adequacy of the recommended method to reflect the probability distribution of annual peak discharges.

Research Topic: What methodologies produce the best representation of flow/stage/frequency relationships along the upper Mississippi River?. The review should include, in addition to probability theory itself, the end uses of the curves such as selecting the heights of flood protection facilities, evaluating the degree of risk of a site or a structure, determining regulatory floodplain limits, and establishing flood insurance rates.

- STREAMGAGING AND FLOOD FORECASTING. State and local authorities need river stage and discharge information for emergency situations, for local flood relief efforts, and for floodplain management. During the Midwest flood, conflicting estimates of flood crests created difficulties for local emergency response efforts. Especially important for floodwarning and forecasting are the presence of streamflow gages at locations critical for providing flood alert for downstream populations centers, and capabilities for remote sensing of gages, data transmission, and communications with other agencies.

  Research Topic: How effective was the streamgaging network and flood forecasting during the 1993 Midwest floods, and based on the results of this analysis, what is the minimum infrastructure required for efficient streamgaging and flood forecasting?

  This assessment should include an evaluation of the ability of the present streamgaging network to monitor the Mississippi River system and provide the public with timely and reliable flood warnings. The assessment should identify gaps, inconsistencies and areas of duplication in the present system and make recommendations on improvements. NOAA's *Natural Disaster Survey Report* (US Department of Commerce, 1994) identifies the need for improvements to real-time hydrologic forecasting and provides 106 findings and recommendations resulting from an interagency evaluation of the 1993 Midwest flood.

- MAPPING. Critical to the development of any computer model used to estimate flood elevations is detailed topographic information. Engineers can use topographic information in a digital format more efficiently in computer models. Topographic information of the appropriate resolution or accuracy does not exist in a digital format for many locations in flood-affected areas of the country, at a scale useful for floodplain management or for use in engineering models. Floodplain managers generally prefer contour intervals of two feet or less. Technologies are beginning to emerge that may produce accurate, high resolution digital elevation models at reasonable costs.

  Research Topic: What are the economic and technical feasibilities of using emerging technologies to acquire digital topographic data and other land use data for more accurate

mapping of flood hazard areas? Floodplain managers use detailed topographic data and other land characteristics in floodplain areas for many applications, such as floodplain boundary delineation, habitat and land cover/land-use mapping, and restoration projects.

- QUANTIFYING AND ASSESSING ENVIRONMENTAL IMPACTS. Environmental quality and species diversity remain as social commodities not sold in conventional markets. Evaluation methods that do not depend on market prices are needed to estimate the benefits of such commodities. The non-market value to be estimated is the amount of income an affected person would be willing to give up for an environmental service. Where environmental outputs can be identified and effects can be quantified in monetary terms, these monetized environmental effects should be included in benefit-cost analyses.

  Significant research exists on non-market evaluation techniques. Most of this research estimates recreation benefits rather than benefits of passive services such as ecosystem health. Economists use two primary approaches to estimate the value of non-market goods: an indirect approach and a direct one (Smith, 1993; Ribando, 1992). Indirect approaches, such as the travel cost method or hedonic analyses, are based on the premise that the value people place on services is revealed by the choices they make in consuming them. These techniques depend on the observation of human behavior in a particular circumstance and cannot be used for hypothetical situations such as wetland restoration.

  The direct approach uses survey techniques to directly elicit a person's value or willingness to pay. The most widely used approach is the contingent valuation method, where respondents are presented with information about the proposed environmental service (either an improvement or degradation) and asked what the change would be worth to them. The direct approach can also be used to evaluate existence values (the satisfaction an individual receives from simply knowing an environmental amenity exists or will continue to exist, even though the individual will never use it) and non-existing or hypothetical situations that indirect methods cannot handle. The reliability of estimates from surveys in these situations is often questionable. Experience with the contingent valuation method indicates it can be successful in estimating values associated with recreation outputs for which the potential user is familiar, for which the product can be clearly defined, and for which a plausible market can be defined. Applications become less successful when the respondent lacks familiarity with the product or when the amount, quality, or other attributes of the product cannot be clearly defined. This is especially true in trying to measure changes in the quality of environmental amenities or other management actions. Research is needed to improve techniques for measuring social or environmental outputs and for establishing criteria to assess the significance of such outputs from a regional and national perspective.
  Research Topic: What techniques or applications are available or may become available for estimating and assessing environmental and social impacts and commensurating these impacts with economic impacts? This research should identify practical methods and improved techniques to allow greater consideration of impacts, both positive and negative, for which no market system exists. Such research would assist in evaluating the economic value of an environmental output or the willingness to pay to avoid an impact.

- GEOMORPHOLOGY. Satellite imagery and data analyses provide evidence that some levee failures along the Missouri River coincided with historic river channels. Evidence indicates that levees were largely responsible for raising flood water to levels that generated the high

energies necessary to overpower and blow the levees, creating the scour holes and generating the sands that damaged the very farmlands the levees were designed to protect. In many areas riparian forests had minimal flood erosion or deposition damage. These areas commonly coincided with levees that did not fail, indicating some protection was given to levees by riverward forested areas. Evidence also indicates that levees placed in high energy zones would not hold, even if it were possible to excavate all the sand from the old channel and place the levees on a clay core. This suggests that levees should not be reconstructed in such high energy erosion zones, but should be set back to allow high energy zones to remain within a designated, functioning floodway. A mix of compatible land uses, such as dry-year farming, open space, recreation, fish and wildlife habitat, could occur within high energy floodways. Any such use, however, should not be eligible for future emergency federal disaster assistance.

Research Topic: What are the relationships between high energy riverine erosion zones, other zones in floodprone areas, and levee failures. Study is needed to better define, document, and map such high energy zones, especially along the Missouri River.

- HYDROLOGIC AND HYDRAULIC BENEFITS OF NATURAL FLOODPLAIN FUNCTIONS. The federal government established the Minnesota Valley National Wildlife Refuge in the lower Minnesota River valley near the Minneapolis/St. Paul metropolitan area, in part, to maintain the floodplain as part of a naturally functioning ecosystem and floodwater storage/conveyance mechanism. Although the government did not establish the upper Mississippi River National Wildlife and Fish Refuge as a mechanism for flood damage reduction and control, it may have played a significant role in reducing local flood damages in the upper Mississippi River valley. Nonstructural flood damage reduction and control capabilities of floodplain land uses such as green spaces and wildlife refuges have not received adequate evaluation (Leopold, 1994).

  Environmental groups have identified upland wetland water-storage capabilities lost to drainage over the past century as contributing factors in the heights of the 1993 floods in the upper Mississippi River Basin (Hey, 1992). At the same time, agricultural interests have indicated that drainage tiles (underground drains) installed to dry out wetlands and wet soils provided a positive benefit in reducing flood heights by voiding the soils of water and creating a capacity in the soils for water storage. Once rains exceed a threshold level, however, and soil surfaces are sealed, the ability of rainwater to infiltrate soil is lost and the water runs off (Satterlund, 1992). Drainage tiles may have contributed to flood heights rather than lessening them.

  Floodplain and upland areas functioning as temporary storage areas can have impacts on flood peaks. The quantification of these impacts has not been well documented. Use of natural storage areas (wetlands) for temporary storage of floodwater to decrease downstream flood heights has not been utilized in modern flood control policy. The mathematical models exist to analyze these impacts, although additional field data may be necessary.

  Research Topic: What are the effects of natural upland storage and floodplain storage in such areas as wetlands and forested wetlands on main stem flooding. The functions of wetlands and their drainage for agricultural purposes need better evaluation.

- BIOTECHNICAL ENGINEERING**.** State, local, and private engineers and planners rely heavily on federal design manuals. Currently these manuals do not address biotechnical

engineering -- channel or bank modification techniques that use vegetation in innovative ways in contrast to traditional bank sloping and riprap protection. Traditional approaches typically focus on maximizing flood conveyance only. Biotechnical engineering techniques can be employed in engineering designs and contribute to the natural functions of floodplains. These practices have not been incorporated into federal government standards because there has been insufficient evaluation of the efficiency of these practices.

Research Topic: What biotechnical engineering practices have been effective in improving riverine bank stability while not reducing flood water conveyance. Such an investigation would support federal agency incorporation of these methods into design manuals.

- FLOOD INSURANCE MARKET PENETRATION. In the course of its studies, the Review Committee was unable to obtain definitive information on NFIP market penetration or on who buys flood insurance and who does not and why. Much of the information that was available was based on inadequate information, personal observation, or speculation. Knowledge of reasons for choice selection is critical to developing strategies to increase compliance with the mandatory purchase requirements and to increase voluntary purchase of flood insurance.

  Research Topic: Which eligible persons purchase flood insurance and which do not and what are the reasons for their decisions? What steps should the federal government take to increase purchase of flood insurance by eligible personnel?

- FEDERAL SUPPORT OF FLOODPRONE FARM ACTIVITIES. Some federal economists and many non-federal groups have proposed phasing out federal subsidies in general and federal farm program payments in particular to floodplain activities, because they represent intrusions into the free market by distorting incentives and thus may encourage floodplain activity. The Review Committee examined the role of federal farm programs as they influence individual farmer's decisions to farm in bottomlands, looking at both program payments and the support provided to farmers by federal levee repairs. It determined that each agricultural producer in the floodplain makes farming decisions based on a collection of factors, many of which differ from location to location. (Input prices tend to be the same at all locations, but production practices and potential yields depend on the characteristics of the land. Cash receipts will depend on whether the farmer participates in a crop price support program. In addition, the level of flood protection will determine whether a given year's yield will be realized and what the expected flood damages will be.) From a farmer's perspective, the viability of farming a particular area depends on the net income that can be earned. Government programs for price and income support, levees, drainage, technical assistance, subsidized crop insurance premiums, and crop disaster assistance all serve to lower the cost of farming on the floodplain.

  Many agricultural levees were constructed and maintained by local districts with no use of federal or state funds prior to 1993, so those flood control structures cannot be considered as part of a past subsidy to floodplain agriculture. If these levees were repaired with federal funds, the added benefit would reduce future production costs for the farmer. Farm programs offer a producer higher profits for growing certain crops, so the type of bottomland agriculture is also influenced by government policies. Farmers with lower levels of flood protection may switch to alternative crops such as growing biomass fuel. The economic viability of such choices is currently being studied. Site characteristics and government

policies will determine a farmer's choices. Programs offering easements, levee set-backs, or "green" payments will have to take factors affecting farmer decisions into account.

Preliminary results from a study funded by EPA and being conducted by the Center for Agricultural and Rural Development at Iowa State University and the Center for National Food and Agricultural Policy at University of Missouri-Columbia indicate that in some areas participation in federal farm programs and the existence of levees determined whether a crop is grown and which crop is chosen. In other areas of the floodplain, agriculture would be profitable even without participation in any farm or levee program.

Elimination of federal farm programs for floodplain farmers might make operations less viable and might influence some to leave the floodplain; however, it would be difficult to determine which floodplain farmers should not receive program payments. A substantial portion of American farming is in the floodplain. Much of the agricultural base of Missouri, Arkansas, Mississippi, and Louisiana exists in the floodplain. If the intent of removing payments or subsidies is to alter behavior that is believed to contribute to environmental problems, then it might be more productive to remove payments or offer "green payments" in all areas where agriculture operates under less than optimal conditions, e.g., flood zones, highly erodible land, drylands, etc.

Research Topics: Do government agricultural support programs unduly influence farmers to operate in flood hazard areas? How does federal support of agricultural activities in flood hazard areas differ for similar support to agricultural activities in other natural hazard areas.?

- MORAL HAZARD. In providing support for a range of floodplain activities, does government create a "moral hazard?" This phrase is used in the insurance industry to describe the situation when an insured party has a lower incentive to avoid risk because an enhanced level of protection is provided.

  If an individual or government entity does not bear the financial consequences of an action there is little reason to mitigate the danger; therefore, the insured party is more likely to be at risk (or will expend too little effort to avoid risk) than one who has to bear all consequences. The insurance provider usually has few ways of observing whether proper care or precautions are taken. Private insurance companies deal with the moral-hazard problem by offering less than full coverage and requiring payments (deductibles) which increase the policyholder's incentive to take protective measures. Another way that insurance providers cope with moral hazard is to base each period's premiums on claims from previous periods. This method increases the policy holder's level of risk avoidance. Some federal provision of hazard insurance is subsidized through reduced premiums and administrative fees which lowers an individual's stake in avoiding harm. The availability of supplementary compensation diminishes the efficiency of insurance to encourage risk sharing. Through provision of disaster assistance and, in some cases, enhanced flood protection, the government may in fact be reducing incentives for local governments and individuals to be more prudent in their actions. Some older studies have indicated that the presence of federal support does not create a disincentive to buy flood insurance.

  Research Topic: Does data from more recent flooding events support the contention that many current federal programs are creating a moral hazard for those who locate in the floodplain?

- FEDERAL FISCAL ROLE IN FLOOD CONTROL. Some people state that the federal government's role in funding flood control projects should be limited to paying costs related to federal benefits, with responsibility for costs associated with regional and local benefits falling to the local sponsor. At present, under the provisions of the Water Resources Development Act of 1986, cost-sharing for flood control projects is set at a local contribution of not less than 25 percent and not more than 50 percent, depending on the circumstances. Levee repairs, carried out under the provisions of PL 84-99 by the USACE, require a 20 percent local contribution, although the requirement for cost-sharing was determined by the Administration, not the Congress.

  The federal interest in flood control was stated most clearly by the Flood Control Act of 1936, "*...the Federal Government should improve or participate in the improvement of navigable waters or their tributaries...for flood control purposes if the benefits to whomsoever they may accrue are in excess of the estimated costs...*" The rationale for this federal involvement was based in part on the magnitude of the physical threat and potential damages to the nation from flooding, and in part on recognition that navigable waters are interstate and activities in one area can have major effects on other areas.

  The Congress, working with the Administration, has set cost-sharing rules based on congressional and Administration determinations as to the nature of the threat and the ability of state and local governments to bear the costs of projects rather than on the allocation of net benefits. Shifts in cost-sharing formulas might alter floodplain behavior.

  Research Topic: What impact does the level of cost-sharing of federal flood damage reduction activities have on decision making by local officials in the conduct of floodplain management activities. Do variations in cost-sharing approaches modify community behavior?

- FUNDING DISASTERS. Natural disasters in the United States have been costly events in terms of both human lives lost and property damaged. From FY 1989 through FY 1993, over $27.6 billion was spent on federal disaster assistance programs. Although flood declarations comprised the majority of Presidential disasters declarations, earthquakes (California) and hurricanes have caused greater per capita damage. All but six states experienced disasters severe enough to warrant Presidential declarations. States in the northeast battled coastal flooding while the south recovered from hurricanes and the midwest from floods.

  The rising frequency and costs of natural disasters have prompted a variety of concerns. Some have questioned the federal government's role in funding disaster recovery, citing the potential for rising expenditures in an era of budgetary restraint, the possible incentives that federal relief creates for people to locate in disaster-prone areas, and the potential for elements of federal, state, and local government to rely on disaster relief for infrastructure repair. Others, assuming that a federal obligation to fund recovery exists, point to hazard mitigation as a cost effective alternative to providing disaster assistance. Funding preventive measures such as relocating structures out of the floodplain can decrease the demand for disaster relief. Currently, the federal government funds disaster relief through emergency supplemental appropriations, exempting disaster relief from the scrutiny received by other spending, while permitting it to add to the federal deficit. This situation may create an incentive for federal agencies to accept backlogs in maintenance for activities in disaster prone areas, recognizing that an emergency spending opportunity for catching up may occur.

Research Topic: What have been the fiscal effects, over time, of funding disaster support outside of the normal budgetary process and what steps could the Administration and the Congress take to better control this activity?

- PEOPLE, THE MEDIA, AND THE FEDERAL FLOOD RESPONSE. Compassion plays a major role in the way people respond to disasters and rush to provide disaster relief. The speed with which the entire nation learns of disasters is almost immediate. For example, because of the television coverage of the 1989 World Series, those watching had the experience of actually being present during a major earthquake. As for the 1993 floods, the nation can remember pictures carried by CNN of the house being swept away when a levee was breached. Viewers were left wondering how this could happen rather than why the house was there in the first place.

  The best media flood-relief stories became those of suffering people and those complaining about the lack of quick government assistance. Politicians and decision makers were bombarded with calls and they responded by declaring additional counties part of the disaster area and by promising quick relief. FEMA Disaster Field Offices, set up in many cities and towns, were themselves flooded with applications for disaster relief. The media attention helped agencies get needed information to citizens, but also may have increased expectations about the level of assistance that was available or the speed at which help could be provided.

  Human compassion and the way news is reported influences how Congress and the nation respond to disasters. A great push arose to replace levees along the Missouri River, many of which should not be replaced without careful design and engineering considerations. If federal response to disaster relief is driven by the immediacy of an event, rather than by rational decision making, the effort to put everything back to the way it was may increase future risk rather than reaching long-term solutions to risk reduction. In the haste of some disaster relief and under the pressure of the media effect, the nation may have subsidized some bad decisions and penalized some good ones, foregoing opportunities for change. A caring, supportive approach for disaster victims must never be lost; but there must be, in tandem, an effort to ensure decision making that reflects long-term as well as short-term goals.

  Research Topic: What influence does media coverage has on rational decision making during and following natural disasters? How can key decision-makers be insulated from pressures generated by media coverage?

- PROPERTY RIGHTS. During the conduct of the Review Committee's study, two senior members of Congress expressed to the Review Committee a concern about protection of property rights in conduct of floodplain management:

  The respect and adherence to the rights of property owners as drafted in our Constitution are of central importance to the federal government's role in floodplain management. Any acquisition of lands, expansion of wetlands, and the purchase of easements and rights-of-way should be done with adequate compensation to the landowner. Likewise, the federal government should refrain from the use of condemnation when attempting to move residents out of the floodplain. Any expansion of buyout and relocation initiatives must be carried out on a willing-seller basis.

Sound floodplain management results from a strong partnership among federal, state/tribal and local governments and the private citizens of the nation. Decisions on land acquisitions should result from consultations within this partnership.

The federal government should not support, fiscally, the rebuilding of some flood damaged structures, to include levees and homes, when it does not make economic or engineering sense. To some, failure to support rebuilding is seen as an abridgment of the rights of the owners of the property. Some individuals stated that the federal government's failure to repair their flood-damaged levees even though they were ineligible for participation in federal emergency repair programs, constituted an abridgment of their entitlement to these repairs and thus was a violation of their property rights. Eligibility criteria for each existing levee repair program were determined in the open by the executive branch of government.

Some individuals complained that any governmental restrictions on an individual's or a group's 'right' to floodfight (e.g. temporarily raise levee heights) constituted another possible abridgment of property rights. The federal government recognizes the rights of individuals and groups to protect their own property from destruction provided that their actions do not increase flood damages to other groups or individuals. The law concerning protection against a common enemy is complex and the rights and responsibilities of individuals and groups involved in such actions vary widely by state and locality. The Review Committee recommended that before federal and state governments provide fiscal or in-kind support to floodfights, they ensure that the actions being taken will not have adverse impacts on other groups or individuals. Individuals and groups retain the ability to 'go it on their own' subject to state and community floodplain management regulations (including floodway regulations adopted by communities to participate in the NFIP). These individuals and groups are subject to whatever liability they generate as a result of their actions. Land use controls developed by a community as a result of participation in the NFIP represent community decisions. Property rights issues are of serious concern to floodplain management personnel.
Research Topic: What floodplain management activities can be conducted without infringement on the property rights of floodplain land owners?

5. SUMMARY

The Flood of 1993 was a hydrometeorological of most unusual proportions. Its waters caused enormous damages across nine states and its memory will linger for years in the minds of those who experienced its power. Analysis of the Flood of 1993 and its causes indicates that much can be done to reduce the impact of future floods on the human and natural environment of the upper Mississippi basin. However, such flood damage reduction activity must be supported by research that will assist floodplain managers in the better understanding, development and execution of effective floodplain management programs.

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Review Committee. Other members of the committee were: Dr. Margriet Caswell, Thomas Wheri, Department of Agriculture, Richard DiBuono, Arnold Robbins, Harry Shoudy, Department of the Army (Corps of Engineers) Robert Clevenstine, Jerry Rassmussen, Department of the Interior, Shannon Cunniff, Joseph Ferrante, Lewis Rosenbluth, Environmental Protection Agency, and Mary Jean Pajak, Michael Robinson, Federal Emergency Management Agency and their work is reflected in this paper.

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Appendix A

FLOODPLAIN MANAGEMENT REVIEW COMMITTEE RECOMMENDATIONS

The Review Committee developed the following recommendations.

- To ensure that the floodplain management effort is organized for success, the President should:

  - Propose enactment of a Floodplain Management Act which establishes a national model for floodplain management, clearly delineates federal, state, tribal, and local responsibilities, provides fiscal support for state and local floodplain management activities, and recognizes states as the nation's principal floodplain managers;
  - Issue a revised Executive Order clearly defining the responsibility of federal agencies to exercise sound judgement in floodplain activities; and
  - Activate the Water Resources Council to coordinate federal and federal-state-tribal activities in water resources; as appropriate, reestablish basin commissions to provide a forum for federal-state-tribal coordination on regional issues.

- To focus attention on comprehensive evaluation of all federal water project and program effects, the President should immediately establish environmental quality and national economic development as co-equal objectives of planning conducted under the Principles and Guidelines. Principles and Guidelines should be revised to accommodate the new objectives and to ensure full consideration of nonstructural alternatives.

- To enhance coordination of project development, to address multiple objective planning, and to increase customer service, the Administration should support collaborative efforts among federal agencies and across state, tribal, and local governments.

- To ensure continuing state, tribal and local interest in floodplain management success, the Administration should provide for federal, state, tribal, and/or local cost-sharing in pre-disaster, recovery, response, and mitigation activities.

- To provide for coordination of the multiple federal programs dealing with watershed management, the Administration should establish an Interagency Task Force to develop a coordination strategy to guide these actions.

- To take full advantage of existing federal programs which enhance the floodplain environment and provide for natural storage in bottomlands and uplands, the Administration should:

  - Seek legislative authority to increase post-disaster flexibility in the execution of the land acquisition programs;
  - Increase environmental attention in federal operation and maintenance and disaster recovery activities;
  - Better coordinate the environmentally-related land interest acquisition activities of the federal government; and
  - Fund, through existing authorities, programmatic acquisition of needed lands from willing sellers.

- To enhance the efficiency and effectiveness of the National Flood Insurance Program, the Administration should:

- Take vigorous steps to improve the marketing of flood insurance, enforce lender compliance rules, and seek state support of insurance marketing;
- Reduce the amount of post-disaster support to those who were eligible to buy insurance but did not to that level needed to provide for immediate health, safety, and welfare; provide a safety net for low income flood victims who were unable to afford flood insurance;
- Reduce repetitive loss outlays by adding a surcharge to flood insurance policies following each claim under a policy, providing for mitigation insurance riders, and supporting other mitigation activities;
- Require those who are behind levees that provide protection against less than the standard project flood discharge to purchase actuarially based insurance;
- Increase the waiting period for activation of flood insurance policies from 5 to 15 days to avoid purchases when flooding is imminent;
- Leverage technology to improve the timeliness, coverage, and accuracy of flood insurance maps; support map development by levies on the policy base and from appropriated funds because the general taxpayer benefits from this program; and
- Provide for the purchase of mitigation insurance to cover the cost of elevating, demolishing, or relocating substantially damaged buildings.

- To reduce the vulnerability to flood damages of those in the floodplain, the Administration should:

  - Give full consideration to all possible alternatives for vulnerability reduction, including permanent evacuation of floodprone areas, flood warning, floodproofing of structures remaining in the floodplain, creation of additional natural and artificial storage, and adequately sized and maintained levees and other structures;
  - Adopt flood damage reduction guidelines based on a revised Principles and Guidelines which would give full weight to social, economic, and environmental values and assure that all vulnerability reduction alternatives are given equal consideration; and
  - Where appropriate, reduce the vulnerability of population centers and critical infrastructure to the standard project flood discharge through use of floodplain management activities and programs.

- To ensure that existing federally constructed water resources projects continue to meet their intended purposes and are reflective of current national social and environmental goals, the Administration should require periodic review of completed projects.

- To provide for efficiency in operations and for consistency of standards, the Administration should assign principal responsibility for repair, rehabilitation, and construction of levees under federal programs to the U.S. Army Corps of Engineers.

- To ensure the integrity of levees and the environmental and hydraulic efficiencies of the floodplain, states and tribes should ensure proper siting, construction, and maintenance of non-federal levees.

- To capitalize on the successes in federal, state, tribal, and local pre-disaster, response, recovery, and mitigation efforts during and following the 1993 flood and to streamline future efforts, the Administration should:

  - Through the NFIP Community Rating System, encourage states and communities to develop and implement floodplain management and hazard mitigation plans;
  - Provide funding for programmatic buyouts of structures at risk in the floodplain;
  - Provide states the option of receiving Section 404 Hazard Mitigation Grants as block grants;

- Assign the Director of the Federal Emergency Management Agency responsibility for integrating federal disaster response and recovery operations; and
- Encourage federal agencies to use non-disaster funding to support hazard mitigation activities on a routine basis.

- To provide integrated, hydrologic, hydraulic, and ecosystems management of the upper Mississippi River basin, the Administration should:

  - Establish upper Mississippi River Basin and Missouri River Basin commissions to deal with basin-level program coordination;
  - Assign responsibility, in consultation with the Congress, to the Mississippi River Commission (MRC), for integrated management of flood damage reduction, ecosystem management, and navigation on the upper Mississippi River and tributaries; expand MRC membership to include representation from the Department of the Interior; assign MRC responsibility for development of a plan to provide long-term control and maintenance of sound federally built and federally supported levees along the main stems of the Mississippi and Missouri rivers; this support would be contingent on meeting appropriate engineering, environmental, and social standards.
  - Seek authorization from the Congress to establish an Upper Mississippi River and Tributaries project for management of the federal flood damage reduction and navigation activities in the upper Mississippi River Basin;
  - Establish the upper Mississippi River Basin as an additional national cross-agency Ecosystem Management Demonstration Project; and
  - Charge the Department of the Interior with conducting an ecosystems needs analysis of the upper Mississippi River Basin.

- To provide timely gathering and dissemination of the critical water resources information needed for floodplain management and disaster operations, the Administration should:

  - Establish an information clearing house at USGS to provide federal agencies and state and local activities the information already gathered by the federal government during and following the 1993 flood and to build on the pioneering nature of this effort; and
  - Exploit science and technology to support monitoring, analysis, modeling, and the development of decision support systems and geographic information systems for floodplain activities.