

EXECUTIVE OFFICE OF THE PRESIDENT
COUNCIL OF ECONOMIC ADVISERS
WASHINGTON, D.C. 20500

May 19, 1994

MEMORANDUM FOR JOHN KELMELIS, SAST

FROM: ERIK LICHTENBERG 

SUBJECT: SAST Draft Final Report

Chapter 9 of the SAST Draft Preliminary Report contains sets of recommendations on topics relating to river basin management, data and information, data management, and research and analysis. I have serious reservations about the recommendations relating to river basin management and to research and analysis.

- SAST's charter was to collect and present data relating to the 1993 Mississippi Flood and to make recommendations about future data needs. SAST's charter unequivocally does not include making policy recommendations for river basin management, and SAST has neither the data, the analytical basis, nor the expertise to make such recommendations. **Therefore, all river basin management ("RM") recommendations should be removed from the report.**
- SAST's recommendations about future research and analysis needs are a laundry-list of components of a comprehensive study that would address all conceivable physical, biological and ecological aspects of the Upper Mississippi Basin. They are therefore useless. A goal of "knowing all there is to know" may be laudable in the abstract, but research is costly, and thus should be targeted to topics in which the gains from improved decision making justify the expenditure of scarce resources. **If SAST can identify top research priorities based on the its experience with the 1993 flood, it should discuss them; otherwise, it should not recommendations about research and analysis.**

cc: Brian Burke
Gerry Galloway
T.J. Glauthier
Katie McGinty
Mark Schaefer

SAST

INTERAGENCY FLOODPLAIN MANAGEMENT REVIEW COMMITTEE
SCIENTIFIC ASSESSMENT AND STRATEGY TEAM
EROS Data Center
Sioux Falls, South Dakota 57198

In Reply Refer To: SAST

May 9, 1994

Mr. Mark Schaefer
Office of Science and Technology Policy
Executive Office of the President
Executive Office Building, Room 441
Washington, DC 20500

Mark
Dear Mr. Schaefer:

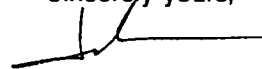
Enclosed is a rough draft copy of the Preliminary Report of the Scientific Assessment and Strategy Team. It is to be an appendix to the Interagency Floodplain Management Review Committee's (IFMRC) report, A Vision for Floodplain Management in the 21st Century.

This is a "close hold" document and its contents are not to be released. Please review it and provide comments to me at my EROS Data Center address. The comments should reach me by May 20, 1994. I am sorry for the short turn around necessary for this review, but the SAST is working to meet the IFMRC deadline. Please review the document for content. Keep in mind that there are four other reports planned from the SAST and if you have comments that would not be appropriate for a preliminary report but would provide useful guidance for the other reports, please make them and indicate which report they are directed at. The reports of the SAST are listed in the introduction.

In addition to this preliminary report, the SAST has provided a series of over 100 maps and overlays to the IFMRC; a number of maps, illustrations, and write-ups for the IFMRC report; numerous ad-hoc maps, reports, and analyses; and is building a database for the Upper Mississippi River Basin. Building and quality assuring the database is an order of magnitude more difficult than all the other activities combined.

The SAST is looking forward to receiving your comments.

Sincerely yours,



John A. Kelmellis, Director
Scientific Assessment and
Strategy Team

Enclosure

SAST
SCIENTIFIC ASSESSMENT AND STRATEGY TEAM

PRELIMINARY REPORT

MAY 3, 1994

**INTERAGENCY FLOODPLAIN MANAGEMENT
REVIEW COMMITTEE**

SAST DRAFT: NOT FOR RELEASE OR ATTRIBUTION

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SAST DRAFT: NOT FOR RELEASE OR ATTRIBUTION**CHAPTER 1: INTRODUCTION**

The great flood of 1993 in the Upper Mississippi River Basin had peak discharges at many locations that exceeded any other peak discharges on record for those locations (Parrett, Melcher, and James, 1993). The human and economic costs were staggering; yet, the ecological benefits were significant. The negative and positive effects of the flood raised old questions about flood control measures and new questions about habitat restoration. The Scientific Assessment and Strategy Team (SAST) was formed to provide scientific advice on flood recovery and future management of the floodplain.

The SAST was established by directive of the White House Assistant to the President for Science and Technology, Office of Management and Budget, and the Office of Environmental Policy on November 24, 1993. The SAST is an interdisciplinary team composed of senior scientists and engineers from the Department of Agriculture (Soil Conservation Service), Department of Defense (U.S. Army Corps of Engineers), Department of the Interior (Fish and Wildlife Service, National Biological Survey, U.S. Geological Survey), Environmental Protection Agency (EPA), and the Federal Emergency Management Agency (FEMA). The SAST was reauthorized to be part of the Interagency Floodplain Management Review Committee (IFMRC) on January 10, 1994, by the Office of Management and Budget, Council on Environmental Quality, and the Department of Agriculture. The SAST has responsibilities to support the IFMRC with information and advice and also has responsibilities independent of the IFMRC to obtain, organize, analyze, manage, and distribute scientific data and information.

There are 18 full time members and numerous ad-hoc members. Initial funding was provided by FEMA with follow on funding provided through two supplemental appropriations to USGS. Salaries are borne by the home agencies of the scientists and engineers involved. Significant in kind support is provided by all of the agencies involved. In depth technical and scientific support is provided by the Earth Resources

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Observation System (EROS) Data Center (EDC) and its in-house contractor, Hughes STX Corporation. States and a number of non-government organizations have been helpful as well by providing data, information, and analysis.

The goals of the SAST are to provide scientific advice and assistance to Federal officials responsible for making decisions with respect to flood recovery in the Upper Mississippi River Basin and to develop and provide information to support the decision making process regarding both nonstructural and structural approaches to river basin management. The SAST objectives are 1) to develop a database of readily available data to support map production, scientific

[more?] (OK)

analysis, and decision making; 2) to produce maps showing base information and vulnerability to flooding; and 3) to prepare reports documenting the products of SAST and the methodology and analysis used to produce them, and identifying the ongoing monitoring, research, modeling, data management and distribution requirements needed to support integrated river basin management.

The Interagency Floodplain Management Review Committee formed in January 1994 to examine floodplain management policies and report to the White House with a review and recommendations on existing and proposed policies. The SAST also provided information to assist in their analysis.

Once the SAST met to discuss floodplain management, it became clear that to address floodplain issues adequately the entire river system needed to be addressed. This system includes the uplands, the tributaries, and the floodplains. Moreover, since the flood of 1993 was such a rare event, to base planning and management decisions on it exclusively and ignore events of greater frequency would be to neglect many of the significant management issues. Thus, the scope was expanded to address issues of the entire system spatially and temporally in addition to maintaining a primary focus on floods. While the SAST was charged with focusing on floods and the structural and nonstructural methods of river basin management, the SAST members acknowledge that any action designed to adapt to or mitigate flooding must also take into account adapting to or mitigating low flows. Further, sustainable development of the river basin is considered in the gathering of scientific data and in scientific analysis.

The SAST activities focus on the River Basin/Watershed and Mainstem/Floodplain scales and include data acquisition, database development, analysis and assessment, mapping, reporting, and data and information management and distribution. The SAST met at EDC in Sioux Falls, South Dakota, for an initial workshop during the week of December 13, 1993, to identify the scope of the problem and to begin to address the numerous logistical issues that the team would encounter. It began concentrated efforts at EDC on January 3, 1994, and continued until March 11, 1994. After that the SAST functions as a distributed team with members working at their

home offices or laboratories. The team also meets for periodic workshops to address specific

issues.

While at EDC, the SAST built a substantial multilayer multiresolution database covering the Upper Mississippi River Basin. The data densities vary spatially, the most concentrated and complete along the floodplain of the Upper Mississippi and Lower Missouri, the most sparse on the Upper Missouri River Basin upstream of Gavins Point. The database contains satellite data (AVHRR, Thematic Mapper, etc.), elevation data, selected digitized photographs, and data on historical channels, manmade structures, geologic, biologic, hydrologic, hydrographic, hazardous/toxic, soil survey, and many other themes.

Some of the products of the activity include special maps, demonstrations of the data application, decision rules for identifying high priority habitat sites, methods for identifying reasonable alternative levee locations, and new understanding of the influence of variables such as focused energy, the relationship between historic and current channel and sedimentation and scour, and land use on the impact of floods on the floodplain of the Lower Missouri and Upper Mississippi floodplains. The use of these products for management and decision making will be described in the Science Report.

Data to populate the database and information for the report came from numerous sources including many Federal agencies, state governments, universities, and non-government organization (private industry and interest groups). Most databases were modified from existing available data to make them intercomparable, to format them uniformly, or to otherwise improve quality. Due to time limitations, many of the problems encountered in the data were identified in the meta-data and not corrected when entered into the database. Many data sets that were in the form of maps and tabular listings were digitized and included if they were useful for answering questions raised in the decision making process. Some databases were built completely from scratch because of the critical need for them and their lack of availability otherwise.

This report is the preliminary report of the SAST. The statements made herein are based on the current state of the database and analysis. Subsequent reports will more fully discuss the details of the scientific issues, conclusions, and recommendations.

APPROACH

To use the scientific method observations must be made, understanding should be increased based on those observations, and the increased understanding should be tested by determining how closely responses of the natural system to forcing functions correspond to predictions made based on the understanding. Typically, there is an iterative cycle of refinement of the understanding and predictions. The system must be monitored to gather data on the observable variables. Those data must be compared to the predicted nature of the variables.

An initial high level model of the system under study was necessary to help identify the questions to consider, the relationships among parts of the system, and the data necessary to understand the system. Figure 1.1 describes the system under consideration and served as a high level conceptual model of system operations.

The approach consists of identifying potential questions that must be answered to support integrated river basin management, identifying the data needs to answer those questions, identifying sources for those data, acquiring those data and incorporating them into a database in such a way that they could be used together, conducting analysis with the data, identifying additional data needs or developing results from the analysis, and when necessary, acquiring additional data. Figure 1.2 illustrates this labor and technology intensive process.

It has been clear for many years ("Floodplain Management in the U.S., Vol. 1, Summary Report", p.61 and "Retrospect and Prospect VI-1" in the same report) that incomplete and inconsistent collection of data is a severe handicap to developing policy for floodplain management. In recent years, technology has been developed that aids in data analysis. Geographic information systems (GIS) and image processing systems provide powerful analytical tools that can aid in research and assessment of river basin management on local to regional scales. Still, data acquisition and database development are the most difficult and expensive parts of implementing these modern technologies. In this case, for the management of the Upper Mississippi River Basin, a considerable amount of data has been acquired already. These data include historical land use and land cover, historical channelways, precipitation, river flows, and

many others. However, most of these data are not in digital form and must be digitized. In many cases, where the acquired data are in digital form, they are not compatible formats; these data are also in the process of being converted. In addition, certain necessary data did not previously exist. These had to be interpreted from aerial photography or satellite imagery, collected in the field, or otherwise acquired.

The database was the central focus of initial activities because analysis could not begin until sufficient data were available. The objective of the first analysis is to identify gaps in the original estimation of data needs. These needs are then satisfied either by acquiring additional existing data or by conducting field, remote sensing, process, or modeling analysis. These analysis excursions into the data refine the understanding of the processes of concern and indicate the relationships necessary to further understanding. Effective database development cannot take place without these types of analysis excursions.

Products from the database include maps, illustrations, analysis results, and statistics. These are provided to policy makers as they become available. The generation of these products further refines the understanding of the process and aids in developing decision rules for scientific river basin management.

Ultimately, the results are reported. The SAST is producing a multivolume report that provides scientific information and makes recommendations. The volumes of this report are as follows:

- Volume 1. Preliminary Report,
- Volume 2. Scientific Report,
- Volume 3. Database Report,
- Volume 4. Scientific Background Report, and
- Volume 5. Proceedings of the Hydraulic, Hydrologic, and Ecologic Modeling Workshop.

Additional reports and scientific papers will be published in the scientific literature as they become available.

GEOGRAPHIC DESCRIPTION OF THE UPPER MISSISSIPPI RIVER BASIN

The Upper Mississippi River Basin consists of areas drained by the Mississippi River above the confluence with the Ohio River at Cairo, Illinois. It includes the entire Missouri River Basin, which joins the Mississippi above St. Louis and extends west to the Continental Divide. The Upper Mississippi River basin covers 23 percent of the conterminous United States, an area of 1,815,000 square kilometers. The entire Mississippi River Basin drains 3,289,000 square kilometers, or 41 percent of the conterminous United States.

The following states are entirely or partly contained in the SAST study area: Iowa, Missouri, Illinois, Wisconsin, Minnesota, North Dakota, South Dakota, Nebraska and Kansas. The SAST study area lies almost completely in the Central Lowlands physiographic province, with small areas in the Ozark Plateaus and Superior Uplands provinces.

For issues related to floodplain management and the areas affected by flooding in 1993, a smaller study area is used. In general, it includes the Mississippi above Cairo, Illinois, and the Missouri below Gavins Point Dam near Yankton, South Dakota, and for most of the issues, the Illinois River. The Missouri River and its tributaries drain most of the northern Great Plains. For the SAST study, the Lower Missouri River is considered to start at Gavins Point Dam, near Yankton, South Dakota, where the river enters the Central Lowland physiographic province; this is the upstream limit of the SAST intensive study area on the mainstem Missouri River. Defined more precisely, in terms of official hydrologic-unit boundaries, this area excludes the Missouri above Fort Randall Dam and several downstream Missouri tributaries -- the Platte, Kansas, and Osage Rivers. It includes the Sioux, Vermillion, and James Rivers; and it includes the hydrologic unit surrounding Gavins Point Dam. The area of the drainage basin above Yankton is about 280,000 square miles; the area at the mouth at St. Louis is about 526,000 square miles. (These areas exclude about 3,000 square miles of noncontributing area in the Great Divide closed basin.) The Lower Missouri River flows about 800 miles from Yankton (river gage datum elevation 1,140 ft above sea level) to the mouth at St. Louis (400 ft), with a nearly uniform slope of about 0.9 foot/mile. The mainstem floodplain ranges from about 2 to 10 miles in width; it is relatively narrower in the last 200 miles of the river's course than upstream. The total area of the lower

Missouri floodplain is about 2 million acres (3,100 square miles).

Most of the drainage area of the Missouri River is in the Great Plains. Annual precipitation depths range from less than 12 inches near the Rocky Mountains to about 20 inches in eastern South Dakota and 32 inches in eastern Kansas; precipitation increases to about 39 inches near St. Louis. Most of the precipitation occurs in the summer, late spring, and early fall months. Mean annual pan evaporation greatly exceeds precipitation throughout most of the basin. Mean annual runoff for the mainstem lower Missouri River is correspondingly low, ranging from 1.35 inches at Yankton and Omaha to 1.99 inches at Hermann, Missouri, the most downstream gage on the Missouri River (mile 97). The high runoff season is in the spring, when precipitation and snowmelt are high, soil is bare, and evaporation losses have not yet increased to their high summer levels. The seasonal distribution of flow in the mainstem is heavily regulated for navigation, power generation, and flood control purposes by major reservoirs in the upper basin above Yankton. About 1/3 of the Hermann flow is derived from the drainage area between Kansas City and Hermann, which amounts to about 1/8 of the total basin area. Mean annual runoff of the smaller tributary basins ranges from about 3 to 5 inches in western Iowa and eastern Nebraska to 10 - 15 inches in central and southern Missouri. This intensive study area covers 699,000 square kilometers and parts of 10 states (SAST database).

The Missouri River drains 73 percent of the Upper Mississippi River Basin, but contributes a small portion of the total streamflow from the basin. Long-term average streamflow of the Missouri River at Hermann, Missouri, is 72,000 cubic feet per second (cfs), compared to 198,000 cfs for the Mississippi River at Thebes, Illinois, about 20 miles upstream from Cairo. (USGS, Natl. Water Summary 1985). Peak flows during the 1993 floods were rated at 750,000 cfs at Hermann and 975,000 cfs at Thebes (Parrett, Melcher, and James, 1993).

The Upper Mississippi River Basin extends from Lake Itasca in northern Minnesota to the mouth of the Ohio River at Cairo, Illinois. For about 660 miles between Minneapolis-St. Paul and St. Louis, the river is a series of navigation pools controlled by a total of 29 locks and dams. The average river slope is about 0.5 foot per mile between St. Paul (river mile 839 above Cairo, gage datum elevation 684 ft) and St. Louis (mile 180, datum 380 ft). Between St. Louis and Thebes,

Illinois, the most downstream gage on the upper Mississippi (mile 44, datum 300.00), the river is undammed and has a slope of about 0.6 foot per mile.

The Upper Mississippi River Basin lies in the continental humid climate zone. Mean annual precipitation is about 24 - 30 inches in southern Minnesota and increases to about 44 inches near Cairo. Precipitation is concentrated mainly in the summer, late spring, and early fall months. Mean annual pan evaporation depths are somewhat greater than precipitation, but not excessively so. Mean annual runoff on the mainstem of the Upper Mississippi River is between 7 and 8 inches upstream from St. Louis and drops to 3.5 - 3.8 inches downstream from the confluence of the Missouri River. Although the river is dammed for navigation, the water storage capacity of the reservoirs is small, and the dams have negligible effect on flood flows and seasonal distribution of runoff. Annual runoff depth from small tributary basins ranges from about 3 inches in southwest Minnesota to 6 inches in central Iowa, to about 8 - 10 inches in Illinois, to 10 - 12 inches in Wisconsin, paralleling the trends in pan evaporation and precipitation.

Figure 1.1 Flow Chart of Data Needs

In Preparation

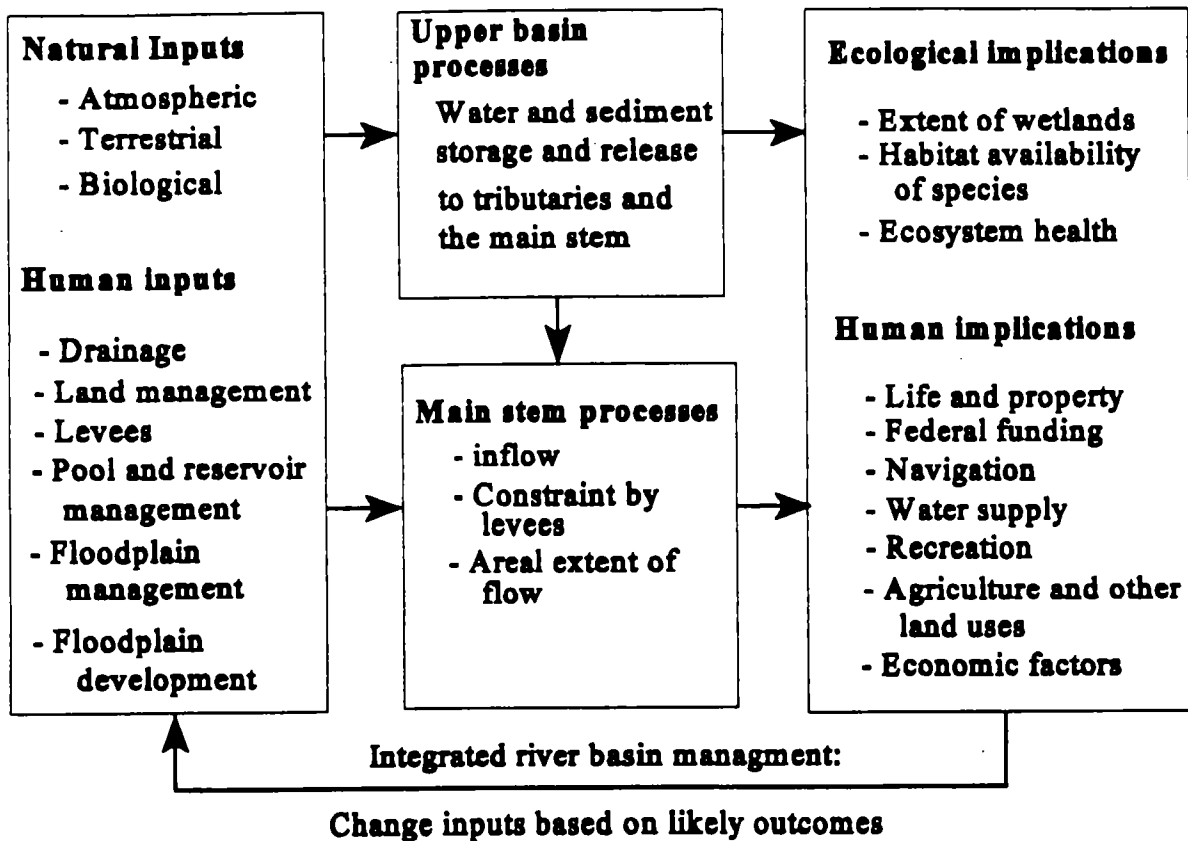


Figure 1.2. Conceptual Model of the Upper Mississippi River Basin. This simple box model illustrates the natural and human processes that drive upper basin and main stem processes. Likewise, the upper basin processes drive the main stem processes as well. Both the upper basin processes and main stem processes have ecological and human or cultural implications. These, in turn, feed back to the system. The model works well to conceptualize the boxes as processes and forcing functions or feedbacks.

CHAPTER 2: DATABASE DEVELOPMENT**SAST DATABASE**

Any scientific analysis, or the actions based thereon, is only as reliable as the original data. In describing the National Spatial Data Infrastructure (NSDI), the Federal Geographic Data Committee (FCDC) said, "Geospatial data form the foundation of an information-based society", (Nancy Tosta, NSDI, written commun., May, 1993). The SAST bears some responsibility for shaping long term policy on many issues, and has the opportunity to set an example as a prototype for a comprehensive, GIS-based Federal approach to planning and emergency preparedness. The SAST focuses much of its effort on the planning, creation, and organization of a quality geographic database.

This section describes SAST database efforts planned through September 1994. Before, during, and after the flood of 1993, many agencies were involved in routine or specialized data-collection efforts. Almost every agency in the affected area has undertaken studies, within its own realm of interest, of the flood. Because of the limitations in resources and time, and despite the continuing outreach efforts of the SAST for data collection and coordination, it is likely that new sources of valuable information will continue to surface.

In general, database efforts follow two tracks. One is the compilation of existing digital data for a very large area. The other is the creation, often involving previously uncompiled data, of very specific data for the floodplain -- especially data related to levees.

THE SPATIAL DIMENSION OF INFORMATION

A geographic information system (GIS) is a collection of computer hardware and software, procedures, and data that can be related to its place on the planet by skilled people. A GIS database typically consists of a set of layers, or themes of data, each of which describes the spatial distribution of some feature or attribute. For example, vegetation and population density might be two themes that can each be mapped as GIS layers. A vector-based GIS stores data or features as points, lines, or polygons that are defined by a set of Cartesian coordinates. Each feature in a vector layer can have many attributes associated with it -- a vegetation layer may have

attributes for dominant species, crown height, canopy cover, and so on. A raster-based GIS stores data as a regular array of cells, such as a satellite image would give or could be obtained by laying a grid over the landscape. Typically, everything in a single raster cell, or pixel, is given a single composite value.

In this report, the term 'coverage' refers to a raster or vector-based GIS dataset that corresponds to a single theme, or layer. It is the principal storage unit for the SAST database. Spatial data can be tied to a location; geospatial data can be tied to a location on, in, or above the Earth. Relational databases, such as spreadsheets or time-series, often can be tied to a point, line, or an area, and thus become attributes of the GIS coverage.

CREATION AND COLLECTION OF DIGITAL DATA

The SAST is building its database by obtaining existing digital data, both standardized and custom; by converting existing data from one form to another; by automating data from paper documents or maps; by interpreting original source data (aerial photography, satellite imagery, field notes, and measurements), and by combining or analyzing existing data to form new data sets. Data were compiled from a number of sources, at a variety of scales, and in many formats which were designed for widely different purposes. The principal databases and the ones that are closest to final form are discussed here. Others will be incorporated as time allows.

A separate report on database documentation will describe individual layers in more detail and will include a more comprehensive list than the one included in this report.

National Geospatial Databases

A number of existing, nationally available geospatial databases were obtained and compiled into GIS layers. Many were available through Federal sources, such as USGS Earth Science Information Center. Some were obtained from commercial vendors; others were freely available to the scientific community.

Hydrography and transportation layers at 1:100,000 scale were obtained as ASCII files in digital-line-graph (DLG) format and were processed into coverages. Layers include hydrography

lines (streams), areas (lakes), and points (springs); roads and trails; railroads; and powerlines, pipelines, etc. Each 30 x 60-minute quadrangle for each layer is a separate coverage. Coverages for about 140 quadrangles are currently in the database.

Reach-File-3 (RF3) data were obtained as existing coverages for the entire Upper Mississippi River Basin. The line work is based on the DLG hydrography but with different attributes and is grouped by hydrologic unit rather than by quadrangle.

Land use/Land cover (LULC) data at 1:250,000 scale were obtained as ASCII files in GIRAS format and processed into coverages. Data are a level-2 classification, based on imagery from the mid-1970's to early-1980's. Each 1 x 2 degree quadrangle is a separate coverage. Coverages for about 50 quadrangles are currently in the database.

Soil-survey data at approximately 1:250,000 scale were obtained from USDA Soil Conservation Service (SCS) as existing coverages for a 17-state area. The data, referred to as STATSGO, are generalized soil groupings, with a number of related attribute files.

Digital-elevation-model (DEM) data were obtained as existing grids (raster datasets) for the entire basin. The data had been compiled from 1:250,000-scale maps at a cell size of 3 arc seconds. A number of derivative grids have been created. Nine 7.5 minute topographic quadrangles DEM were also obtained.

Data from the AVHRR satellite were obtained as existing grids and clipped to the basin. These data have a cell size of 1.1 kilometers. The obtained data were already classified for various categories, including vegetation type and greenness index.

A set of Landsat Thematic Mapper (TM) satellite image data containing 96 preflood scenes covering the entire river basin, 25 peak flood scenes covering the area of intensive study and 25 post flood scenes of the area of intensive study was obtained. Each image was received in a stacked grid format of six or seven sensor bands, with 28.5-meter cell size. Each scene, or image for a single date, required 300 megabytes of compressed storage. The Landsat satellite acquires repetitive data of the same location at intervals of approximately 16 days. In addition, several SPOT and ERS-1 satellite images were obtained.

Several national databases of point data with extensive attribute information were obtained. Some covered all states in the basin; some covered only those states in the principal study area. Some were received in spreadsheet or ASCII format; others were processed already into GIS coverages. These include the National Inventory of Dams, highway and railroad bridges, USGS streamflow gaging sites, NOAA weather stations, and a variety of EPA-oriented waste or point-discharge sites. Data from the 1990 census, separated into block groups, were also received and processed. The census data contain statistics of population, housing, and income.

A number of freely available national coverages were also incorporated into the database. These include average annual precipitation and runoff, surface geology, hydrologic units, standard quadrangle boundaries, state and county boundaries, and many coverages derived from 1:2,000,000-scale national maps.

Other National Databases

Some valuable national databases were obtained that were not in GIS format, but nevertheless could be related to features in GIS coverages. For example, county-based 1990 census data contain hundreds of attributes and can be related to county coverages by the FIPS code. Data for the 1987 census of agriculture likewise were obtained and related to county coverages.

Statistics regarding crop production, crop payments, crop disaster payments, and crop insurance payments were also obtained through SCS. After some processing, these were tied to FIPS codes and also related to county coverages. Statistics for 1993 continue to arrive, and efforts continue to obtain more statistics on county business patterns, distribution of food stamps and surplus food, emergency housing loans, rural utilities, and more.

Time-series data for selected USGS and NOAA streamflow and weather observation sites were obtained from those agencies. The data have been tied to point coverages of the sites.

A multitude of weather-satellite images and surface-analysis (weather map) images are available from NOAA or its affiliates. These have not been obtained, but would be a valuable addition to a comprehensive database of the 1993 flood.

Regional and Local Databases

Many sources of data contained valuable information on a regional or local scale. The SAST focused its data-creation efforts on layers directly related to the floodplain.

Various databases relating to the main river system have been obtained, and continue to be obtained, from various agencies. These include pool boundaries, river-mile points and associated attributes, forestry data, lock and navigation data. A set of Missouri River charts, mapped in 1879 and published in 1891, has been obtained and digitized. The charts include delineation of channels and land cover.

Several classifications in the floodplain have been derived from TM satellite imagery. This includes maximum extent of 1993 flooding of natural floodplain as determined by satellite imagery, and a level 1- landcover classification.

All available digitized quadrangles of the National Wetlands Inventory (NWI) --about 3600-- were obtained. As of mid-March, 16 counties have been incorporated into the database. This is a very detailed database, mapped at 1:24,000 scale. Unfortunately, large blocks of the study area are not available. The SAST has contracted approximately 150 more quads to be digitized.

100- and 500-year flood boundaries from Flood Insurance Rate Maps (FIRM) were digitized from contract. The existing paper maps were "rubbersheeted" to fit existing base maps, then digitized and appended into 30 x 60-minute quadrangles, or partial quadrangles in most cases. Forty quadrangles, covering the principal floodplains of the Mississippi and Missouri Rivers, were created.

Aerial photography, pre-, during-, and post-flood; black-and-white and color, at 1:20,000 and 1:40,000 scales have been investigated or obtained from SCS and the US Army Corps of Engineers (USACE). Several sets of photos have been obtained and are being used for analysis in selected areas to determine channel morphology and areas of scour and deposition.

Accurate and detailed knowledge of levees is crucial for understanding of flooding and for responsible planning in the floodplain. Unfortunately, no single existing database, paper or digital, was either consistent or complete. The SAST undertook a major effort to create a comprehensive

levee database. Data were obtained in digital and paper form from USACE. Data were digitized from maps. Questionnaires were distributed; local offices were visited; returned questionnaires and tables of data were automated. A substantial set of attributes was added to the coverage of levee centerlines. Work on this database continues, in the knowledge that it is the best and most comprehensive basinwide compilation on Upper Mississippi River Basin levees. However, at the time of this preliminary report, considerably more effort is necessary to complete the attribute list and quality assure the data.

Streamflow and Reservoir Storage Data

Water data are collected by the US Geological Survey Water Resources Division at more than 1000 sites throughout the study area. Daily-mean flows and instantaneous flood peak flows are measured at most of these sites. Reservoir storage and elevation data are collected at a few sites. The records are updated throughout the year and are finalized and published annually in USGS annual water data reports for each state. Copies of these reports for the study area are in SAST files.

Selected portions of the WRD data base have been transferred to the SAST.

These data include:

- o daily flow data for about 50 long term sites on the main-stem Mississippi, Missouri, Illinois, and Des Moines Rivers, plus a few major tributaries,
- o peak flow data for the 154 sites at which major 1993 floods were reported in USGS Circular 1120-A,
- o daily-, monthly-, and annual-mean flow data through 1988 for selected long-term sites suitable for climate-variation studies (the Hydro-climatologic Data Network, HCDN),
- o daily reservoir storage data at major reservoirs in the study area for the 1993 water year.

Data for additional sites can be obtained from the USGS District offices for the states in which the sites are located. See the annual state data reports and contact the District offices for

information on gaging station location and for obtaining copies of the data.

In addition to the basic flow data, a set of equations for estimating flood flows at ungaged sites has been developed by the USGS. The equations express the annual flood peak flow of a specified recurrence interval as a function of drainage basin characteristics. Drainage area in most cases is the most significant basin characteristic in determining the flood magnitude; in many cases it is the only significant characteristic. Different sets of equations apply in different states and different regions within some states, reflecting regional variations in flood characteristics. The equations generally are applicable to basins with drainage areas between about 1 square mile and a few thousand square miles. The equations have been developed over the years by individual USGS Districts and have recently been compiled into a software package called NFF, which runs on PC-compatible computers. The NFF user's manual and program disk are in the SAST files.

In addition to the flow data, stage-discharge rating relations were obtained for a number of mainstem sites. These are printed-format tables that can be used to determine the water surface elevation (relative to local gage datum) for any given flow rate. The local gage datum elevations are given in the daily values file in the database and in the published USGS annual water data reports.

Climate Data

Historical data on monthly temperature, precipitation, and evaporation for NOAA/NWS climate divisions throughout the area of heavy rain in 1993 have been obtained from the Midwest Climate Center. These data cover the entire historical period through September 1993 for the following climate divisions -- Iowa 1-9; Illinois 1-6 and 8; Kansas 3 and 6, Minnesota 2 and 4-9; Missouri 1-3 and 5; North Dakota 5 and 9; Nebraska 2, 3, 5, and 6; South Dakota 3, 7, and 9; and Wisconsin 1,2, 4,5, and 7-9.

Daily precipitation and temperature data for April-September 1993 for individual observing sites in Iowa, Illinois, Minnesota, Missouri, and Wisconsin were obtained from the Soil Conservation Service National Technical Center in Lincoln, Nebr.

Climate data are, as of March 1994, in a state of rapid development. The Soil Conservation Service and the National Climatic Data Center (NCDC) both are working on developing improved climatic data sets.

ORGANIZATION OF DIGITAL DATA

With any database so comprehensive, planning and organization are essential. The objective was to compile a variety of information that could be used by many persons for many purposes, both now and in the future. The following sections describe the initial structure of the database. As the database evolves, the structure will be improved.

Hardware, Software and Data Formats

The SAST digital database was compiled and is currently stored on a computer network at the EROS Data Center. Currently the database is approximately 250 gigabytes including uncompressed satellite data. Accessibility to the database will be through online access for specific datasets and offline or near-online access for others.

The principal GIS software is ARC/INFO. All GIS vector-based databases, or coverages, are processed and stored in ARC/INFO format. Most of the raster-based data are stored in ARC/INFO GRID format. Raster data are processed using ARC/INFO GRID or LAS, which is an image-processing software system used at EDC.

Relational data, such as county-based census statistics, are stored in INFO files and incorporated into the ARC/INFO RELATE environment. These related data become part of the spatial database and are used for spatial analysis or display. Much of the relational data was received in the form of PC-based spreadsheets. Because many associates request the data in spreadsheet format, and because the data often undergo considerable manipulation during conversion to INFO, the original spreadsheet data are stored in a separate directory in DBase format.

Time-series data generally have not been fully integrated into the SAST database structure. As feasible, site-description information for sampled data has been converted into ARC/INFO point coverages.

Geographic Projection and Coordinates

All vector-based coverages were converted to an Albers equal-area projection that is commonly used for national maps. The projection uses standard parallels of 29° 30' 00" and 45° 30' 00", a central meridian of 96° 00' 00", and a latitude of origin of 23° 00' 00". No false northing or easting is used. In general, all coverages were stored in double-precision coordinates.

Thematic Mapper imagery was received in the projection corresponding to the local Universal Transverse Mercator (UTM) zone that applies for the extent of each satellite image. Thus, different TM images may be stored in different map projections, ranging from UTM zone 12 in the west to zone 16 in the east. Because of the loss of information involved in projecting raster data from the source, the TM imagery was not projected into the standard Albers projection.

All other raster databases, however, were projected into the standard Albers projection. This includes the DEM grids and their derivative products, and the AVHRR imagery.

All GIS data, including vector and raster formats, are stored in units of meters relative to the North American Datum of 1927. Elevations are based on the National Geodetic Vertical Datum of 1929.

Naming Conventions and Item Definitions

Near the beginning of the data collection effort, standard nomenclature was established. This included criteria for the naming of computer directories and files, the naming of GIS databases, the naming of items in the databases, and the definitions of commonly used items. Due to the diverse nature of the database and the wide range of sources, not every database has been modified yet to meet these standards. A partial description of the standard nomenclature is presented in Appendix A.

Organization of Data Directories

Some vector-based coverages, tabular data, and time-series data are stored online on the SAST computer network. The database structure of the online directories will be discussed in the Database Report. This structure is expected to change somewhat as the database is finalized.

Due to the very large data storage requirements of the Thematic Mapper inventory of satellite imagery, it currently is not practical to store that entire database online. Only a sampling of those images is stored online. All the TM data are stored on 8-millimeter tapes, as ARC/INFO grids, archived in UNIX 'tar' format.

Documentation

For any collection of data, long term utility depends on adequate documentation. An informed analysis requires knowledge of the source, accuracy, method of creation, history of modification, known inadequacies, description, and purpose of the data at hand.

Work is underway to complete the documentation of the collective SAST database. A documentation program, developed for the Distributed Spatial Data Library (DSDL) of the USGS, is being used for all major coverages. In order to obtain sufficient metadata, or documentation, for data received from outside sources, a documentation request form has been posted to all suppliers of data.

The documentation complies with the requirements of the National Spatial Data Infrastructure and the Federal Geographic Data Committee.

DISTRIBUTION OF DIGITAL DATA

All non-proprietary digital data will be available for release to Federal agencies and the public at large. Given the magnitude of the SAST data collection effort and the spirit in which it was conceived, it is imperative that the results be distributed as widely as possible. Future emergencies are better prepared for than responded to.

Follow on efforts will include management and distribution activities, including a clearing house and online accessibility from the Internet for some data sets. Among the

approaches being investigated are hypertext application written with the Mosaic software and a Wide Area Information Service (WAIS) application. The mosaic hypertext application can provide a window-based browser environment for interested persons to read or download documents or graphics. In this way, SAST documents would connect with the World Wide Web, a global scientific information service (Krol, 1994). In the WAIS environment, choices can be made using spatial searches.

Initial release of some data is as beta test versions to selected users. The feedback from these users will aid in improving the quality of the data sets. Once selected datasets are available for release, some will be made available on CD-ROM. However, due to the size of the database (in excess of 250 gigabytes by May 2, 1994), releasing the entire database on CD-ROM is impractical.

FURTHER DEVELOPMENT OF DIGITAL DATA

Difficulties in Obtaining Data

- o Early in the effort the SAST developed a list of critical data sets. Some were relatively easy to obtain, such as Thematic Mapper satellite data or standard Digital Line Graphs, because their existence was widely known. Others were more difficult to find because no central clearing house exists for information about the data. The interdisciplinary interagency nature of SAST is a primary reason it is effective in identifying the data that were acquired. Despite this effectiveness, a number of issues had to be addressed:

- Making the right contact.

Considerable effort was required to find out exactly what data are available and where best to obtain them.

- Getting cooperation.

Generally, this was not a problem, but in some cases it was difficult to get beyond the initial contact which ranged from, "We have everything" to "We don't have anything", with the truth somewhere in between -- and actually get the data in hand. Some people did not know much about sharing data; some did not much care.

- Establishing transfer protocols.

SAST received data from a wide variety of sources, in many different formats, and via a number of transfer methods. SAST received spreadsheets, ASCII files, data in Federal format, and data in proprietary format. SAST received data on floppy disks, on 8-mm tapes with various densities and blocking factors, on cartridge tapes, on 9-track tapes, on CD-ROMs, via Internet, and in packages.
- o Some data sets were in the hands of government agencies but relatively few people knew of their existence. An example is the post-flood aerial photography of the Missouri River taken by the Army Corps of Engineers. These data were identified during workshops or discussions with government and non-government personnel. Often, acquiring the data took considerable time and energy in the form of phone calls and visits to the organizations.
- o Some data sets, though promised by the agencies, did not arrive and had to be obtained in person by a SAST member. Some data that had been identified and requested were never released to the team by the agency.
- o Some data cost more than the team could afford, were proprietary, or had such severe limitations on their use that purchase was inappropriate.
- o Some important data were not in digital form, such as historical floodplain data, and had to be digitized.
- o Some data did not exist or did not exist in appropriate form. Where these data were critical, they either had to be created or they would not be available for analysis.
- Developing new data sets in the short time that was available for the first phase of the SAST effort required initiative and follow-through. For instance, the levee database required considerable effort. Input came from a variety of sources, levee information forms were produced and distributed widely, and low quality maps and sketches were obtained from the disaster field offices. This information was then transferred to better

source material and field work was conducted. Considerable follow through was necessary to obtain responses to questions, and a considerable digitizing effort was necessary to compile the data. A major quality assurance effort is still necessary because the initial information came from a variety of sources and had inconsistent and often only partial or erroneous attribution.

Difficulty in compiling data

- o Many data sets are spatially incompatible for the meaningful analyses that should be done. For instance, many of the economic data are maintained at the county level and are difficult or impossible to disaggregate to sub county units, such as the floodplain within the county. This makes meaningful analysis of crop losses in the floodplain difficult or impossible. More detailed data could be obtained at a significantly higher cost.
- o Many data sets were in different formats and structures and had to be made compatible before they could be compiled into single data sets. For instance, some USACE data were in Intergraph format, while SAST work was conducted in ARC/INFO. There were insufficient resources to make the conversion in a timely manner for Phase I SAST activities.
 - A number of data processing and conversion methods needed to be obtained or created. From the beginning, a database structure was established, with standardized naming conventions and definitions. There were problems with combining coarse and detailed data, with understanding how one dataset was similar to or different from another, and with handling updates to data that SAST had already processed. Time-series data requires an inherently different structure and format.
 - Varying standards for data caused significant difficulty. Even within the same agency, different offices had entirely different approaches to data. Some had structured GIS databases, some had paper maps, and some had data in random form.
- o Data initially produced in different organizations frequently had different definitions for attributes, different accuracies and reliabilities, were collected in different ways, or were

stored in different ways. This range of differences required the SAST to spend considerable time converting the data to compatible forms for compilation.

- o The compilation effort required extraordinary coordination. All compilation tasks had to be completed by the same limited staff. In an "emergency" effort, each task seems to have a high priority. With new tasks arriving from the IFMRC without regard to the realities of data, processing, or analysis, it was difficult to assign priorities, schedule work, juggle tasks, remain efficient, and produce results on schedule.
- o Transition from data collection to analysis. SAST has just begun to conduct exploratory analysis. It can be difficult to apply any body of data to specific analyses or interpretations and a considerable amount of time is necessary to conduct sophisticated scientific analysis. The analysis conducted by SAST will be published in subsequent reports.

UPPER MISSISSIPPI AND MISSOURI RIVER BASINS
SHADED TOPOGRAPHIC RELIEF



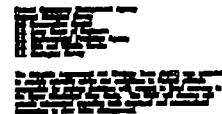
Federal Emergency Management Agency
National Biological Survey
Bul. Conservation Service
U.S. Army Corps of Engineers
U.S. Environmental Protection Agency
U.S. Fish and Wildlife Service
U.S. Geological Survey

The Scientific Assessment and Strategy Team (SAST) was established to provide scientific advice and assistance to Federal officials responsible for making decisions with respect to flood recovery in the Upper Mississippi River Basin. The SAST will develop and provide information regarding both structural and nonstructural approaches to river basin management.

Scale 1 : 2,000,000
Kilometers
50 0 50 100 200 300
Miles
50 0 50 100 200
Albers equal area projection: 28.5N, 45.5N, 90W

UPPER MISSISSIPPI and MISSOURI RIVER BASINS

Basin Extent and Hydrography



BASELINE 1900 DATA CONTINUED SCALE 1:1,000,000

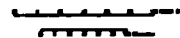
UPPER MISSISSIPPI and MISSOURI RIVER BASINS SEASONAL LAND COVER REGIONS



Land Cover Regions

- ☐ Small Grains/Row Crops
- ☐ Row Crops
- ☐ Small Grains
- ☐ Irrigated/Dry Land
- ☐ Irrigated
- ☐ Cropland/Grassland
- ☐ Cropland/Woodland
- ☐ Grassland
- ☐ Desert Shrubland
- ☐ Shrubland/Grassland
- ☐ Savanna
- ☐ Northern Deciduous Forest
- ☐ Southeast Deciduous Forest
- ☐ Western Deciduous Forest
- ☐ Southeast Coniferous Forest
- ☐ Western Coniferous Forest
- ☐ Western Woodlands
- ☐ Northern Mixed Forest
- ☐ Western Mixed Forest
- ☐ Southeast Mixed Forest
- ☐ Alpine Tundra
- ☐ Barren
- ☐ Water

The Forest Land Use Regions were adapted from the Forest Land Use Regions of the United States, published by the U.S. Forest Service, Washington, D.C., 1961. The Forest Land Use Regions were adapted from the Forest Land Use Regions of the United States, published by the U.S. Forest Service, Washington, D.C., 1961.



CHAPTER 3: PHYSIOGRAPHY

INTRODUCTION

The SAST was formed to explore alternative strategies for structural and nonstructural approaches to control peak flows from flood events. The mainstem river systems --- floodplains-- are the pathways through which surface water is ultimately transferred out of the river basin. Water accumulates in the streams via surface water runoff from the upland areas of the river basin. Thus, it is imperative to understand the hydrologic processes of the entire basin to address the goal of SAST. To understand the hydrologic processes of the uplands portion of the basin, both the biological and physical properties of the basin have been studied. The objective of the analysis is to show the interrelationships between the primary physical characteristics: soils, geomorphology, topography, drainage density, and land cover; and the biological or ecosystem processes of the basin.

The river basin assessment is divided into terrain classification, soils, wetlands, hydrology, cultural/land management, and ecology sections. The assessment describes the upland part of the basin with respect to potential contributions of water and water borne sediment to the floodplain. The impacts of agricultural drainage and land management practices are discussed with respect to surface water hydrology. Four watersheds in distinct terrains have been modeled with respect to land use and land management and surface water runoff. The terrain classification of the basin is used to extend information from these model watersheds.

TERRAIN ANALYSIS

An initial activity of the river basin analysis is to develop a terrain classification system that depicts the hydrologic response of the basin. Hydrologic response is affected by land use and management practices, slope gradient, aspect, and variance; drainage patterns and density; surficial deposits, soil texture, permeability, water storage capacity, soil hydrologic groups; and land cover. The terrain classes integrate among these factors to characterize the hydrologic response of an area. These terrain classes are used as a means to extend limited research and model results on hydrology to other similar areas of the basin and to evaluate alternative land management and structural means to control surface water runoff and stream flow.

The Upper Mississippi/Missouri River Basin is physiographically, ecologically, and climatically diverse. Physiographically, it ranges from the Rocky Mountains on the western border; to rolling Rocky Mountain outwash areas of the Great Plains; to relatively level glaciated plains in the middle of the basin; to rolling till prairies and loess uplands; to the dissected plateaus of the Ozarks. Vegetation ranges from predominately grasslands or wheat in the Great Plains, to the intensively managed corn belt region, to pasture and woodlands of the Ozarks.

Preliminary geographic analysis shows that this region can be divided into as many as 70 terrains. Further analysis is needed to determine if each of these 70 terrains is unique with respect to hydrologic response. Other land resource maps (Soil Conservation Service, 1981, Agricultural Handbook 296) subdivide the basin into about 44 Major Land Resource Areas (MLRA's). The MLRA's are separated by differences in soils, topography, climate, water resources, potential natural vegetation and land use.

An analysis of the slope gradients in the STATSGO database has been completed. Figures 3.3 and 3.4 show the areal distribution of slope groups in the basin and the distribution of gradients within each of the slope groups. The distribution of slope gradients within each map unit in STATSGO was computed in terms of five-percent slope intervals from 0 to 70 percent slope with additional categories for slope gradients greater than 70 percent, and water. The distribution was represented as a set of 16 proportions for each map unit. A multidimensional distance between the map units was computed, and a clustering algorithm was used to group the map units into a set of 9 groups (fig. 3.4). These slope groups are plotted on a regional map and characterized by a histogram showing the distribution of slope gradients within a group (fig. 3.3). The colors in figure 3.3 depict slope groups sa1 to sa9. Group sa9 is water. Slope groups range from sa1 which has the flattest slope gradients, to sa8 which has the steepest gradients.

The mauve color shows the nearly level closed drainage terrain of central Iowa, Minnesota, east central Illinois, and the Dakotas. The linear blue areas within the mauve in northwestern Iowa and southwestern Minnesota are glacial moraines. The area west and south of the Missouri River in North and South Dakota and Nebraska has a wider distribution of slope gradients depicting the rolling nature of this nonglaciaded area. The east-west color patterns in the western part of the basin demonstrate the general nature of slopes and the drainage east from the Rocky Mountains. The dissected, sloping loess areas along the Missouri and Mississippi are shown in classes sa3 and sa6. This open drainage terrain is characterized by blue stringers representing the many streams in the area. The dissected area of loess-covered broad interfluves in southern Iowa and northern Missouri is uniquely separated as slope group sa4. This is roughly

the Grand River drainage basin.

In very general terms, the basin is characterized by the following landscapes:

- level to gently rolling glaciated (prairie pothole) cropland of western North Dakota, northeastern Montana, and central South Dakota (dominately slope group sa1)
- rolling soft shale cropland plains of southwestern North Dakota and northwestern South Dakota (dominately slope groups sa2 and sa6)
- rolling high plains grass and wheat lands of Montana, eastern Wyoming and Colorado, and western South Dakota that are characterized by clay shale, siltstone, and soft sandstone (dominately slope groups sa6 and sa7)
- rolling to steeply sloping sand dunes and grasslands of the Nebraska sand hills (dominately slope groups sa6 and sa7)
- mostly loess-covered, level to gently rolling winter wheat and range region of the central Great Plains of Nebraska and Kansas (dominately slope groups sa1 and sa2)
- rolling till prairies and deeply dissected loess uplands and till plains of the western part of the corn belt in eastern South Dakota, Nebraska, and Kansas, and western Iowa and Missouri (slope groups sa3 and sa6)
- nearly level till plains of southern Minnesota, central and eastern Iowa that include the largely artificially drained pothole region of the corn belt

(slope group sa1)

- deeply dissected loess hills cropland along the Mississippi River (slope groups sa6 and sa7)
- nearly level to gently rolling clayey till plain of southern Iowa and northern Missouri that is about 50 percent cropland and 50 percent pasture and woodland (slope group sa4)
- nearly level clayey till plain of northern Illinois and western Indiana corn belt (slope group sa1)
- steeply sloping and dissected, wooded, northern part of the Ozark highlands (slope group sa6)
- Rocky Mountain foothills (slope groups sa7 and sa8)

SOILS IN THE BASIN

PARENT MATERIAL

Parent material refers to the surficial materials in which the soil has formed. Almost all of the soils in the Upper Mississippi and Missouri River basin formed in parent materials that have been transported from their residual or parent rock areas. Except for portions of the western parts of South and North Dakota and the extreme southern part of the basin, the parent materials are of loess or glacial till origin. Most of the parent materials are calcareous or weakly calcareous. Figure [] shows the distribution of parent materials in the area.

(Figure in Preparation)

DISTRIBUTION

The distribution of soils in the basin is presented by soil order in table [] and figure 3.5. Mollisols, prairie soils formed under grasslands with dark colored surface layers and high base status, make up over 50 percent of the basin. Mollisols are the dominant soil order in Montana, Colorado, North Dakota, South Dakota, Nebraska, Kansas, Minnesota, Iowa, and Illinois, ranging from a high of 90 percent in North Dakota to a low of 9 percent in Wisconsin. Alfisols are the dominant soil order in Wisconsin, Indiana, and Missouri. Alfisols in the more humid eastern part of the basin formed under forest vegetation. In the extreme western part of the basin, Alfisols formed under a mix of deciduous, Savannah, short and mid grasses, and forbs vegetation.

[Table in Preparation]

HYDRIC SOILS

Hydric soils in the basin occur as depressions (potholes) in young, glacial, closed drainage landscapes of the Dakotas, Minnesota, Iowa, and Illinois; in depressional areas on wide interfluvial areas of southern Iowa and Illinois and northern Missouri; and in backland and backswamp areas on floodplains along rivers with wide floodplains and on floodplains of low gradient streams. The highest concentration of hydric soils in the basin is in the floodplains of the Missouri and Mississippi Rivers and in the glacial pothole and depressional (closed drainage areas) of central Iowa, southern Minnesota, the northern half of Indiana, and central and northeastern Illinois. Hydric soils comprise 40-70 percent of this area. A large portion of the hydric soils in this, the

major corn belt region of the basin, represents former wetlands that have been drained for agricultural use.

The Missouri River has a relatively wide floodplain through Nebraska and Iowa. The pattern of hydric soils in the floodplain is that the highest percentage of hydric soils is located away from the river and next to the uplands. This pattern conforms to landforms in the floodplain: natural levees next to the stream where sediment is deposited as a result of rapid loss in water velocity; backland areas that generally slope to backland depressions; and occasional oxbow lakes.

The area of hydric soils as a percentage of the total area of a State ranges from about 1 percent in Montana and Wyoming to over 35 percent of the area in Minnesota. The total area covered by hydric soils is about 26 million hectares, roughly equivalent to the original area of wetlands before the region was settled. The largest concentration of hydric soils in the basin is in areas that are drained for agriculture. Thus, the glacial area of the corn belt states consists of millions of closed depressions that were noncontributing to downstream flows before settlement and are now prime areas for nonstructural means for controlling surface water.

TOPOGRAPHY

The basin is characterized by two distinct kinds of landscapes: (1) open systems where the drainage net is from low order stream to a larger trunk stream, and (2) closed systems where the drainage is trapped within a common depository. Within these landscapes, hill slope geometry (linearity, convexity, or concavity along the slope length and width) is an important factor affecting water movement. Convergent slopes, which are concave in both slope length and width

directions, are areas of maximum accumulation of runoff water. These convergent slopes are potential storage areas of runoff water. In contrast, divergent slopes, which are convex in both directions, are areas of maximum runoff.

In open systems, surface water runoff generally flows to a stream and out of the system. Water may accumulate in convergent areas of open landscapes such as head slopes (convergent back slope) and convergent foot and toe slope positions. These wetter areas may support hydric soils if there is a water restricting layer that crops out on the hill slope.

Closed landscapes are generally related to the areas of glacial drift in the drainage basin. Closed landscapes lack stream outlets: thus, all water, sediment, and other materials from the surrounding area are trapped. Trapped or ponded water must either evaporate, recharge the ground water, or overflow in undefined surface drainage to other depressions or eventually to a stream. Constructed open ditch drainage systems change closed landscapes into open landscapes with respect to both surface and ground water hydrology. Before agricultural drainage, closed landscapes were considered noncontributing with respect to surface water runoff.

SURFACE AND SOIL PROFILE STORAGE OF WATER

In the basin, the potential for water storage both above and below the ground is broadly estimated at 580 billion cubic meters, using information in the STATSGO soil database for the basin (SAST database). This storage capacity is much greater than the amount of water that flowed past St. Louis during the flood of 1993 and indicates the tremendous storage capacity of the upland areas of the basin. However, antecedent moisture conditions are also important.

Because much of the basin, particularly the areas that received the highest rainfall, was wet, the buffering capacity of the basin was depleted and unable to store water from the rains of June and July 1993.

Subsoil Water Storage

The ability of a soil to store water varies with texture, density, organic matter content, and initial moisture content of the soil. Infiltration rates are a particularly important factor in the potential water storage in soils. Most medium textured soils, such as those in the basin, average 1.25 to 2.5 cm/hr infiltration rates (Donahue and others, 1977). Rainfall intensities greater than those averages will exceed the infiltration rates of many soils and water will run off into streams in open drainage systems or into depressions in closed drainage systems, before the soil becomes saturated. Infiltration generally increases with an increase in organic matter, stability of soil aggregates, or soil cover. These properties are supported by management practices such as residue management and no- till systems. Structural practices such as terraces trap water on the soil surface and allow for seepage of water into the soil. These management practices increase infiltration and thus increase the ability of the soil to store water from rainfall. Additionally, transpiration of plants and evaporation from the soil surface lower soil moisture content. Thus, soils with dense live plant covers will have more storage capacity available for water retention than soils with sparse or no live coverage.

Surface Water Storage

In the closed drainage areas of the basin, glacial landscapes with depressions or potholes pond water. When the depressions fill, surface water may flow from pothole to pothole through an ill-defined drainage network and eventually find an outlet to a stream. However, this is an extremely tortuous process in comparison to open drainage systems and the water in the depressions is still stored. Surface water storage in the basin is almost entirely in the prairie pothole region of North and South Dakota, Minnesota, north central Iowa, and east central Illinois. The rest of the basin consists of open systems with only minor areas that store water on the surface.

In the basin, estimates show 10 times more storage capacity in the soil than above ground. Subsoil storage is important in all of the basin but in open drained areas, subsoil storage is the major component and is dominant in Iowa, Missouri, Kansas, Montana, Colorado, and Nebraska. Relatively high surface water storage is found in the Dakotas, Minnesota, Illinois, Indiana, and Wisconsin.

SAST DRAFT: NOT FOR RELEASE OR ATTRIBUTION**WETLANDS OF THE UPPER MISSISSIPPI RIVER BASIN**

In this review, the area of wetlands in the basin is discussed with respect to changes in wetlands from presettlement to the present, the value of wetlands for biodiversity and for water quality, and wetlands as a means for flood redirection in the basin.

Presettlement vegetation consisted of deciduous hardwood forests in the eastern Ozark Plateau parts of the basin, tall grass prairies in the central part, and mixed and short grass prairies in the western part. In the prairie region, woodlands occurred in riparian zones and around upland wetlands.

The amount of presettlement wetlands in the basin is estimated at 58 million acres (Kusler, 1993; Table 3.1). Presently there are about 23 million acres of wetlands remaining in the basins (Kusler, 1993). The loss of 35 million acres of wetlands has mostly been a result of agricultural drainage (Kantrud, 1989; Van der Valk, 1989), and channel modification and flood control (Funk and Robinson; 1974, Eckblad, 1988; Jahn and Anderson, 1986).

The wetlands in the northern Great Plains (prairie potholes) and sand hills are critical to breeding, migration, and wintering waterfowl (Tiner, 1984). The prairie pothole region occupies only 10 percent of the total continental waterfowl breeding range but produces over 50 percent of the continental waterfowl. Wetlands in the prairie potholes provide cover and nesting to a total of 15 waterfowl species, 57 species of nongame birds, and 39 mammals (Kantrud and others, 1989; Fritz in van der Valk, 1989). Prairie potholes support a diverse community of invertebrates including 44 mollusk species in North Dakota alone. Drained wetlands (prairie potholes) can be restored to a close semblance of their natural state (Kusler and Kentula, 1990), and typically

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recover much of their former biotic function within a year of restoration. However, natural wetlands consistently have greater biodiversity than restored wetlands within at least the first few years of establishment (LaGrange and Dinsmore, 1989; Delphy and Dinsmore, 1993; Hemesath and Dinsmore, 1993; Galatowitsch, 1993).

Depressions and fringe wetlands are extremely important to preservation of water quality (van der Valk and others, 1979; Mausbach and Richardson, 1994). Precipitation, runoff, topography, pedology, and vegetation affect the extent to which a wetland can enhance water quality (Furness, 1983; Wigham and others, 1988). Wetlands where the soil becomes anaerobic can remove excess nitrates from the soil and water through denitrification processes, and wetlands reduce nitrate to nitrogen gas (Mausbach and Richardson, 1994). Other studies show that wetlands help degrade agricultural pesticides to environmentally safer compounds (Mausbach and Richardson, 1994). Wetlands also serve as sinks for phosphorous (Mitsch and others, 1977; Johnston and others, 1984). Wetlands are valuable for preventing sediments from entering lakes and streams (Kunsler and Brooks, 1988). Wetlands are natural filters for water quality in the basin.

ROLE OF WETLANDS IN FLOOD REDUCTION

Glaciation created the landscapes of the upper reaches of the Mississippi and Missouri Rivers. The morphology of these landscapes in the northern prairie region consists of end moraines, stagnation moraines, ground moraines, outwash plains, and lake plains. The upland areas contain numerous glacial depressions of various shapes, sizes, and depths that store runoff.

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For example, most wetlands in the prairie pothole region occur within depressions in end moraines and ground moraines. Local relief from hilltop to adjacent lowland may be 15 to 45m in end moraines and only a few meters in ground moraine (Winter, 1989).

Closed flow systems are still common in the basin, covering thousands of square miles. These landscapes do not contribute to stream flow by runoff, and therefore, do not fit the classical definition of "watershed" unless they are artificially drained. Winter (1989) states that, "Where it is not extremely flat, such as in morainal areas, a natural drainage network has not developed, and the many depressions are not connected by an integrated drainage system". Over 1000 square miles of the 1760 square mile drainage area above the Jamestown, North Dakota, reservoir is still considered to be noncontributing to runoff (due to absence of artificial drainage) (Wiche and others, 1990). Future drainage would convert these closed systems to open systems.

Investigators have documented the depressional storage in some of these closed flow systems within the northern prairie portion of the landscapes. Wiche and others (1990) used digital elevation models in 5 test sites consisting of 26.4 square miles in North Dakota. Total storage capacities were 809.8, 330.5, 326.3, 321.8, and 199.2 acre-feet per square mile. Hubbard and Linder (1986) measured the water held in 213 wetlands representing 50 percent of the surface water of the study area in South Dakota. These wetlands held about 20 ha-m of water. The authors concluded that immense quantities of runoff could be impounded by prairie wetlands, acting to limit flooding and to recharge ground water supplies. Ludden and others (1983) studied wetland storage capacities in the Devils Lake Basin of North Dakota. They found that the wetlands in the area store about 72 percent of the total runoff from a 2-year frequency flood and

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about 41 percent of the total runoff from a 100-year frequency event. The Devils Lake Basin itself is a large closed flow system that does not contribute to the Red River watershed. These studies indicate that significant amounts of runoff can be stored in natural unaltered landscapes in the northern prairie region.

The primary loss of water in these closed landscapes is through evapotranspiration and groundwater seepage. Evaporation amounts in inches vary from reservoirs in the Midwest from north to south and from east to west: Milwaukee (29); Minneapolis (32); Bismarck (39); Havre (43); Kansas City (47) and North Platte (51) (Van der Leeden and others, 1991). Kantrud and Steward (1977) studied the water losses from 135 wetlands of different water regimes over a 6 year period (fig.). On the average, wetlands are either dry or their water depths are substantially reduced by the November freeze-up. The depressions are therefore available for runoff storage the following spring.

In contrast, thousands of square miles of formerly closed depressional areas have been opened by artificial drainage in the basin. Wetlands as a percent of surface area of many states have declined drastically since the 1780's European settlement (Dahl 1990): Illinois, 22.8 to 3.5; Iowa, 11.1 to 1.2; Minnesota 28.0 to 16.2; Missouri, 10.9 to 1.4; North Dakota, 10.9 to 5.5; South Dakota, 5.5 to 3.6; Wisconsin, 27.3 to 14.8.

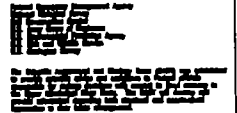
Moore and Larson (1979) studied the effects of drainage projects on surface runoff from small depressional watersheds throughout the North central region of the United States. They were interested in the role played by prairie pothole depressional wetlands in regulating high rates

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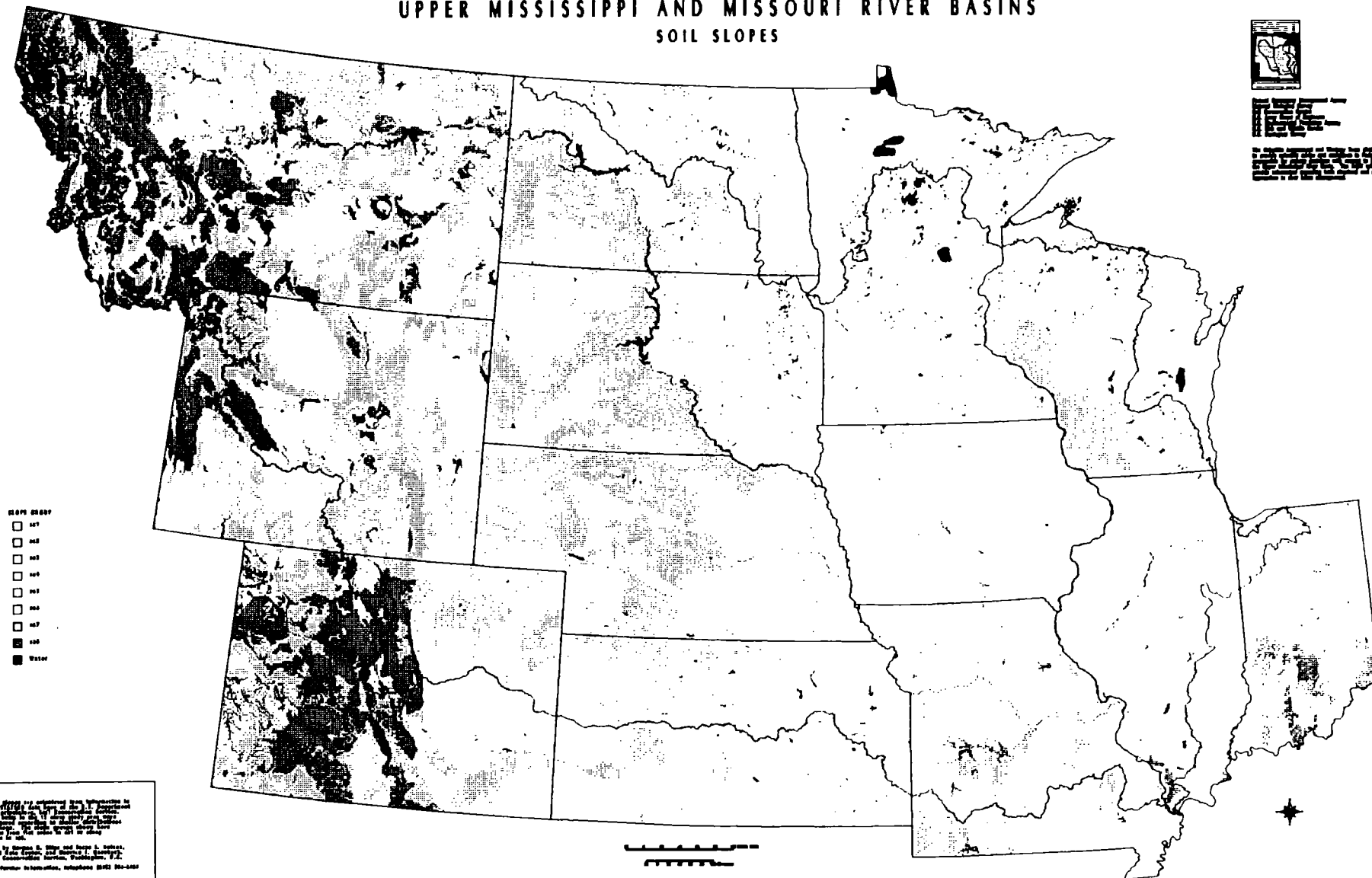
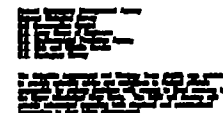
of runoff (flood flows) from major summer storms and from spring snowmelt, before and after drainage for agriculture use. In 23 watersheds in Minnesota, they determined that the mean annual flood increases in proportion to watershed area and inversely with the percentage of lakes and wetlands within the watershed. Their data demonstrate the impact of artificial drainage, which not only increases the watershed runoff area but decreases the amount of depressional storage.

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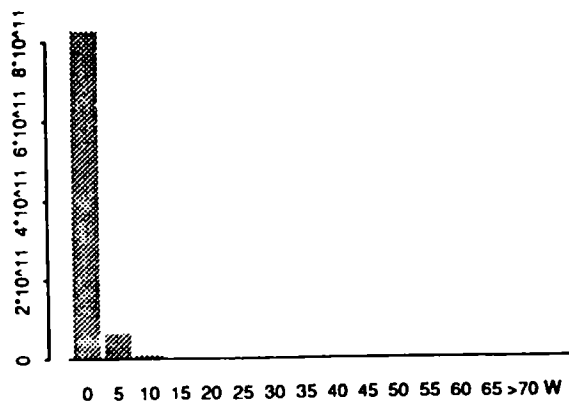
UPPER MISSISSIPPI AND MISSOURI RIVER BASINS SOIL SLOPES



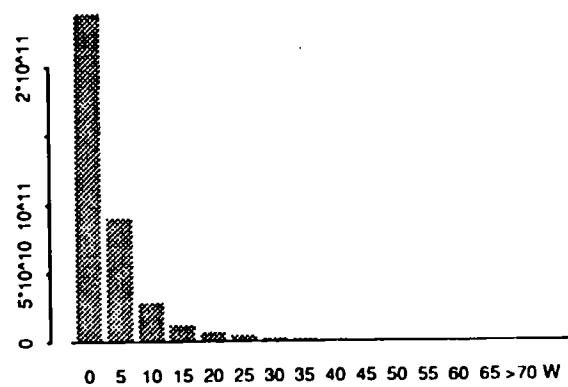
- SOIL SLOPE
- 1-5
 - 6-10
 - 11-15
 - 16-20
 - 21-25
 - 26-30
 - 31-35
 - 36-40
 - 41-45
 - 46-50
 - Water

SOIL SLOPE DATA WAS OBTAINED FROM THE
NATIONAL SOIL SURVEY DATA CENTER, ARS
SOUTH CENTRAL REGIONAL OFFICE, TAMU
SYSTEM, TAMU, TEXAS 77701-1141
FOR FURTHER INFORMATION, TELEPHONE (817) 254-4444

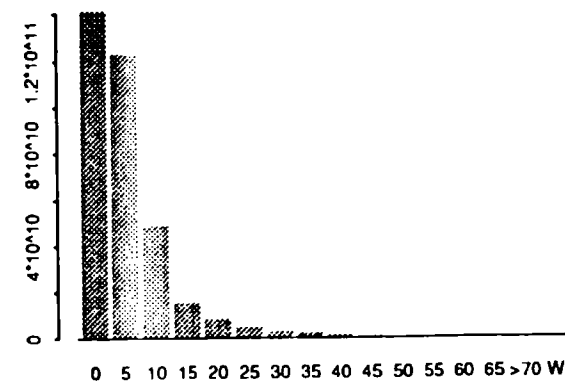
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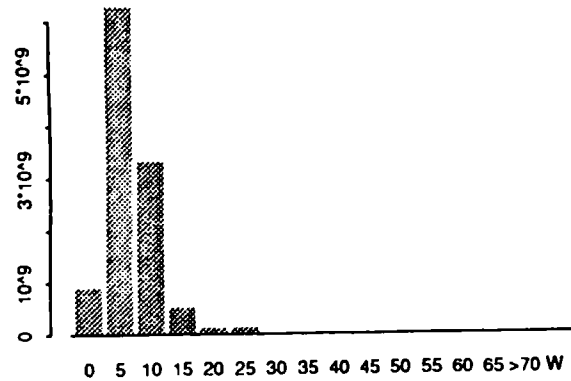
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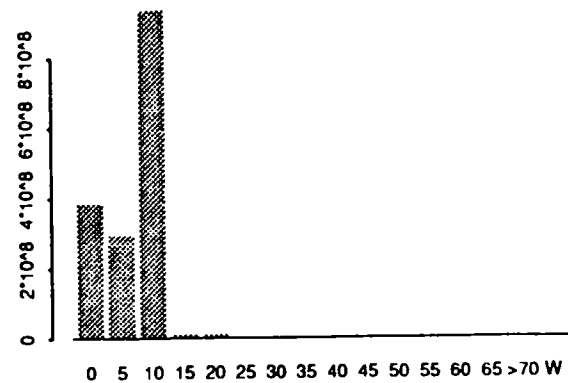
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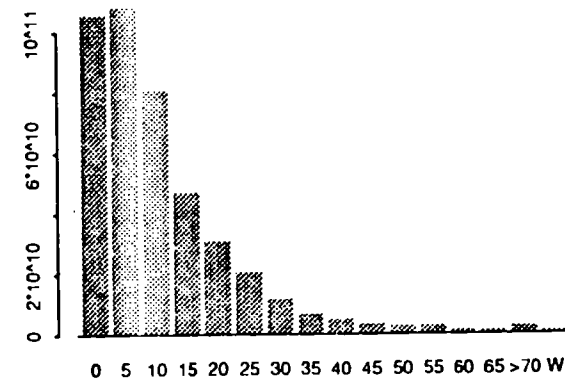
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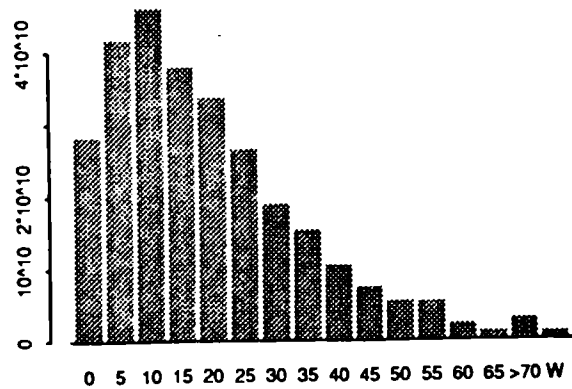
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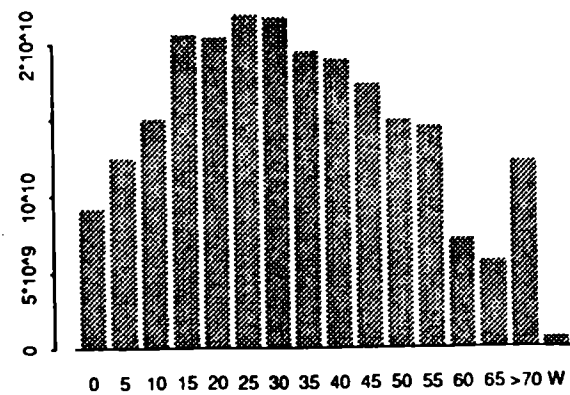
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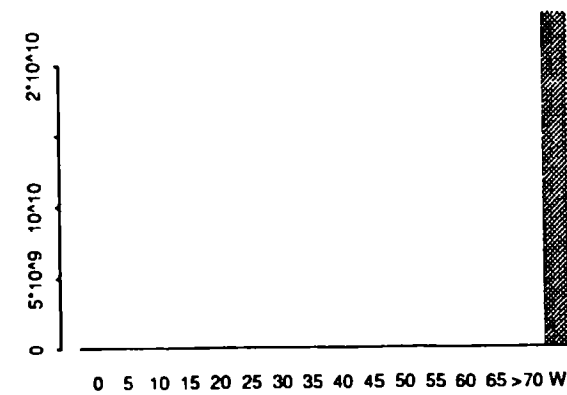
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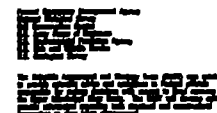
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sa9

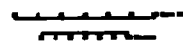


UPPER MISSISSIPPI AND MISSOURI RIVER BASINS SOIL ORDERS

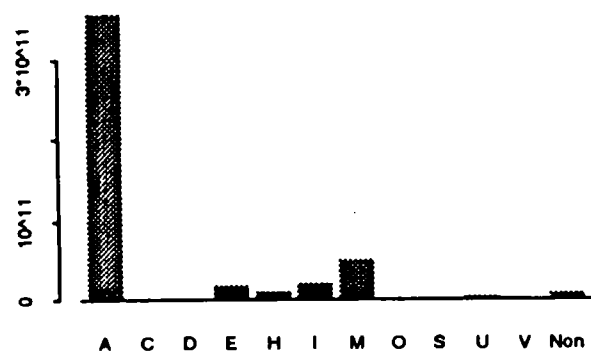


- SOIL ORDER**
- 00 1 Alfisols
 - 00 2 Mollisols
 - 00 3 Vertisols
 - 00 4 Inceptisols
 - 00 5 Entisols
 - 00 6 Histosols
 - 00 7 Aridisols
 - 00 8 Spodosols
 - 00 9 Water
 - 00 10 Gelisols
 - 00 11 Oxisols

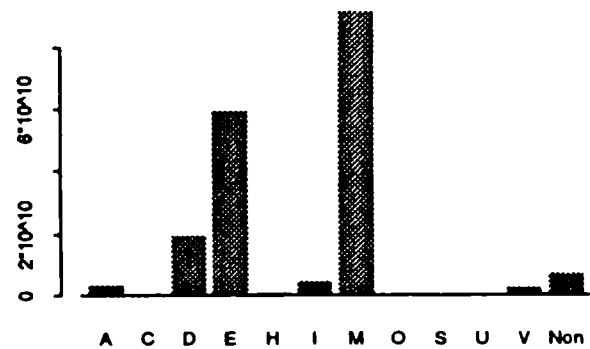
For further information, telephone (800) 555-5555



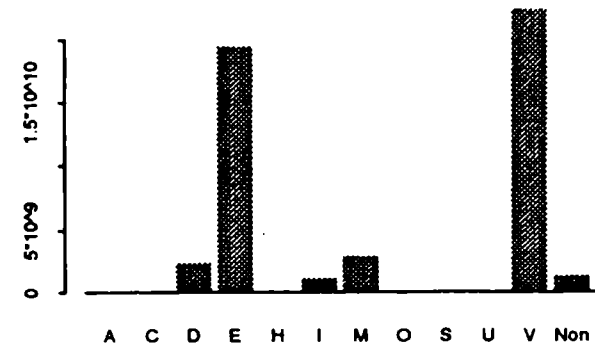
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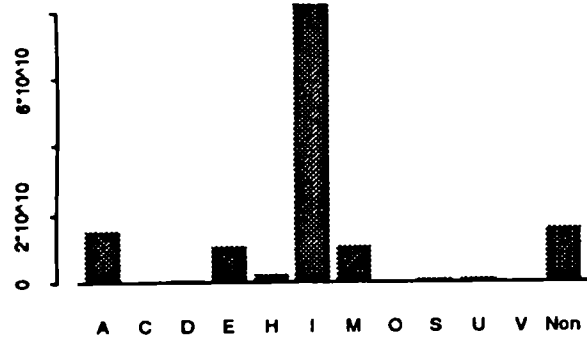
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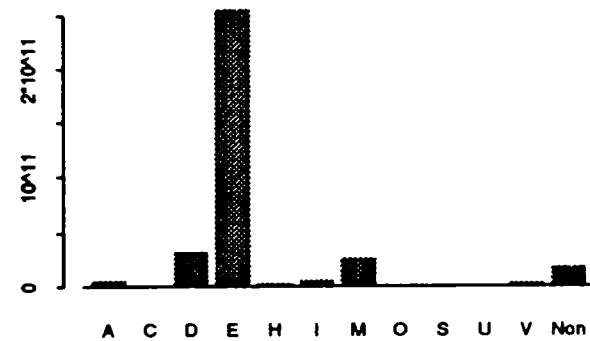
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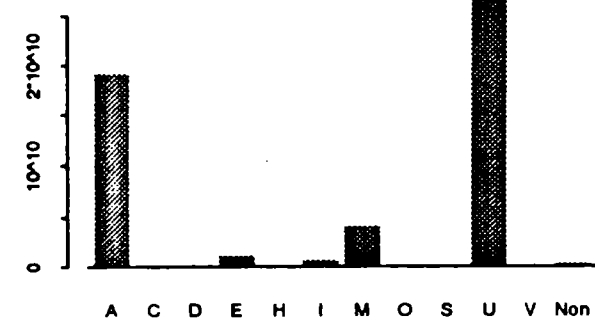
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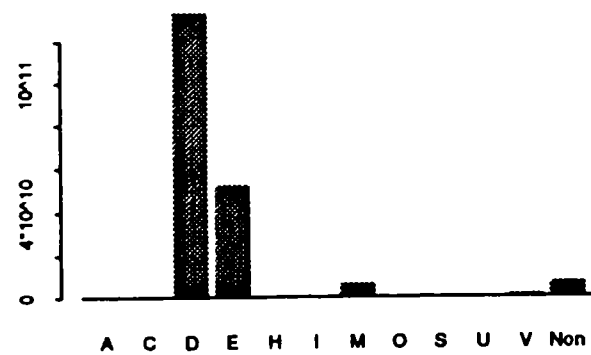
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OG 6



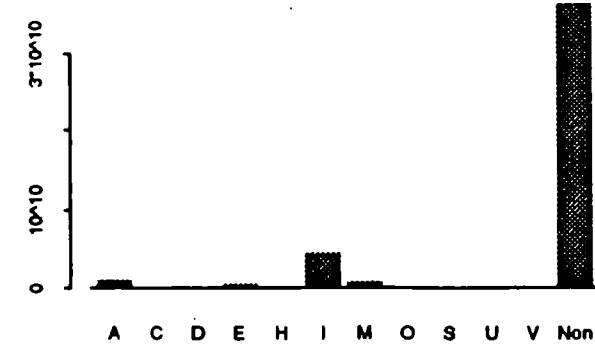
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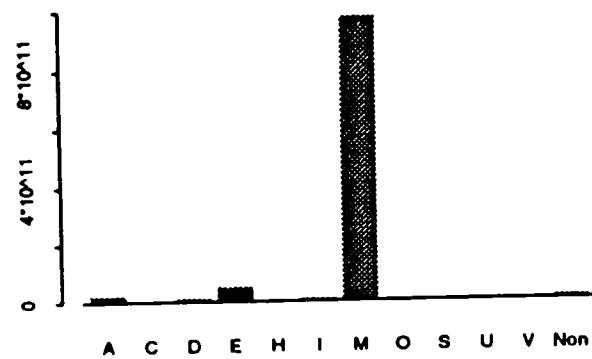
OG 8



OG 9



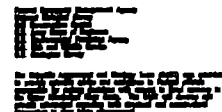
OG 10



OG 11



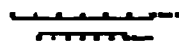
UPPER MISSISSIPPI AND MISSOURI RIVER BASINS HYDRIC SOILS



- PERCENT OF POLYMER
- 0.00 - 0.00
 - 0.01 - 0.10
 - 0.11 - 0.20
 - 0.21 - 0.30
 - 0.31 - 0.40
 - 0.41 - 0.50
 - 0.51 - 0.60
 - 0.61 - 0.70
 - 0.71 - 0.80
 - 0.81 - 0.90
 - 0.91 - 1.00
 - NONSOIL
 - WATER

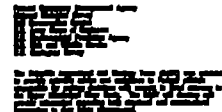
Hydric soils are designated from information in the 1:250,000 scale maps of the U.S. Department of Agriculture, Soil Conservation Service. Maps are not to be used for purposes of generalization or for purposes of soil classification. The proportion of the hydric soil pattern are recorded for each map unit.

Map by George E. Sipes and James J. Nelson
For further information, telephone (603) 850-0024



UPPER MISSISSIPPI AND MISSOURI RIVER BASINS

AVAILABLE WATER CAPACITY ($m^3 m^{-2}$)



AVERAGE AVAILABLE
WATER CAPACITY
PER SURFACE AREA
BY POLYGON

- 0.000 - 0.000
- 0.000 - 0.020
- 0.020 - 0.040
- 0.040 - 0.060
- 0.060 - 0.080
- 0.080 - 0.100
- 0.100 - 0.120
- 0.120 - 0.140
- 0.140 - 0.160
- 0.160 - 0.180
- 0.180 - 0.200
- 0.200 - 0.220
- 0.220 - 0.240
- 0.240 - 0.260
- 0.260 - 0.280
- 0.280 - 0.300
- 0.300 - 0.320
- 0.320 - 0.400
- 0.400 - 0.500
- 0.500 - 0.600
- WATER

The available water capacity shown on this map is based on the average available water capacity of the soil in the upper Mississippi and Missouri River basins. The available water capacity is the amount of water in the soil that is available to plants. It is determined by the soil's texture, structure, and organic matter content. The available water capacity is expressed in terms of the volume of water per unit area of soil. The available water capacity is a key factor in determining the soil's ability to store and release water. The available water capacity is also a key factor in determining the soil's ability to support plant growth. The available water capacity is a key factor in determining the soil's ability to support plant growth. The available water capacity is a key factor in determining the soil's ability to support plant growth.

Map by Douglas E. Siler and Peter J. Garton
Data Source: USDA
For further information, telephone (802) 954-2554

DATE: 1980 DATA SOURCE: USDA SCALE 1:1,000,000

UPPER MISSISSIPPI AND MISSOURI RIVER BASINS SURFACE WATER PONDING ($m^3 m^{-2}$)



U.S. GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
BULLETIN 1170-A

AVERAGE SURFACE
WATER PONDING
PER SURFACE AREA
BY POLYGON ($m^3 m^{-2}$)

- 0.00 - 0.00
- 0.001 - 0.04
- 0.041 - 0.08
- 0.081 - 0.12
- 0.121 - 0.16
- 0.161 - 0.20
- 0.201 - 0.24
- 0.241 - 0.28
- 0.281 - 0.32
- 0.321 - 0.36
- 0.361 - 0.40
- NO DATA
- WATER

The surface water ponding shown on this map is based on data from the U.S. Geological Survey, and is not a representation of the actual water ponding. It is a generalization of the data and should not be used for detailed studies. The data were obtained from a survey of the surface water ponding in the Upper Mississippi and Missouri River Basins, and are presented in this map for informational purposes only. The data were obtained from a survey of the surface water ponding in the Upper Mississippi and Missouri River Basins, and are presented in this map for informational purposes only.

Prepared by Margaret S. Bly and James J. Nelson
USGS Data Center
For further information, telephone (800) 850-8586



3.1

Table 12 Loss of wetlands in the flooded area of the Mississippi/Missouri River Basins north of St. Louis.

State	Original Wetlands Mil. acres	% of Wetlands Lost by 1980	Total Wetlands Lost Before 1980 Mil. Acres	Remaining Wetlands Mil. Acres	% of Wetlands in Flood Basin	Current Wet- lands in Basin Mil. Acres	Wetlands Lost in Flooded Basin Mil. Acres
Illinois	8.21	85	6.98	1.23	65	0.80	4.54
Iowa	4.00	89	3.56	0.44	100	0.44	3.56
Minnesota	15.07	42	6.33	8.74	80	6.99	5.06
Missouri	4.84	87	4.21	0.63	50	0.31	2.11
Montana	1.15	27	0.31	0.84	40	0.33	0.12
Nebraska	2.91	35	1.02	1.89	100	1.89	1.02
N. Dakota	4.93	49	2.41	2.51	15	0.38	0.36
S. Dakota	2.74	35	0.96	1.78	95	1.69	0.91
Wisconsin	9.80	46	4.51	5.29	75	3.97	3.38
Total	53.65		30.29	23.35		16.81	21.06

Potential flood storage in lost wetlands in flooded area – U.S. Fish and Wildlife estimate.

Wetlands lost in flooded area, mil. acres, = 21.06

Potential storage, ft./acre = 1.5

Potential Storage, mil. acre feet, = 31.59

Adapted from U.S. Fish and Wildlife data presented at State Assoc. of Wetland Managers' Meeting (1993), J. Kusler, Ed.

CHAPTER 4: HYDROLOGY

HYDROLOGIC CYCLE

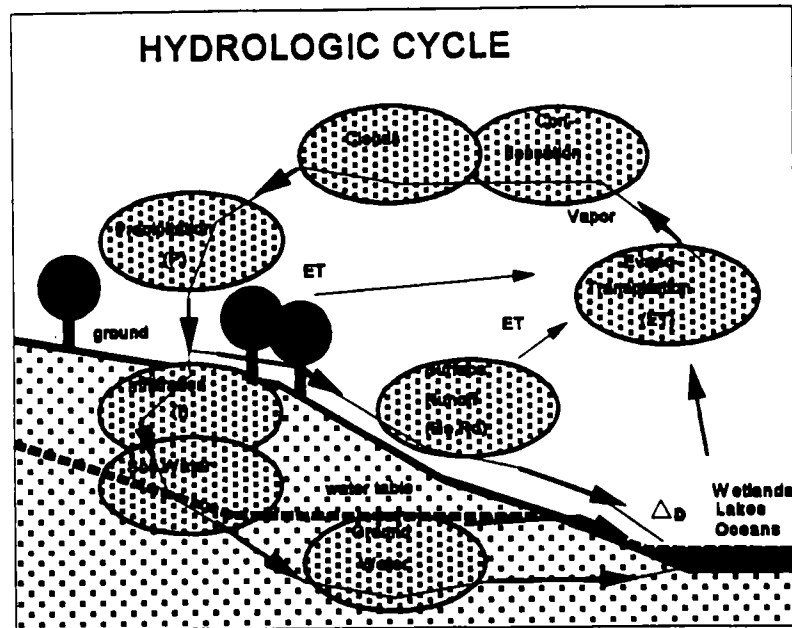


Figure 1. The Hydrological Cycle in its broadest form. ΔD = Storage

4.1
Figure 1 illustrates the hydrologic cycle -- the continual cycling of water from the atmosphere as precipitation, into the soil and groundwater system as infiltration and percolation, over the land surface as runoff, and back into the atmosphere as evaporation and evapotranspiration.

The flow of water through the hydrologic cycle is described by the water budget or hydrologic storage equation, which is simply an expression of the principle of conservation of matter. The water budget states that the change in the quantity of water stored at any location in the hydrologic cycle is the difference between the sum of all inflows and the sum of all outflows.

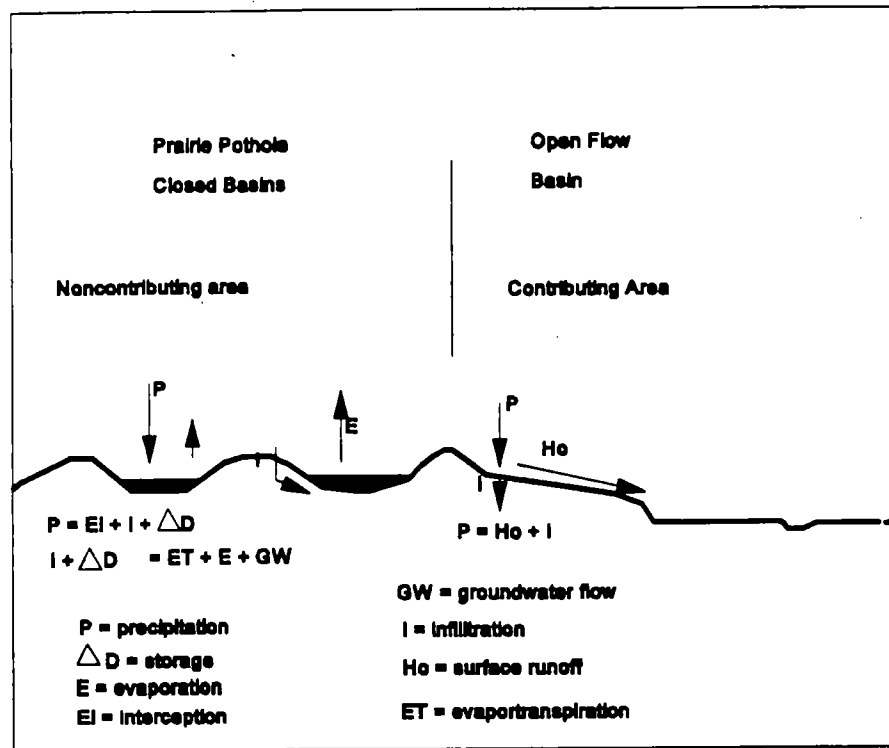


Figure 2. A closed landscape is contrasted with an open flow system

Figure ^{4.2} contrasts the two major hydrologic environments of concern in the study area in terms of their water budgets. The closed or noncontributing landscape is characterized by large quantities of surface storage, which is largely absent in the open or contributing landscape. Note that in addition to the open system's becoming an area contributing runoff, the storage, evaporation, and groundwater recharge components of the hydrologic cycle are reduced or eliminated. In the open landscape, the storage equation often can be simplified to state that inflow equals outflow, since storage (and hence change of storage) is negligible.

In many past studies, various aspects of the hydrologic cycle have been ignored. In particular, the impact of storage in noncontributing closed landscapes, in soil, and in groundwater often has not been appreciated (Richardson, personal commun., 1994). The storage component in closed landscapes is of major importance for reduction of flood runoff.

GROUNDWATER

Groundwater conditions in the alluvial flood plains of the SAST study area are directly related to surface water conditions. The porous alluvial sediments underlying the floodplain and main channel provide substantial storage capacity for water and allow the stored groundwater to communicate freely with the water in the river channel. When flow rates and stages are low in the main channel, water drains out of the alluvium and sustains the flow in the river. When river flows and stages are higher than the groundwater level in the alluvium, water flows out of the river channel into the alluvium and the groundwater level rises. The diversion of water out of the channel provides some attenuation of the flood peak; however, groundwater flow velocities and discharge rates are low relative to surface water flows. In addition, the rising groundwater levels may have significant effects on the floodplain. Alluvial river channels commonly are bounded by low embankments (natural levees) naturally formed when sediment is deposited by flood water that is beginning to overflow onto the floodplain. When the river is confined by natural or man-made levees and remains for sufficient time at a stage higher than the land surface in the flood plain behind the levee, the groundwater level eventually will rise to the surface and inundate the floodplain even though the levee is not overtopped. Rainfall directly on the floodplain and lateral runoff to the floodplain from adjacent upland areas also contribute to this so-called interior flooding problem.

Groundwater conditions in upland areas also are related to rainfall-runoff conditions that cause flooding in rivers and valleys. Rainfall that exceeds the infiltration capacity of the soil will either run off the land surface or accumulate (pond) in local depressions until removed by infiltration or evaporation. Water that does infiltrate migrates as groundwater and eventually re-emerges at the foot of hillslopes or in the alluvial valleys. Soil materials in the upland areas commonly are less permeable than alluvial valley fill, so groundwater velocities in the uplands tend to be lower than velocities in the floodplains; this and the greater distance between the uplands and the river channel imply that groundwater flow from the uplands has relatively little effect on river flood peak flows. However, upland areas are much greater than the floodplain area, so the total volume of groundwater flow from the uplands over time is important in replenishing the alluvial valley aquifers and maintaining flow in the rivers between rains.

Groundwater and surface water quality also are directly interrelated. The quality of the groundwater is determined by the quality of the precipitation and infiltrating water, by the quality of any river water that flows into the alluvial aquifer, by the characteristics of the soil materials through which the groundwater moves, and by the rates of flow and transport in the groundwater and surface water systems. The quality of the river water in turn is affected by the quality of the groundwater that drains into it. Depending on local conditions, either the surface water or the groundwater may be of better quality.

Primary groundwater quality concerns relative to flooding are effects of non-point source contaminants as related to land use and effects of point source contaminants that may be released during floods either by inundation of storage facilities or by spills and leaks.

Groundwater contributions needs to be quantified to assess whether or not the

groundwater resource needs to be further considered in development of flood policy. It would be useful to have information that could be used to quantify the range of groundwater flow and transport rates into receiving streams under high and low flow conditions. This information could be used to determine the relative importance of groundwater contributions during flood flows. Development of this information would require hydrogeologic and geochemical model studies as well as enhancement and maintenance of monitoring programs for groundwater levels and quality.

THE 1993 FLOOD

A persistent series of heavy summer rain storms following an unusually wet winter and spring caused severe flooding in the SAST study area in the summer of 1993. Hydrologic characteristics of the floods have been described in reports by Parrett and others (1993) (flood peak discharges), Wahl and others (1993) (precipitation), and Perry (1994) (effects of reservoirs). The following discussions of the 1993 flood are based on these references.

Precipitation

The extent and duration of the flooding in the Upper Mississippi River Basin primarily was due to excessive precipitation in the region from January through August 1993. Most weather stations in the Upper Mississippi River Basin reported normal to slightly more than normal precipitation during the period January to March 1993, but the potential for widespread flooding was not a major concern at that time.

Precipitation during April and May was variable throughout the region. Nearly all stations had normal or above normal precipitation during these months with many stations in Iowa and

Missouri reporting twice the normal April to May precipitation. By the end of May, soil moisture throughout most of the region was excessive, reservoirs were reaching capacity, and river stages were above normal.

During June through August, a weather pattern dominated by a low-pressure system over the western United States and a corresponding high-pressure system over the southeastern United States developed over the Upper Mississippi River Basin. An eastward-flowing jetstream extended from Central Colorado northeastward across Kansas to northern Wisconsin. This created a convergence zone between the warm, moist flow from the Gulf of Mexico and the cool dry air from Canada. This condition caused precipitation throughout the region to be substantially greater than normal; in many locations precipitation amounts for July and August were greater than twice the normal. By the end of June, soils throughout the region were saturated and the rainfall that occurred in July produced excessive runoff and severe flooding throughout the region (Wahl and others, 1993).

The Effect of Storm Timing

Flooding on the mainstems of the Missouri and Mississippi Rivers was aggravated by the timing of several rainstorms in late June through July. During June 17-18, 2 to 7 inches of rain fell in southern Minnesota and northern Iowa causing near record flooding on the Minnesota and Mississippi Rivers in Minnesota. The flood crest from this storm reached Clinton, Iowa, on July 5, 1993. Two rainstorms in early July caused record peaks on the Iowa, Skunk, and Des Moines Rivers in Iowa, and significant flooding throughout the region. The flood crests from these rivers entered the Mississippi River about the same time that the flood peak from the June rainstorm reached the Mississippi River at Keokuk. The coincident timing of the flood peaks

from these tributary streams increased the peak discharge on the Mississippi River downstream from Davenport, Iowa. The discharge from these combined floodwaters reached St Louis, Missouri, on July 20, 1993.

Rainstorms on July 15-16 and July 22-24 in the Dakotas, Nebraska, western Iowa, Kansas, and Missouri caused record flooding on the Lower Missouri River. The flood crest from these storms reached the Mississippi River at St. Louis on August 1 and caused a second and greater peak discharge. This flood crest reached Thebes, Illinois, on August 7.

Flooding on the Mississippi River downstream from the confluence of the Ohio River did not cause severe problems. Discharge on the Ohio River basin was reduced by the generally dry conditions throughout the basin. As a result, the large channel capacity of the Mississippi River below the confluence of the Ohio River was able to convey the combined discharge without serious flood problems. (Parrett and others, 1993).

Peak Discharges and Volumes

Flood peak discharges that exceeded the 10-year recurrence interval were recorded at 154 streamflow gaging stations; at 45 of these stations, the recurrence intervals exceeded 100-years, and at 56 stations the discharges exceeded either the previous maximum known discharge or the previous maximum regulated discharge (Parrett and others, 1993).

The 1993 floods were notable for their areal extent, duration, and volume of runoff. The Mississippi River remained above flood stage for 144 days at St. Louis and for 152 days at Thebes and the Missouri River exceeded flood stage at Hermann for 116 days; 3-day mean flows exceeded the 100-year recurrence-interval level for 3-day mean flows at at least 22 streamflow gaging stations, and 120-day mean flows exceeded the 100-year level at at least 43 stations;

April-September mean flows were greater than twice the historical mean flows for the period at at least 53 stations (R. Southard, U.S.Geological Survey, written communication, 1993). The annual mean flows and runoff depths for 1993 are compared with historical mean flows and runoff depths at selected stations in table 4.1 and figure .

The areal extent and duration of the flooding ensured that the flood waves from many tributaries would reinforce each other when they reached the main stem rivers. Thus, the main stem flows tended to be more extreme in terms of recurrence interval or exceedance probability than the individual tributary floods.

Effects of Reservoirs

The effects of flood control reservoirs on flood peaks varied significantly between the Missouri and Mississippi river basins. Flow volumes on the Mississippi River tributaries on the Iowa and Des Moines River basins (R. Southard, U.S.Geological Survey, written communication, 1993) were as great as ten times the reservoir volumes. Consequently, during the flooding in July the storage capacity of the reservoirs was exceeded. Local flood damage was reduced through the operation of these reservoirs. For example, storage operations at Saylorville reservoir on the Des Moines River upstream from Des Moines reduced the July maximum daily outflow by about 10,500 cfs, or 20 percent of the computed unregulated outflow; the corresponding reduction in stage is about 2 feet. Although the flood peaks on these rivers were reduced, the overall effect of these reservoirs on the flood crest on the main stem of the Mississippi River was minimal.

The flood control reservoirs on the Missouri River basin had a significant effect on reducing flood discharges on the lower Missouri main channel and on the Mississippi River downstream from the confluence of the Missouri River. Runoff from the Upper Missouri River Basin was contained by the dam system upstream from Gavin's Point Dam. This reduced the flow on the Missouri River by about 80,000 cfs. Reservoirs on the Kansas River reduced the flood crest entering the Missouri River by about 85,000 cfs or 34 percent of the computed unregulated flow. The combined effect of flood-control reservoirs in the Missouri River reduced the average discharge on the Missouri River at Hermann (and at the confluence of the Mississippi River) for the month of July by about 211,000 cfs, which is about 36 percent of the unregulated July discharge at Hermann. The corresponding reduction in Mississippi River peak stage at St. Louis is about 5 feet.

HYDROLOGIC ISSUES AND RESEARCH NEEDS

Effective analysis of flood management options requires a wide range of hydrologic information, including information on precipitation-runoff relations, magnitude and frequency of precipitation and flood events, and effects of land use and land management practices on flood response. Analysis and research activities that could provide useful information include the following:

Regional hydrologic modeling of rainfall-runoff, erosion, and transport processes. --
Simple water-balance analyses, comparing rainfall, streamflow, and reservoir data for 1993 and selected historical floods, would provide valuable information on water storage capacity of

drainage basins. Calibrations of rainfall-runoff models for various representative basins would provide information on flood response characteristics of basins in different terrain and landscape types. Models of groundwater-surface water interactions and transport of sediment and other water quality constituents also would be needed to address water quality and subsurface-flow aspects of flooding. Correlations of flood response characteristics with drainage basin physiographic characteristics would be needed for extrapolating results of detailed model studies to the regional scale needed for policy analysis. Identification of weather patterns associated with extreme flooding would provide a physical basis for improved estimation of flood magnitude-frequency relations.

Regional analysis of statistical frequency and magnitude of flood occurrence. -- Reanalysis of historical flood records (and paleo-hydrologic evidence of prehistorical flooding) is needed to update estimates of flood magnitude-frequency relations. Analysis of the effects of the 1993 flood on the estimates is needed for appraisal of statistical sampling errors. Development of regional relations between drainage-basin characteristics and flood-magnitude-frequency relations is needed to permit flood estimation at ungaged sites; it would also help to improve the accuracy of estimates at gaged sites. As part of this effort, the adequacy of the stream gaging network for defining regional flood statistics could be evaluated and needed improvements identified. Statistical analysis of weather patterns associated with extreme flooding could provide a basis for assessing effects of potential climate changes on flood frequency and magnitude. Finally, improved flood magnitude-frequency relations could be used to update and improve flood-insurance rate maps and flood plain delineations.

COMPARISON OF WATER YEAR 1993 AND MEAN ANNUAL RUNOFF
Upper Mississippi and Lower Missouri Rivers

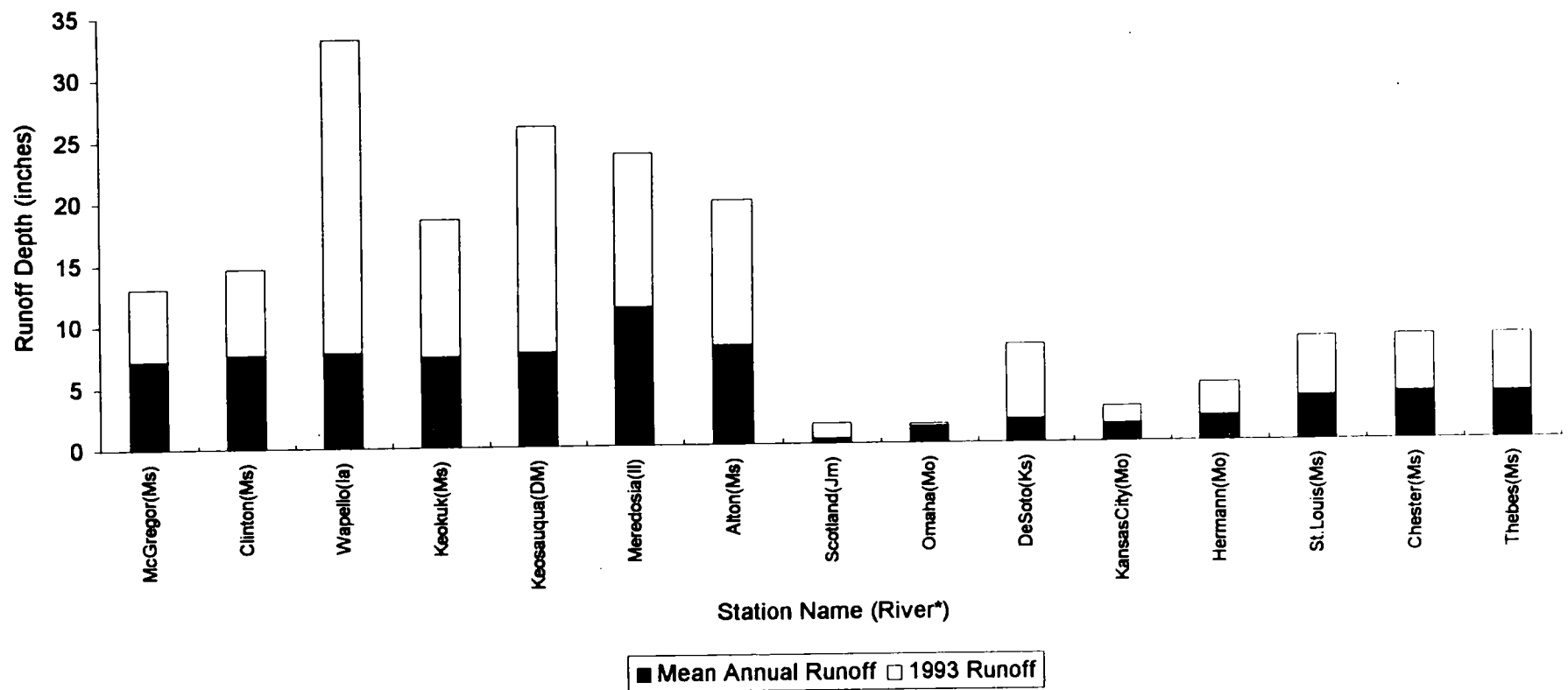


fig 4.3

Table 1 -- Comparison of water year 1993 mean discharge and runoff with mean annual discharge and runoff for period of record.

Station Name	Drainage Area sq mi	WY 1993		Period of record thru WY 1992	
		Mean Flow cfs	Runoff Depth inches	Mean Flow cfs	Runoff Depth inches
Mississippi River at McGregor, Ia.	67500	64720	13.02	35520	7.15
Mississippi River at Clinton, Ia.	86500	92300	14.64	48000	7.62
Iowa River at Wapello, Ia.	12499	30550	33.20	7120	7.74
Mississippi River at Keokuk, Ia.	119000	162500	18.55	64520	7.36
Des Moines River at Keosauqua, Ia.	14038	26920	26.05	7909	7.65
Illinois River at Valley City, Ill. (Meredosia)	26742	46810	23.77	22110	11.23
Mississippi River at Grafton, Ill. (Alton)	171300	250700	19.87	101500	8.04
James River near Scotland, S.D.	16505	1959	1.61	414	0.34
Missouri River at Omaha, Neb.	322800	36410	1.53	32000	1.35
Kansas River at DeSoto, Kans.	52200	30570	7.96	7060	1.84
Missouri River at Kansas City, Mo.	458200	102100	2.86	50050	1.40
Missouri River at Hermann, Mo.	524200	181800	4.71	76780	1.99
Mississippi River at St. Louis, Mo.	697000	429700	8.37	181900	3.55
Mississippi River at Chester, Ill.	708600	441700	8.46	198500	3.81
Mississippi River at Thebes, Ill.	713200	446000	8.49	198000	3.77

CHAPTER 5: CULTURAL/ LAND MANAGEMENT

AGRICULTURAL DRAINAGE

Over 60 percent of the depressions in the closed drainage areas of Iowa, Minnesota, and Illinois are tile or open ditch drained (USDA SCS NRI data, 1982). Agricultural drainage systems are installed to lower the water table or remove surface water to (1) provide trafficable field operations, (2) protect the plant from excess water conditions, and (3) control salinity in irrigated arid and semi-arid areas (Skaggs and others, 1994). The stages of tile drainage installation result in changes in surface runoff and peak flows.

During the first stage, the land is cleared or plowed; this process decreases infiltration, increases the wetness of the land (by decreased evapotranspiration), and increases surface runoff. Open ditch drains are then constructed to act as outlets for the removal of excess water. Since they are direct conduits to streams, these open ditches essentially remove all the surface storage of the depressional areas and result in increased peak flows. Research results have shown that drainage improvement (surface drainage) plus land conversion from natural vegetation to row crops increases peak runoff rates at the field edge by a factor of 200 to 400 percent over the rates in the natural condition (Skaggs and others, 1994). Improved drainage also reduces time to runoff peaks.

During the second stage, tile drainage systems are developed for each field of a farm. The outlets for these systems are in the open ditches constructed in the first stage. Once installed, subsurface tile systems lower the water table and remove water from depressional areas at a design rate of 1.25 cm/day. Traditional subsurface drainage systems lower the peak flows created in the first stage of drainage activity by 35 to 55 percent (Skaggs and others, 1994). By increasing storage capacity in the soils and storage in drained depressions, traditional tile results in

controlled removal of water from depressions over a period of days and decreases the peak flows in streams. However, the combined effect of agricultural drainage increases flow in streams over surface flow from natural systems. Exact figures depend on topography, field drainage systems, and distance to open ditch systems.

Some tile drainage systems have standpipes from the soil surface to the tile line; they are used to lower the risk of crop failure from ponding. These standpipe tile drains are more efficient in removing water than traditional tile since the standpipe provides an open conduit from the surface ponded water to the tile line. Standpipe drains act more like open drainage systems, transmitting water directly to stream channels. Standpipes also remove water from depressions at a faster rate than traditional tiles since the capacity of the standpipe is orders of magnitude larger than soil pores.

Traditional tile drainage systems help keep the depressions empty and thus provide the maximum amount of surface water storage so that full storage capacity is realized during rainfall events. The tile systems then drain the depressions in a controlled manner over a period of a few days. This drainage has the effect of broadening the peak of the hydrograph and decreasing flow rates in comparison with open ditch systems. Tile systems with standpipes, however, will drain water to streams at rates that approach those of surface drains and thus, are not effective for surface storage of water.

FEDERAL PROGRAMS INVOLVED

Soil water storage in the basin is affected by Federal programs and legislation. The Conservation Reserve Program (CRP) provides incentive payments for farmers to return highly erodible land to grassland or woodland. Although directed toward reducing erosion and applied with considerable variations by the states, these practices decrease surface water runoff (fig. 5.1)

Figures () show estimated reductions in surface water runoff due to FSA and CRP activities.

The Food Security Act (FSA) also includes erosion provisions that relate directly to surface water runoff. Residue management and reduced tillage are key elements of the conservation compliance systems required. These practices increase infiltration of water into the soil and reduce the amount of surface water runoff. The reduction of surface water runoff directly affects peak flows of streams including flood events.

Additionally, the wetland provisions of FSA (and FACTA, the Food, Agriculture, Conservation, and Trade Act of 1990) encourage the protection of wetlands, especially in the pothole region of the drainage basin. These pothole wetlands (^{5.2}figure) provide surface storage of water and thus reduce peak flows during flood events. These programs, however, are not designed to restore converted wetlands.

Programs such as CRP and FSA that encourage infiltration of water into the soil and thus reduce runoff are important to fully attain the potential subsoil storage of water. These programs are especially important in the open drainage areas of the basin since subsoil storage is one of the few (if not the only) nonstructural approaches to reducing stream flows. In formerly closed (depressional) drainage areas, programs such as the USDA-SCS Wetland Reserve Program and USDI-FWS Small Wetland Acquisition and Partners for Wildlife Programs, which encourage reclamation of depressional or wetland areas that have been open ditch drained, are important to decreasing surface runoff and improving the water quality of the area.

MODEL WATERSHEDS

Four watersheds were selected for hydrologic model studies within the basin. The three watersheds used for land practice and land use studies were selected to represent three distinct areas of the Upper Mississippi River Basin as determined by the USDA Major Land Resource Areas (MLRA). The fourth watershed used for a more detailed evaluation of wetlands was selected based on available data concerning wetland drainage and the pre-existence of a calibrated hydrologic model. The upper end of the fourth basin also represents a fourth Major Land Resource Area. The basin locations and associated MLRA boundaries are shown in Figure and are described as:

Boone River above the gage near Webster City, Iowa, MLRA 103 - Central Iowa and Minnesota Till Prairie, a relatively flat watershed with low relief prairie pothole terrain;

West Fork Cedar River above the gage near Finchford, Iowa, MLRA 104 - Easter Iowa and Minnesota Till Prairie, a relatively flat watershed but having a well defined drainage system;

Whitebreast Creek above the gage near Dallas, Iowa, MLRA 108 and 109 - Illinois and Iowa Deep Loess and Drift, and Iowa and Iowa and Missouri Heavy Till Plain, a relatively steep watershed with well incised drainage;

Redwood River basin above Redwood Falls, Minnesota, MLRA 103 and 102A - Central Iowa and Minnesota Till Prairie and Loess Uplands and Till Plains, a higher relief pothole area (102A) and low relief pothole area (103) in eastern portion of watershed. This watershed also has a large amount of surface drained potholes and has experienced an increase in flood severity.

The objective of the modeling was to show the effect of various management, land use, and storage practices on the outflow hydrographs for differing types of basins. Alternatives selected for Boone River, West Fork Cedar River and Whitebreast Creek watersheds were:

1. Maximizing wetland storage in upland and/or floodplain areas,
2. Demonstrating effect of CRP lands on flooding,
3. Maximizing infiltration by using all applicable land treatments such as conservation tillage, terraces, and permanent cover,
4. Flood prevention structures - i.e. traditional SCS small watershed structures to temporarily store water and release it slowly,
5. A combination of all non-structural practices - i.e alternatives 1, 2, and 3, and
6. A combination of all possible alternatives - alternative 5 plus alternative 4 to demonstrate the maximum possible reduction for the watershed without the inundation of large areas for medium to large reservoirs.

Alternative 3 included the use of conservation tillage on all agricultural lands, terraces on lands with slopes from 5 percent to 14 percent (C and D slopes), and permanent cover (grass, trees, etc) on all lands with slopes greater than 14 percent (E slopes and greater). This alternative also included the effect of current CRP lands.

The objectives of modeling the Redwood River were somewhat different than those for the other study basins. The objectives were to determine if increasing wetlands would reduce flood peaks and if so, to what extent. The six alternatives studied were restoration of:

- a. all depressional hydric soils with detention structures (19% of watershed),
- b. 50% of all depressional hydric soils as in a (10% of watershed),
- c. 25% of all depressional hydric soils as in a (5% of watershed),
- d. small wetlands with 50% assumed to be landlocked - i.e. 50% had no outlet to stream after restoration while remaining 50% served as detention structures,
- e. large wetlands and lakes over 100 acres in size, and
- f. large and small wetlands (combine alternatives a and e) with no assumption of landlocked wetlands.

No land treatments (CRP or maximum infiltration) were applied to the Redwood River basin in addition to the wetland studies since the purpose of the study was to look specifically at the effect of wetlands on flood peaks. Additionally, with the exception of alternative d, the wetlands were assumed to be restored as detention storage areas. This means that the water stored in the

wetland would be released slowly through a control structure over a period of several days making the full storage of the wetland available for the next storm. This maximized the amount the effect of the wetlands in the watershed simulation.

Effects of an alternative are given in percent reduction in peak discharge from present conditions after adjustment to remove the effects of current CRP lands. The four events evaluated for all watersheds were the 1-, 5-, 25-, and 100-year storms. Watershed runoff volumes are not directly comparable due to a differing storm duration used on the Boone River watershed and were not used for comparison. Watersheds were modeled using the SCS TR-20 model for Whitebreast Creek and Redwood River and the U.S. Army Corps of Engineers HEC-1 model for the Boone River and West Fork Cedar River. All watersheds were modeled using a antecedent moisture condition II which is a soil that is moist prior to the storm. It should be noted that differing antecedent moisture conditions have major effects on the amount of runoff that a storm produces in a given watershed.

It should also be noted that while the Whitebreast Creek and Redwood River studies were rather detailed (especially the Whitebreast Creek model), the Boone River and West Fork Cedar River models used much less detail due to time constraints involved in the SAST effort and the lack of pre-existing detailed models.

Results of Watershed Studies

The results from the four watersheds are presented in Table 5.1. The results from four of the alternatives tested for the Redwood River are also included for comparison when the alternatives were similar to those used for the other three watersheds. The results of the combination of all alternatives for the Boone River, West Fork Cedar River, and Whitebreast Creek are plotted in Figure 5.1 as are the results for alternative d for the Redwood River. Alternative d (small wetland restoration with 50% landlocked) produced the greatest overall reduction in flood peaks for the Redwood River, but total reductions if the maximum infiltration alternative were to be installed in the watershed could be expected to produce somewhat higher peak reductions. The amount of additional peak reductions, if any, would have to be determined by an additional modeling effort.

Three of the watersheds show a trend of reducing effect with increasing storm return period while the Whitebreast Creek model shows the opposite effect for 5- year or greater storms. This is probably a result of the timing of runoff in the watershed and is an excellent example of the reason why results from one basin cannot be directly applied to other basins.

The total of all applicable treatments for the Boone River includes the effects of CRP lands twice, due to a miscommunication, but the CRP effects are so small on the Boone River watershed that the total values will not change by more than about 1percent when the extra reductions for CRP are removed.

The three basins which were modeled for floodplain wetlands show that areas where significant wetlands exist, they can have a noticeable effect on discharge peaks from the basin. While the amounts are not large, 5 to 6 percent maximum for the flatter basins with potholes, they are noticeable. On the steeper Whitebreast Creek basin, floodplain wetlands had no significant effect except possibly for the 50- year storm.

The two basins where upland wetlands were modeled show widely differing results. Part of the difference is the topography of the two basins. The Boone basin is very flat with very low relief potholes, while the Redwood basin has significantly more relief. Additionally, the characterization of potholes was taken from 7.5 minute USGS topographic maps for the Boone River basin and are very crude. To more accurately model low relief watersheds such as the Boone River, much better quality elevation data is needed. Many of the potholes in this region may be only a few feet deep and do not show up on current 7.5 minute quads. With current technology, high resolution digital elevation maps (DEMS) would greatly facilitate modeling efforts in all watersheds. If a more accurate model were created for the Boone River it is anticipated that the decreases due to upland wetlands would be slightly higher but probably not as high as the reductions noted on the Redwood River. No significant amount of upland wetlands was found in the West Fork Cedar River or in the Whitebreast Creek watersheds and this alternative was not modeled for these watersheds.

The tests of CRP land effects on flood peaks appear to show that on steep watersheds the CRP is not as effective as on basins with less steep terrain such as the West Fork Cedar River. The alternative is not extremely effective on the Boone River since the land is also relatively flat and less of it qualifies as highly erodible land - a requirement to participate in the CRP program.

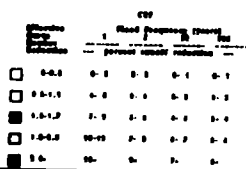
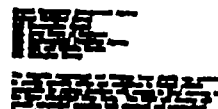
The maximum infiltration alternative showed good results on all three watersheds to which it was applied, but was especially effective on the steep Whitebreast Creek watershed. This is due to the amount of steep land in the watershed and the effect of terraces and other practices in increasing infiltration and reducing runoff. If the simulation had been done using a wetter antecedent moisture condition similar to that which existed in 1993 prior to the heavy rains, the peak reductions would be less since the soils would not infiltrate as much water. This would result in much smaller reductions in peak flows. For dry conditions, this alternative would probably result in very high reductions in peak flows.

The two basins where detention structures were used were Whitebreast Creek and Redwood River. The alternative f for the Redwood River watershed is actually identical to the alternative 1 for Whitebreast Creek and the alternatives are directly comparable. The results from Whitebreast Creek are not what were expected and no explanation can be given at this preliminary stage of analysis. Perhaps the shape of the Whitebreast Creek watershed plays a role in the differing results, since it is more elongated than the other three basins and the timing of the flows from the various sub-basins have a significant effect on the results. The results from the Redwood River follow the trend that was expected - i.e. lessening reductions from increasing storm sizes.

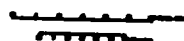
Conclusions

It has been demonstrated that differing alternatives can be applied with varying degrees of success in reducing peak flood flows depending on basin topography. Currently recommended SCS practices can be very effective in reducing peak runoff from basins, depending on slope, topography, and storm size. Generally as the drainage area increases, upland treatment measures have less effect in decreasing peak flows, although land treatment was effective even for the 100-year storm on the Whitebreast Creek watershed. Detention structures or wetlands can aid in lowering flood peaks where opportunity exists, but wetlands cannot be used in all watersheds to effectively reduce flood peaks. In the watersheds modeled the maximum reduction for floodplain wetlands was 6 percent of the peak flood discharge. Upland wetlands were more effective in areas where large amounts of wetlands which could store large amounts of water existed, such as the Redwood River watershed. In short, land treatment and detention storage can play a significant role in reducing flood peaks in many watersheds but are not a panacea for flood

problems.

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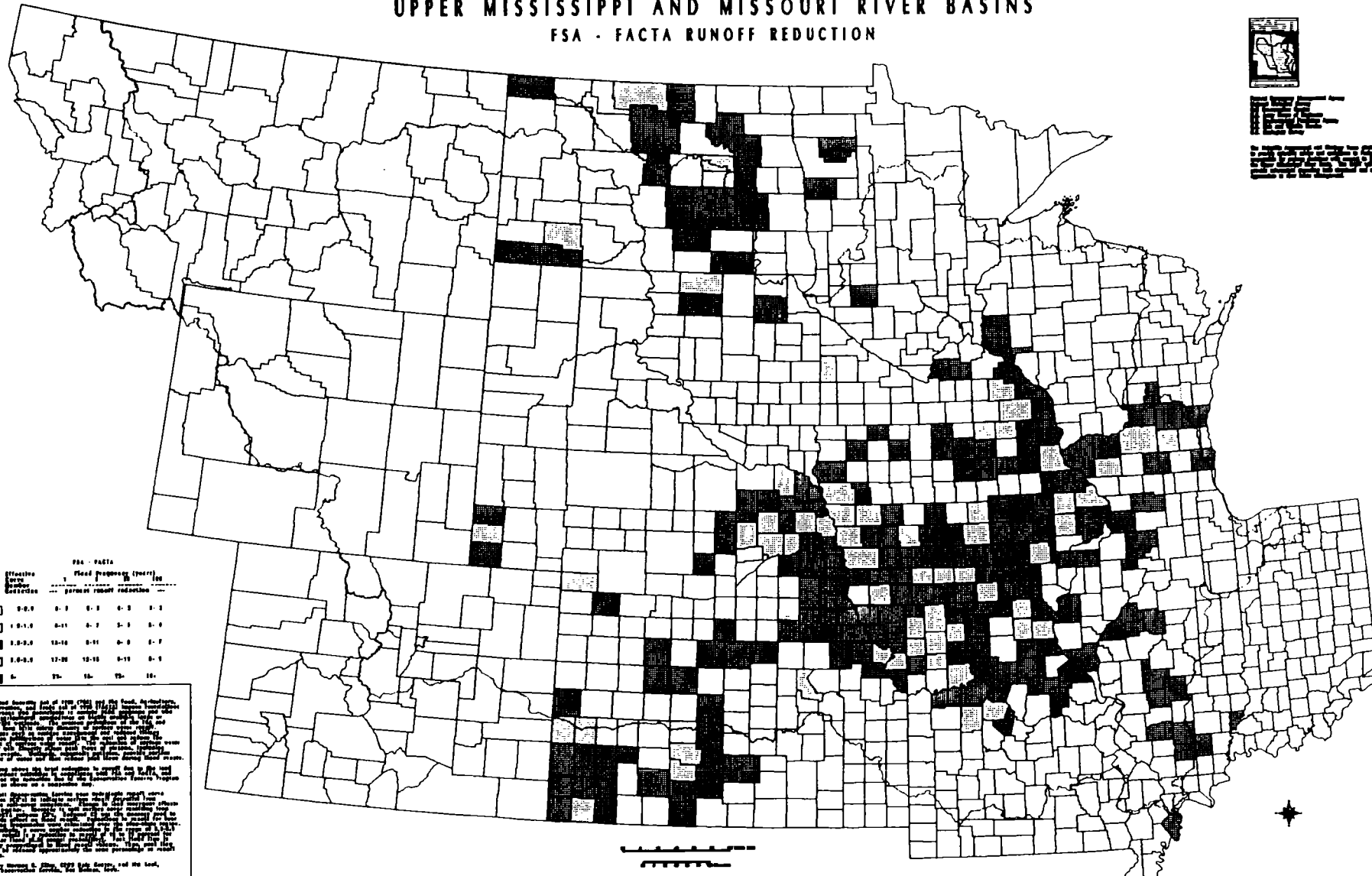


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UPPER MISSISSIPPI AND MISSOURI RIVER BASINS FSA - FACTA RUNOFF REDUCTION



NATIONAL WATER RESEARCH INSTITUTE
U.S. DEPARTMENT OF AGRICULTURE
WASHINGTON, D.C. 20250



FLOOD PEAK REDUCTIONS

MAXIMUM LAND TREATMENTS + STORAGE

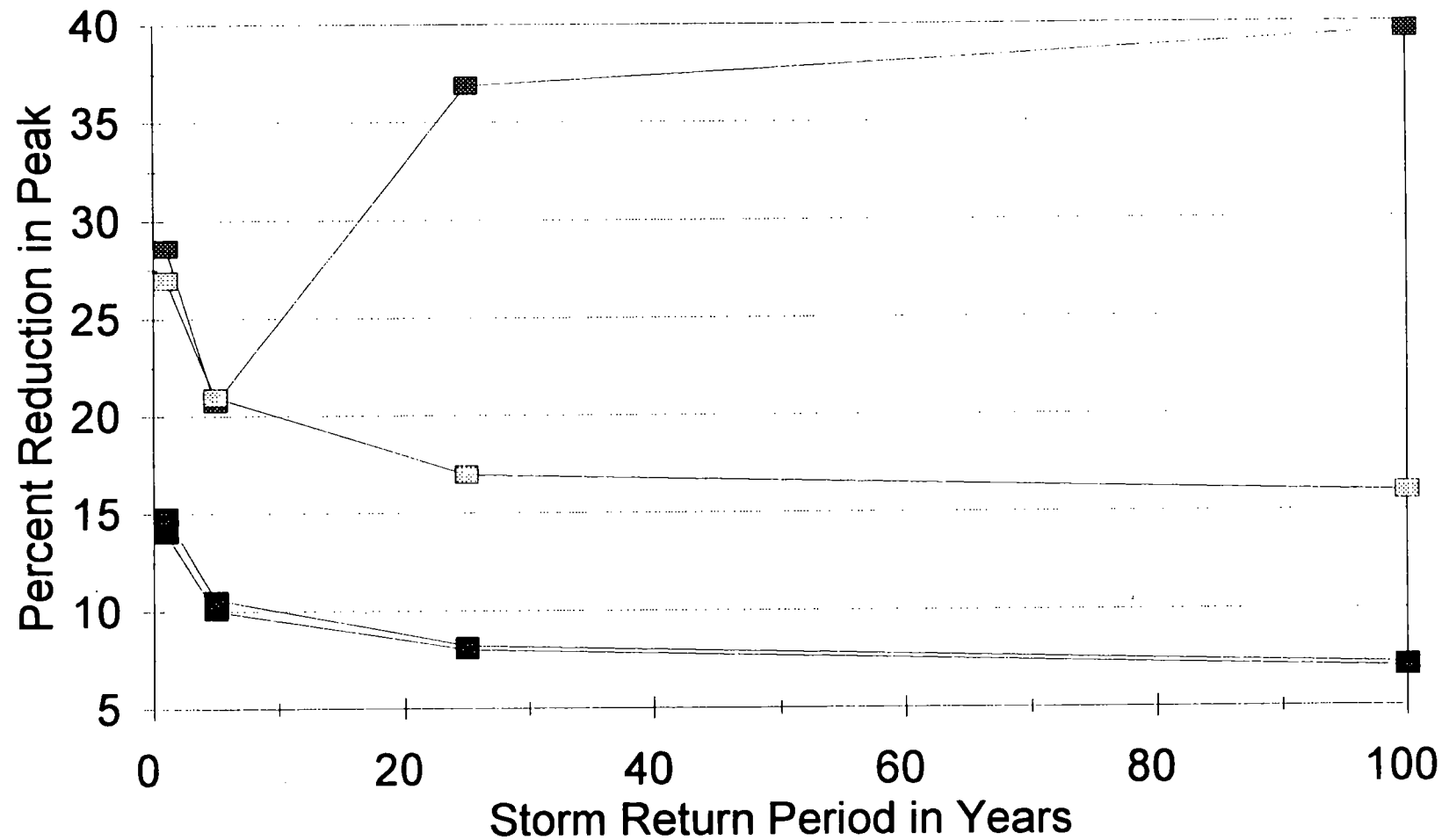


Fig 5.3

FLOOD PEAK REDUCTION BY WATERSHED AND TREATMENT					
RETURN PERIOD	Boone River	W. Fk. Cedar	Whitebreast Creek	Redwood River	
FLOODPLAIN WETLANDS					
1	5		0.5		
5	3		0.8		
25	2		2		
100	2		-0.2		
UPLAND WETLANDS (Option a)					
1	2			23	
5	2			15	
25	2			11	
100	1			10	
CONSERVATION RESERVE PROGRAM LANDS					
1	3	7.1	4.4		
5	1	4.8	4		
25	1	3.7	4		
100	1	3.1	4		
MAXIMUM INFILTRATION					
1	6	14.9	20.6		
5	3	10.6	14.8		
25	2	8.2	17.9		
100	2	7.2	20.4		
DETENTION STRUCTURES (Option f)					
1			7.7	26	
5			14.8	16	
25			26.8	12	
100			28.1	11	
TOTAL OF ALL APPLICABLE TREATMENTS					
1	14	28.6	14.9	27	
5	10	20.7	10.6	21	
25	8	36.9	8.2	17	
100	7	39.6	7.2	16	

Table E.1

CHAPTER 6: FLOODPLAIN GEOMORPHOLOGY

DIFFERENT RIVERS - DIFFERENT REACHES - DIFFERENT FLOOD IMPACTS

Comparison of the effects of the 1993 floods on the Upper Mississippi and Missouri Rivers shows that river reaches in broadly similar physiographic regions may respond very differently to floods. A fundamental characteristic of the Upper Mississippi and Missouri Rivers and their tributaries is that, although these rivers share a number of common features, each river and its associated floodplain are distinctly different. Although the Mississippi River is formed by glacial meltwater and the Missouri River was strongly affected by glacial meltwater, differences in river discharge and slope, floodplain width, and sediment load strongly affect flood response. For example, the annual discharge of the Upper Mississippi River is generally comparable to the annual discharge of the Missouri River, but the sediment yield of the Missouri averages more than 5 times that of the Upper Mississippi. Thus, the average slope of the lower Missouri River floodplain is about twice the slope of the middle Mississippi River floodplain downstream from the confluence of the two rivers. Moreover, the floodplain of the lower Missouri is, on average, about half the width of the floodplain of the middle Mississippi. Consequently, impacts of the 1993 flood along these two rivers were very different. Levee breaches along the lower Missouri commonly resulted in high-velocity flows across its relatively narrow and relatively steep floodplain. These high-energy flows caused extensive deep scour and thick sand deposition across prime agricultural bottomlands. In contrast, levee breaches along the middle Mississippi produced less intense erosion and sedimentation; thus impacts were largely limited to passive inundation of large bottomland tracts.

Different reaches along the same river may also exhibit significant geomorphological, hydrological, and ecological differences. Along the reach immediately downstream from Gavins Point Dam, the Missouri River is presently deepening its channel. However, south of its confluence with the Platte River, a braided stream, channel aggradation is the present norm; whereas further downstream aggradational and depositional tendencies appear to be approximately balanced. More locally, within the relatively narrow floodplain of the lower Missouri (between Glasgow and St. Charles), local reaches characterized by tight (high amplitude, short wavelength) meanders served as principal locations for extensive deep scour and concomitant deposition of thick sand deposits. Within these local reaches, as much as 30 percent of the floodplain was severely damaged by these processes; elsewhere such damage was limited, on average, to less than 7 percent of the floodplain.

GEOMORPHOLOGY AND SURFICIAL GEOLOGY OF THE LOWER MISSOURI RIVER VALLEY

The lower 180 miles of the Missouri River valley, between Glasgow and St. Charles, averages about 2.1 miles in width. The floodplain along this reach is incised between 200 and 400 feet below the surrounding upland which is underlain by almost flat-lying carbonate bedrock (limestone and dolomite). Valley filling sediments, typically 20 to 25 m thick, are primarily composed of highly permeable sand with intermixed gravel. Less permeable silt and clay typically dominate the uppermost 2 to 5 m of this section. These finer-grained deposits are generally thin and patchy, except on terraces and along valley margins remote from the present channel.

Because the valley is relatively narrow throughout this lower reach, the meandering river channel divides the floodplain surface into distinct segments, each almost completely bounded by the river channel and the valley sides. These areas, locally termed "bottoms", occur as two distinct morphologic types: (1) the loop bottom, a relatively small, roughly equant bottomland area bounded by a single, continuously curving meander loop, and (2) the long bottom, a large, roughly recilinear segment, bounded by a straight channel reach which typically runs along the valley wall.

As noted by Schmudde (1963), the surface of each long bottom is interrupted by one or more, low (1- to 3 m high), subtle but noticeable, riverward-facing scarps. These scarps typically subparallel the general trend of the river channel, but are commonly set back from it as much as one mile or more. The area between the river channel and these terrace-bounding scarps generally occupies between 25 and 75 percent of the floodplain. These lower bottomland surfaces are characterized by bar and swale microtopography with an undulating relief of 0.5 to 2.0 meters. Vestiges of former channels commonly bound the terrace scarps on their riverward side; the deeper channels may retain water through much of the year and thus represent significant potential for wetland restoration within these active bottomland areas.

In contrast, terraces and terrace scarps seldom occur within loop bottoms, however, loop bottom surfaces are typically very similar microtopographically to the lower surfaces of the long bottoms. The characteristic ridge and swale microtopography of these surfaces typically extends diagonally downvalley from the upstream channel side of the bottom towards the opposite valley margin. Surface elevation and ridge and swale definition diminish in the same general direction.

An important characteristic of the Missouri River has been the migration of its channel meanders (mostly prior to 1940, Figure____) and the concomitant reworking of its floodplain surface. On average, these reworked areas comprise approximately one third of the entire floodplain surface; however, loop bottoms, particularly their downstream portions, have been almost completely reworked by historic channel migration.

Between Kansas City and St. Charles, the average longitudinal gradient of the Missouri River averages about one foot per mile. However, the downstream gradients of individual loop bottoms may be significantly steeper than this average. Consequently, the upstream end of a loop bottom may be as much as 5 feet high than the downstream end of the neighboring bottom immediately upstream. The local depositional buildup of sandy overbank deposits along the upstream margins of loop bottoms is largely responsible for this difference in height. Therefore, where unprotected by levees, the downstream portions of the loop bottoms are typically flooded first. This backwater overflow has little velocity and, therefore, limited competence to transport bedload; thus deposits from backwater flooding are generally thin and widely dispersed. However, where active overflow is channeled along existing elongate depressions on the floodplain (e.g., abandoned channels, chutes, point bar swales) sufficient flood-flow velocities may be maintained either to scour or at least to transport relatively coarse sandy bedload materials. These elongate depressions often serve as principal locations for deposition and scour, particularly on loop bottoms.

After the 1993 flood, sand bars often more than one foot thick were deposited within and beyond riparian fringes along the channel banks; beyond this riparian fringe these deposits thinned

and disappeared within a few hundred feet of the trees. Similar overbank bar deposits were formed within and adjacent to this riparian fringe during the 1960 flood.

FLOODPLAIN ZONES

For purposes of this report, the term floodplain refers to all of the alluvial surfaces adjacent to a river channel that can be inundated by large floods. During the 1993 flood, floodplains along the Upper Mississippi and Missouri Rivers were inundated when the river stage exceeded the design elevations of flood-control levees or when the levees failed; and more than 90 percent of the total floodplain areas was inundated.

The floodplains of the lower Missouri and middle Mississippi Rivers can be divided into at least 5 flow-energy zones: (1) the active river channel -- artificially constrained into a relatively deep, narrow channel by the dikes, wing-dams, and levees of the present navigation/flood control system; (2) the active high-energy floodplain -- land adjacent to the existing river channel constructed primarily by the river during its present, structurally-controlled regimen. This zone also encompasses the historic - recently prehistoric channel belt, which is delineated geomorphically by abandoned meander channels, ridge and swale point bar morphology, chutes and cutoff channels, and natural levees; (3, 4, and 5) the low energy floodplain -- one or more (low, intermediate or high) river terraces within or marginal to the active floodplain area that represent higher, older (middle to early Holocene or late Pleistocene) levels of the river. These surfaces generally lack the characteristic microtopography of the high energy zone.

These natural floodplain zones were impacted differently by the 1993 (and earlier) floods.

The high energy floodplain was actively flooded to depths of 3 to 4 m, and extensive areas of deep scour and thick sand deposition were created by the localized concentration of the rapidly flowing flood waters; low river terraces were less energetically inundated to depths of 1 to 3 m and were subjected to much fewer and less extensive areas of scour and deposition; higher terraces were passively flooded to lesser depths; the highest river terraces were not flooded.

RIVER REGIMEN CONTROLS

Factors that affect river stage and flow (regimen) include river discharge and velocity, channel width, depth and slope, sediment volume and grain size, and bank erodibility. Various river reaches are also affected by the width of the active, high-energy floodplain and by the position of bounding bedrock bluffs and bedrock outcrops within the floodplain and channel. Along the lower Missouri River, artificial influences include channel shortening (by about 46 miles in Missouri), channel narrowing (to 1100 feet or less), concomitant reduction of total channel surface area (by about 50 percent), and flow constriction by bridges, embankments, and flood control levees.

LEVEE-INDUCED FLOOD EFFECTS

Preliminary analyses of aerial photography, Landsat TM imagery, and historic maps of the Missouri River floodplain reveal that more than 90 percent of the areas affected by significant erosion and deposition during the 1993 flood are associated with breached flood control levees in the active high energy floodplain zone. Breached levees are commonly located on: (1) upstream sides of abrupt meander loops, (2) at points of intersection between the present (structurally

controlled) channel and older channels, (3) along tributaries crossing the high energy areas of the floodplain, and (4) at locations downstream from large levee breaks where coherent, high velocity flow was established across the floodplain. Erosional zones of extensive scour and stripping extend as far as 1.5 km downstream from the largest breaches. Ruptures and extensive scour zones across interior levees, eroded channels, and zones of discontinuous soil stripping are commonly aligned downstream from the larger holes. Thick sand deposits of thin to moderately thick sand, commonly veneered with a silt/mud drape, extend beyond these thick sand deposits. Thin flood deposits cover much of the active floodplain but do not represent a significant long term impact on agricultural productivity.

LEVEE-INDUCED DEPTH OF SCOUR

Scour holes, locally known as "blow holes" or "blew holes", are extraordinarily deep holes eroded into floodplain alluvial deposits by the high intensity flood scour related to levee breaching. Levee scour holes are centered in levee breaches and extend downstream beyond the line of the levee. Small scour holes are generally circular, 30 - 80 m in diameter. Large scour holes are elongate, 200 to 500 m wide and as much as 1,000 m long. Maximum depths of levee scour holes typically range between 8 and 16 meters. Cobbles in adjacent blowout splay deposits derived from these deep scour holes indicate that the depth of scour commonly exceeds the entire thickness of Holocene alluvial deposits and penetrates into underlying glacial outwash sediments.

FLOOD EROSIONAL AND SEDIMENTATION EFFECTS

Many existing flood control systems currently protect life and property on the floodplain and have prevented considerable damage in urban and industrial areas. During the 1993 flood, however, levee breaks in agricultural areas focused flood-flow energy at hundreds of blowout splays resulting in extraordinary levee damage, deep scour, and extensive sand deposition on the floodplain. Locally, constricted flood flow in breaches through railway embankments and in the vicinity of railroad and highway bridges also acted to focus flood-flow energy thereby adding to the scour sand deposition problem. On average, approximately 7 percent of the floodplain between the Grand River and St. Charles was seriously and significantly impacted by these processes.

Analysis of flood effects along the lower Missouri River reveals that more than 90 percent of the erosional and depositional features of the 1993 flood are associated with beached flood control levees (SAST report). Typically, levee breaches are located on or near channel banks (1) along the downstream banks of abrupt meander bends, (2) at points of intersection between the present channel and older channels, (3) along tributaries crossing the active-high-energy areas of the floodplain, and (4) at various locations downstream of large levee breaks where coherent, high-velocity flow was established across the floodplain. Levee scour holes are typically centered in and attain their greatest depths just at the levee beach. Small levee scour holes are circular, 30 - 80 m in diameter. Large scour holes are elongate and as much as 300 to 500 m wide and 1,000 m long. Maximum depths of levee scour holes are 8 to 16 m (preliminary data, US Army Corps of Engineers, Missouri Department of Conservation, Chrazastowski, and others, 1994, SAST, 1994) Erosionally scoured and stripped zones that cut through the plow zone and into

underlying substrata commonly form immediately downstream of the deep scour holes. Within these scour zones, shallow parallel channels and grooves, as much as 1.5 m deep, and scattered scour holes, as much as 4 m deep and 60 m long, have formed along major flow paths. These erosional zones extend as far as 1.5 km downstream from the largest levee breaches (SAST report). In Illinois, erosional scars extend as much as 400 m downstream from several breaches. Along the lower Missouri River between Kansas City and St. Louis, where more than 500 levee scour holes formed in levee breaches, cobbles in deposits derived from these holes indicate that the depth of scour in many instances penetrated through the entire thickness of Holocene alluvial deposits into the underlying glacial outwash sediments.

The thickness of sediment deposited by flood water generally decreased away from the river channel. Along the lower Missouri River, moderately thick to thick sand deposits locally cover more than 50 percent of the floodplain in constrained bottomland areas, (for example, Lisbon Bottoms, Jameson Island). In contrast, moderate to thick flood deposits cover less than 3 to 5 percent of the floodplain along most other reaches, particularly those areas upstream from Galsgow where the floodplain attains widths of as much as 10 to 15 km. Deposits related to levee breaches are large, crescent shaped sand deposits that are thick enough to conceal preexisting features of the floodplain surface. At the downstream margins of the scour zones associated with these breaches, crescentic sand deposits, as much as 1 to 3 m thick, formed where the flood flow fanned out from the levee break. These lobe-shaped sand bodies locally extend as much as several hundred meters downstream from the scour zone margin. Other thick sand deposits were laid down in bars in the lieu of trees and buildings, in borrow pits adjacent to levees, and in the river

channel where the flood current was dispersed. Thin, fine-grained flood deposits were deposited discontinuously in areas distant from active channel belt; however, these thin deposits present no adverse long term impact on agricultural productivity.

MISSOURI RIVER LEVEES - THE PROBLEM

The present system of levee protection along the Missouri River floodplain lacks coordinated planning and management. Design and coordination processes for existing private levee districts are needed to effectively manage levee protection. Many districts have been flooded between 5 and 10 times during the past 50 years, which reflects the design capacity of protection of many of these levees. However, failures have often been catastrophic resulting in substantial deep scour accompanied by concomitant deposition of thick sand deposits over significant areas of the floodplain. Within the reach from Glasgow to St. Louis (about 225 river miles), approximately 5 to 7 percent of the floodplain (13,000 to 18,000 acres) was substantially damaged as a result of the levee failures during the 1993 flood. More than 90 percent (probably as much as 95 percent) of this deep scour and thick sand deposition was directly related to levee breaches.

Eyewitness accounts indicate that the majority of levee breaches are caused by overtopping and subsequent incision by gullies. However, levee failures are also caused by underflow and piping beneath the levee (manifested by sand boils along the landward base of the levee) and by interflow and piping within the levee structure itself (resulting in either gullying or slumping of the levee face). Although the relative importance of these various levee failure

mechanisms is not well documented, eyewitness accounts suggest that these processes are not uncommon.

The vast majority of levee breaks resulting from the 1993 flood are associated with one or more of the following floodplain settings:

- (1) areas occupied by one or more active channels within the past 120 years - 72 percent
- (2) along downstream channel banks between the initiation and inflection points of meanders - 17 percent
- (3) along tributary channels subjected to significant cross flow conditions during flooding - 17 percent
- (4) along chutes (minor subsidiary channels) - 8 percent
- (5) none of the above - 6 percent

(percent indicates relative abundance within the 225-mile reach between Glasgow and St. Louis).

Factors contributing to levee breaks along the Missouri-Mississippi Rivers include:

- (1) highly permeable substrata (channel sands not overlain by a 2- to 4-m carapace of silt and clay)
- (2) channel banks subject to high energy flow conditions
 - (a) downstream banks of meanders between points of initiation and inflection
 - (b) channel banks opposite a deflecting cross flow (tributary, chute or flood

channel)

- (3) levee irregularities and (or) discontinuities
 - (a) high angle junctions between levee segments
 - (b) "eyebrow" repairs
- (4) inadequate levee design/construction/repair
- (5) inadequate levee maintenance

Preliminary geomorphic mapping of the Missouri River floodplain and preliminary analysis of the spatial distribution of levee failures during the 1993 flood indicate that the following reaches are particularly susceptible to catastrophic levee failure and (or) extensive deep scour and thick sand deposition:

- (1) areas of high amplitude - short wavelength meanders (loop bottoms)
 - Rhoades Island (approx. RM 237 - Marshall 1:100,000 map sheet)
 - Lisbon Bottom to Wallace Island (RM 205 to 222 - Moberly 1:100,000 map sheet)
 - Easley to Hartsburg (approx RM 151 to 175 - Jefferson City 1:100,000 map sheet)
- (2) long bottoms where remnants of historic channels intersect the upstream end and extend along much of the length of the long bottom Miami
 - DeWitt Bottom (approx RM-252 - Marshall 1:100,000 map sheet)
 - Overton Bottom (approx RM-180 - Jefferson City 1:100,000 map sheet)
 - Berger Bottom, Boeuf Island (RM-82 to 92, RM-78 - 82, Fulton 1:100,000 map sheet).

- (3) significant floodplain constrictions (usually artificial - bridges, power plants, etc.)
I-70 bridge - Overton Bottoms (approx RM-180 - Jefferson City 1:100,000 map sheet).
powerplant - Labadie Bottoms (RM-54 to 57 - St. Louis 1:100,000 map sheet).

Recommended strategy for analysis and evaluation of levee risk/reliability (possible joint USGS - USACOE program)

- (1) detailed geomorphic/hydrologic/topographic mapping of the floodplain to develop an overall geotechnical context and to identify areas (zones) of high risk.
- (2) in depth historical analysis of levee breaching to document levees with high failure rates.
- (3) detailed geotechnical evaluation of high risk zones and high failure levees.
- (4) on the basis of (1) identify alternative "fall back" alignments for high failure levees.
- (5) set appropriate protection limits for each levee district
- (6) develop new levee designs and "fail soft" strategies for high risk zones.

Levee Damage History - Lower Missouri River

A random sample of levee districts that were severely impacted by the 1993 Flood

USACOE#	District (Area) Name	Damage Years									
9F	Mittler et. al.	'45	'46	'52	'53	'58	'66	'73	'82	'86	
13 - #2	Greens Bottom	'82	'86								
16	Darst Bottoms	'44	'50	'58	'60	'61	'73	'86			
18 - Sec 4	Labadie Bottoms	'42	'47	'51	'58	'67	'73	'86			
23	Pinckney-Peers	'42	'44	'48	'51	'73	'86				
24	Berger Bottoms	'42	'44	'48	'51	'57	'61	'73	'86		
44	Overton Bottoms	'42	'47	'48	'51	'57	'65	'73	'82	'86	
51	Lisbon Bottoms	'43	'44	'48	'52	'59	'60	'67	'69	'73	
		'79	'82	'86							
53H	Cambridge	'82	'83	'84	'85						
55A - Sec 2	Rhoades Island	'61	'73	'74	'82	'83	'84	'86			
60A	Miami - DeWitt	'43	'47	'51	'67						

Table 6.1

**Levee Damage Summary
Lower Missouri River Grand River to St Louis**

1:100000 Map Sheet	Flood Plain Miles	Total Breaks	Historic River Channels	High Energy Reaches	Tributaries	Chutes
St Louis	51	103	69	16	17	13
Fulton	61	121	89	18	28	17
Jefferson City	63	197	149	31	28	5
Moberly	26	83	55	20	11	5
Total	201	504	362	85	84	40

Table 6.2

CHAPTER 7: FLOODPLAIN ECOLOGY

STATUS OF THE ENVIRONMENT

The Missouri, Upper Mississippi and Illinois Rivers, like nearly all large rivers of the world, are no longer undisturbed functioning ecosystems. Humans have used floodplains for agriculture, settlement, and commerce from prehistoric to modern times. This interaction and intervention in natural floodplain processes has disturbed the natural ecological balance, reducing habitat availability for many species of flora and fauna. According to Marler (1993), all 750 miles of the Missouri River below Sioux City, Iowa have been channelized for navigation and agricultural development of floodplain lands. The channel has been further constricted by dikes and revetments which have narrowed the River from over one mile wide to as little as 800 feet wide. Channel narrowing by construction of training structures and by sediment reduction from impoundment is causing bed degradation. Channel narrowing and subsequent bed degradation have led to the perching of tributary streams. At low discharges, stream channels are drained, preventing fish access. The increased gradient of perched tributaries also leads to the loss of infrastructure because of head cutting. This problem is especially noticeable where the Missouri River borders Nebraska and Iowa (Miller, 1994).

Important macro-and microhabitats that once provided mid-channel sandbars, timbered islands, side channels, sloughs, and backwaters with a diversity of depths, velocities and substrates, have been degraded or eliminated. Former riverine and floodplain wetlands with seasonal hydrologic connections to the Missouri River have been drained, filled, and converted to croplands. Past and continuing construction of levees has further isolated remnant habitats. In

most places, remaining riparian habitat is confined to narrow strips riverward of levees (Marler, 1993).

Hesse (1989) reported that from Sioux City, Iowa to St. Louis, Missouri, channelization has shortened the Missouri River channel by 204 km (127 mi); 223,394 ha (552,000 ac) (83percent) of the channel and its erosion zone are gone as a result of rock dikes and earthen levees. Land use on the floodplain along this portion of the river has been changed by channelization; 95 percent, or more than 728,460 ha (1.8 million ac), of the fish and wildlife habitat has been replaced by row crop agriculture. In addition, over 405,000 ha (1 million ac) of tributary valley lands have been inundated by 75 Federal dams on 53 tributary streams. In all, nearly 1.8 million ha (4.4 million acres) of river channel, backwater, riparian wetland, timber and grassland have been destroyed along the Missouri River ecosystem.

The Mississippi River has also been dramatically altered. According to Marler (1993), the Upper Mississippi River drains an area in excess of 150,000 mi²; 66 percent of the 1,106,854 acres in the Upper Mississippi floodplain are used for crops and pasture land. These agricultural lands depend on an extensive levee system for protection against flooding. Theiling (1994) report that the upper floodplain reach (UMR navigation Pools 1-13) has the least disturbed floodplain habitat because of the presence of the Upper Mississippi River Fish and Wildlife Refuge. Aquatic habitats, however, have been adversely impacted by the negative effects of impoundment, sedimentation, and low flow water regulation. Aquatic habitat on the lower floodplain reach (UMR navigation Pools 14-26) has been affected by conversion of floodplain habitats to

agriculture, hydrologic perturbations, and sedimentation. This reach also has few public lands and those public lands are widely separated. The Middle Mississippi (confluence of Missouri River to confluence of Ohio River) is unpooled, steep, lined with rip-rap, and greatly incised throughout its length. The channel is downgraded by 12 feet and the width has been constricted by half since 1837. Less than 5 percent of the total aquatic area in this reach is off-channel habitat. Aquatic plants are almost entirely absent in the Middle Mississippi (Theiling, 1994).

The Upper Mississippi River water level elevation at St. Louis, MO, has increased 9 feet between 1880 and 1993 at high discharge (780,000 CFS); it has decreased 8 feet at low discharge (60,000 CFS) over the same period (National Biological Survey [NBS], Onalaska WI). A similar analysis by the NBS is underway for lower Missouri River at four locations.

The Illinois River is also a highly modified ecosystem. Bellrose, Paveglia, and Steffeck (1979) summarize the use of the Illinois River as follows. Aquatic and terrestrial habitats of the Illinois Valley have experienced a series of alterations to the system since 1900: first, a permanent rise in water level from water diverted from Lake Michigan; second, the draining of more than half of the 161,878 ha. (400,000 acre) floodplain through the construction of levees and pumping stations; third, an upsurge in untreated urban and industrial effluent during the 1920's; fourth, the creation of a 2.7 m (9 ft.) channel and its attendant navigation dams in the 1930's; and fifth, an acceleration in sedimentation rates following World War II.

Sparks (1992) evaluated the impact of these alterations to the system on the Illinois River fishery. He found that in 1908, a 200-mile reach of the Illinois River produced 10 percent of the total U.S. catch of freshwater fish--more than any other river in North America (excluding rivers

with anadromous fish, such as the Columbia). More than 2,000 commercial fishermen were employed on the river and the commercial yield was 24 million pounds annually, or about 178 lbs/ac of permanent water. By the 1950's the yield had dropped to 38 lbs/ac; since the 1970's the yield has been 4 lbs/ac, totaling only 0.32 percent of the total U.S. freshwater harvest. Similar downward trends were recorded over the same period for other indicators of biological productivity: waterfowl and sport fish populations. The declines are attributable to two major changes: diversion of Chicago's effluent from Lake Michigan to the river, and intensification of agriculture in the upland drainage and floodplain.

National wildlife refuges on this system offer important native habitats that were once abundant to the river's floodplain. According to Marler (1993), approximately 9,000 acres of the Illinois River floodplain are contained in the Illinois River National Wildlife and Fish Refuges. From the Chippewa River in Wisconsin to the Rock River in Illinois, the Upper Mississippi River National Fish and Wildlife Refuge totals approximately 200,000 acres. Downstream, the Mark Twain National Wildlife Refuge includes 28,000 acres which are directly managed by the U.S. Fish and Wildlife Service. On the Missouri River, approximately 15,000 acres are included in two National Wildlife Refuges, De Soto and Squaw Creek. Information on state and private lands managed for fish and wildlife was unavailable at the time of report preparation.

Analysis of impacts of the flood of 1993 and resulting recommendations for integrated floodplain management must be placed in the context of how historical environmental riverine conditions have been altered by hydrologic and hydraulic modifications and changes in land cover/land use.

SPECIES DIVERSITY

The historic ecological conditions of the Upper Mississippi River Basin have provided a refuge for "ancient fishes" and resulted in high biodiversity for a number of animal groups. For example, the basin has served as a primary center of diversity of North American fish fauna. The Mississippi River basin exhibits the highest diversity of freshwater fishes for any region of the world at comparable latitudes (Robison, 1986). It comprises about 260 species in 13 families, or just over 43 percent of the approximately 600 freshwater species known from North America. Ancient fishes such as jawless lampreys, sturgeons, gars, and two families with only one or two living representatives continue to survive in the basin. The bowfin, historically found in tributaries to the Missouri River, is the only living species in the family Amiidae. For survival, it requires river backwaters and oxbows that have extensive growths of aquatic vegetation. Draining of marshes, restriction of channels by dikes and dredging, agricultural use of bottomlands, and drought have eliminated most natural pools along these tributaries. Another example of ancient fishes in the basin is the paddlefish, which survives in the Mississippi and Missouri Rivers, and has only one living relative that occurs in China. Paddlefish survival is jeopardized by pollution, alteration of the natural hydrographs on these rivers and mainstem reservoir dams (i.e., Missouri River) which obstruct reproductive migrations (Cross, 1967).

The Mississippi River basin's mussel fauna is also highly diverse, harboring most of the 297 species in the United States. In addition to conserving species during harsh climatic periods, the north-south orientation of the Mississippi and the extension of the Missouri into the arid west make these rivers ideal migration corridors for waterbirds (ducks, geese, swans, herons and

egrets), shorebirds (e.g., sandpipers) raptors (owls, hawks and eagles) and songbirds (warblers, finches, etc.) (Sparks, 1993). Forty percent of North America's waterfowl and shorebirds utilize the Mississippi flyway to move annually between their breeding grounds in the north and their wintering areas along the Gulf coast or South America.

Changes in land use and land cover from historic conditions have caused significant degradation of the natural vegetation communities and overall biodiversity. For example, changes in channel morphology have altered river sinuosity and braiding. Hydraulic model simulations for the lower Missouri below Gavins Point (Latka, 1994) indicate that 98 percent of the channel in late summer and autumn was less than three feet deep during median flow conditions before regulation and eighty-seven percent after regulation. This eleven percent difference in depth, necessary to increase water velocity to meet down stream navigation requirements, significantly changed channel geometry and flow regime of the river. The changes have altered microhabitats for native fish communities sensitive to shallower and slower water depth and velocity. Channel geometry at Marshall, MO (RM 325-424), located on the Missouri River, for 1897 and 1991. **Figure 1** illustrates the reduction in sinuosity. Between 1879 and 1972, eight percent or forty-six miles of the lower Missouri River (in Missouri) has been lost (Funk and Robinson, 1974).

The alterations in channel hydrology and morphology have resulted in a loss of habitats such as grasslands, oxbows, side channels, and sand island/sand bars. For example, the total acreage of sand island and sandbar habitat has decreased significantly on the Missouri and Mississippi Rivers. This habitat is critical for least terns and piping plovers which are on the Federal threatened and endangered species list. This habitat is also important to native

invertebrates and vertebrate species such as fish. Forty-six species, or two-thirds of the total lower Missouri fish fauna, utilize sand island habitats (Grace, 1985). Sandbars and sand island habitats are dynamic. Recently deposited and exposed sandbars are rapidly colonized by willows and succeeded by cottonwood which dominates the canopy for up to 30 years (Galat, Robinson and Hesse, 1994). Anderson, Ohmart, and Disano (1978) discovered that the horizontal and vertical foliage diversity and the presence of cottonwood and/or willow trees were positively correlated with the number of species in an area. Monitoring of wildlife present on the revegetation site for one year led to the discovery that the growth of annuals is important for attracting large wintering populations the first winter after planting.

Surface area of islands in the lower Missouri River (Rulo - St.Louis, MO) was reduced by over 90 percent between 1879 and 1954 (Funk and Robinson, 1974). For three locations in the Mississippi River, Pool 8 (MN, WI), Pool 26 (MO, IL) and the open river reach at Cape Girardeau (MO, IL) the reduction in acreage of sand and mud ranged from 81 to 91 percent between 1891 to 1989 (EMTC -SAST database). Nearly 80 percent of the island habitat in lower Pool 8 was lost between 1939 and 1989 (EMTC-SAST database).

A reduction in biodiversity can also be seen in changes in land use and land cover. Figure illustrates changes which have occurred between 1891 and 1989 for Pool 26 (St. Louis, Missouri area) on the Mississippi River. Over the 98 year period water increased from 15,507 acres to 17,445 acres; marsh increased from 55 acres to over 1,000 acres; Grasses/Forbs decreased from over 5,000 acres to just under 2,000 acres; woody terrestrial vegetation decreased from 18,000 acres to just under 16,000 acres; sand/mud decreased from 2,300 acres to 200 acres; agriculture

increased from 17,400 acres to 20,000 acres and urban/developed increased from 350 acres to 2,700 acres (EMTC-SAST database). Increases in open water and marsh and decreases in sand/mud are related to the construction of Lock and Dam 26 in the 1930's.

Figure 3 illustrates changes which have occurred between 1891 and 1989 for an open river reach at Cape Girardeau, MO. Unlike Pool 26 which was created by the construction of the Lock and Dam, the open river, below Lock and Dam 27, is free flowing. Between 1891 and 1989 open water decreased from 16,800 to 12,100 acres; marsh increased from 0 acres to 15 acres; grasses/forbs decreased from 2,900 to 2,400 acres; woody terrestrial vegetation decreased from 21,700 to 13,500 acres; sand/mud decreased from 4,400 to 840 acres; agriculture increased from 23,000 to 38,700 acres; and urban/developed increased from 40 to 1,400 acres.

Pool 8, located at La Crosse, WI represents an area on the Upper Mississippi River which is considered to be highly productive. Between 1891 and 1989 open water increased 21 percent to 42 percent; aquatic vegetation increased from 2 percent to 20 percent; grasses/forbs decreased from 43 percent to 10 percent; woody terrestrial vegetation decreased from 48 percent to 17 percent; agriculture decreased from 5 percent to less than 1 percent; urban/developed increased from 2 percent to 10 percent; and sand/mud decreased from 2 percent to less than 1/2 percent (EMTC-SAST database). Again, the increase in open water and aquatic vegetation are related to construction of Lock and Dam 8. The reduction in woody terrestrial vegetation is also partially related to the navigation project. Large tracts which would be inundated by the damming of the river were cleared of trees prior to flooding.

At Marshall, Missouri preliminary analysis of historic 1879 land cover/land use indicates

that approximately 76 percent of the 1:100,000 quadrangle was available habitat, including forest, wetlands, sandbars, and grasslands. The 1879 land cover data are not representative of the bluff-to-bluff floodplain. About 60 percent of the floodplain in the Marshall Quadrangle is coincident with the early land cover/land use data. It should be noted that the categories brush, sandbar, and willows represent early successional stages related to periodic flooding.

Published estimates for changes in land cover for lower Missouri River between 1879 and 1982 report cultivated land increased 43-fold while concomitant declines occurred in deciduous vegetation (41%), wetlands (39%), sandbars (97%) and grasslands (12%) (Funk and Robinson, 1984).

Altered river hydrology and geomorphology have also negatively impacted biodiversity and ecological processes in the Upper Mississippi River System floodplains, resulting in the listing of a number of Federal and state and candidate species within the basin (Table). The importance of large floodplain rivers to rare, threatened, and endangered species is also shown by the location of element occurrence data for biologically significant species (plant, invertebrate, and vertebrate) and communities. (Figure). Although biases in the data collection exist due to uneven sampling, the data clearly demonstrates that the mainstem rivers and tributaries provide important habitat to these species.

FLOODING AND THE MAINTENANCE OF BIODIVERSITY

Within the basin, the upper Mississippi, lower Missouri, and Illinois Rivers share attributes common to all large river-floodplain ecosystems. The dynamic nature of floodplain rivers is

critical for the maintenance of biodiversity, fish and wildlife production and migration pathways, transport of sediments and nutrients to support rich floodplain and estuary fish and wildlife resources, and conveyance, storage and moderation of floods. Fishes capitalize on highly productive floodplain environments for feeding, spawning, nurseries, and refuge from adverse river conditions. Floodplain wetlands are considered the essential component responsible for the high fish production recorded in large, low gradient rivers (Welcomme, 1985).

At Marshall, MO, located on the Missouri River, Landsat Thematic Mapper (TM) data acquired before and after the flood indicates that approximately 70,100 ha (63%) of the floodplain was impacted. Over 2600 ha of preflood wetlands were impacted by sand deposition. The post-flood TM scene indicated an additional 18,750 ha of water on the Missouri River floodplain (SAST database).

Periodic flooding is a characteristic hydrologic feature of large river-floodplain ecosystems. Just as fire is now recognized as necessary for the maintenance of prairies, periodic flooding is critical to the ecological integrity of large river-floodplain ecosystems. Floods connect the river channel to its adjacent floodplain. This idea is best expressed as the "Flood Pulse Concept" whereby pulsing of river discharge is the major force responsible for the maintaining the complex physical structure, rich biodiversity, and high plant and animal productivity associated with large floodplain rivers (Junk, Bayley and Sparks, 1989).

The flood of 1993 had an exceptional effect on the floodplain ecosystems. Infrequent large flood disturbances, like the flood of 1993, are necessary to sustain the dynamic functioning

of this river system. Some habitats, like patches of mature floodplain forest, are destroyed, while other habitats, like sand islands, are created. Many individual animals succumb, but whole populations of others surge, such as annual plants and wetland spawning fishes.

Equally important, however, are recurrent, smaller magnitude flood pulses. These pulses provide a predictable reconnection of the river and floodplain and permit nutrient exchange and access to critical habitat.

While the timing and duration of the flood pulse are critical to fishes which gain access to the floodplain for feeding and spawning, ideal conditions for spring spawning fishes occur during years in which the flood and temperature rise are coupled. Figure . illustrates the coupling of temperature and flood pulse (Junk, Bayley and Sparks, 1989). So important is the annual rise of temperature and discharge, that the amount by which fish yield per unit water area is increased by a natural predictable flood pulse has been termed the "Flood-Pulse Advantage" (Bayley, 1991). The idea that rivers and their floodplains are so intimately linked that they should be understood, managed, and restored as integral parts of a single system is the cornerstone of floodplain restoration (National Research Council, 1992), and integrated floodplain management.

Seasonal low water periods and periodic droughts are also essential to maintain the dynamic equilibrium of the Upper Mississippi River as different plant and animal communities benefit from the habitats and resources made available at these times.

The timing and severity of changes in water levels are important to floodplain productivity. Prior to the modification of the natural hydrograph, changes in water levels were fairly gradual and flooding lasting for longer. Now water level changes are more abrupt, with

sharper increases and decreases, and floods last for shorter periods of time (Bayley, 1991). This is detrimental to floodplain productivity.

Periodic flooding allows for connection between the floodplain and mainstem river channels and reworks the channel floodplain geometry. According to Peterson (1994) some evidence may suggest that the recent flood has affected fish distribution and relative abundance in the Mississippi River. For example, high numbers of young-of-the-year white bass (844/net day) and black crappie (6,500/net day) were captured in fyke nets. In one 24-hour set, 8,600, mostly young-of-the-year fish, weighing 400 pounds and representing 22 species were collected. To put these numbers in perspective, that single catch represented 50 percent of the total 1992 catch.

Several young-of-the-year blue suckers (candidate species for inclusion on the Federal Threatened and Endangered Species list) were collected and may represent the first documented evidence of blue sucker reproduction in the open river portion of the Upper Mississippi River System. Blue sucker and black crappie are uncommon to the open river. Since 1991, only 5 adult blue suckers have been captured by Open River Field Station biologists. Prior to recent large catches, only 54 black crappies were captured in the open river since 1991.

Maher and Thieling (1994) investigated the migration of riverine fishes into flooded terrestrial habitats associated with the extended flooding during the spring and summer of 1993. Fish communities were sampled at three separate areas of the lower Illinois River floodplain. Each area contained four separate habitat types: a floodplain depression lake adjacent to the main channel, a forested area around the lake, an open area outside the forested area which was primarily agricultural, and the shoreline as the flood waters rose and receded.

A total of 52 species were collected in the three study areas. Fish density and species richness were highest in shoreline habitats. Catch rates were highest in the shoreline habitats for bluegill, followed by gizzard shad, black crappie, golden shiner and largemouth bass. Common carp was the most abundant species in all other habitats. Channel catfish catch rates were highest in the forested areas. The duration of the flood allowed nest building sunfishes enough time to successfully spawn. This was reflected in high catches of young of the year largemouth bass, black crappie, and bluegill.

The middle portion of the mainstem Missouri River was reconnected to the floodplain for four months in spring-summer 1993. During this period of reconnection, the spring temperature rise was more strongly coupled with rising river stage than was recorded on average for the preceding decade.

On the Missouri River, 728,460 hectares of essential floodplain habitat have lost their nutrient transfer ability and hydrologic connection to the main channel by the lack of an annual flood pulse (Hesse, Chaffin and Braubender, 1989). The elimination of an annual flood pulse can, in large part, be attributed to the need to maintain adequate flows for navigation by specific mainstem reservoir releases. These minimum and full service target flows are provided in spite of the fact that the U.S. Army Corps of Engineers estimated demand for river transport at twelve million tons (General Accounting Office, 1992) has never been met. Between 1984-1988 for example, the average tonnage was 6.7 million tons. Of that amount, only 2.5 million tons (35%) can be attributed to the transport of commercial materials like farm products, chemicals, petroleum products, and metals (Ferrell, 1993). The remainder of the material transported on the Missouri

River goes to the repair and maintenance of the channel.

OPPORTUNITIES TO INCREASE BIODIVERSITY

The Upper Mississippi, Illinois, and Missouri Rivers all experienced damage to levee systems because of the 1993 flood. Some areas were extensively damaged and there is some uncertainty whether these lands can be restored to the pre-flood condition. An ecosystem approach should be taken in the evaluation of these damaged areas and that they be evaluated with respect to existing and future needs of the system and system components.

An area on the lower Missouri River, located in the Kansas City and Marshall quadrangles illustrates the potential for increasing habitat along the Missouri River to enhance opportunities for the restoration, maintenance and enhancement of biodiversity. The success of any future acquisition and long term management plan is dependant on landowner support and coordination with state and Federal agencies.

Figure 7 shows locations of ecologically important areas overlaid on the 1879 historic floodplain. These areas represent the historic oxbows, wetlands, and backwater areas essential for riverine fish habitat and waterfowl species (Dieffenbach, 1994). For example, Sunshine lake is a Missouri River habitat complex that contains an oxbow lake, wetlands, cropland, bottomland forest, sandbars and blew holes. this is one of the few remaining natural oxbow lakes on the Missouri River. If levees that failed during the 1993 flood event are modified or not rebuilt, this area could be managed to provide important habitat for a wide variety of wildlife. Wetland and aquatic areas would provide spawning and rearing areas for riverine fishes,

nesting and brood areas for wood duck, feeding and resting areas for migratory birds, including waterfowl. Restored bottomland forests would provide perching and resting areas for bald eagles, herons and egrets, while also providing cover for a wide variety of mammals and resident birds. Sand bars would provide rearing and feeding areas for riverain fishes and feeding areas for wading birds.

Fish species that would find this area as suitable habitat are buffalo fish, channel and flathead catfish, freshwater drum, paddlefish, crappie, bluegill, longnose gar, gizzard shad and numerous minnows. Bird species that would use this area include mallard, wood duck, Canada goose, great blue heron, and neotropical migrants such as the yellow warbler, yellow-throated warbler, and possibly the willow flycatcher.

The blew holes in this area created by levee failure and riverine scour, if not filled in as part of levee reconstruction, would provide important off-channel habitat (Farabee, 1994). These areas would provide important habitat for nesting, rearing, and resting for avian species that frequent the Missouri River floodplain, i.e., blue and snow geese, Canada geese, mallard, redwing black birds, killdeer and great blue heron. Blew holes also provide off-channel habitat for spawning, rearing, and over-winter habitat for fish species such as largemouth bass, crappie, bluegill, common carp, buffalo, black bullhead, channel catfish, and flathead catfish.

The St. Louis quadrangle provides an example of important biological areas along the Upper Mississippi River (Figure 9), including mussel beds, heron rookeries, bald eagle nest sites, etc. These areas provide needed habitat and represent the few remaining areas which reflect the naturally functioning ecosystem in that stretch of the river.

FRAMEWORK FOR RESTORATION

The SAST hosted a workshop of basin ecologists to develop questions for evaluating ecological impacts of the 1993 flood. Over 75 questions were drafted and will be used to: 1. develop environmentally sound management alternatives for restoration of the Upper Mississippi/Missouri ecosystem; 2. provide recommendations for additional information needs and analyses; and 3. provide an ecological focus on measures to reduce flood risks and damage. The questions are grouped into the following broad categories as they impact the ecosystem: river-floodplain physical processes, basinwide ecology, river-floodplain ecology, riparian vegetation, upland wetlands, tributaries, contaminants, and modeling.

These recommendations complement the concepts identified in the National Research Council's (NRC) 1992 report "Restoration of Aquatic Ecosystems". The report defines the ideal natural state of a river-floodplain as being in "dynamic equilibrium". This is the idea that local features of a river are created, undergo change through time, and eventually disappear, while the overall pattern (e.g., meandering, braiding) remains constant on a larger spatial and temporal scale. Physical processes of rivers provide the template upon which biological processes are patterned. Figure 6 illustrates the relationship between water level and biological processes associated with large floodplain rivers. The NRC report concludes, "the essence of a fluvial system is the dynamic equilibrium of the physical system, which in turn establishes a dynamic equilibrium in the biological components" (page 206). The natural dynamic equilibrium of the upper Mississippi, Missouri and Illinois Rivers is best approximated by turn of the century conditions since no unaltered reaches exist today. Periodic flooding was, and remains, vital to

establishing and maintaining this dynamic equilibrium.

Evaluation of impacts from the flood of 1993 should include NRC's goal and supporting objectives for river restoration. The goal of restoration is defined as, "...to restore the river or stream to dynamic equilibrium, not to "stabilize" a channel or bank". The NRC suggests four objectives to achieve this goal that would provide ecological information for decisions related to floodplain management in the upper Mississippi River Basin:

1. Restore the natural sediment and water regime, where regime refers to the daily-to-seasonal variation in water and sediment loads and the annual-to-decadal patterns of floods and droughts.
2. Restore the natural channel geometry, if restoration of the water and sediment regime alone does not.
3. Restore the natural floodplain plant community, which becomes a functioning part of the channel geometry and floodplain hydrology.
4. Restore native aquatic and wetland plants and animals if they do not recolonize on their own.

These objectives form a sound ecological basis on which to incorporate ecological restoration as part of integrated floodplain management, including human needs for agriculture and recreation. This approach considers not only structural methods of management, but non-structural methods such as regulatory floodways, purchase of easements to prevent construction, and purchase of land and removal or relocation of structures (NRC, 1992). When stream or river management actions are taken without recognizing whether the aquatic ecosystem is in dynamic

equilibrium or disequilibrium, the manager is gambling with the stream or river rather than ensuring improved ecosystem function and dynamic stability (Heede and Rinne, 1990).

RECOMMENDATIONS FOR ADDITIONAL INFORMATION NEEDS AND ANALYSES

Of the questions that were generated as part of the SAST effort, initial recommendations resulted regarding the need for further study and analyses of various aspects of the basin's ecology. These preliminary recommendations are grouped into the following broad categories as they impact the basin's ecosystem: river-floodplain physical processes, basinwide ecology, river-floodplain ecology, riparian vegetation, upland wetlands, tributaries, contaminants, and modeling. Many of the questions identified for ecosystem analysis were also proposed by other SAST groups, particularly in the areas of hydrology, geomorphology and wetlands. This is to be expected as ecosystem analysis is an integrative discipline.

River-floodplain ecological processes

1. Identify the projected reduction, if any, in sediment runoff to tributary streams from upland impoundments, CRP practices, various agricultural practices, stream riparian corridors, etc.
2. Analyse the post-flood change to channel bed degradation.
3. Analyse post-flood changes to sand island and sandbar habitat.
4. Additional channel geometry and channel cross section data should be acquired for the lower Missouri River (eg., 1920, 1954, 1972). Analyses should include time trends and associations of levee breaks in the Flood of 1993 with historic channel geometry. A similar

analysis is recommended for the Upper and Middle Mississippi River.

Basinwide Ecology

1. Document changes in land cover and land use that have occurred in the Upper Mississippi River Basin over the last 100 years.
2. Document changes that have occurred in the composition, distribution and density of native flora and fauna of Upper Mississippi River Basin. Identify what factors are responsible for these trends.
3. Quantify how much of the Upper Mississippi River Basin and floodplain are currently set aside or managed primarily for ecological benefits.
4. Develop a basin-wide plan to restore the system to a dynamic equilibrium that integrates the diverse uses of the basin to include human and ecosystem needs.

River-Floodplain Ecology

1. Identify the predicted distribution and area of floodplain wetlands at various flood stages under the present levee system, no-levees, and several setback and levee height scenarios. Recommend elevation analysis of flood extent and riverine habitats proposed by NBS for Pool 26, Mississippi River.
2. Identify how floodplain wetlands reduce the flood peak. Analyze the reduction in flood height at various flood discharges, levee designs and setbacks ranging from the present condition to a no levee scenario

3. Expand analysis of the the distribution, acreage and classification of historic and current land cover/use (including wetlands) in floodplain of Upper Mississippi River Basin on Mississippi River to include aquatic habitats for Pool 26, complete processing and analysis for lower Missouri and conduct a similar evaluation for selected sites on Illinois River.

4. Support Missouri Department of Conservation evaluation of ecological benefits of newly scoured areas on the lower Missouri River. Conduct similar analyses at selected sites on the Upper Mississippi and Illinois Rivers.

5. Incorporate additional LTRMP post-flood fishery data in the SAST final report and further evaluate the temperature-stage coupling relationship for the Upper Mississippi, Missouri and Illinois Rivers.

6. Develop an ecosystem plan for the river floodplain management that integrates among the diverse uses of the area to include urban, agriculture, and ecosystem needs.

Riparian Vegetation

1. Identify if riparian forests/corridors functioned as energy dissipaters and reduced levee failures during the 1993 flood.

Upland Wetlands

1. Identify the the distribution and acreage of upland wetlands and how has this changed over the past 5, 10, 20, etc. years.

2. Identify which drainage basins would benefit from upland wetland restoration. To what degree would these restored upland wetlands reduce peak flows.

3. Identify how upland wetlands and/or impoundments reduce or supplement summer low flow discharges.

Tributaries

1. Document how restoring tributary sinuosity/meandering could help alleviate flood damage and contribute to restoration of river-floodplain productivity.

2. Document how mainstream floodplain damage can be reduced if tributary floodplain area was increased.

Contaminants

1. Identify the sources, sinks and transport mechanisms of anthropogenic materials in the Upper Mississippi, Missouri and Illinois Rivers and their major tributaries, especially in relation to critical spawning and rearing habitats of aquatic resources.

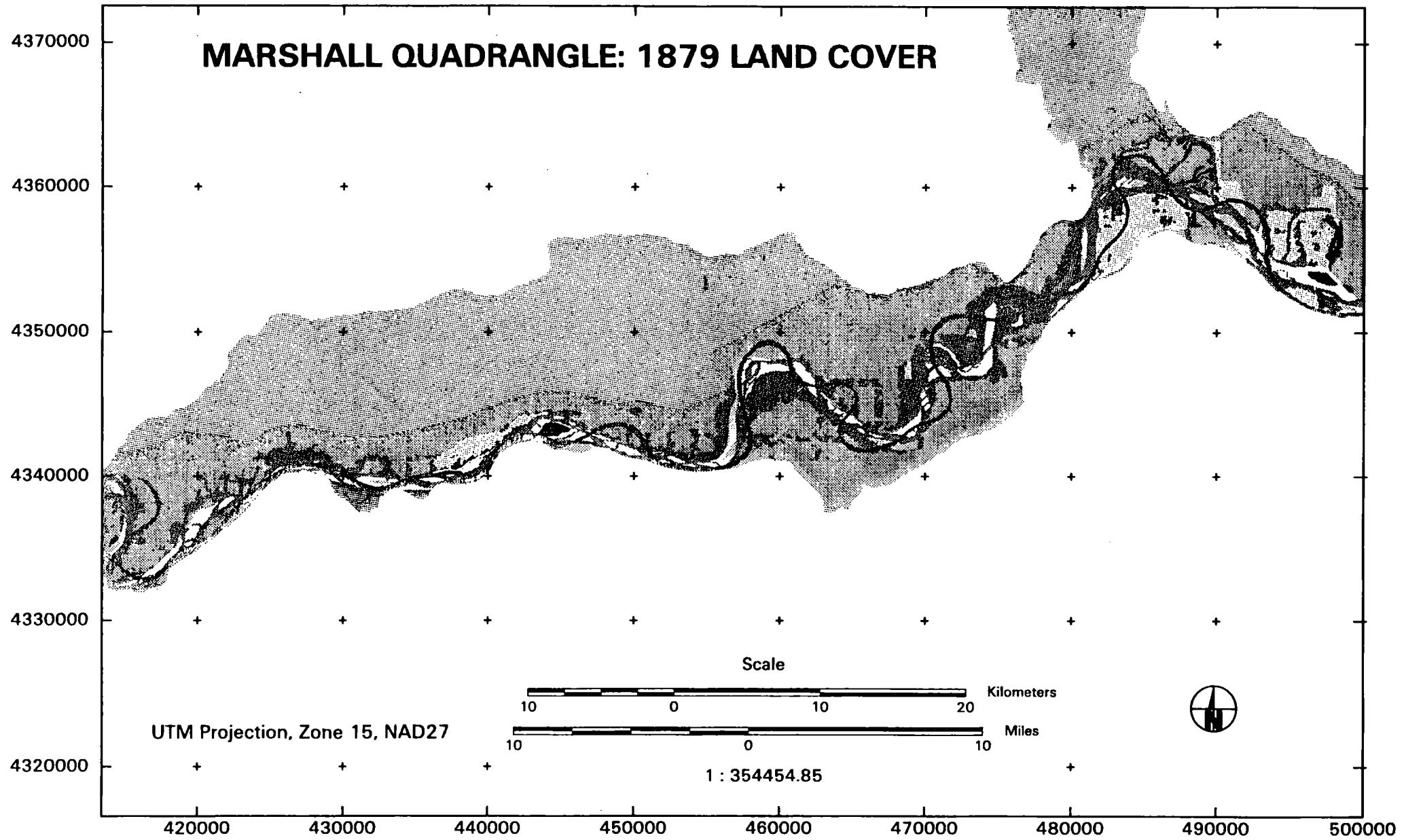
2. Quantify the biological availability and ecotoxicity of contaminants associated with Upper Mississippi, Missouri and Illinois River sediments.

3. Quantify/identify the effect that the flood had on temporal and spatial distribution and trends of contaminants.

Modeling

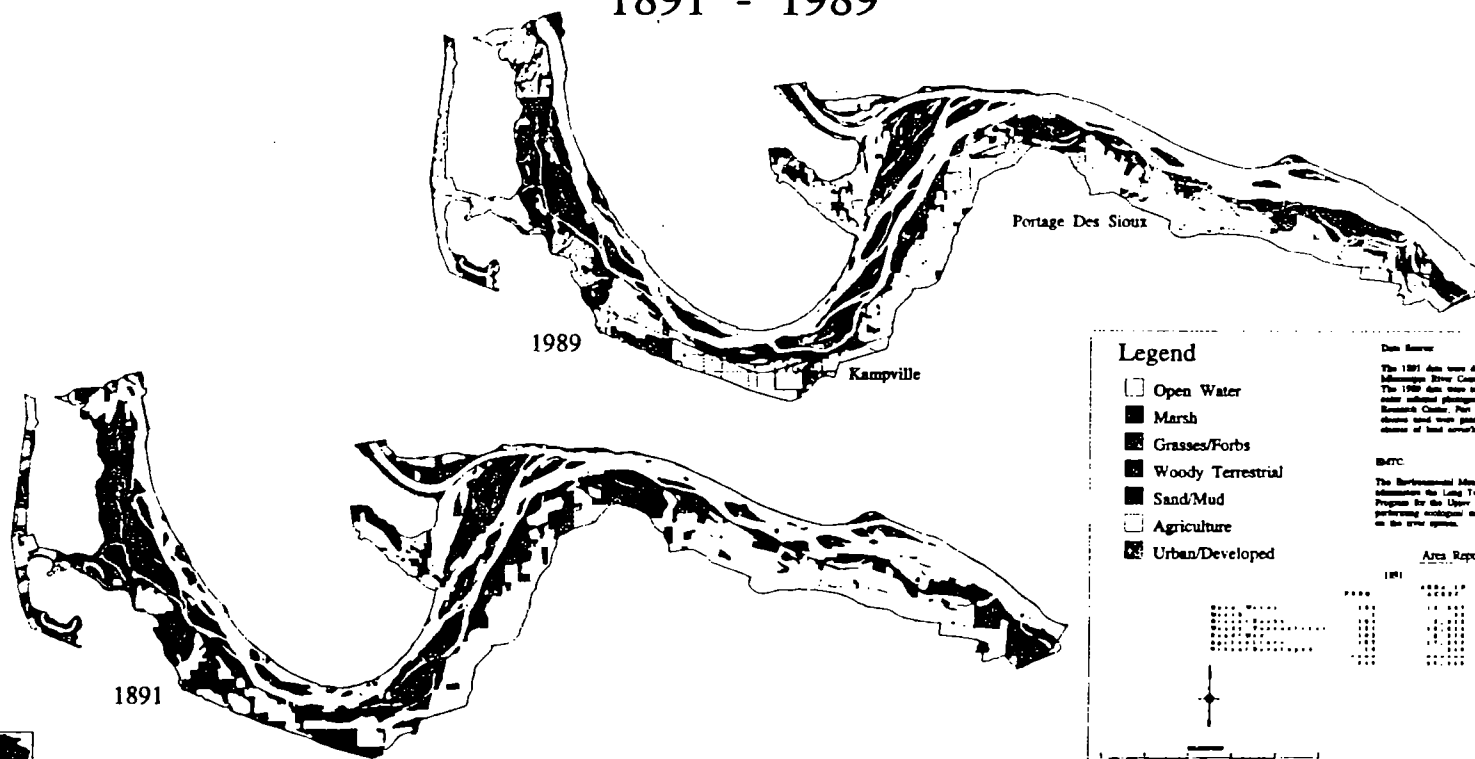
1. Evaluate if the current one-dimensional UNET hydraulic model adequate to evaluate effects of alternative flood and levee scenarios on river-floodplain ecology.

MARSHALL QUADRANGLE: 1879 LAND COVER



- | | | | |
|------------|-------------------|-------------------|--------------|
| Floodplain | Forest, Deciduous | Marsh | 1991 Channel |
| Grass | Urban | Sandbar | |
| Open Water | Brush | Willow | |
| Bluff | Agriculture | Forest, Evergreen | |

Change in Land Cover/Land Use Pool 26, Upper Mississippi River 1891 - 1989



Legend

-  Open Water
-  Marsh
-  Grasses/Forbs
-  Woody Terrestrial
-  Sand/Mud
-  Agriculture
-  Urban/Developed

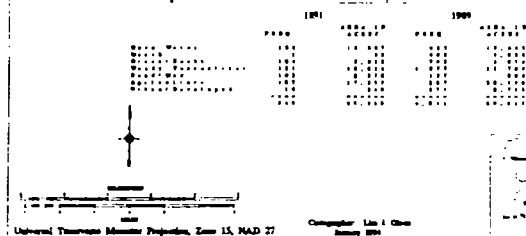
De lauréat

The 1991 data were derived from 120,000-scale Mississippi River Concentration Survey beam scans. The 1989 data were interpreted from 115,000-scale color calibration photographs by the National Biology Research Center, Fort Collins, CO. The survey dates and maps were generated from the original chains of land cover/land use for each date.

B-ETC

The Environmental Management Technical Center administers the Long Term Resource Monitoring Program for the Upper Mississippi River System performing ecological monitoring and research on the river system.

Area Report



Universal Transverse Mercator Projection, Zone 18, NAD 27

Cartographer: Lisa A. Oliver
January 1994

Change in Land Cover/Land Use Open River, Upper Mississippi River 1891 - 1989



Legend

- ☐ Open Water
- ☒ Marsh
- ☒ Grasses/Forbs
- ☒ Woody Terrestrial
- ☒ Sand/Mud
- ☒ Agriculture
- ☒ Urban/Developed

Area Report

	1891	1989
Open Water	10,000	10,000
Marsh	10,000	10,000
Grasses/Forbs	10,000	10,000
Woody Terrestrial	10,000	10,000
Sand/Mud	10,000	10,000
Agriculture	10,000	10,000
Urban/Developed	10,000	10,000

Data Source

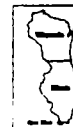
The 1891 data were derived from 1:250,000-scale Mississippi River Commission Survey base maps. The 1989 data were interpreted from 1:125,000-scale aerial infrared photographs by the National Wetlands Research Center, Fort Collins, CO. The same names and codes presented from the original source of land cover/land use for each date.

Notes

The Environmental Management Technical Center administers the Long Term Resource Monitoring Program for the Upper Mississippi River System, performing ecological monitoring and research on the river system.

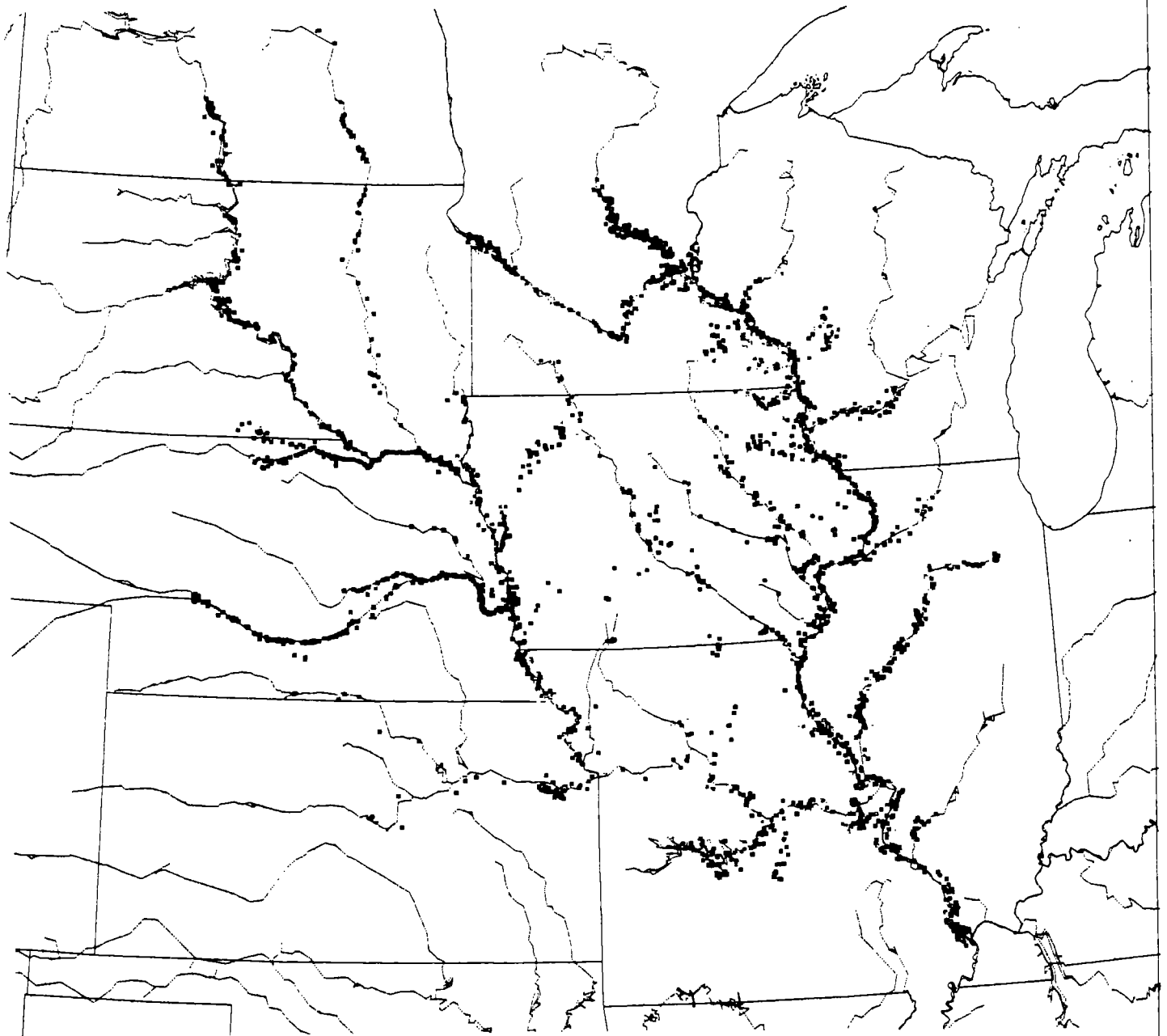


Unscaled Transverse Mercator Projection, Zone 15, NAD 83
Cartographer: Mike J. Olson August 1999



Natural Heritage Inventory

Upper Mississippi River System Distribution



⊠ Community

Plant

⊠ Invertebrate

⊠ Vertebrate

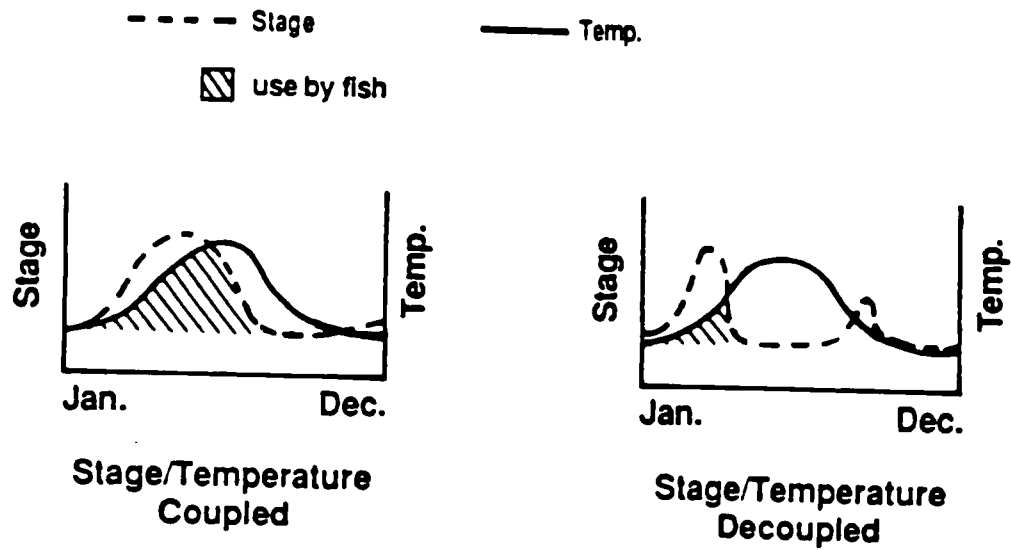


Fig. 7.5 Hypothetical examples of river stage and temperature relationships for a large temperate river floodplain. A) Shows an extended spring flood that, in combination with a normal temperature regime, provides good conditions for fish using floodplain habitats. B) Shows a short-duration, early flood that is decoupled from temperature. This restricts productivity of fish and invertebrates in the floodplain, but permits greater productivity of macrophytes. (Sources: Junk et al. 1989, Sparks et al. 1990.)

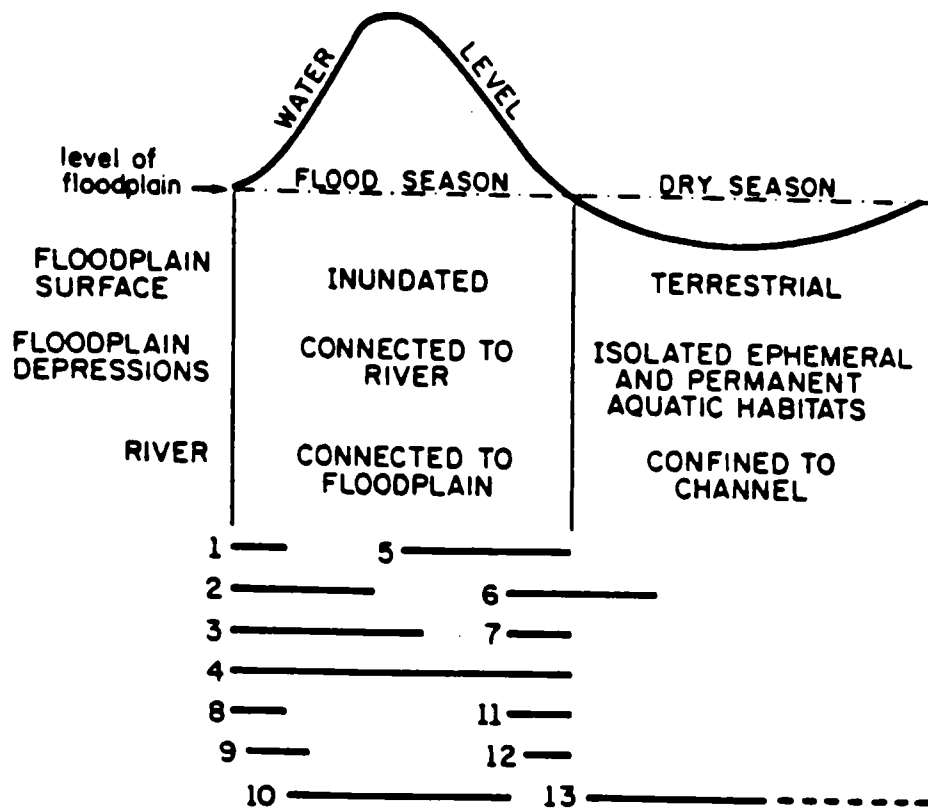
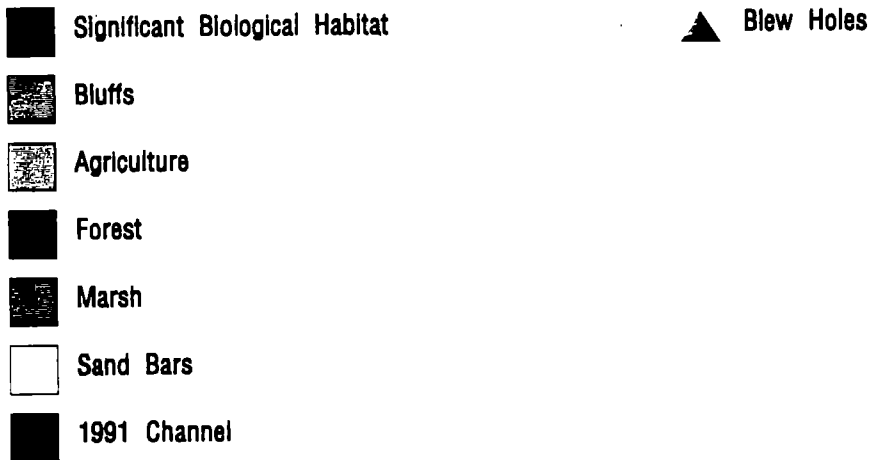


Fig. 7.6 Idealized changes in water level over an annual cycle for a riverine floodplain. Numbered horizontal bars indicate characteristic annual periodicity patterns for some major interactions as follows: 1) nutrients released as floodplain surface is flooded; 2) nutrient subsidy from river; 3) rapid growth of aquatic plants and invertebrates on floodplain; 4) major period of detrital processing on floodplain; 5) DOM and FPOM exported to river; 6) maximum plankton production in floodplain depressions; 7) drift of plankton, benthos and macrophytes to river; 8) fishes enter floodplain from river and fishes that survived dry season in floodplain depressions move to floodplain surface; 9) major period of fish spawning on floodplain; 10) period of maximum fish growth; 11) fishes move from floodplain to river; 12) heavy fish predation losses at mouth of drainage channels; 13) high mortality of fishes stranded in floodplain depressions. (Source: Ward 1989.)

Missouri River
Significant Biological Habitat
1879 Land Cover with 1991 Channel

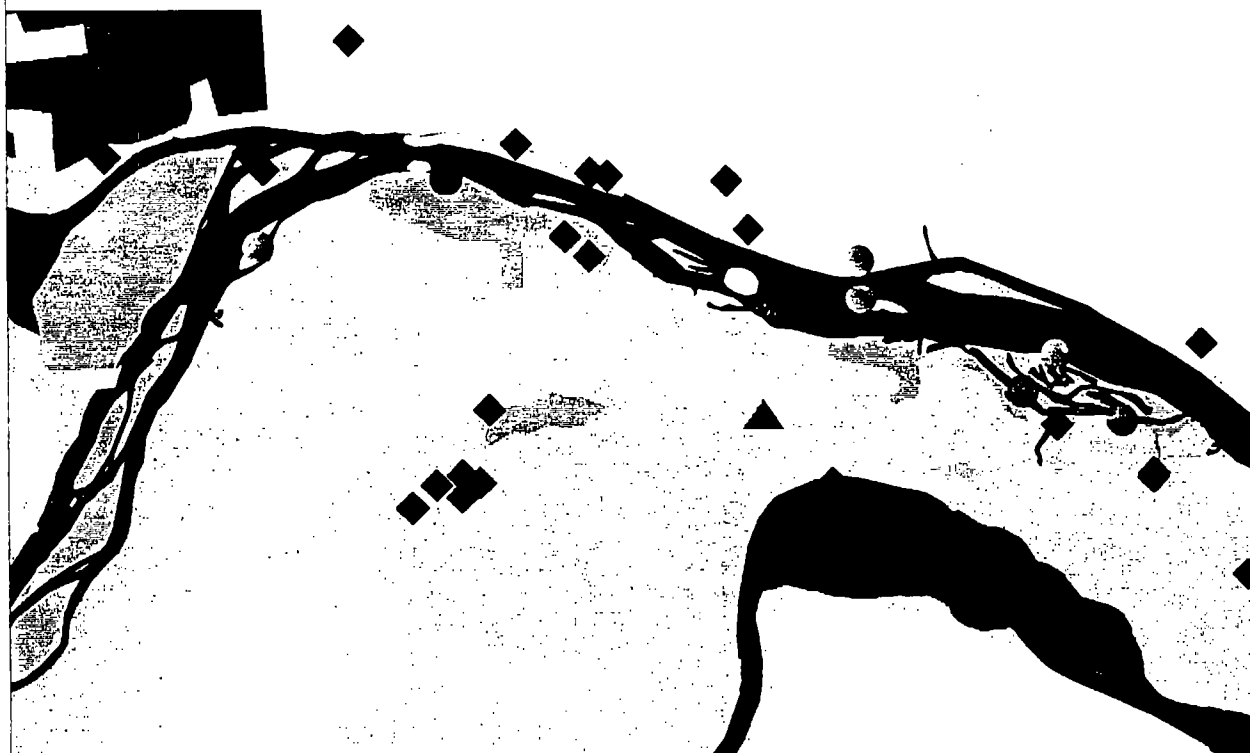


Portions of Kansas City and Marshall 100k USGS Quads

Mississippi River

Significant Biological Habitat

Portion of Saint Louis 100k USGS Quad



- | | |
|--|---|
|  Maximum Flood Extent |  Bald Eagle Sites |
|  1991 River Channel |  Herron Rookeries |
|  National Wildlife Refuges |  National Heritage Inventory Sites |
|  Illinois State Parks |  Blew Holes |
|  Wildlife Habitat | |
|  Mussel Beds | |
|  Significant Biological Habitat | |

TABLE 7.1. Numbers of Rare, Threatened, and Endangered Species
Endemic to Rivers of Upper Mississippi River Basin

TAXONOMIC GROUP	MISSOURI RIVER		UPPER MISSISSIPPI RIVER		ILLINOIS RIVER	
	State Listed or Candidate	Federal Listed or Candidate	State Listed or Candidate	Federal Listed or Candidate	State Listed or Candidate	Federal Listed or Candidate
Plants	7	7	164	11	43	8
Insects	0	6	14	1	6	3
Mussels	0	2	20	7	0	0
Fish	16	10	22	4	3	0
Amphibians	0	0	4	1	1	1
Reptiles	2	4	20	4	4	3
Birds	4	14	30	4	10	3
Mammals	3	3	12	4	2	1
TOTAL	33	45	286	36	69	19
GRAND TOTAL	78^a		322^b		88^b	

^aUSFWS (1990, 1992)

^bThe Nature Conservancy

CHAPTER 8: CULTURAL/MANAGEMENT PRACTICES

STRUCTURAL

Human beings have lived in the upper Mississippi and Missouri River basins for several thousand years. The floodplain played an important role to these early civilizations with some having substantial populations, earthworks, and material culture (Bareis and Porter, 1984; Emerson and Lewis, 1991; Smith, 1990).

Human impacts in the basin within the last 200 years have included clearing of the floodplains and upland areas for agricultural production, removal of snags from the channels for navigation, narrowing and dredging of the channel for navigation, construction of navigation dams, protection of cities and floodplains by the construction of levees, and the construction of large multipurpose reservoirs to provide power, water for irrigation, municipal/rural/industrial water supplies, recreation, flood control, and other public benefits.

During the early to mid-1800's communities began to grow on the floodplains of the

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Upper Mississippi and Missouri Rivers to take advantage of the transportation network that was developing on the rivers and the proximity to water for the population. Because the early major transportation links were the rivers, some of the towns and cities were located on the floodplain near the river channel or on high areas at the river's edge and expansion into flood prone areas. Later, as farming spread inland from the rivers and the road networks began to improve, towns were located on the uplands - too late for many of the major cities that were already growing rapidly. For major cities that relied on the rivers for the greater part of their transportation and commerce, location at the river's edge was critical.

The fact that the cities had to be located at the river's edge, meant that either the cities must tolerate flooding or some type of protection must be constructed to protect the cities from flooding. After more debate, the policy that led to the construction of levees for local protection was developed (Humphrey and Abbot, 1861). When these failed due to excessive river flows, flood control reservoirs were constructed upstream to store flood waters and release them slowly.

Besides commerce, the other floodplain activity was agriculture. The floodplain of the rivers often contained the most fertile land in the country and was of prime value for agricultural production. A logical result of farming in the floodplains was that owners who had struggled to clear these highly productive lands wanted to protect them from flood waters. This desire to protect their investment from floods led to demands for agricultural levees along the river as well as flood control storage upstream to reduce the required levee heights. Protection of the floodplain investments that were encouraged by two centuries of national policy has resulted in nearly continuous levee systems along the Upper Mississippi and the Lower Missouri Rivers.

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In an effort to protect adjacent farmlands and provide ample space for flood passage the Pick-Sloan plan was passed by Congress in 1944. This plan called for a floodway from Sioux City to the mouth of the Missouri that was 3000 feet wide from Sioux City to Kansas City and 5000 feet wide below Kansas City.

In 1962, based on new construction methods for levees, additional reservoirs, and flood control structures, it was recommended that the floodway be decreased to 3000 feet in width for the entire length. This recommendation was based on proposed reservoirs on the Grand River that were never constructed. Federal levees that were constructed in an effort to protect extremely productive agricultural lands along the river were built in accordance with the calculated floodway requirements. The private levee systems that were built along the Missouri River were placed as close to the river as practical, and for the most part do not allow for the recommended floodway. A study done by the U.S. Army Waterways Experiment Station for FEMA showed the agricultural levees had little effect on the flood stages of the Missouri River from Waverly to Jefferson City, Missouri because their relatively low heights would overtop during major flood events - precisely what happened during the 1993 flood event.

Today the Upper Mississippi River below Muscatine, Iowa, and Lower Missouri River below Sioux City, Iowa are flanked by agricultural and municipal levees for most of their length. On the Missouri River, reservoirs control most of the flows while flood flows on the Mississippi are mostly unaffected by reservoir regulation. The levees and flow regulation have resulted in the loss of wetlands and environmental changes along the rivers.

These environmental problems must be

balanced with demands for further flood control if we are to preserve the diverse species in these reaches of the rivers.

It must be remembered that these river systems are dynamic and extremely variable. Little is known about the historic channels of the Missouri and Mississippi Rivers before the early 1800's when policy began to be directed toward controlling the rivers for navigation or flood control purposes.

The earliest known survey seems to be about 1821 when river widths were roughly equivalent to but slightly wider than those that exist currently on the Middle Mississippi River (Simons and others, 1974). Simons' analysis dated the end of the natural river system at 1888 but much of the floodplain clearing had been done before that time and dikes had already been built in St. Louis to constrict the river from 4200 feet wide to a width of 2100 feet - the same width of the river today at St. Louis. The 1821 width at St. Louis was 3100 feet. In the 1840's the river at St. Louis had expanded from 3100 feet to 4200 feet and had become so shallow that navigation was threatened. This may have been due to major floods about this time or to a combination of the floods and the clearing of floodplain lands that was well underway by the 1840's

Floods have been common on the Upper Mississippi and Missouri Rivers. As a result of flooding, multipurpose reservoirs (including flood control) have been constructed on most major tributaries and on the mainstem of the Missouri River. For the 1993 flood, while damages were in the \$16 billion range, additional damages estimated at about \$19 billion were prevented by the U.S. Army Corps of Engineers flood control structures and reservoirs in the system (USACE, 1994). Additionally, it appears that the majority of the \$16 billion in damages occurred in upland

areas and not in the major floodplains themselves (Interagency Floodplain Management Review Committee)

NONSTRUCTURAL

Nonstructural methods of flood control are becoming more common in the uplands and floodplains of the Midwestern United States. Often the primary purpose of these nonstructural methods is capturing the maximum amount of rainfall for agricultural crops. In other cases, prairie pothole wetlands that are being restored for the use of waterfowl are also providing additional flood storage on the watershed. The general public is also beginning to understand the water purification function of wetlands and is moving to restore and create wetlands for water quality purposes. An example is the current effort of the Redwood River Basin Association in Minnesota (RRBA, 1994).

The Redwood River Basin Association is proposing to restore up to 5,000 acres of wetlands for water quality improvement. These wetlands should not only improve water quality but can have an impact on flooding if properly restored. With proper techniques and an awareness of the relationship of wetland types and their effect on flooding, restoration can not only improve water quality but to some extent reduce downstream flooding.

The construction of wetlands on the floodplains or in the watershed will only reduce peak flooding in direct proportion of the storage volume of the wetland to the total flood volume in the basin. In large floods the wetland volume in short sections or small wetlands becomes negligible,

but on reaches of the river with very wide floodplains or with large amounts of wetlands in the upland, wetlands may have an appreciable effect on flooding.

Recent large floods are increasing public awareness that levees and flood control works do not guarantee that lands in the floodplain will never flood. This renewed awareness of the dangers of dwelling on the floodplain has prompted some residents to move to higher ground, as is the case with the towns of Soldiers Grove, Wisconsin and Valmeyer, Illinois. Still, the misconception that a 100-year levee protects a city for the next 100 years has arisen despite efforts to help floodplain residents understand that a 100-year flood has a probability of 0.01 in any given year and does not necessarily occur only once in a 100-year period. This probability has been explained as having a bag of 100 marbles with one blue marble and 99 white marbles. If the marbles are returned to the bag after each selection, there is a 1 percent chance of drawing the blue marble from the bag. There is also a chance of drawing the marble in two consecutive years. This understanding should be conveyed to floodplain residents.

The flood insurance program has heightened awareness of the danger of floods; however, it has also promoted additional development in the floodplains by the use of a 100-year protection level as the cutoff for floodplain regulation. This 100-year regulation in conjunction with cost sharing has resulted in demands by communities to remove or reduce freeboard heights from levee designs in order to reduce the communities' cost share and to allow development on the floodplain. This sets the stage for a future increase in flood damages when the 100-year levees are overtopped or breached. The removal of additional levee height may place a much higher risk on the occupants of the floodplain than they are given to understand by developers and some

This explains it
Summed up
Full report

political leaders.

Finally, other nonstructural measures (such as flood proofing and other FEMA recommended actions) are also being taken and these efforts, including relocation, should be continued and increased where possible.

8.8

BLANK

SAST DRAFT: NOT FOR RELEASE OR ATTRIBUTION**UNET MODEL RESULTS**

Hydraulic modeling on the floodplain was performed using the UNET model, a one-dimensional mathematical model that simulates the unsteady state flow conditions of the Mississippi River during flood. The UNET model, developed by Dr. Robert Barkau, was applied to the Mississippi River from Hannibal, Missouri (Lock and Dam 22) to Cairo, Illinois; the Missouri River from the mouth to Hermann, Missouri; the Illinois River from the mouth to near Meredosia, Illinois; and the Kaskaskia, Merrimac, and Salt Rivers from the mouth upstream to the first river gaging station. The purpose of the modeling effort was to obtain an approximation of the effects of levees on the flood of 1993 and other selected flood events. This was done by modeling these events under different levee configurations including the absence of levees from the length of the modeled floodplains except for those around St. Louis. It was considered that the levees around major metropolitan or industrial areas would continue to exist under any management practice in the foreseeable future. If it is desired to determine the effect of not repairing the existing levees, a much more detailed effort would be required, especially for the Missouri River where levee heights, locations, and break locations are not as well defined.

The model was calibrated using the 1993 flood with the arrangements of levees that existed prior to the flood. Levee failure was simulated and the hydraulic roughness values (Manning's "n" values) were calibrated to match data from USGS gaging stations and observed high water marks. The model reproduced the 1993 flood hydrograph including the effect of levee breaches and overtoppings and associated reductions in stages at gaging stations. Cross sectional data are very good for the Mississippi and Illinois Rivers but data quality on the Missouri River was much lower due to the lack of accurate levee and limited cross section data. Therefore, the results of the model study on the Missouri River should be used with caution.

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After the model was calibrated to the 1993 flood with the levees in place, the river system was modeled assuming the agricultural levees were absent. The Manning's "n" value associated with the overbank for future conditions is unknown since absence of levees would have a major influence on decisions regarding future land use behind current levees; therefore, a range of roughness values was simulated which incorporate, in general, the range of land cover variations that could occur. The first Manning's "n" value, $n=.040$, represents an unrealistically low value normally associated with short grasses or bare soil and serves as a lower limit. The second Manning's "n" value, $n=.080$, represents the hydraulic roughness associated with a mixture of agricultural crops. The third Manning's "n" value, $n=.160$, represents the hydraulic roughness associated with little undergrowth and the fourth Manning's "n" value, $n=.320$, is representative of a dense brush or very dense forest. A Manning's "n" value of $n=.640$ is shown for reference but is probably too high for forests in this area. To provide an upper limit, the river was also simulated with no overbank conveyance, thus simulating the entire range of possible overbank conditions.

The results of this model study, as shown in Table 8.1, indicate that removal of agricultural levee systems (urban levees were retained due to the extreme cost of moving large municipalities out of the floodplain) would result in significant stage reductions in areas with wide floodplains, if the full floodplain conveys water and Manning's "n" values are low - i.e. if the land remains in farmland or open meadow. Future land use would be determined by the economics; thus it is unclear whether the floodplain would revert to forest, meadow, partially remain in farmland, or what combination would result from levee removal. However, it would take many years for any floodplain forests to be restored. Flood estimates for large floods must be based on eventual conditions and not on transient intermediate conditions that may or may not exist at time of a large flood. Reliable predictive understanding of land cover change is necessary to improve the ability to more accurately model the hydraulic effects of different structural and

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nonstructural approaches to flood control and mitigation on the floodplain. It is clear that the $n=.040$ value is too low for most conditions on the floodplain. Thus, "n" values on the floodplain could be expected to vary from $n=.080$ to $n=.320$ depending on the land cover.

The maximum reduction in flood elevation is at Chester, Illinois where an "n" value of $n=.040$ resulted in a reduction of 11 feet. This is due to the unrealistically low "n" value along a reach of the river that is very wide. In a more realistic scenario where the floodplain is assumed to either remain as farmland ($n=.080$), return to forests ($n=.160$), or revert to dense forest with underbrush ($n=.320$), the change in water surface varies from a reduction of 7.2, 3.8, and 1 foot respectively. At these reductions the area would still be under water at peak stage but the energy and flow characteristics would be different.

A physical model study done at the Waterways Experiment Station (WES) in 1979 (Foster and Allen) showed that the removal of remaining trees between the river bank and levee along the section from St. Louis to Cape Girardeau would lower the stage at Chester by 4.6 feet and as much as 7.6 feet near Grand Tower. This study further indicates the extreme effect that mature trees and undergrowth can have on flood heights under conditions of a fully forested floodplain.

Flood height reductions at St. Louis are about 2.5 feet lower with no trees in the floodway for the WES study and from 2.8 feet lower with the $n=.040$ condition to 1.0 foot higher for the $n=.320$ overbank conditions of the UNET study.

On the Missouri River at Washington, with an "n" value of $n=.040$ the stage would be 4.0 feet lower but 2.1 to 4.5 feet higher for forested conditions ($n=.160$ to $n=.320$ respectively). At St. Charles, flood heights would be the same regardless of floodplain "n" values and only 0.9 feet higher if all levees had held.

Tests with the Pick-Sloan (3000 foot) Floodway on the Missouri River showed variable results - from a reduction of 2.5 feet to an increase of about 1 foot in flood

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stages over the 1993 peaks due to the various floodplain "n" values tested.

According to the model, if all levees had held throughout the entire portion of the Missouri River system that was modeled, the 1993 flood stage would have increased by a maximum of about 2.5 feet with the increase in most areas being less than 2.0 feet.

The other floods which were analyzed using the UNET model occurred in 1973 and 1986. Those analyses showed similar trends but to a lesser degree since flood peaks were lower than for the 1993 flood. Comparisons for the three floods at selected gages are shown in Table 8.2.

The UNET model analyses further indicated that failure of the levee near the peak of the flood near St. Louis reduced the maximum flood elevation by about 2 feet due to water drawn into the floodplain areas behind the levee system. If there had been no levee or if the levee had failed earlier, this effect would not have been present and the flood would have peaked at a higher level.

These results also indicate that the levee system did not cause the flood. The fact that water overtopped most levees but flooding still increased indicates that for a flood of the magnitude and duration of the 1993 flood levees had a moderate impact. These results assume current management and operations upstream from the inflow boundaries of the UNET model. These results are not directly extendable to other locations which require individual modeling analysis.

The UNET is a one-dimensional model and as such assumes that the calculated velocity exists across the entire river. The UNET models levees as storage cells. The model cannot accurately predict velocities in the river during levee breaches nor accurately model velocity distributions within the levee systems. To accurately model river flows near levee breaks at least a two-dimensional model must be developed. Currently the lack of accurate digital elevation models hampers the development of two dimensional models. In order to adequately model a floodplain scenario with a mix of forest, meadow, and dense scrubs, a two-dimensional model should be used.

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SAST DRAFT: NOT FOR RELEASE OR ATTRIBUTION**CONTAMINANTS**

The flood of 1993 highlighted the need for a comprehensive assessment of placement of industrial and hazardous waste storage facilities within the floodplain. It was not practicable to measure the water quality impacts resulting from inundation and transference of hazardous waste products during the flooding event for the entire river lengths that were affected, and consequently no comprehensive analyses were done. Nonetheless, the potential for water quality degradation can be surmised. At minimum, the conclusion can be drawn without substantial analysis that inundation of hazardous substances is a scenario that is best avoided altogether, and it is this premise that provides the basis for identifying such facilities within a floodplain.

Although the supporting water quality analysis is not included in this preliminary report, the SAST acknowledges that individual scientists and agencies may have conducted studies of limited reaches in the river. U.S. Geological Survey water quality monitoring stations continued to collect and analyze samples during the flood event, except for locations that were put out of commission by the flood, and the data continued to be stored in the EPA STORET system.

The National Biological Survey's National Fisheries Contaminant Research Center is working with SAST to provide any necessary supporting water quality analysis and identify research needs.

For the purposes of this preliminary report, the analysis of contamination issues is limited to the potential point sources of contamination that are present in the floodplain, specifically, those sources that were impacted by the flood. The merit of this approach is apparent when considering the following example. The break of the Columbia and Harrison levees in Monroe County, Illinois, was witnessed by viewers across the nation as the major television networks displayed aerial coverage of a farm building being pushed off its foundation and then swept away by raging flood waters. Hundreds of acres of row crops were inundated, as was the town of Valmeyer, Illinois. As in many areas that were flooded, the waters receded and left scour holes, deep deposits of sand and silt, and scattered woody debris. However, Monroe County is a relatively short distance downstream from St. Louis, a major urbanized area, and the floodplain was also littered with containers of substances unknown including bottles, spray cans, and even 55 gallon drums. The problem was so common and widespread that farmers considered having

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people walk the fields before their advancing plows this spring to remove debris. The Monroe County Soil and Water Conservation District considered setting up a collection point for farmers to deliver their potentially hazardous debris. The ramifications of hazardous substances turning up in farm fields are potentially serious, although the actual impacts to agricultural production are not known. What is known, however, is that the various source locations of these substances need to stay dry to avoid this scenario in the future.

Point Source Contaminants

Superfund sites are contaminated sites on the National Priorities List that are scheduled for clean up under the Comprehensive Environmental Response Compensation and Liability Act. The locations of superfund sites were provided by EPA Region 5 (Minnesota, Wisconsin, and Illinois) and Region 7 (Nebraska, Iowa, Missouri, and Kansas). Condensed EarthSat coverages have been obtained for four states: Illinois, Kansas, Missouri, and Iowa. The accuracy of the polygon coverage is excellent and very useful for analytical purposes. EarthSat coverages show the total number of superfund sites throughout the 1993 flood extent area is 34. The total number of these sites occurring in Mississippi and Missouri Rivers floodplain is 22.

The *Toxic Release Inventory (TRI)* contains point coverage of facilities that manufacture, process, or use a minimal amount of toxic substances. This minimal amount is generally 25,000 pounds per year but may differ depending on the type of chemical. EarthSat coverages were obtained for four states: Illinois, Kansas, Missouri, and Iowa. The point data has good accuracy, having been recently updated, and is useful for analytical purposes. The total number of TRI facilities that were impacted is 97. The total number located on the floodplain is 207. Figure 8.2 displays impacts to superfund sites and TRI sites for the St. Louis area.

Permitted dischargers such as wastewater treatment plants are included in a database entitled Permit Compliance System (PCS). Specifically, the data of interest to SAST in the PCS are included in the National Pollutant Discharge Elimination System (NPDES). These data were obtained in a spatial, digital format from EPA Region 5 for Minnesota, Illinois, Wisconsin, Indiana, Michigan, and Ohio and from the State of Kansas for Kansas. Iowa supplied the spatial data for only the wastewater treatment plant portion of the PCS. PCS data and NPDES data are

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available on the SAST database for Missouri and Nebraska (and all the states within the study area) in a relational database, which must be translated to a spatial format to be useful for analytical purposes. The PCS and NPDES are not very accurate in terms of specific point locations of occurrence and may contain gross errors.

Listings of wastewater treatment plants impacted by the flood of 1993 are contained within a Federal Emergency Management Agency (FEMA) database, as well as corresponding location information and disaster assistance payments. At present, these data have not been made available to SAST. However, the total number of impacted wastewater treatment plants is known. According to a March 17, 1994 U.S. EPA Summary Status Report, 425 municipal wastewater facilities were damaged by the flood, and 389 of these facilities have received FEMA funding. The remaining 36 facilities are under review to determine if they qualify for assistance.

Drinking Water Supplies

According to the EPA Summary Status Report, 289 municipal water supplies were impacted by the 1993 flood. Of these, 247 have received FEMA funding, and the remaining 42 are under review to see if they qualify. According to the report, most of the public water supplies are now operational, with Kansas City, Kansas, the only system still experiencing operational difficulty.

SAST also obtained information concerning public water systems from EPA Regions 5 and 7. In Region 5, the only facility still not operational is Valmeyer, Illinois due to abandonment. The city of Valmeyer is in the process of relocating to higher ground, where a new municipal water supply will be constructed to replace the former supply. Two other supplies, Central Alexander County Water District in Illinois, and Black River Falls in Wisconsin are operational but continue to have ongoing problems. The extent of ongoing problems with drinking water systems in Region 7 is not known at present, other than the situation in Kansas City, Kansas.

According to the Safe Drinking Water Act, a public water system means a system for the provision to the public of piped water for human consumption and that has at least 15 service connections or regularly serves 25 individuals daily at least 60 days of the year. A public water system is either a community water system, which includes municipal water supplies, or a

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noncommunity water system, which includes smaller supplies such as restaurants, gas stations, campgrounds, etc. Another wide range of water supplies, private wells, are not public water systems and are not subject to the Safe Drinking Water Act. These systems are very numerous, and it is estimated that approximately 3000 such water supplies were impacted by the 1993 flood in Illinois alone. SAST does not have data concerning the status of these supplies. Oversight of these supplies generally occurs within the various State boards of health.

Site specific information for public water systems is included in a relational database called FRDS. This data can be translated to a spatial format. However, the locational accuracy for this data is not very good in the database and is further complicated by the fact that a single public water supply can be serviced by several wells separated by considerable distances. For the purposes of SAST activities, only the list of impacted public water systems was sought.

Another database maintained by EPA is the Resource Conservation and Recovery Information System (RCRIS), containing sites subject to RCRA. These sites include incinerators, storage and treatment facilities, and disposal facilities. This information is not available from the EPA Regions for the Mississippi and Missouri River basins and must be obtained from EPA Office of Administration and Resources Management. The data have not yet been made available to SAST due to high cost.

Recommendations

1.) Protect the environment from environmentally hazardous materials either by reducing the risk of mobilization or removing them from flood prone areas. Analysis conducted by SAST indicates that point sources containing hazardous waste were impacted by the 1993 flood event. Specifically, the SAST database demonstrated that some superfund and toxic release inventory sites occurred within the flood extent as identified on satellite data.

If potential point sources must stay on the floodplain, these facilities must be kept dry to the greatest extent practicable during flooding events. Where such facilities are together in high concentrations, industrial levees should be in place to protect them. Figure 8.2 of the East St. Louis area illustrates the use of industrial levee districts to protect a large number of facilities. For individual facilities located on the floodplain, particularly in areas hard hit by flooding or in

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areas where levees are not expected to be rebuilt, consideration should be given to moving these facilities to higher ground above the bluff. The SAST database provides the necessary data for making these decisions, including levee location, levee breaks, and location of facilities.

2.) Establish an office that has oversight responsibilities. The office should coordinate with the Regions that share the Mississippi River as a common border but take the lead in risk reduction, pollution prevention, and ecosystem management in the floodplain. The program office should be located in a Mississippi River community. The Upper Mississippi/ Missouri River office would also take the lead in implementing any future reauthorization of the Clean Water Act for the Upper Mississippi and Missouri River watersheds including addressing non-point source pollution.

3.) Databases that are crucial to managing the watersheds should be upgraded to provide good quality point locations that are suitable for analysis. Databases identified by EPA as needing improvement include RCRIS, FRDS, PCS, and NPDES. These databases cover more than 42,000 facilities in nine states in the flood study area. The data would greatly improve the accuracy of the SAST floodplain analysis, and therefore funding of this effort should be given serious consideration.

4.) The tracking system of damage to all infrastructure should be improved to allow for a better reporting mechanism. The system in place in 1993 produced data gaps that made tracking of specific damaged structures difficult. For example, the SAST was unable to obtain a list of wastewater treatment plants impacted by the flood. This was due to the fact that disaster assistance payments were made to communities under general categories such as utilities and so specific facilities could not always be identified.

SAST DRAFT: NOT FOR RELEASE OR ATTRIBUTION**CRITICAL INFRASTRUCTURE**

Critical Infrastructure is defined as:

"structures, facilities and installations of such a type and function that: (a.) if rendered unserviceable would impose significant hardship on the public they serve, or (b.) if flooded would pose a threat to public health, public safety and/or the environment. Examples of the former include (but are not limited to): municipal water treatment plants, municipal drinking water well fields, water treatment plants, interior drainage pumping stations, major highway bridges, major passenger and freight railroads, critical access roads, major airports, hospitals and related medical care facilities, electric generating plants, military bases, and government buildings (owned or leased), including those of the U.S. Postal Service and other quasi-public entities. Examples of the later include (but are not limited to) facilities that either produce, handle, or store potentially explosive chemicals and gasses, and sites holding hazardous, toxic, or radioactive wastes." (IFMRC, 1994)

Every state in the Nation has areas where critical infrastructure is at risk from flooding. Much of this infrastructure, by its very nature, must exist on the floodplain - rail and highway bridges, for example. A large amount of other critical infrastructure has also been located on the floodplain by various public, quasi-public, and private agencies and enterprises. Even recently constructed Federal government facilities experienced damage in the 1993 flood - an embarrassment to the agencies involved. The fact that the Federal Government suffered damage from flooding would appear to be in violation of Executive Order 11988 from 1978. Several of these critical infrastructure made national news during the 1993 flood, such as the water treatment plant in Des Moines, Iowa which was inundated and left the city without potable water. Other problems included propane tanks floating down the river and floodplain, hazardous sites as listed by EPA being inundated, and agricultural chemicals being transported from storage sites.

Transportation infrastructure both affects flooding and is affected by flooding. Bridge and railroad infrastructure affect floods by causing constrictions in flow area and additional resistance to

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flow due to bridge piers and decks. The constriction and resistance can produce very high velocities under bridges and lead to failure of bridges due to high velocities removing the material supporting bridge piers. The constriction and resistance caused by the bridges also result in increased water depths upstream from the bridge and may increase flooding in that area. Current standards for bridge construction vary with bridge type but are normally governed by FEMA floodplain regulations.

A major problem for critical highways or rail lines occurs when flood waters such as those in the 1993 flood rise above approaching roadway levels. This makes the bridges unusable even though the bridges themselves may be safe and above water. Depending on the velocity of the water as it moves over the bridge approaches, the approach sections may or may not be damaged. At one point during the flood, all bridges over the Mississippi and Missouri Rivers in the State of Missouri were closed, except for one bridge at Rocheport. As the water moves over the roadways and rail embankments, sections of pavement or track are often removed from the roads or railways leaving the transportation links unusable until repairs are made after the flood waters recede. This occurred at the Highway 54 and 63 bridge at Jefferson City, Missouri. The failure of an agricultural levee at Hermann, Missouri resulted in \$1.3 million in highway repairs. These repairs were again jeopardized by spring flooding on the Missouri River in 1994 since the damaged levee had not been repaired.

Highway crossings built to previous or current Federal standards caused severe scour under and near the structures as witnessed at the Glasgow, Missouri rail and highway crossing on the Missouri River, the Interstate 70 crossing west of Columbia Missouri, and to a lesser extent the Interstate 435 crossing of the Missouri River north of Kansas City, Missouri. These constrictions in the waterway not only cause severe scour under the bridges but can raise upstream flood elevations

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and affect water surface profiles significantly. Along the Missouri River near Jefferson City, the Highways 54 and 63 bridge and associated highway embankments, homes, and buildings raised river slope from the normal 0.8 ft per mile to over 2 feet per mile.

At the Glasgow crossing, the Missouri River washed away the railroad embankment, creating a scour hole where the adjacent highway had been on the west side of the floodplain, destroyed the west end of the railroad bridge across the river on the east side of the floodplain, and caused a large scour hole that extended from upstream of the railroad and highway bridges, under, and well below the bridges. The material from this scour hole then covered farm land downstream from the bridge crossings. Similar conditions existed at other locations on both the Missouri and Mississippi Rivers.

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ECONOMICS

Excessive soil moisture and flooding caused serious economic and infrastructure losses across the study area. Five hundred thirty two counties received disaster-designation (Table 8.3 below). Twenty-five million people and 14.7 million jobs are located in these counties. (Benjamin, 1994). Various groups are summarizing the damages incurred during the 1993 flood, but results are not yet available. To date, the most frequently quoted figure of total damages is 15 billion to 30 billion dollars.

Characteristics of Disaster - Designated Counties

State	Designated <u>Counties</u> (number)	Share <u>of all counties</u> (percent)	Population (million)	Employment (million)
Illinois	39	38	7.5	4.3
Iowa	99	100	2.8	1.6
Kansas 57	54	1.9		1.1
Minnesota	57	66	2.1	1.1
Missouri	103	90	4.8	2.9
Nebraska	52	56	1.3	0.8
North Dakota	39	74	0.5	0.3
South Dakota	39	59	0.5	0.3
Wisconsin	<u>47</u>	<u>65</u>	<u>3.7</u>	<u>2.2</u>
Total	532	67	25.0	14.7

Much of the economic data collected by the SAST reflects Federal funds expended for the period of the flood and the recover period. The data set contains county level data on most USDA payments; structure, payment, policy data on the flood insurance program, structure

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level data on USACE levees and SCS repaired farmer owned levees; the transportation network; production data for 1992 and 1993; and 1989 and 1993 tillage information for the Illinois side of the Mississippi River, structural and damage data. The 100- and 500-year flood boundaries from the flood insurance studies are digitized. The 1990 census is entered at the block data level. Much of the regional economic data is available from the Bureau of Economic Analysis on the REIS CD-ROM.

USDA PAYMENTS

Brief analysis of the data indicates that as of April 13, 70 percent or \$1.9 billion of the \$2.7 billion in total USDA flood payments went to the prairie pothole region of the Dakotas, Minnesota, Wisconsin, and northern Iowa. Eighty percent of the crop insurance and seventy percent of the disaster program payments went to this mostly upland area. Minnesota, not Iowa or Missouri, had the greatest amount of crop damage and the largest number of flooded crop acres, and received the largest share of USDA payments.

The bulk of the crop loss and the bulk of the USDA payments went to farmers whose fields were too wet to plant or so wet that they were planted too late for a good harvest. The maps show a direct correlation between the percentage of hydric soils in counties and the amount of crop disaster and crop insurance paid (figures 8.3, 8.4, 8.5). These damages would have been greater except for the millions of wet acres not planted this year due to the ASCS set-aside acreage (10 percent of the corn base acres in 1993), Conservation Reserve Program, and the Wetland Reserve Program.

Less than 30 percent of the crop losses were due to direct flooding in the river valleys. However, three quarters of the ASCS Emergency Conservation Program and SCS Emergency Program funds were expended in the floodplains.

An examination of the pattern of crop disaster and crop insurance claims after the 1993 flood shows the complex interrelationships between the two programs (Table). As of April 15, the disaster program had paid out 50 percent more than the crop insurance program. Only North Dakota had greater insurance payments than disaster payments. The amount of disaster

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payments in Missouri was four times the amount of crop insurance payments. It appears that the presence of the crop disaster program harms the effectiveness of FCIP.

CROP PRODUCTION LOSSES

The 1992 and 1993 crop production data obtained from the National Agricultural Statistics Agency are in the SAST GIS database. The table below shows the production for eight crops in the nine state area, (Gary Benjamin, 1994).

Crop	Amount	% change from 1992
Corn	4,063	-38%
Soybeans	1,052	-23%
Barley	176	-30%
Oats	134	-36%
Sorghum	325	-35%
Wheat	1,107	-14%
Dry Beans	6	-33%
Hay	56	+2% (major quality losses)

Note: In million bushels for all grains, million hundredweight for dry beans, and million tons for hay.

The figure below shows the distribution of the counties 1993 corn production relative to the 1992 corn production. The 1992 crop was a record corn production in much of the region. After the bumper 1992 crop, ASCS set aside acreage requirements were raised from 5 percent to 10 percent. Thus, expected corn production with normal weather should have been about 90 percent of the 1992 production. Actual US corn production in 1993 declined 33 percent nationwide, 38 percent in the nine state region, and over 50 percent in Minnesota and Iowa. Figure shows counties with higher than the 1992 crop, with a normal production between 85

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and 100 percent with production between 65 and 85 percent, with 50 to 65 percent with 30 to 50 percent, and counties with less than 30 percent of production. Counties with yields greater than 65 percent of 1992 yields receive little USDA payments, those with less than 65 percent of 1992 yields had major USDA payments.

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interest rates and a 25 percent efficiency charge on the use of Federal tax dollars.

Principles and Guidelines use nominal interest rates (currently 8%) for long term water resource projects; however, both economic theory and the 1993 OMB circular require using real interest rates. These nominal rates lead planners to the short-run solutions or discourages any action at all. With an 8 percent discount rate, no Federal planner need look beyond 20 years for a complete cost/ benefit analysis. But when working on natural resource projects that may take 10 years to construct and then last hundreds of years, planners need to look beyond the first 20 years.

This change in the Federal mindset is also seen in the difference between the Conservation Reserve Program and the Wetland Reserve Program. The CRP provided 10- year leases to take cropland out of production for conservation purposes. While the annual cost was reasonable per acre, the 10 years of rental payments could have bought much of that land. Unless changes are made by the year 2000, most CRP land will return to crop production. The Wetland Reserve Program has a higher initial cost and affects fewer acres initially. However, with the Wetland Reserve Program, the Federal Government is buying easements at a cheaper price than the total costs of the CRP and actually restoring wetlands as well. The Federal Government must think long term when dealing with natural resources.

The 1983 Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies should be either completely revised or eliminated. Without the Water Resource Council to maintain and update Principles and Guidelines, it has become obsolete. The application of OMB Circular A-94 is as appropriate for water resource projects as it is for other Federal projects.

Commercial barge traffic on the Missouri River was predicted to increase from one billion ton-miles in 1969 to three billion ton-miles in the 1990's. (Missouri River Basin Comprehensive Framework Study, 1969.) However, commercial tonnage averaged only about one billion ton-miles per year from 1969 to 1987. Commercial shipping then dropped in half from 1987 to 1990 (GAO-RCED-92-4). Sixty-five percent of that tonnage was sand, gravel, and other waterway improvement material. There are railroads along both sides of the river that can easily

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carry the additional half trainload per day of commercial traffic.

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WATER SURFACE PROFILE

Miss. River - L&D 22 to Cape Girardeau

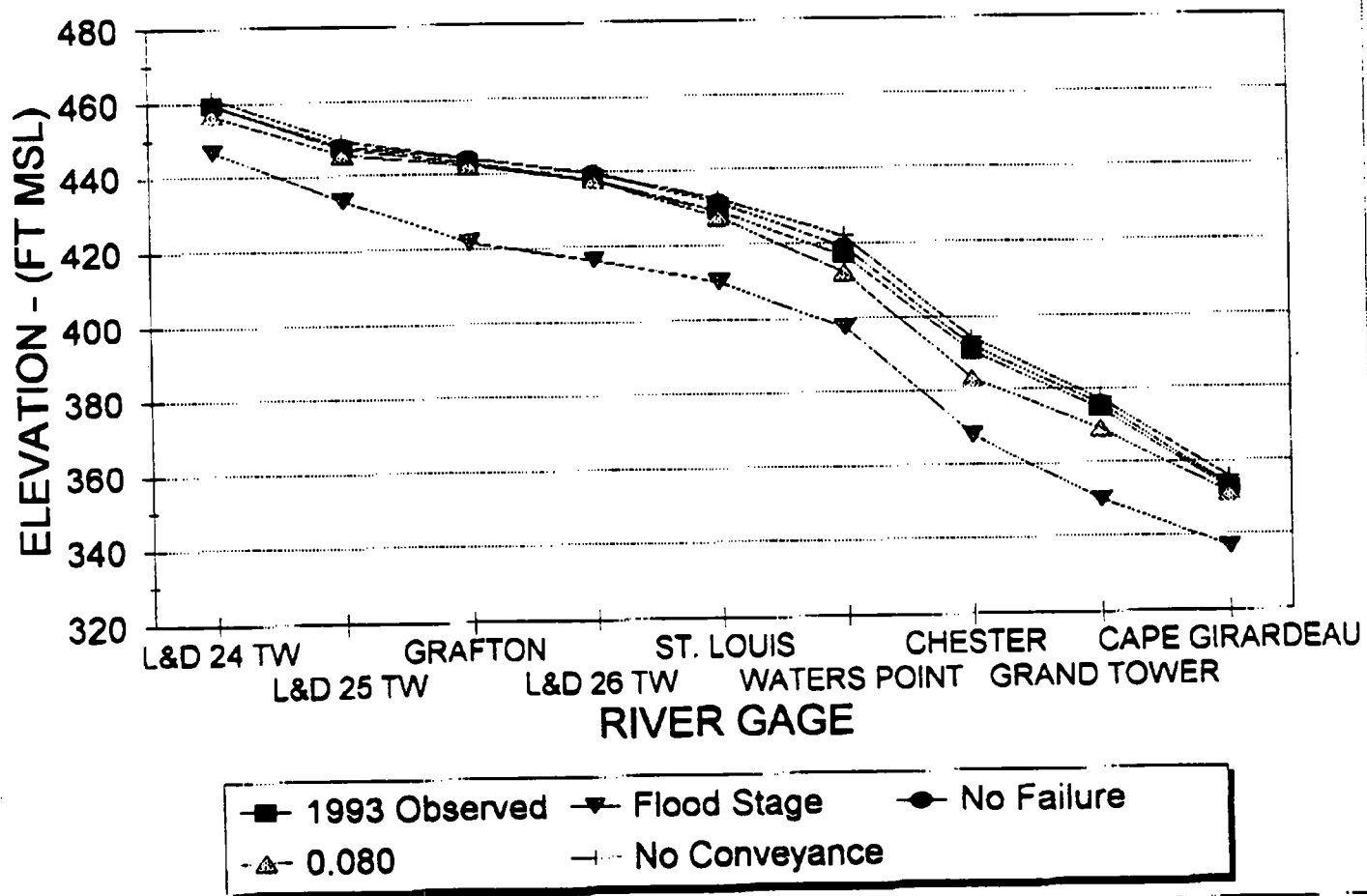
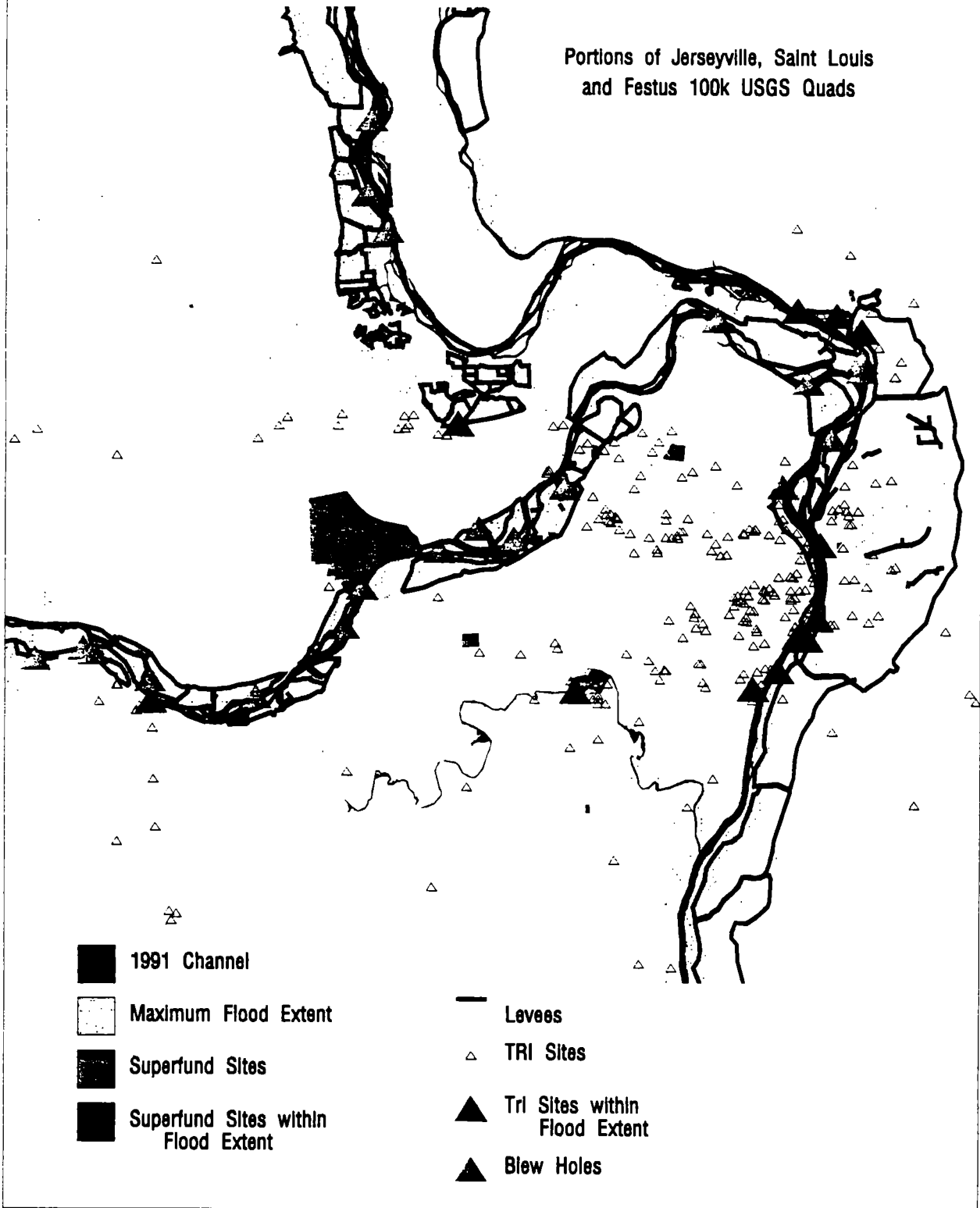
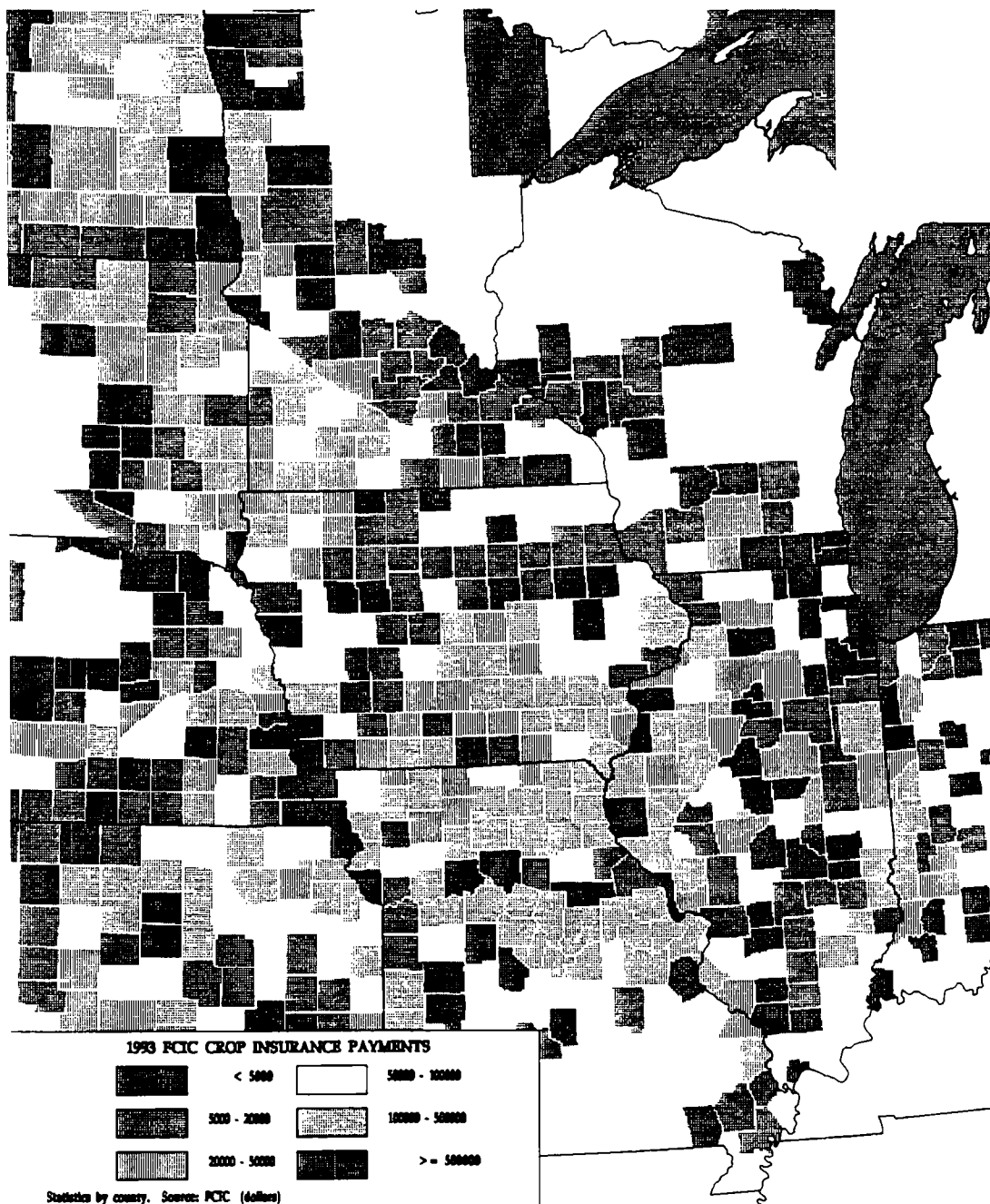


Fig. 8.1

Hazardous Waste impacts Associated with 1993 Flooding

Portions of Jerseyville, Saint Louis
and Festus 100k USGS Quads

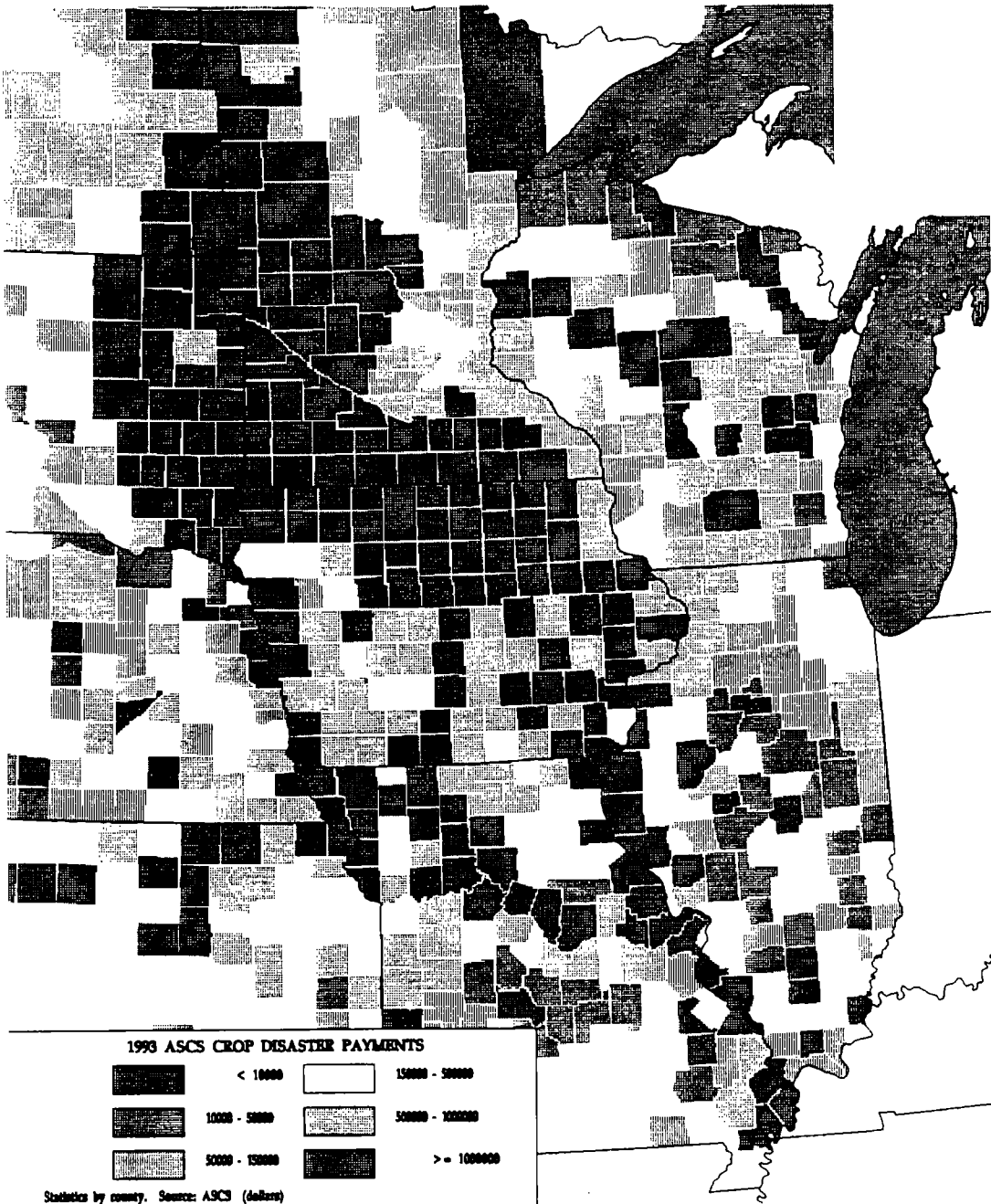




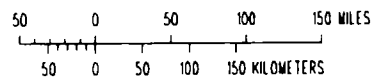
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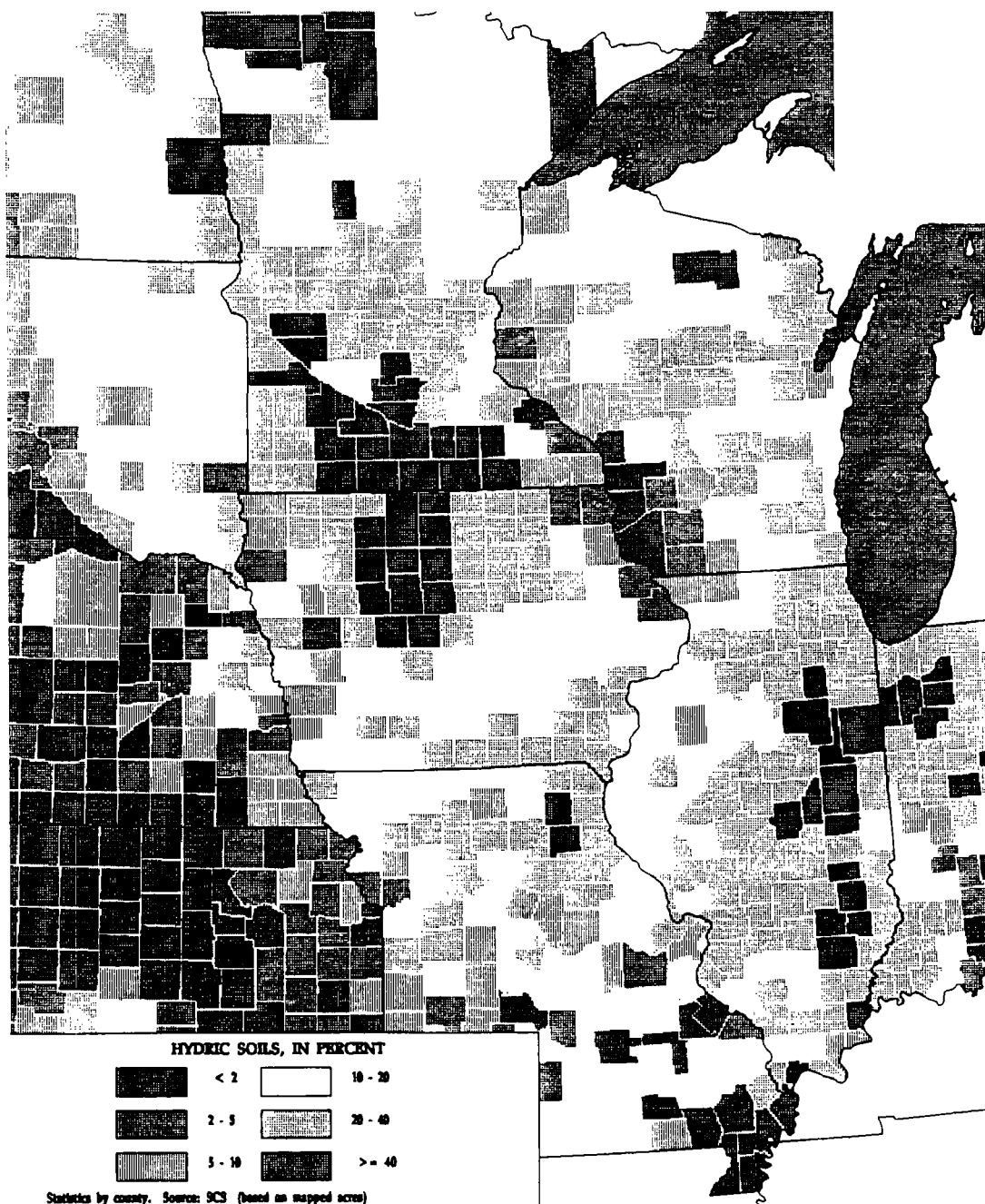
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Statistics by county. Source: ASCS (dollars)
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 and 45 30 00, central meridian -96 00 00



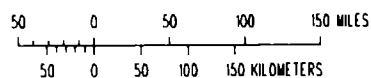
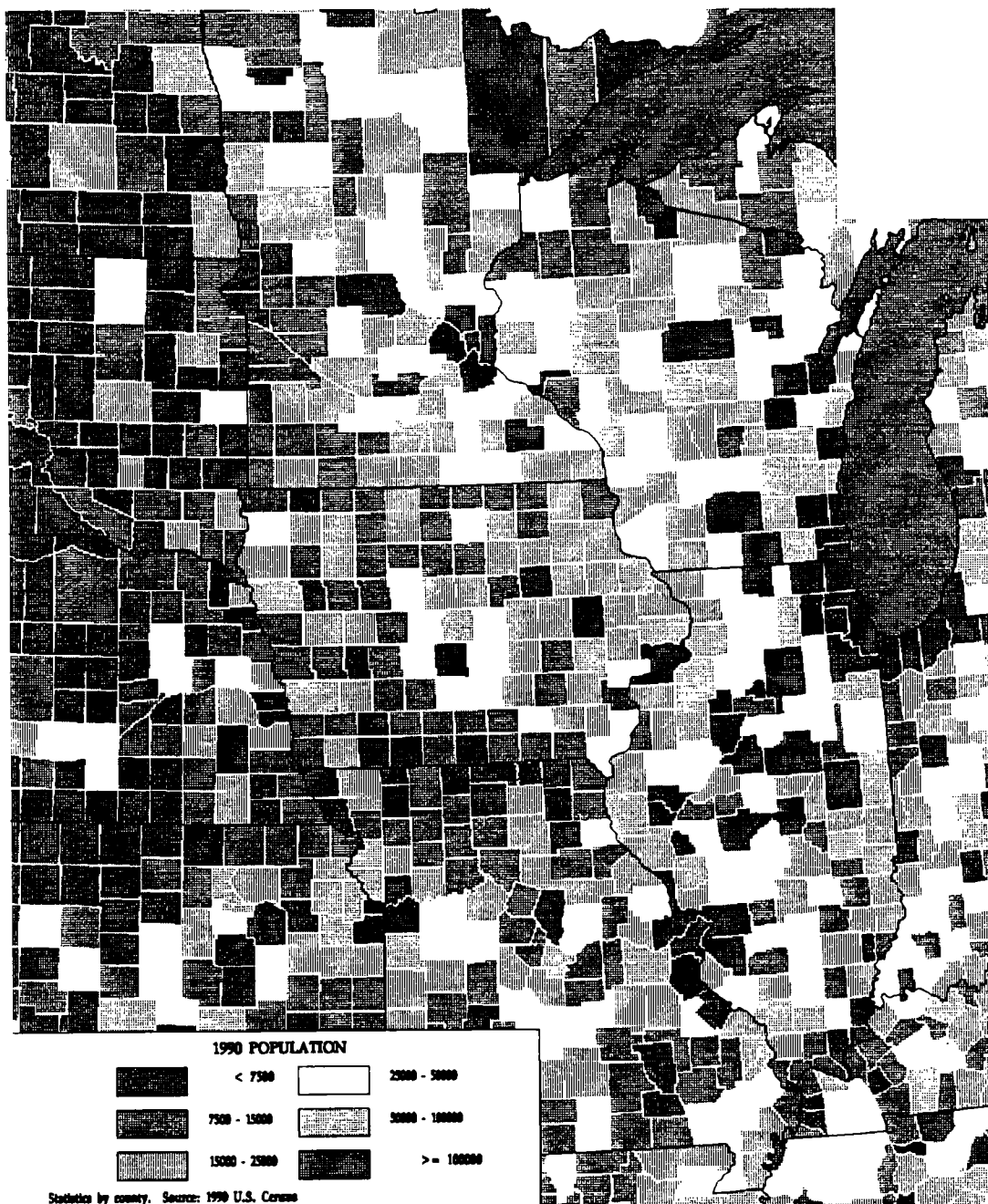
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Statistics by county. Source: SCS (based on mapped acres)
 Base from U.S. Geological Survey digital data
 Albers equal-area projection, standard parallels 29 30 00
 and 45 30 00, central meridian -96 00 00

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		MAXIMUM STAGE DIFFERENCES FOR 1993 FLOOD WITH NO LEVEES					
	1993 Flood with	Manning's "n" Value Used to Model Floodplain					No Conveyance
	No Levee Failures	0.040	0.080	0.160	0.320	0.640	
MISSISSIPPI RIVER							1.8
L&D 24 TW	0.1	-4.9	-2.8	-1.2	0.1	0.9	2.3
L&D 25 TW	0.7	-3.1	-1.6	-0.3	0.8	1.5	1.1
GRAFTON	1.1	-1.4	-0.7	-0.2	0.3	0.6	1.8
L&D 26 TW	1.7	-0.9	-0.3	0.2	0.8	1.3	3.2
ST. LOUIS	2.3	-2.8	-1.5	-0.2	1.0	1.9	5.2
WATERS POINT	2.4	-8.2	-4.6	-1.4	1.2	2.9	3.5
CHESTER	1.6	-11.0	-7.2	-3.8	-1.0	1.0	2.7
GRAND TOWER	1.4	-8.3	-5.3	-2.7	-0.6	0.9	3.1
CAPE GIRARDEAU	0.8	-2.9	-1.3	0.2	1.3	2.1	
ILLINOIS RIVER							2.0
VALLEY CITY	0.3	-1.5	-0.7	0.2	0.9	1.4	1.3
HARDIN	1.0	-1.4	-0.6	-0.0	0.5	0.8	
MISSOURI RIVER							8.4
HERMANN	1.8	-6.1	-2.5	1.0	3.9	5.9	7.9
WASHINGTON	1.6	-4.0	-1.0	2.1	4.4	5.9	-0.5
ST. CHARLES	0.9	-0.1	-0.1	-0.3	-0.4	-0.4	

Table 8.1

COMPARISON OF NO LEVEE OPTIONS FOR 1973, 1986, AND 1993 FLOODS								
		Manning's "n" Value Used to Model Floodplain						
		No Levee Failures	0.040	0.080	0.160	0.320	0.640	No Conveyance
MISSISSIPPI RIVER GRAFTON	93	1.1	-1.4	-0.7	-0.2	0.3	0.6	1.1
	73	1.3	-1.7	-0.7	-0.1	0.2	0.3	0.5
	86	0.4	-0.9	-0.6	-0.5	-0.4	-0.4	-0.4
ST. LOUIS	93	2.3	-2.8	-1.5	-0.2	1.0	1.9	3.2
	73	1.5	-3.1	-2.4	-1.8	-1.2	-0.8	-0.3
	86	0.5	-1.9	-1.3	-0.8	-0.4	-0.1	0.2
CHESTER	93	1.6	-11.0	-7.2	-3.8	-1.0	1.0	3.5
	73	1.4	-9.7	-6.3	-4.3	-2.8	-1.7	-0.3
	86	0.3	-5.7	-3.7	-2.0	-0.8	-0.1	0.6
GRAND TOWER	93	1.4	-8.3	-5.3	-2.7	-0.6	0.9	2.7
	73	1.2	-6.9	-4.9	-3.4	-2.2	-1.5	-0.5
	86	0.4	-5.1	-3.6	-2.3	-1.5	-1.0	-0.5
ILLINOIS RIVER HARDIN	93	1.0	-1.4	-0.6	0.0	0.5	0.8	1.3
	73	1.2	-1.9	-1.5	-1.2	-1.0	-0.9	-0.8
	86	0.3	-0.8	-0.3	0.0	0.1	0.2	0.3
MISSOURI RIVER WASHINGTON	93	1.6	-4.0	-1.0	2.1	4.4	5.9	7.9
	73	0.0	-3.2	-1.2	0.5	1.8	2.6	3.6
	86	0.3	0.3	-1.2	0.8	2.2	3.1	4.1
ST. CHARLES	93	0.9	-0.1	-0.1	-0.3	-0.4	-0.4	-0.5
	73	0.5	-3.0	-1.4	-0.4	0.3	0.6	0.9
	86	0.7	0.4	0.1	-0.3	-0.6	-0.9	-1.2

Table 8.2

PRELIMINARY RECOMMENDATIONS AND RATIONALE

River Basin Management

RM-01 Manage the river basin as an integrated whole.

Rationale: While each location or subregion has a unique aggregate of characteristics that must be considered when making management and policy decisions, those decisions should be tested against the whole system to determine their potential impacts on the physical, ecological, social, and economic sectors of the system.

RM-02 Consider the unique characteristics of each location or subregion in policy and management decisions.

Rationale: The development of the initial physiographic subregionalization scheme for the uplands and the clear variety of geomorphologic subregions on the floodplain are indications of the variety of terrain and terrain responses that must be considered in decision making. Test hydrologic and hydraulic model runs have indicated that variations in geometry and land cover can affect the hydrologic responses of portions of the system. It is well understood that different soils and surficial geology affect the sub-surface water flow. Likewise, other variables affect system response which, in turn, affect unique

ecological or cultural features in the floodplain.

- RM-03** Address interdisciplinary decision criteria when making management and policy decisions.

Rationale: It is clear that there is a wide variety of scientific, engineering, economic, and social variables affecting the results of policy and management decisions in the river basin. These variables are imperfectly understood and their interrelations are seldom well understood by people in a single discipline. Therefore, an interdisciplinary approach must be used when making management and policy decisions. Specific criteria for addressing some of the variables must be developed to augment those that already exist. These will aid in planning and management.

- RM-04** Wherever feasible and desirable, move people and property off the floodplain.

Rationale: The floodplains of major rivers are integral parts of the flood-pulse system. At varying times and levels, flooding will take place regardless of, and occasionally because of, human intervention. Therefore, the costs (economic, social, and environmental) must be compared to the benefits that are derived from maintaining activities on the floodplain.

- RM-05** Conduct river basin management based on principles of sustainable

development, that is, to ensure that the economic, ecological, and social benefits are accrued to the current and future generations without jeopardizing the future generations.

Rationale: River basin management must evaluate the environmental, institutional, economic, and social factors involved in the basin to achieve a management plan that will be acceptable by the public yet remain environmentally sustainable across generations. It is clear that some activities have current and future costs which can be greater than current and future benefits and that these costs must be borne by future generations.

RM-06 Where structural means of flood control are used, they should be designed with the natural dynamic geomorphology of the floodplain taken into consideration.

Rationale: Preliminary indications are that some levee breaches on the Lower Missouri River floodplain were partially the result of being located in places where the river attempted to reclaim a previous natural channel rather than follow the current manmade channel. Also, some levee blowouts took place where historic sand bars formed substrate upon which the levees were built. These sand bars became saturated and, when hydrostatic pressure became high enough, produced boils which caused the levees to cave in at those points. In addition, some levees have failed and been repaired many times indicating that either placement, construction, or maintenance of the levees must be reevaluated.

RM-07

Where non-structural means of flood control are used they should be evaluated with consideration of their benefits and costs just as structural means are. This should include a broad evaluation of benefits, other than merely flood control.

Rationale: Like structural methods of flood control, non-structural methods have both costs, often opportunities lost, and benefits, often other than flood control.

RM-08

Reexamine the method of calculating the 1% chance of occurrence flood for the flooded area and, if appropriate, produce new maps indicating vulnerability to flooding. This should include reexamining methodology as well as recalculating frequency.

Rationale: An event the size of the 1993 flood may alter the statistical results of previous calculations. In addition, the last examination of the methodology was made in 1987. The methodology should be periodically reexamined in light of new methodology, technology, and data.

RM-09

Protect the environment from environmentally hazardous materials either by reducing the risk of mobilization or removing the materials from flood prone areas.

Rationale: Analysis conducted by SAST indicates that point sources containing hazardous waste were impacted by the 1993 flood event. Specifically, the SAST database demonstrated that some superfund and toxic release inventory sites

occurred within the flood extent as identified on satellite data. If potential point sources must stay on the floodplain, appropriate steps must be taken to prevent mobilization of toxics during times of high groundwater or flooding. Where such facilities are located in high concentrations, industrial levees should be in place to protect them. Figure () of the East St. Louis area demonstrates the effectiveness of industrial levee districts that protect a large number of facilities. For individual facilities located on the floodplain, particularly in areas hard hit by flooding or in areas where levees are not expected to be rebuilt, consideration should be given to moving these facilities to higher ground above the bluff. The SAST database provides some of the necessary data for making these decisions, including levee location, levee breaks, and location of facilities. Additional data needed include detailed surficial geology, toxics transmissivity indices, and detailed soils data.

RM-10 Agencies with responsibilities in the Upper Mississippi River Basin but whose responsibilities are divided among districts or regions within the basin must ensure cooperation and coordination among the districts or regions.

Rationale: The SAST found inconsistencies in data gathered by in data gathered by different offices, regions, or districts of some agencies. It is also clear from the data and information collected that there are differences in management across organizational boundaries. This is particularly important where organizational boundaries divide physical or biological subregions among organizational units.

RM-12 Support programs that encourage the restoration of wetlands in closed

basins (potholes), and support management practices that increase infiltration of water into the soil.

Rationale: For larger floods, once runoff water reaches the mainstem streams, few nonstructural options exist to control floodwaters. Department of Interior and USDA programs that support restoration of wetlands increase surface storage of water. Programs such as Conservation Wetland Reserve Program return highly erodible lands to grassland and thus increase infiltration of water into the soil. Management practices such as no-till and residue management also increase the infiltration of water into the soil.

RM-13 If habitat restoration is a national priority, develop and implement a basin-wide restoration plan designed to enhance natural habitat, such as reconnect extended portions of the floodplain back to the mainstem Upper Mississippi, Missouri, and Illinois Rivers. This should be based on a comprehensive ecosystem plan.

Rationale: Current knowledge about large floodplain rivers indicates that without connection of the floodplain to the mainstem river system, the ecosystem cannot remain self-sustaining. The basin-wide plan should identify, by river reach segments, based on physical or biological boundaries, areas where there is high potential for ecological restoration using the principles of ecosystem management and sustainable development. All ongoing Federal actions must be included in such a plan. The restoration plan, based on sound science/data /information would form the basis of an integrated floodplain management approach for the Upper Mississippi River Basin. The restoration activities currently being

implemented for the Kissimmee River in central Florida could be evaluated as one model to design and implement basin-wide restoration plan targeting specific river reaches.

- RM-14** Identify structural and non-structural alternatives for flood control that allow for protection of essential property and infrastructure but provide for reconnection of the floodplain back to mainstem rivers.

Rationale: Nonstructural alternatives, such as, purchase easements to prevent construction, purchase of land, land use planning on high energy floodways, and removal or relocation of structures should be identified and implemented where feasible to reduce the direct and cumulative impacts of flood damage in the Upper Mississippi River Basin. Preliminary SAST research has identified/reconfirmed the fact that some levee construction along the Missouri River, for example, occurred in areas where substrate was historic floodplain (sand) rather than bedrock. In these cases, continued levee reconstruction using current methods is inappropriate since the structures can not be considered structurally sound. Nonstructural alternatives such as floodways would allow for protection of property through the careful placement of levees and still allow for necessary ecosystem functioning.

- RM-15** Reevaluate the costs and benefits of levees with a history of recurring breaks.

Rationale: Levees with recurring breaks may be costing more than their value.

restoration, even more important than the flood reduction benefits.

RA-24 Re-examine the economics of federal projects on the Missouri River in order to identify opportunities for alternatives that preserve and enhance the natural values of the floodplain while reducing the vulnerability of society to the dangers and damages that result from floods and droughts.

Rationale: Federal projects involving flood control, navigation, or hydropower have had significant impacts on riverain biota. The physical impacts to riverain environments have included:

- (1) a reduction in surface water area.
- (2) a reduction of the variability in bed form morphometry,
- (3) a reduction in sediment loads and
- (4) a loss of the connection between river and floodplain. The resulting loss of habitat instrumental in the decline and subsequent listing of several aquatic species within the Missouri River Basin because of a disruption in nutrient processing and a modification of energy flow.

If current social and economic environments do not justify the continued maintenance of existing projects, or portions thereof, an opportunity exists to:

- (1) mitigate for the decline of the Missouri River as a viable riverain resource,
- (2) provide for additional floodplain storage and conveyance and
- (3) save taxpayer dollars which could be reprogrammed to maintain viable Federal projects.

RA-25 Develop a spatial ecological model of the floodplain using accurate DEM, land cover/land use, and bathymetry data.

Rationale: This model, when tied to discharge/water elevation data, allows predictive modelling of the impacts of different water levels on different habitats. Specifically, it would show what habitat types and their size would be at different water levels, as well as what the connectivity of aquatic habitats would be at different water levels.

APPENDIX A: DATABASE NOMENCLATURE

Partial description of standard nomenclature for SAST databases. This table contains excerpts from an online documentation file, and may not conform to traditional standards for presentation of tabular data.

DEFINITION OF UPPER MISSISSIPPI RIVER BASIN

For purposes of this project, this entire Upper Mississippi River Basin is called the 'full basin'. The coverage corresponding to this area is called 'basin_bound'.

DEFINITION OF FLOODPLAIN STUDY AREA

For purposes of this project, this smaller study area is called the 'study area'. The coverage corresponding to this area is called 'study_bound'.

CHARACTERS USED IN NAMES

Directories	Directory names should not contain any non-alphanumeric characters, except for '_' or '-'. For consistency, it is recommended to use '_', but not '-'.
Coverages	Coverages are directories, and should be named accordingly.
Grids	Grids are directories, and should be named accordingly. When grids and coverages are stored in the same workspace, it is recommended to add the suffix '_g' to the name of the grid.
Info file names	The recommended delimiter is '!'.
Info items	The recommended delimiter is '-'. Do not use items defined as numeric

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(type N).

Files The recommended delimiter is ' '.

LIBRARY NAMING CONVENTIONS

Not finalized...

COVERAGE NAMING CONVENTIONS

Area Names

Basin	The entire Upper Mississippi above Cairo, including the Missouri.
Study	The floodplain study area, the Upper Mississippi and the pertinent areas of the Missouri below Gavins Point Dam.

River Basin Names:

Il	Illinois
Mo	Missouri -- prefix for coverages specific to the Missouri River Basin.
Ms	Mississippi -- prefix for coverages specific to the Upper Mississippi River Basin, not including the Missouri.

State Names:

The two-letter abbreviation should be used: co,il,in,io,ks,mi,mo,mn,nd,ne,mt,sd,wi,wy

Scales: Map scale of source of a standard data layer:

24	1:24,000
100	1:100,000

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250	1:250,000
2m	1:2,000,000 or 1:2,500,000

INFO ITEM NAMING CONVENTIONS

For consistency, and to ensure that databases can easily be related, the following conventions should be used.

States and Counties:

fips-code	5,5,i	5-digit state/county code
state-code	2,2,i	2-digit state code
cnty-code	3,3,i	3-digit county code
state	2,2,c	2-character state abbreviation
state-name	20,20,c	state name
cnty-name	32,32,c	county name

Hydrologic Units:

huc	8,8,i	8-digit hydrologic unit code (catalogging unit)
huc-unit	8,8,c	character version of huc, padded with zeroes
huc-2	2,2,i	2-digit hydrologic region code
huc-4	4,4,i	4-digit hydrologic subregion code
huc-6	6,6,i	6-digit hydrologic accounting unit code

Latitude/Longitude:

lat	6,6,c	latitude, in ddmms, padded with zeroes
-----	-------	--

long 7,7,c longitude, in dddmmss, padded with zeroes
dlat 4,9,f,5 latitude, in decimal degrees
dlong 4,9,f,5 longitude, in decimal degrees

Sampling Sites:

site-num 15,15,i site designation number
site-name 50,50,c site name
elev or datum 4,8,f,2 elevation of site (usually in feet)
darea 4,10,f,2 drainage area (usually square miles)
cdarea 4,10,f,2 contributing drainage area

USGS Quadrangles:

quad-code 8,8,c standard USGS quadrangle index code, based on the southeast corner
 (e.g. 38096-A1)
tic-se 7,7,i numeric equivalent of the quad-code, based on the southeast corner (e.g.
 3809611)
lat-se 6,6,c latitude of the southeast corner, in dddmmss
long-se 7,7,c longitude of the southeast corner, in dddmmss
quad-name 40,40,c name of quadrangle, without state abbreviation
states 14,14,c set of 2-character state abbreviations

TIC NAMING CONVENTIONS

The following applies to all tics based on standard map quadrangle corners. Tics should be named to match the TIC-SE item in quadrangle coverages. This is a 7-digit integer. Digits 1-2 are the degrees part of the latitude. Digits 3-5 are the degrees part of the longitude. Digit 6 refers to the minutes-seconds of latitude, described below. Digit 7 refers to the minutes-seconds of longitude, described below.

Explanation of digits 6 and 7:

Digit minutes seconds USGS index

----- ----- ----- lat long

1 00 00 A 1

2 07 30 B 2

3 15 00 C 3

4 22 30 D 4

5 30 00 E 5

6 37 30 F 6

7 45 00 G 7

8 52 30 H 8

For example, the point 38-37-30, 98-15-00 would have a TIC-ID of 3809863, and correspond to the southeast corner of the USGS quadrangle 38098-F3. The polygon coverages quad250, quad100, and quad24 contain appropriately numbered tics at each quad corner. The program pullquad.aml may be used to select subsetsof these quadrangle coverages.

APPENDIX B: DATABASE MASTER DIRECTORY

Master directory structure of online databases on the SAST network. The database will be finalized by September 1994 and, until then, is subject to change. This table contains excerpts from an online documentation file, and may not conform to traditional standards for presentation of tabular data.

DIRECTORY STRUCTURE

/missgis	top-level directory for all GIS data
/sys	standard copies of programs, lookup tables, etc.
/atool	aml programs, linked to arcexe61
/symbols	symbol sets, linked to arcexe61
/projection	standard files for map projections
/lookup	lookup tables
/proc	custom programs for processing, display, etc.
/logo	coverages or map compositions of agency logos
/master	master copies of permanent databases
/usa	coverages for the conterminous USA (also includes county-based INFO files)
/basin	coverages for the Upper Mississippi Basin
/state	coverages for individual states
/ia,il,mn, and wi	states that have provided data so far
/dbf	database files, not in coverage format
/levee	coverages and data related to levees

/masterlib	master copies of coverages that fit into a librarian tile structure (not populated yet, data stored elsewhere)
/quad250	libraries based on 250K quad boundaries (land use...)
/quad100	libraries based on 100K quad boundaries (hydrography, transportation...)
/quad24	libraries based on 24K quad boundaries
/huc	libraries based hydrologic unit boundaries (river reach files...)
/images	remote-sensing imagery and other image data
/avhrr	AVHRR data and derivative products
/flood_anal	EarthSat's AVHRR flood-analysis
/landcov	EDC's landcover analysis
/ers1	ERS-1 satellite images
/photo	collection of scanned photographs
/spot	SPOT satellite data
/weather	NOAA satellite images and weather maps
/tmimages	Landsat Thematic Mapper data (currently stored elsewhere)
/flood	images from July-August 1993
/mask	images used as masks to clip other images
/post_flood	images from October 1993 or later
/pre_flood	images from 1992 or earlier

The following directories are still in progress, and will be integrated into the master directory structure.

/work1	in-progress working directories
ri_levee	levee data from Rock Island District, USACE
omh_levee	levee data from Omaha District, USACE
st_louis	misc. collection of coverages for St. Louis
statsgo	soil-survey grouped data, from EROS (17 states currently stored in /maps/statsgo)
valmeyer	land cover for Valmeyer area, from EarthSat
wat_models	for models of several small watersheds in Iowa
/work2	in-progress working directories
bio_miss	themes digitized from 1879 Missouri R. surveys
eps_tapes	point data from EPS--TRI, NPDES, NPL, etc.
firm	100-yr. and 500-yr. flood boundaries, from EarthSat (currently 40 100K quads)
/temp	in-progress working directories
demdata	DEM data for entire basin, 3-arc-second data
dem15	DEM data for entire basin, 15-arc-second data
satdata	analysis of TM data in floodplain
/temp2	in-progress working directories
climate	for processing 1993 climate data for Midwest
landuse	Land Use/Land Cover giras data at 250K scale (currently 48 quads)
nwi	national-wetlands-inventory coverages
wrddata	data from USGS/WRD--streamflow, sites, etc.

/data5 and /data7	in-progress working directories
/dlg_100k	hydrography and transportation (7 themes) from the 100K DLG database (currently 129 quads)
/rainman	online access to CD-ROM of the Hydro-Climate Data Network (HCDN) published by USGS
/temp3	currently for in-progress working directories
/tm_flood	TM images during 1993 flood
/tm_post	TM images after the 1993 flood
/tm_covers	coverages classified from TM data, such as flood extent, natural floodplain, etc.
/temp4	currently for in-progress working directories
/rf3	reach-file-3 data (hydrography at 100K)

APPENDIX C: MAP SERIES

List in Preparation

APPENDIX D: SELECTED REFERENCES

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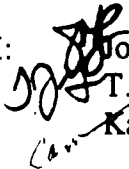
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APPENDIX E: WHITE HOUSE DIRECTIVE

THE WHITE HOUSE
WASHINGTON

November 24, 1993

TO: G. Edward Dickey, Acting Assistant Secretary of the Army (Civil Works)
Gary Foley, Acting Assistant Administrator for Research and Development,
U.S. Environmental Protection Agency
James R. Lyons, Assistant Secretary of Agriculture for Natural Resources
and Environment
James Lee Witt, Director, Federal Emergency Management Agency

FROM:  John H. Gibbons, Assistant to the President for Science & Technology
T.J. Glauthier, Associate Director, Office of Management and Budget
Katie McGinty, Director, White House Office of Environmental Policy

SUBJECT: Directive on the Establishment of a Scientific Assessment and Strategy Team in
Response to Flooding in the Mississippi River Basin

The purpose of this directive is to establish an interagency Scientific Assessment and Strategy Team (SAST) responsible for providing scientific advice and assistance to officials responsible for making decisions with respect to flood recovery in the upper Mississippi River basin. The team will develop and provide information to support the decision-making process regarding both nonstructural and structural approaches to flood control.

A key responsibility of the SAST will be to organize the information in existing databases to aid in the near-term and long-term decision-making process. Specifically, the team shall identify broad areas of the major floodplains of the upper Mississippi River and the lower Missouri River that, from a scientific perspective, are most suitable for alternative flood control approaches including wetland restoration. We anticipate that this information will be helpful to states and communities, as well as federal agencies, in making decisions with respect to flood recovery and the longer-term protection and cost-effective use of resources in the Mississippi River basin.

This effort will be coordinated by Mark Schaefer of the White House Office of Science and Technology Policy (OSTP) and Mollie Beattie of the Department of the Interior with the Assistance of Michele Altemus. The team will carry out its activities at the U.S. Geological Survey's Earth Resources Observing System (EROS) Data Center (EDC) in Sioux Falls, South Dakota, and will be directed by John Kelmelis of the USGS.

The SAST will be comprised of scientists and engineers with a broad range of expertise related to river basin management, flood control, and ecosystem management. At a minimum, the following departments and agencies will be represented on the team: Department of Agriculture, Army Corps of Engineers, Federal Emergency Management Agency, Department of the Interior, and the Environmental Protection Agency. Each of these agencies shall nominate individuals to serve on the SAST for a period of approximately eight weeks. Nominees must have a strong scientific background and be familiar with geographic information systems. The required skill mix for the team is attached. Please fax the nominations to Mark Schaefer of the Office of Science and Technology Policy no later than Friday, December 3 (telephone: 202-456-6202; fax: 202-395-1571).

Resources to support this effort will be provided through existing agency budgets supplemented by funds dedicated to flood recovery.

SCIENTIFIC ASSESSMENT AND STRATEGY TEAM (SAST)*

***Note:** All team members should have some experience in remote sensing, geographic information systems (GIS), or modeling

Team Leader [1]

Center Liaison [1]

Biologists [3] (ecologist, aquatic/fisheries, programs/policies)

Cartographers [2] (wetlands mapping, topographic)

Engineers [2] (structural and nonstructural flood control)

Hydrologists [3] (flood flow modeling, uplands modeling, water quality)

Geologist [1] (Upper Midwest surficial geology/geomorphology)

Soil Scientist [1] (general, hydric soils)

Agricultural Scientist [1] (floodplain agriculture/resource valuation)

TOTAL: 15 people

Suggested Format for Resumes/Biographies
(for submitting nominations for participants on the
Interagency Floodplain Management Committee and the
teams working under that committee:
Science and Assessment Strategy Team,
River Flows Management Team, and
Floodplain Restoration Team.)
(Please designate which team the resume is for.)

One page maximum.
Single Space

NAME
Current Title
Current Office
Current Agency

First Paragraph: Current position and responsibilities. Identification of key/significant activities/accomplishments.

Second/Third/Fourth Paragraphs: Previous responsibilities/experience. Identification of key/significant activities/accomplishments.

Final Paragraph: Education, other miscellaneous background

For SAST resumes please note scientific discipline experience and GIS and Remote Sensing software packages used, if any.

APPENDIX F: CONTRIBUTORS

List in Preparation



Pre Flood (1992)

6.2



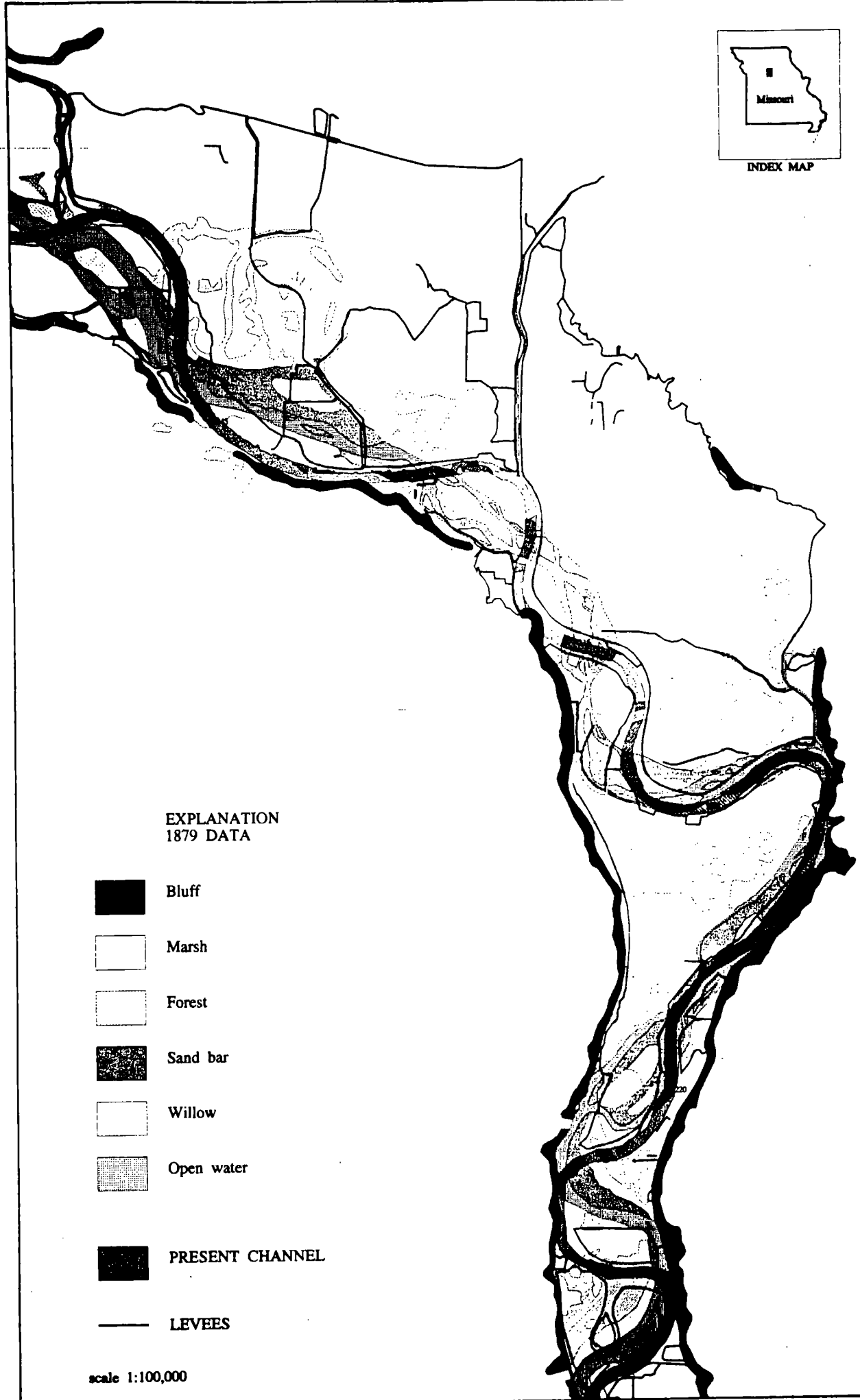
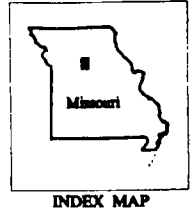
Sept '93 Flood

6.5









EXPLANATION
1879 DATA

-  Bluff
-  Marsh
-  Forest
-  Sand bar
-  Willow
-  Open water
-  PRESENT CHANNEL
-  LEVEES

scale 1:100,000

EXECUTIVE OFFICE OF THE PRESIDENT

**COUNCIL OF ECONOMIC ADVISERS
17TH AND PENNSYLVANIA AVENUE, NW
WASHINGTON, DC 20500**



THE OLD EXECUTIVE OFFICE BUILDING

TO: See Below

OFFICE:

FAX NUMBER:

TEL NUMBER:

FROM: Erik Lichtenberg

FAX NUMBER: (202) 395-6853

TEL NUMBER: 395-5040

ROOM: 328

NO. OF PAGES (inc cover) 3

DATE: 5/24/94

SUBJECT: Name Fax

MESSAGE:

Brian Burke	67028
TJ Glauthier	54639
Bruce Long	54652
Katie McGinty	62710
Will Stelle	62710

EXECUTIVE OFFICE OF THE PRESIDENT
COUNCIL OF ECONOMIC ADVISERS
WASHINGTON, D.C. 20500

May 24, 1994

MEMORANDUM FOR BG GERRY GALLOWAY

FROM:

ERIK LICHTENBERG *EL*

SUBJECT:

Draft Report of the Floodplain Management Review Committee

I believe it useful to reiterate two of the main points that emerged in the meeting I had yesterday with Margriet Caswell and Harry Shoudy. One relates to the plan for river basin management contained in the draft report, the other has to do with the crude cost-benefit analysis contained in my memo of May 20.

First, it is clear from the report the FMRC has grappled seriously with a wide variety of issues relating to the Flood of 1993 and to floodplain management more broadly. In doing so, it has obtained some important insights into the problems plaguing efforts to better manage floodplains, and that those insights are extremely useful for guiding future policy. But, Margriet, Harry and I discussed yesterday, I believe that presenting a detailed plan for a revitalized Water Resources Council, River Basin Commissions and the UMR&T Project actually detracts from the report's ability to communicate those insights. Readers will focus on the details of the plan, comparing it to similar organizational structures (e.g., past versions of these organizations, or similar organizations in the Lower Mississippi Basin). They will draw their assessments of the report mainly from their evaluations of these specific proposals, ignoring the general lessons the Committee learned. I therefore urge you to rewrite the report to emphasize your findings about the underlying problems characterizing floodplain management, omitting the detailed organizational proposals or, at most, relegating them to an appendix as an example of how current problems might be addressed organizationally. I am well aware of the need to issue the report soon. I make this suggestion because I firmly believe that the conclusions audiences draw from the report as it is currently written will be largely the opposite of those intended by the Committee.

Second, I agree that the crude cost-benefit analysis in my previous memo erred in certain ways, notably:

- It was incorrect to annualize expected damage, since expected damage is already on an annual basis; and
- It is inaccurate to characterize the Flood of 1993 as a 500-year event, since the recurrence interval of the event varied from location to location.

Correcting these errors, of course, increases the estimate of expected annual damage avoided from providing protection against an event like this one. On the other hand, there are several factors that would tend to reduce the estimate of the expected annual increment in damage avoided. For example, protection against, say, a 500-year event might not suffice against a 1000-year event, so that the

reduction in the probability of damage would be less than 0.002. Some types of damage might be unavoidable even with increased protection, e.g., crop loss. All told, I think it reasonable to say that the annual benefit of increased protection against an event like the Flood of 1993 is unlikely to exceed \$50 million, and is probably much lower. This implies that the qualitative conclusion I drew still stands: One cannot use this event alone to justify a need for greatly increased protection basin-wide, nor a need for an expensive organizational structure for management of the Upper Mississippi. Other benefits may justify additional measures, but not this single event.

cc: Brian Burke
T.J. Glauthier
Bruce Long
Katie McGinty
Will Stelle

Burke

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
WASHINGTON, D.C. 20500

May 20, 1994

To: Katie McGinty and T.J. Glauthier
From: Mark Schaefer 
Subject: Flood Report

This is an addendum to the memorandum that I provided to Gen. Galloway on May 18. Since that time I have had a chance to review the draft report of the SAST, and I have a few additional suggestions regarding the main report.

Here are the key issues from my perspective:

- 1) In general the draft is too oriented towards the status quo; that is, thinking in terms of structural controls, continuing the same broad policies that lead people to live and work in the floodplain, and giving inadequate attention to the value of natural resources. Making substantive policy changes in these areas would have been easier had there been a serious economic analysis. Our policies at the present time do not make sense either economically or environmentally -- in other words, we are not on the path to sustainable development in the Mississippi River basin.
- 2) I'm disappointed that an in-depth economic analysis was not done, but it's not too late to call for such an analysis in this report. (Establish a blue-ribbon commission to examine etc., or there are other mechanisms.) This kind of analysis is critical if the federal government is serious about making fundamental policy changes that will benefit the region and the nation over the long run.
- 3) The draft places major responsibilities in the hands of the Corps of Engineers, and does not adequately involve or give appropriate responsibility to the Department of the Interior. For example, the National Biological Survey and the U.S. Geological Survey have major responsibilities for ecosystem management within the United States, but this draft recommends that responsibility for managing "ecosystems on the Upper Mississippi River and Tributaries" be placed under the Corps (p.9).
- 4) There are several very good recommendations in the SAST report that, if incorporated into the main report, would strengthen it considerably. I'd suggest adding the following (or strengthening related existing recommendations):

- a) Re-examine the economics of federal projects on the Missouri River in order to identify opportunities for alternatives that preserve and enhance the natural values of the floodplain while reducing the vulnerability of society to the dangers and damages that result from floods and droughts (p. 9-29).
- b) Conduct economic analysis of the effect of emergency declarations on floodplain management activities. Investigate appropriate measures to eliminate the incentives responsible for persistent, reoccurring emergency payments p.9-8).
- c) Conduct river basin management based on principles of sustainable development, that is, to ensure that economic, ecological, and social benefits.... (p. 9-3).
- d) Wherever feasible and desirable, move people and property off the floodplain (p.9-2).
- e) Develop and implement a basin-wide restoration plan designed to enhance natural habitat.... (p. 9-6).
- f) Identify structural and non-structural alternatives for flood control that allow for protection of essential property and infrastructure but provide for reconnection of the floodplain back to mainstem rivers (p.9-7).
- g) Reevaluate the costs and benefits of levees with a history of recurring breaks (p. 9-7).

Recommendations such as these are more direct and forceful, and they indicate that this Administration is serious about improving federal policies pertaining to flood control and ecosystem management.

Overall, I think it is important to reach an interagency and White House consensus on the Floodplain Management Report, rather than quickly release a document that everyone is not comfortable with.

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
WASHINGTON, D.C. 20500

May 18, 1994

Memorandum for B/G G.E. Galloway

From: Mark Schaefer ^{MS}

Subject: Draft Floodplain Management Report

Thank you for providing me a copy of the revised draft. This version is substantially better than the previous one, I believe there are still significant weaknesses. Here are some general comments and suggestions. b - r

1) The federal expenditures/cost-effectiveness issue should be given more attention early in the document. On page 2, two goals are listed. One related to reducing vulnerability of the nation, and the other to preserving natural resources, but there is no major economics-related goal. I would suggest something like:

- Ensure that federal expenditures are cost-effective and that federal policies and economic incentives encourage the sustainable use of natural resources.

2) On balance, this document places nearly all major floodplain management responsibilities either directly or indirectly in the hands of the Corps of Engineers. For example, p. 181: "Seek authority from the Congress to redirect the USACE Floodplain Management Assessment ... under the Mississippi River Commission, operating under the USACE." [This assessment should be undertaken on an interagency basis.] And on p. 192, "The USACE should continue development of basin-wide hydrologic and hydraulic models...." [This should be done in collaboration with the USGS and National Weather Service.] In general, I feel more authority for floodplain management should be directed to the Department of Interior.

3) Responsibility for managing "ecosystems on the Upper Mississippi River and Tributaries" (p.9) is to be placed under the Corps. I think it would be a major policy mistake to give the Corps responsibility for ecosystem management anywhere in the United States. This should be in hands of the Department of the Interior and the Environmental Protection Agency.

4) The report states that "The National Flood Insurance Program needs improvement." (p.5) This is a very mild characterization of a program that is not working. It is beneficial in the long run to be more direct about the weaknesses of current programs.

5) Again, it is apparently too late to fix this weakness, but it appears that we are doing little to examine the incentive systems that are responsible for human activity in the floodplain. Environmental groups will likely point to this as a fundamental flaw in the report.

6) The report endorses the same system of cost-sharing that is now in place (but it correctly says that we should not make special exemptions and move from 75/25 to 90/10 in disaster assistance in the future). I think the report should call for an examination of the relative federal contributions in all cost-share programs to determine whether the incentives these programs establish are cost-effective and support sustainable development.

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
WASHINGTON, D.C. 20500

May 8, 1994

Memorandum for BG G.E. Galloway

From:

Mark Schaefer 

Subject:

Draft Report of the Flood plain Management Review Committee

The hard work of the last four months has led to many excellent recommendations in your draft report. The recommendations designed to promote integrated, broad-based ecosystem and hydrologic strategies for the Mississippi and Missouri River basin seem right on target. The recommendations regarding better coordination and greater flexibility in federal land acquisition efforts are also very good. I strongly support the recommendation for developing a common data base on the upper Mississippi River basin. Also, it is very important to continue the momentum of the SAST in order to upgrade substantially the quality of information on the physical and biological characteristics of the river basin.

I have strong reservations about some of the recommendations pertaining to levee construction and continued high or even increased federal expenditures for subsidies, disaster assistance, and crop insurance programs. This Administration's "Vision for Floodplain Management in the 21st Century" should not maintain or increase extremely costly federal incentives to live and work in the floodplain. The personal and financial risk of living or working in the path of a major river should be increasingly born by the individual, not the federal government, otherwise we will only perpetuate the costly mistakes of the past. We should create incentives to move out of the floodplain and thereby allow this area to function as a natural buffer during periods of heavy rainfall. This makes both economic and environmental sense. We have an opportunity to adopt policies that move us from a lose-lose to a win-win situation.

In general, I think the report is too directed towards structural changes and does not place enough emphasis on the value of natural resources.

In addition, the cost information (Part VI) is critical, and I think the task force should review this information carefully before the report is released for general comment.

Again, there are many first-rate recommendations in this report, but OSTP feels the draft should not be released until some major policy questions are resolved.

EXECUTIVE OFFICE OF THE PRESIDENT
COUNCIL OF ECONOMIC ADVISERS
WASHINGTON, D.C. 20500

May 6, 1994

MEMORANDUM FOR BG GERRY GALLOWAY

FROM: ERIK LICHTENBERG

SUBJECT: Working Draft Report of the Floodplain Management Review Committee

I have a number of comments on the draft report, both of my own and on behalf of the Economics Advisory Group (EAG) pursuant to our meeting yesterday.

Chapter 4

In this and subsequent chapters, the report asserts a need for far-reaching legislative and institutional changes, ranging from a new Federal Floodplain Management Act to revision of the Water Resources Act to the creation of a set of loosely affiliated federal and federal-state bureaucracies with capabilities for planning, technical assistance, and, conceivably, regulation. These recommendations are problematic in several ways:

- The need for these legislative and institutional changes is nowhere motivated by a conceptual framework discussing the proper allocation of authority and responsibility among federal, state, and local governments.
- The need for these legislative and institutional changes is nowhere substantiated by concrete evidence of failures on the part of the existing set of institutions.
- The report does not discuss specifically what this new legislation and these new institutions would accomplish, aside from planning for planning's sake. Creating new institutions has a cost; it should be justified by the real benefits expected, not on abstract principle alone.

I urge you to consider carefully whether this set of changes is in fact warranted. The conceptual framework adopted by the EAG in December provides some elements of a conceptual framework. Recommendations that you continue to believe justified should be supported by:

- Delineating the proper areas of authority and responsibility for state governments, local governments, interstate authorities, and the federal government;
- Discussing the shortcomings of the current management framework relative to that conceptual framework and in light of concrete evidence of the adverse effects of those shortcomings; and
- Specifying how the proposed new legislation and new organizational structures will solve the problems created by the current set of institutions.

Chapter 5

The report urges reauthorization, expansion and addition of new criteria for the Conservation Reserve Program (CRP) and the Emergency Wetlands Reserve Program (EWRP). It does not document the flood control benefits generated by CRP at present, nor does it make a case that CRP expenditures would be justified by likely reductions in flood damages in the future. Nor does it substantiate its assertion that the present selection criteria are economically and environmentally inefficient. While one could find broad agreement that the criteria used in the first nine or ten sign-ups were inappropriate in light of the stated goals of the program, the criteria used in the last three or four sign-ups were modified substantially to place greater weight on environmental benefits. It is true that reducing runoff for flood protection has never been included in CRP criteria, and that such a goal would be a useful addition. But a blanket indictment of CRP is unwarranted.

Chapter 6

As you know from our meeting yesterday, the EAG as a whole disagrees with the report's recommendation that all levees in urban areas protection against a Standard Project Flood (SPF). To the contrary, we believe that the level of protection should be determined in accordance with cost-benefit criteria, specifically, maximization of net benefits (into which monetized environmental benefits and costs and external additional flood damage/flood protection costs upstream and downstream have been incorporated).

The chapter as a whole appears to place excessive emphasis on levee construction. This may be due largely to style: The chapter discusses appropriate levels of protection in cases where protective measures like levee construction are appropriate and omits any mention of the possibility that levee construction might be unjustified or that relocation, elevation or other mitigation measures might be more appropriate protective measures than levees. As a result, the report appears to give a very broad endorsement of a comprehensive levee construction campaign in both urban and agricultural areas. This misperception should be addressed in the revisions by including explicit discussions of:

- The full range of protective measures available, including relocation and elevation in addition to levee construction;
- The importance of cost-benefit criteria in deciding which of these protective measures are appropriate; and
- The real possibility that no protection may be the appropriate course of action in some cases, specifically those for which the costs of providing protection in any form exceed the benefits obtained from protection at the margin.

The discussion of agricultural levees should state explicitly that expected damage from scour and sand deposition and expected downstream benefits of floodwater retention should be incorporated into cost-benefit analyses for determining the appropriate levels of protection for agricultural areas. The assertion the 10-year flood level is a reliable rule-of-thumb should be substantiated with empirical evidence demonstrating that a 10-year protection level is widely justified according to cost-benefit criteria.

The proposal relating to crop insurance on page 119 is nonsensical as written. It appears to call for having the FCIC pay out disaster payments during flood events rather than having USDA pay for disaster assistance in areas the Secretary has declared as crop disaster areas. The report appears to recommend that this "insurance" be entirely subsidized, making the term "insurance" a misnomer. This proposal could easily increase Federal costs because the proposed FCIC payments would be made for all damage caused by flooding, not just flooding extensive enough to warrant a disaster declaration. Moreover, such a program would be a subsidy targeted at floodplain agriculture which could make it profitable to cultivate of row crops in flood prone areas not economically suited for doing so. In other words, it would perpetuate and possibly exacerbate misallocation of resources in the floodplain rather than correcting it.

Chapter 7

The proposals relating to the Principles & Guidelines (P&G) for water resources management on pages 133-135 contradict the recommendations of the EAG regarding treatment of environmental benefits. As you recall, quantification and monetization of environmental goods and services was a methodological issue explicitly discussed by the EAG. Contrary to the proposals presented in the draft report, the EAG determined that

- There exist reliable methods for quantifying and monetizing environmental benefits and costs in terms of both direct and indirect uses; and
- There is a clear, consistent rationale for including these monetized environmental effects into cost-benefit analyses. Moreover, failing to do so contradicts the generally adopted tenets of modern welfare economics.

The proposed new objectives for the P&G on page 134 reflect this by calling for enhancing environmental quality. The proposal that environmental effects be included only in a descriptive system of accounts--and, by implication, that they not be monetized and included in cost-benefit analyses--contradicts these tenets. Moreover, as we discussed in yesterday's meeting, the proposed system of accounts lumps together efficiency considerations like environmental quality with distributional or equity considerations like regional economic development. We urge that this section be revised to be consistent with the EAG's recommendations on these issues.

In this chapter and elsewhere, the report recommends that the Council on Environmental Quality (CEQ) be given broad new responsibilities. These recommendations are inconsistent with the Administration's view on the appropriate role for CEQ and its reliance on the Office of Environmental Policy as the lead agency for environmental affairs.