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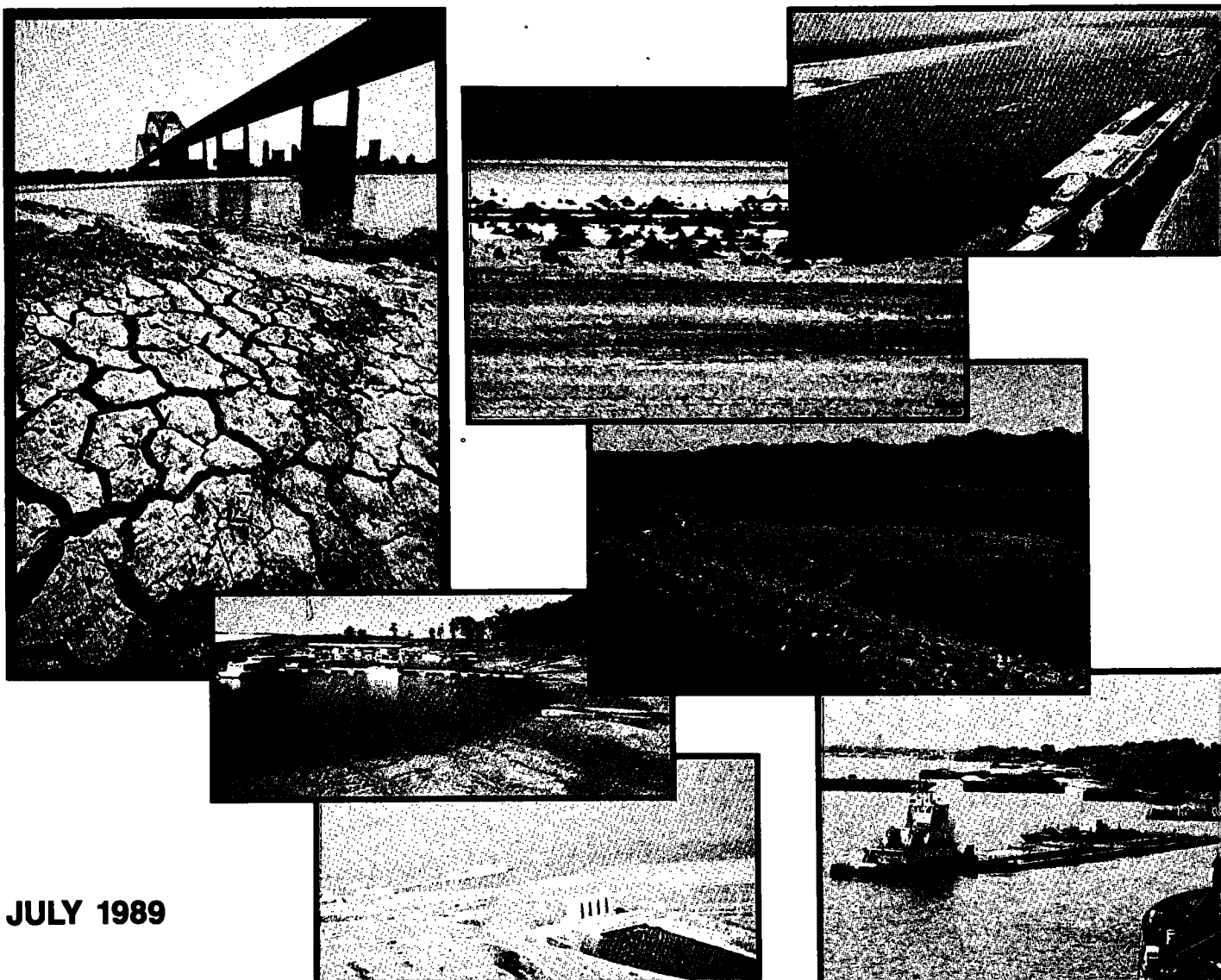
US Army Corps
of Engineers

Surviving The Drought
1988

CORPS OF ENGINEERS RESPONSE TO DROUGHT CONDITIONS



JULY 1989

The Corps Commitment to Drought Mitigation:

The drought of 1988 was, indeed, an extreme situation that tested the will and capability of the Nation's citizens and their institutions. Planning was incomplete and mistakes were made, but collectively, citizens, industry and governmental institutions proved that working together, there exists sufficient expertise and infrastructure to significantly mitigate the impacts of drought. Drought '88 presented an opportunity for the Corps to serve the Nation, and our projects and our people performed tirelessly and well in this time of extreme. The challenge is to be even better prepared for such events in the future through better and more coordinated planning efforts.

SURVIVING THE DROUGHT

Corps of Engineers Response to Drought Conditions in 1988

Prepared by
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EXECUTIVE SUMMARY

The combination of high temperatures and low precipitation, often of record-breaking dimensions, produced drought conditions affecting a large part of the continental United States by June 1988. The impacted area stretched from eastern Oregon and eastern Washington, across the Northern Plains States of Idaho, Montana, and Wyoming, into the Central States from North Dakota south to Texas, and on to the Eastern States. The Southwest, the Northeast, and the State of Florida experienced little or no drought conditions impacting on Corps missions or projects.

Water resources were managed to provide navigation, municipal and industrial water supply, agricultural water supply, water quality, hydropower and recreation. Reservoirs and navigation systems were operated in a manner to balance competing requirements of downstream and upstream interests in the face of reduced inflows.

Extraordinary efforts and coordination with Federal, state and local agencies, industry, and other interests were required to maintain the navigation channel on the lower Mississippi River and some tributary entrances. Unprecedented dredging operations, limits on tow size, limits on barge loading, and judicious management of Federal reservoirs allowed waterborne commerce to continue on the Mississippi throughout the period of record low-water levels. Navigation on two smaller systems, the Apalachicola-Chattahoochee-Flint and the Alabama River System, could not be maintained throughout the entire period, however.

Municipal, industrial, and agricultural water supplies became precariously low in some areas. Reservoir operations that balanced releases to serve authorized purposes and conserve water, and the emergency transport of water, helped keep the situations under control.

Water quality was threatened by the combination of low water levels and high temperatures conducive to algae growth, oxygen depletion and other problems for fish and wildlife. Water quality was maintained at or above standards in most areas through judicious reservoir releases. Conditions below New Orleans required the transport of water, in addition to the construction of a barrier sill on the Mississippi River earlier than planned, to stem the progress of a salt water wedge endangering municipal water supplies.

Due to the need to conserve available water, overall hydropower production at Corps projects was about 22%-25% below normal. In some cases, replacement energy had to be purchased by the power marketing agents.

At about 12% of Corps projects, low water closed some boat access ramps and other shore facilities, and exposed boaters and swimmers to additional hazards. Ramp extensions and safety measures alleviated some of these problems. In some cases, facility closures simply resulted in the shift of a portion of the visitation to the more serviceable

areas. There were reduced special releases for whitewater rafting, and some recreational lockages were limited. Overall, recreation visitation remained high throughout the summer.

Lessons learned from the drought experience and recommendations were submitted by field offices. Predominant findings are summarized as follows:

1. Clarification of authorities, guidelines and procedures for emergency water supply assistance would be helpful.

2. Coordinating plans of action with states, municipalities, industries and other Federal agencies is extremely valuable.

3. There is some need for improved data to support water management decisions.

4. Field offices would have benefitted from receiving periodic drought information reports from HQUSACE.

5. Requests for information on the drought situation by HQUSACE were too frequent.

INTRODUCTION

The combination of high temperatures and low precipitation, often of record-breaking dimensions, produced drought conditions affecting the majority of the continental United States by June 1988. Some areas were in their second, third or fourth year of drought. The impacted area stretched from eastern Oregon and eastern Washington, across the Northern Plains States of Idaho, Montana, and Wyoming, into the Central States from North Dakota south to Texas, and on to the Eastern States. The Southwest, the Northeast, and the State of Florida experienced little or no drought conditions impacting on Corps missions or projects.

Several states within the affected zone were declared agricultural disaster areas. Many water utilities and municipalities implemented periods of voluntary and mandatory restrictions on water use to conserve dwindling supplies. Several wells that served small communities and individuals for domestic and livestock water ran dry. Stream flows and lake levels at many locations were at record lows. Industries dependent on waterborne commerce suffered substantial losses. Natural habitats became less able to support wildlife. Forest fires became a major threat in many areas.

The Corps, in pursuing its normal water management functions, was acutely aware of the developing drought. Water levels on streams and lakes regulated by flood control and multi-purpose projects were closely monitored. Communication with other Federal agencies, local and state governments, and industry was heightened as the need for special measures to cope with the drought became apparent.

Reservoirs and navigation systems were operated in a manner to assure continued supplies for downstream and upstream users in the face of reduced inflows. Most of the regulated systems, those in the Missouri River Basin, Upper Mississippi River Basin, and Ohio River Basin, and the Tennessee-Tombigbee Waterway successfully supported all uses (navigation, water supply, water quality, hydropower and recreation) throughout the drought. The systems performed as designed under low water conditions.

Some systems in the Southeast experienced greater stress due to the fact that the drought there, by some estimates, has been prevalent since 1980-1981. Conditions on these systems were so severe that some uses, such as recreation and hydropower, were temporarily impacted to maintain sufficient water for the more essential uses of water supply and water quality. Balancing competing demands on water resources is always a challenge, but during times of scarcity, the difficulties are magnified. Communication and coordination with all concerned parties were essential to water management.

Emergency dredging was utilized extensively on the lower Mississippi River, on the lower end of some of its tributaries, and in some of its harbors as record low water caused unprecedented shoaling. In some instances, on the upper Mississippi River, channel maintenance required cutting through rock. Coordination with the U.S. Coast Guard, the towing industry, and others, resulted

in efficient responses that allowed waterborne commerce to continue on the Mississippi River and its tributaries.

Emergency assistance was given for transporting water to some communities whose supplies were exhausted. Technical assistance was offered in numerous instances. Clearinghouse functions were adopted as necessary to direct worried citizens to the proper resource agency. Participation on state and local task forces and committees for drought action planning was frequent.

Low flows on the lower Mississippi River allowed saltwater intrusion from the Gulf of Mexico to occur earlier in the year than usual, with the potential to migrate farther upstream than normal. To protect municipal water supplies at New Orleans and below, a saltwater barrier sill (underwater levee), planned for construction later in the year, was constructed ahead of schedule in the Mississippi River below New Orleans. In addition, millions of gallons of freshwater were transported by barge to water treatment plants at Placqumines Parish, LA, for diluting the saline water taken from below the sill.

Prudent management of water resources for navigation, municipal and industrial water supply, agricultural water supply, water quality, hydropower and recreation helped the Nation survive the drought.

MANAGING WATER RESOURCES FOR NAVIGATION

In a period of drought, preservation of navigation is a major concern on rivers used for waterborne commerce, including defense related transportation. Waterborne commerce occurs on the inland waterways through a network of locks and dams, and free-flowing stretches of river. Systems of locks and dams were constructed to provide stable flows for navigation during periods of high and low water. Reservoir systems often store water for supplementing flows for navigation. Open water navigation channels are maintained principally by means of scheduled dredging, dikes, and revetments.

The parts of the network stressed the most in 1988 were those in the central and southeastern U.S. The central U.S. rivers involved were the Mississippi, the Missouri, the Illinois, the Ohio and its tributaries, the McClellan-Kerr Arkansas Navigation System (White River Entrance), the Ouachita/Black Rivers and the Red River. These rivers form the major north-south water transportation network of the U.S. The southeastern rivers were the Alabama River System, Appalachicola-Chattahoochee-Flint System, and Black Warrior-Tombigbee. Located between these systems was one that did not suffer from the drought, the Tennessee-Tombigbee Waterway, engineered to connect to the Mississippi by way of the Ohio.

The Mississippi River above St. Louis, and all the major tributaries to the Mississippi River (except the Missouri River) including the Illinois, the Ohio, and the Arkansas, have locks and dams which can control the flow of water to the extent of conserving it, to assure adequate depths for navigation upstream. The locks enable boats to navigate the stair steps created by the navigation pools. Those sections of waterway controlled by locks and dams, even though surrounded by drought devastating to crops, livestock, and community water supplies, continued to provide project depths of 9 feet for commercial and recreational navigation. The projects performed as intended. Reduced channel widths were experienced at Pool 26 above Lock and Dam 26 on the Mississippi due to low water. Even so, no significant problems were encountered and no special actions were required.

Emergency dredging was employed, as required, to maintain navigation channels. To conduct these operations, nine contractor and four Corps dredges were used. Additional dredges were used for channel maintenance in inland harbors. Rock removal, and snagging and clearing operations were also required to a lesser degree.

MISSISSIPPI RIVER

The Mississippi River below St. Louis to the Gulf of Mexico has no lock and dam structures. Likewise, the Missouri River, the lower Ohio River where it joins the Mississippi, and the White River entrance to the Arkansas River are free-flowing. Maintenance dredging and river training-works (dike and revetment systems that promote natural dredging by physically preventing the channel from shifting) had always been sufficient and cost-effective measures for keeping channels at adequate depths and widths for commercial navigation on

these stretches of river. The Drought of 1988, however, produced the lowest flows and stages on record for many parts of the rivers causing unprecedented problems for channel maintenance.

By early June, reports of shoalings and grounded tows were coming in from the mouth of the Missouri, the lower Ohio, and several locations on the Mississippi. The channel was becoming narrower and shallower. The Corps responded by alerting the towing industry to navigation problems, and also by dispatching dredges utilizing emergency permitting authorities, and using expedited contracting procedures for procuring supplementary dredging services. The U.S. Coast Guard responded by increasing the number of buoys, performing additional reconnaissance and establishing advisories and safety zones as the situations merited. From early June through mid-July, there were 26 temporary closures upstream from Baton Rouge. Some of these closures lasted up to 3 days while dredges worked to clear the channel. All of these closures occurred below St. Louis, where no locks and dams are constructed. Temporary blockages of shorter duration, due to grounded tows, were more frequent.

Dredging through shoals and dredging to deepen and widen channels were the most common actions taken by the Corps. In some instances, channel maintenance required cutting through rock. Plans for emergency rock removal for several locations south of St. Louis on the Upper Mississippi River were coordinated with, and approved by, the Missouri Department of Conservation, the Illinois Department of Conservation and the U.S. Fish and Wildlife Service. These plans included mitigation measures for fish and wildlife. Additionally, snagging and clearing of old pilings and other debris surfaced by the low water was undertaken near Memphis in July.

Traffic was delayed by the closures, blockages, and slow-going necessitated by the more confined channel. By June 27, there were 11 dredges working on the waterways and 110 tows being delayed due to closures. Between June 1 and 29, there were 72 groundings of tows. About 42% of those happened between June 24 and 29. Most of these groundings involved barges with drafts greater than 8.75 feet and tows with 18 or more barges.

The Lower Mississippi River Committee (LOMRC) was convened on June 21 with representatives from the Corps and towing industry. A Coast Guard command post was set up at Memphis to monitor the navigation situation on the Lower Mississippi.

The Coast Guard implemented temporary size, depth, and configuration restrictions on tows within designated safety zones to prevent further groundings. These restrictions caused the barges to be light-loaded (thus drawing less draft) with fewer barges per tow. Other safety devices instituted at some areas included one-way/alternating traffic and daytime traffic only. The exact nature of the restrictions were changed as river conditions changed. The combination of these factors caused shipments of commodities to take much longer to reach their destinations. But, because of the actions of the Corps in concert with the Coast Guard and towing industry, particularly by means of the ad hoc River Industry Executive Task Force (RIETF), commerce continued.

From mid-July through the end of the drought period, there were four more blockages on the Mississippi River due to shoaling. Dredging continued at problem spots to insure that further blockages would not occur. Navigation was still difficult and slow due to low water conditions. As of August 19, the Mississippi from St. Louis to Baton Rouge was still limited to 20 barges per tow upbound and 16 barges per tow downbound with drafts of 8.5 feet. Normal tow sizes for the Mississippi are around 30-40 fully loaded barges per tow with 9-foot drafts and large horse-power tow boats, some drawing 9 feet or more.

Low water was also affecting bank stability on the Lower Mississippi and, as of August 3, 12 significant bank failures had been identified. The Corps took action to make repairs during the low water season.

At the height of the drought experience, it was discovered that one of the roller gates at Lock and Dam 26, just above St. Louis, was passing excessive flow. If inflows were to decrease below the level of the uncontrolled outflows through the gate, the pool and navigation depths upstream would have been jeopardized. Repairs were devised and implemented that allowed continuation of full pool conditions above Lock and Dam 26 during this operation.

On September 2, the U.S. Coast Guard at Memphis cancelled the safety zone on the Lower Mississippi River. This zone had extended from mile 882.7 to mile 507, between Cairo, IL, and Vicksburg, MS. At the same time, it issued a navigational advisory on tow draft, size, and towboat power, recommending limits of 8.5 feet drafts, 25-barge tows upbound, and 20-barge tows downbound. On September 28, the Lower Mississippi River Committee recommended that all operators limit tows to a maximum of 25 jumbo hopper barges north and south bound.

Some inland harbors also had to be dredged due to shoaling, and some, like Rosedale Harbor and Lake Providence Harbor, were closed for much of the summer. Other harbors, such as Memphis Harbor, experienced restricted depths.

It had been suggested by the Governor of Illinois and others that diversions from the Great Lakes via Lake Michigan be increased to augment flow on the Mississippi. The Corps studied the hydrologically complex system and concluded that the suggested diversion would not substantially enhance navigability or reduce the need for continued dredging on the Lower Mississippi.

MISSOURI RIVER

The Missouri River empties into the Mississippi just above St. Louis. It has a series of dams on the mainstem and tributaries that are operated for flood control and navigation. Releases were made to maintain instream flows for habitat, water supply and navigation. Controlled releases also contributed significantly to the flow for navigation on the Mississippi River.

By spring 1988, it became apparent to the Corps that low flows were inevitable for the summer, and the decision was made in coordination with the towing industry to shorten the navigation season by delaying its start

(April 8) and advancing its termination (November 15).

By late June, the Corps river reconnaissance teams were increased to identify portions of the river that were less than project dimension (9' X 300'). They determined that most of the crossings (normally shallow areas on the river) had narrowed. Buoys were reset to mark constricted channels, and the navigation industry and the U.S. Coast Guard were informed of the changing river condition.

Channel reconnaissance by the Corps continued through October to keep abreast of changing conditions. Information was relayed to the towing industry. During that period, deteriorating structures were identified and repaired before shoaling could occur around them. Emergency dredging was performed on the half-mile stretch at the Missouri's confluence with the Mississippi, and later at two other locations upstream (mile 41 and 13) to improve a restricted navigation channel. This dredging was the first required on the Missouri River navigation channel since 1979. Conditions still required the towing industry to reduce barge loadings and the number of barges per tow. By mid-July, "double tripping", where tows would have to break up and take as few as one barge at a time through problem spots, became common at the mouth.

Navigation target flows continued to be met through reservoir releases. Management of system releases for downstream flows were complicated by concerns below the most downstream mainstem dam, Gavins Point Dam. Endangered species of birds were nesting below the dam on river islands and sandbars. Releases could not be increased until the young birds had fledged and left the nests. The progress of the fledglings was monitored closely by the Corps in coordination with the U.S. Fish and Wildlife Service. As river stages continued to drop on the Missouri, Corps reservoir managers waited for the birds to leave. As of August 23, most of the birds had left and no eggs were found. In a decision made jointly with the Fish and Wildlife Service, the Corps began gradually increasing releases the following day. This situation is another example of how the Corps must responsibly balance conflicting water uses in its water management decisionmaking.

Calendar year runoff into the Missouri River above Sioux City was forecast to be 50% of the normal annual runoff, the fifth lowest in 91 years of record-keeping. Prudent management of reservoir releases, accurate river reconnaissance, and responsive emergency dredging allowed the Corps to maintain the channel for a relatively successful navigation season and, at the same time, meet other needs.

OHIO RIVER

The Ohio River and its tributaries form an extensive network of waterways that connects much of the interior eastern U.S. with the Gulf of Mexico, by way of the Mississippi River and the Tennessee-Tombigbee Waterway. The Ohio River Navigation System is controlled by locks and dams, except for the 18-mile reach between the last lock and dam, (number 53), and the confluence with the Mississippi at Cairo, IL. Sufficient water supply for navigation and other purposes was maintained throughout the system above L&D 53 due to the efficient operation of the 77 reservoirs in the

basin. However, the uncontrolled 18-mile stretch between L&D 53 and the mouth suffered record-breaking low water and required extensive dredging by the Corps and traffic control by the U.S. Coast Guard to keep tows moving.

Falling stages and associated shoaling created major bottlenecks on this lower section of the Ohio, especially in the vicinity of Mound City, IL. On June 13, several tows ran aground. The U.S. Coast Guard declared a safety zone on June 14 that eventually included the entire reach from the lower approaches of L&D 53 to Cairo, IL, in which traffic control and tow restrictions were implemented. As river conditions changed, tow size restrictions varied from 8 to 15 barges per tow with variations depending on the direction of travel and mix of loaded and empty barges. Draft restrictions also varied. The zone was closed to traffic on several occasions to permit Corps dredging of shoals. One-way traffic and intermittent delays were required to permit passage in the vicinity of dredge operations.

From June 14 through July 4, an emergency channel was under continuous dredging within the U.S. Coast Guard safety zone. The channel had to be closed to traffic from June 14 - 18 to allow dredges to move in and reopen the channel. Personnel were on the scene 24 hours a day, 7 days a week during the emergency dredging operation. Care was taken to avoid dredging in an area within the zone known as American Bar, where an endangered species of mussel existed.

Through August, continuous dredging was required for the lower Ohio. Dredging was completed by August 21, and on August 22, the U.S. Coast Guard discontinued the safety zone on the lower Ohio. No navigation problems have been reported since.

WHITE RIVER ENTRANCE

The McClellan-Kerr Arkansas River Navigation System empties into the Mississippi River about midway between Cairo, IL and Baton Rouge, LA. The system is controlled by locks and dams, although the last 10-mile reach of the northern entrance to the system from the Mississippi is free-flowing. This reach is also where the system meets the White River and is known as the White River entrance to the system. By late June, the overall system was suffering from low flows but remained open to navigation with restrictions. There were no blockages except on this last 10-mile reach at the White River entrance.

Shoaling on the lower White River existed at six locations by late June. Dredges were used to restore the channel. Coast Guard tow-size and draft restrictions were in effect for upstream and downstream tows. Restrictions were changed as conditions changed.

On July 4, a tow carrying Army National Guard equipment back from exercises in Indiana to Fort Chaffee, AR, could not pass the White River channel because of excessive draft. The following day, fuel was unloaded to reduce draft, permitting the tow to navigate the channel. On July 8, record low water was recorded in the channel. By July 12, one loaded barge at a time was allowed to pass downstream and two at a time upstream.

Dredging continued around-the-clock and conditions stabilized by July 21. At this time, the Corps placed

mooring buoys upstream on the Arkansas River system in Pool 2 to provide temporary mooring facilities near Lock 2 for tows that had to be broken-up in order to meet size restrictions in the White River channel. This action helped reduce transit time for the tows.

By early September, only one or two dredges, still working around-the-clock, were needed and navigation restrictions were eased permitting larger tow sizes. Dredging was essentially completed by mid-October, but navigation was still restricted to daylight operations and narrow tow widths.

TENNESSEE-TOMBIGBEE WATERWAY

By June and July, decisions had been made by the Corps, in coordination with the Tennessee Valley Authority (TVA), to manage the water resources on the Cumberland and Tennessee Rivers in such a way as to preserve navigation channel dimensions. Adjustments in reservoir operations were made as well, to supplement flows for the lower Ohio and Mississippi Rivers, particularly from the Barkley Reservoir where practically steady releases were maintained foregoing normal power peaking operations from June through November.

The Corps was able to notify shippers in June that access to the northern end of the Tennessee-Tombigee (Tenn-Tom) was guaranteed through January 1989. The route guaranteed movement of critical shipments needed to keep plants open that might otherwise have been forced to shut down. The more predictable and trouble-free route offered by the Tenn-Tom attracted a significant amount of commerce that would have normally used the Mississippi. Traffic through Bay Springs Lock, located on the upper Tombigbee, increased by 260% during 1988 over 1987. Prudent operation of the Tenn-Tom, TVA projects, and related systems resulted in a highly successful navigation season with no groundings or blockages reported.

There are two tributary waterways to the Mobile River, -- the Black Warrior-Tombigbee System and the Alabama River System. Both are controlled by locks and dams. The Black Warrior-Tombigbee experienced no navigation problems during the drought. Continuous minimum releases were possible from Selden Lock and Dam on the Black Warrior and the Coffeeville Lock and Dam on the Tombigbee. No water quality or water supply problems were reported.

The Alabama, however, became virtually un-navigable for most commercial users after July 4. On this date, reduced releases from upstream pools were required to meet the more critical needs of water quality and water supply in accordance with decisions made by the Corps in coordination with the State of Alabama. The available releases were insufficient to provide authorized navigation depths. Constrictive controlling depths and widths were experienced from July through September. Tow-size restrictions were in effect through November 8. By mid-September dredging to restore channel depths and widths began and continued into November.

APALACHICOLA-CHATTAHOOCHEE-FLINT

The Apalachicola-Chattahoochee-Flint (ACF), draining an area east of the

Alabama River, is controlled to some extent by locks and dams. The Flint River portion of the system is uncontrolled. The ACF experienced very low flows, and upstream releases were not available to augment flow for navigation. As a result, the system was closed to commercial traffic from July 5 to September 6. In early September, though, the Corps was able to release enough water from upstream projects for a 2-week period to provide a 7.5 foot channel enabling critical farm and fertilizer products to be moved. The ACF remained open afterwards, with draft restrictions, thanks to fortuitous regional rains.

MANAGING WATER RESOURCES FOR MUNICIPAL AND INDUSTRIAL WATER SUPPLY

Municipal and industrial water supplies became particularly limited in sections of the northwestern, central, and southeastern areas of the country. Groundwater levels in some locations reached record lows, individual and community wells went dry, and reservoirs were often low, prompting restrictions on water use by local governments. Corps multipurpose reservoirs were managed to conserve pools for water supply and emergency withdrawal of water. Constant communication and coordination were maintained with local and state governments and other Federal agencies regarding availability of water and authorities for emergency assistance. Representatives attended state drought forums, participated in task forces, and assisted in preparation of state drought response plans. Technical assistance was also provided.

In the Northwest, Idaho reported that 15 community water systems in the eastern part of the state were in trouble due to lack of water. Many southeastern Idaho communities employed water rationing.

In parts of northern California, some water-use restrictions and other conservation measures were immplemented at the non-Federal level in response to dry conditions. No requests for assistance were received.

In the Kansas River basin, Corps lakes were all within a few feet of their multipurpose level and could easily be refilled with less than half the average spring runoff. Only a few small communities experienced water supply problems. Minimum flow releases were maintained for downstream habitat and water supply. A new permit arrangement allowed water to be supplied to an Iowa farmer for livestock and domestic purposes, and emergency water to be supplied to Osage City, KS.

In the Missouri River and Upper Mississippi River basins, the situation was worse. The states of Montana, North Dakota, Missouri, Iowa, and Illinois requested assistance for some of their communities. Requests from individual farmers and ranchers were also received. Each request was examined, usually including field investigations, under authority of Public Law 84-99 as amended by Public Law 95-51.

The Illinois Emergency Services and Disaster Agency requested emergency assistance for the Village of Papineau, IL, on June 20. Fifty-six of the 70 private wells serving 200 people had gone dry. A plan was developed to utilize an unused well near the center of town. A temporary piping transportation system was designed. After appropriate state and railroad approvals were obtained, water deliveries began.

In mid-July, permits were prepared at the request of the Iowa Emergency Services for emergency water withdrawal for domestic use from four reservoirs in Iowa in anticipation of future need.

In late September, a temporary water supply system was installed for the community of Pembina, ND, which

provided water from the Red River. The request for assistance came from the Governor.

In late October, the Illinois Emergency Services and Disaster Agency and the Mayor of Blandinsville, IL, requested emergency assistance to provide potable water for the community's 900 residents. The city's reservoir was down to an estimated 60-day supply. Freezing temperatures would further reduce the supply as ice formed. After field assessments, the Corps determined that a once-used city well could provide the needed water. Special state permits were obtained and a temporary piping system from the well to the reservoir was designed and constructed.

In early November, assistance was provided to Edmore, ND. A temporary pumping system was installed to pump water from a nearby reservoir to the city's well system. The operation provided water for 3 months. Subsequently, water hauling was required.

Water intakes on the Missouri mainstem were inventoried to determine which ones might have problems with ice if water levels were reduced in the winter months.

In many cases, the Corps could not provide assistance under the authorities of Public Law 84-99 as amended by Public Law 95-51, but referred the applicant to the appropriate Federal or state agency that could provide assistance. For example, the community of Elk Horn, IA, requested assistance for transporting water to the drought stricken area in mid-July. The Corps promptly investigated the situation, and determined that the problem was outside Corps purview, but that the National Guard could assist. The Guard hauled water to the area 3 days later. The Corps contacted other Federal and state agencies regarding assistance, resulting in a state grant for constructing two wells in the town.

In some situations, outright assistance was not required, but close operational cooperation and coordination was. Regulation of outflows from the dam at Lake Winnebago offers an example. Four cities drew their water supply from the lake. The city of Oshkosh, WI, was facing a serious shortage. Voluntary restrictions on water use were implemented locally, and close communication was established. Industries on the Lower Fox River were vulnerable to low flows and would have to cut back production if sufficient water were not available. Daily contact between the local office and the Wisconsin Department of Natural Resources, the Fox Valley Water Quality Planning Agency, and local industries provided the information necessary to maintain the balance between water users above and below the Neenah/Menasha Dams.

One incident that dramatized the problems of providing scarce water to a variety of users involved the water supplies for Minneapolis/St. Paul, MN metropolitan area, and competing interests upstream. June was the driest month on record for Minnesota. By June 27, Minneapolis, which draws its entire municipal water supply from the Mississippi River, implemented water use restrictions in anticipation of lower river flows. On July 26, Minneapolis and seven suburbs instituted a complete ban on all non-essential water use. St. Paul, which receives a portion of its municipal water supply from the Mississippi,

followed suit on July 28. The Governor of Minnesota requested increased discharges from the lakes on the headwaters of the Mississippi to augment flow for the Twin Cities water supplies and wastewater assimilation in the river.

Increased discharges were planned to come primarily from Lake Winnibigoshish, the most upstream lake. It was feared that the discharges would lower lake levels impacting wild rice crops, fishing and the recreational boating, and a fishing industry already struggling to get vacationers from docks to deeper water. The wild rice crop was an economic mainstay for local Indian tribes, and the matter of Indian water rights became an issue.

On July 28, six people demonstrated at the Corps facilities at the lake protesting the requested increased releases. Shots were fired. Later in the day, more demonstrators appeared and camped. By August 1, there were 25 to 30 people demonstrating.

The Corps District Commander met with the Leech Lake and Mille Lacs Indian bands and other interested parties on a tour of the affected area before deciding whether or not to make the releases. By August 4, rainfall and a favorable forecast occurred that resulted in increased flow in the Mississippi at Minneapolis/St. Paul. The District Commander made the decision not to increase headwater releases because the rain was producing sufficient flow. Rains continued and, by August 16, Minneapolis/St. Paul and 15 suburbs cancelled water restrictions.

In the Ohio River Basin, reservoir managers noted that streamflows and precipitation in March were much below normal. In anticipation of drought conditions, reservoirs were filled earlier than usual. This action assured availability of almost 95% of seasonal storage for streamflow augmentation during the summer, fall, and early winter. By continuously monitoring the water supply shortages reported by many communities in Ohio, Indiana, West Virginia, Kentucky, and Tennessee during June, July, and August, they were prepared to provide drought assistance if local and state resources became exhausted.

As conditions worsened in June, management objectives for water use during drought were developed. These gave water supply the highest priority over water quality, navigation, hydropower and recreation uses. In late June, after coordinating with the Tennessee Valley Authority (TVA), reservoir releases were made that were well above assured minimums, and benefitted water quality and navigation on the lower Ohio and lower Mississippi. During the most critical point in the drought, reservoirs were supplying approximately 60% of the Ohio River flow at Pittsburgh, 45% at Cincinnati, and in conjunction with TVA, 55% at Paducah, KY, providing adequate water supplies for communities and industries. Communities that depended on withdrawals from Corps projects for water supply did not experience any shortage. However, many communities, large and small, dependent on tributary streams, springs and wells, ran perilously low on water requiring local and state measures for conservation, new intake construction, or new system connections. Fortunately, drought conditions eased for most of the basin by the end of September.

The close work with states in the basin provided information for state drought planning, and offered the opportunity to explain emergency authorities. Emergency services were never requested. Normal Corps water management procedures enabled states and local governments to deal with drought problems efficiently. Examples include an expedited permit processing for new water intakes for two communities, Murfreesboro and Livingston, TN, and for a temporary intake at Rogersville, TN. Also, data were compiled for water intakes to determine what lake levels would affect the intakes. Intake owners were advised of forecasted lake levels so they could take measures to insure continued reliability of the intakes. The City of Columbus, OH, was able to increase withdrawals from the Alum Creek project to meet the shortfall from its main water source.

In the Southeast, smaller communities, dependent on groundwater, ran out of water. Many larger communities had to conserve water. The National Guard hauled water to 15 communities in Alabama for several months. All water supply utilities in Georgia were required by the state to prepare water conservation plans, and some communities had to ration water. No emergency services were required, but responsive reservoir operations coupled with heightened communication with state and local governments alleviated the situation.

A drought contingency plan for the Neuse River Basin was developed in response to meetings held with the City of Raleigh and North Carolina State officials. Projects on the Savannah River were operated to reduce discharges for water conservation in late fall of 1987 in accordance with the Draft Savannah River Basin Drought Contingency Plan. Discharges were further reduced in April 1988 to the minimum necessary to meet downstream water supply and water quality requirements for the cities of Augusta, North Augusta, and Savannah. Water supply and quality were maintained for downstream industries and utilities, the Savannah River Plant (nuclear weapons plant), and the Savannah National Wildlife Refuge. Site inspections and recommendations to downstream water users regarding their intake structures were made. Salinity levels were carefully monitored on the lower Savannah River near the City of Savannah's intake structures for municipal water supply. Low flows on the river allowed saltwater to creep upstream. Flows on the regulated river proved to be sufficient to keep the wedge from reaching the intake structures and impacting the city's water supply.

The water supplies of communities from New Orleans south to the Gulf of Mexico were also endangered by salt water intrusion. This is discussed under water resources management for water quality.

MANAGING WATER RESOURCES FOR AGRICULTURAL WATER SUPPLY

The northwest, midwest, east, south, and southeast suffered a shortage of water supplies for crops and livestock. Many crops were lost and much rangeland was too dry to support livestock. Particularly in Eastern Oregon, Idaho, and North Dakota, upland grazing ranges and springs dried up earlier than normal. When ranchers moved their stock back onto farmsteads, they sometimes had insufficient water to serve both livestock and domestic needs. Ponds normally used for stock watering were drying up in many places. In Idaho, the Weiser and Boise Rivers ran low. In eastern Oregon, rivers were near record low flows by mid-July.

Ranchers had to make economic decisions in choosing between transporting their stock to rented pastures where sufficient rains had produced satisfactory grazing land, buying feed, transporting water to their stock, or selling off livestock. Water for irrigation was carefully managed where still available. Many states, particularly in the midwest, east, and southeast, were declared agricultural disaster areas. Arkansas, Oklahoma, and Texas were also hard hit.

The district offices maintained liaison with states, local water users, and other Federal agencies, especially the Agricultural Stabilization and Conservation Service (ASCS), to coordinate requests for assistance from states, localities, and individuals. Agricultural water problems were generally referred to the ASCS which had appropriate assistance programs for emergency feed, and water for crops and livestock.

North Dakota seemed to have the most requests for assistance. In September, three district offices worked in concert with the ASCS, the Farmers Home Administration, the Governor's office, State Water Commission, Congressional staffers and others to determine what drought assistance could be provided to about 90 individuals from North Dakota requesting water supply for humans and livestock. North Dakota's drought affected ranchers who were bringing livestock back to the farmsteads and finding that water supplies were insufficient to sustain both livestock and human needs. Field investigations showed that most applicants had not fully explored alternatives for assistance and seemed to be searching for funds to drill wells. The applicants were not eligible for emergency assistance under the provisions of Public Law 84-99 as amended. Applicants were advised of help through financial institutions and programs under the Farmers Home Administration and the ASCS.

In Oregon and Idaho, several requests for assistance were received from individual ranchers, especially in August. For one rancher in Oregon requesting assistance, an investigation in coordination with state agencies lead to the determination that the health and welfare of the applicant were not significantly threatened; that the applicant had transported water himself in past dry years ('77, '78, and '82); and that water was available on his property, but needed to be transported to feeding troughs. Other cattle ranchers monitored the

investigation, and dropped their requests for assistance when this one was disapproved.

In a service of still another kind, the Corps assisted the Mississippi Department of Natural Resources in gathering historical and current data on stream discharges. The State of Mississippi used the data to monitor and restrict irrigation in the Yazoo River Basin in Mississippi.

MANAGING WATER RESOURCES FOR WATER QUALITY

Low stream flows, low reservoirs, and high temperatures combined to produce low dissolved oxygen levels, encourage algae blooms, and render some cooling water too warm for that purpose in many areas. Low flows in streams and rivers allowed salt water to migrate farther upstream than usual. Pollutant loads in streams with low flows became more concentrated as less water was available for dilution. In some situations, water quality was degraded to the point that it was unfit for human consumption without additional treatment before being consumed, was not useful for industrial purposes, and could no longer support some aquatic life.

In the Pacific Northwest, low flows and high temperatures reduced the assimilative capacity of streams by early August. This meant that some industries curtailed production of effluent so as to not exceed standards for discharges into the Clearwater and Snake Rivers. The problem was particularly threatening near Lewiston, ID. With continued low flows, a local lumber and pulp mill could not meet discharge standards and faced a plant shutdown potentially causing a significant economic hardship in the area. In cooperation with the Bonneville Power Administration, Idaho Power and the town of Drofino, ID, the decision was made to increase releases from Dworshak Dam to allow the mill to keep operating.

In Wisconsin, close contact was established with water users and state officials to identify and evaluate options for the drought's impact on water quality in the Lower Fox River. Meetings were held in June with representatives of hydropower, paper mill, sewage treatment, municipal water supply, natural resource and water quality interests. Actions involved continuous monitoring of flow and water quality.

In the Ohio River Basin, concentration of acid mine drainage from coal fields threatened fish life and the water supplies for four communities upstream from Tygart Dam in West Virginia. In a cooperative effort with the West Virginia Department of Natural Resources, chemical treatment, pumping from limestone quarries, and water quality monitoring were implemented. Water quality elsewhere in the upper basin was maintained largely due to reservoir releases to augment downstream flows. Low dissolved oxygen levels, algae blooms and excessive mineralization did not materialize to an alarming or widespread extent.

Most of the project lakes in Kentucky and West Virginia sections of the greater Ohio Basin were also operated for desired outflow temperatures and high quality discharges. Algae blooms on a few lakes caused some taste and odor problems.

In the Cumberland River Basin, efforts were intensified to document the effects of the drought on water quality. Sampling runs were made every 2 weeks on the mainstem Cumberland River projects and others. Between the end of July and the end of September, releases were limited but provided acceptable water quality conditions downstream. The dissolved oxygen content of the Cumberland River did not fall below 4.0 mg/l.

The Tennessee Valley Authority Cumberland Steam Plant required an inlet water temperature of about 30 degrees C (86 degrees F) or less for cooling purposes in order to comply with the National Pollution Discharge Elimination Standards (NPDES) permit limit for temperature when the used water was discharged. Changes in releases from storage projects to provide sufficient flows for achieving required temperatures were effective in keeping the water temperature within required limits, even through the warmest months.

Special releases were made at Lock E on the Tennessee-Tombigbee from June through September to augment flows at Fulton, MS, to improve mussel habitat and water quality on the East Fork.

Water quality became a concern for numerous, highly populated communities in southern Louisiana, including New Orleans, that derive their municipal water supplies from the Mississippi River. The problem was saltwater which was moving upstream from the Gulf of Mexico at the unexpectedly rapid rate of about 2.3 miles per day by mid-June, threatening the water supplies of Plaquemines, St. Bernard, Orleans, and Jefferson Parishes.

Such saltwater intrusion occurs almost annually in the Lower Mississippi River, normally in September or October, but usually affects only lower Plaquemines Parish. The most significant factor controlling upstream migration of the saltwater is the magnitude of the river flow. The low-flow conditions during the drought allowed the wedge to progress upstream earlier in the year and at a faster rate than normal.

The denser saltwater moves upstream under the freshwater. The most upstream position of the saltwater is called the toe. The toe is defined as that point where the chloride concentration at the bottom of the river is 5,000 parts per million (ppm). At the toe, no saltwater reaches the surface of the river. Downstream from the toe, freshwater and saltwater mix, forming a salt-fresh interface that takes the shape of a wedge. At about 20 miles downstream of the wedge toe, the chloride concentration at the surface will reach or exceed 250 ppm, the Environmental Protection Agency standard for drinking water.

Plans and specifications had already been made the preceding fall for construction of a barrier sill (underwater levee) in the Mississippi at river mile 63.7 Above Head of Passes (AHP), near Myrtle Grove in Plaquemines Parish, to retard migration of the normal wedge. Plans had also been made to haul water by barge to Plaquemines Parish for use in diluting water supply. The sill and water-hauling were mitigation features for the Mississippi River Ship Channel Project. Both efforts were initiated, modified, and completed ahead of schedule due to the unusual circumstances caused by the drought.

Expedited procurement procedures allowed construction of the sill to commence on June 30. It was completed on August 1. The original design called for the sill elevation to be -60 feet National Geodetic Vertical Datum (NGVD), assuming that the saltwater wedge had not yet reached the location of the sill. By the time construction began though, the toe was located some 16.3 river miles upstream of the sill site. During Phase I of the construction, additional studies were made to take into

account this location of the wedge. It was determined that raising the sill to elevation -45 feet NGVD would essentially stop the migration of the wedge. Modifications to the plans were made, and the completed sill was constructed to -45 feet NGVD with an average height of 25 feet, a crown width varying between 30 and 115 feet, and side slopes of about 1V:8H. It consisted of roughly 470,000 cubic yards of material, and extended nearly 1,700 feet across the river.

On July 6, the Mississippi River dropped to its lowest flow, 114,000 cubic feet per second (cfs). The sill was essentially completed to elevation -55 feet by July 10 and to -45 feet by July 22. The toe reached its furthest location, river mile 104.5 (AHP), (below New Orleans), on July 11. The wedge gradually began to recede on July 14, and became discontinuous above the sill by August 11. At this time, surface salinity levels above the sill had returned to normal. Below the sill, they were still above 250 ppm of chloride, but were declining.

Technical assistance had been provided to various local water districts for developing contingency plans to supply freshwater to treatment plants and potable water to residents. Activation of these plans was not required as the sill succesfully interrupted the progress of the wedge.

The second part of the mitigation plan was to transport by means of certified, flush-deck water barges, untreated freshwater pumped from the Mississippi River at mile 104.0 (AHP) to water treatment plants at Boothville (river mile 18.6 AHP) and Pointe-a-la-Hache (river mile 49.0 AHP) in Plaquemines Parish. The freshwater diluted the water taken by communities from below the wedge. This action was originally planned to last a maximum of 20 days. In actuality, barging operations commenced on July 14 and were discontinued December 2. Plaquemines Parish provided a supplementary water-barging operation between July 5 and August 5.

Four barges were converted for pumping purposes. Pump barges were used to fill barges upstream, and to transfer the freshwater to holding barges or reservoirs at the water treatment plants. A total of approximately 130,950,000 gallons of freshwater was provided.

MANAGING WATER RESOURCES FOR HYDROPOWER

The Corps operates 73 multi-purpose projects with hydroelectric power production. This accounts for about 3% of the total U.S. power production and about 30% of the total hydropower production. Most Corps projects produced below their historical normal levels during the drought, with overall generation about 22%-25% below normal.

The major impact of the drought on hydropower was in the Southeast. In the Savannah River Basin, there had been no releases for the express purpose of hydropower production since November 1987. Hydropower produced, meeting minimum requirements, was incidental to achieving water supply and water quality objectives. Releases from the Buford Dam at Lake Lanier, GA, in 1988 were the lowest on record, and, again, power production was incidental to water supply and water quality requirements. The reduced power production at 11 Corps projects in Alabama, Georgia, and South Carolina resulted in the Department of Energy (DOE) purchasing replacement energy to meet about 58% of their contractual requirements with their customers. Beginning April 16, the Southeastern Power Administration (SEPA) purchased replacement energy from utilities. The cost to SEPA of purchasing the replacement energy for Calendar Year 1988 was over $13 million.

Hydropower production at Ohio and Kanawha River projects was well below normal. In the Cumberland River portion of the basin, a new agreement was negotiated with TVA, SEPA, and DOE, effective July 24, to generate power at a level requiring only 80% of the flows called for under the previous agreement. This step was taken in order to conserve water to maintain lake levels that would ensure adequate storage for water supply, water quality, navigation, and recreation later in the year. This plan allowed the DOE better control of the timeframe for purchasing replacement energy.

On November 22, after rains during November raised the levels of the tributary projects, normal hydropower operations resumed and there was a return to the original agreement with SEPA. Total Ohio River Basin hydropower generation for the drought period was about 57% below normal.

In October, the Western Area Power Administration began purchasing replacement energy because hydropower production was about 14% below normal from projects in the Missouri River Basin.

There were also reductions in power production elsewhere. In the Northwest, hydropower production was reduced to between 20% and 25% below normal, in the Southwest it was 35% to 38% below normal, and in the lower Mississippi Valley area it was between 20% and 27% below normal. These shortfalls did not result in DOE purchasing replacement energy, however.

MANAGING WATER RESOURCES FOR RECREATION

Recreation visitation at Corps lakes remained high throughout the summer. Low water made some boat ramps unusable, and required that some swimming and boating be restricted, but the beaches were still used for sunbathing, picnicking, and the like. The combination of the usual number of boaters using a lake reduced in size because of the drought presented potentially hazardous situations. Only about 12% of Corps water resource projects across the Nation suffered recreational facility closures and low water hazards.

In the Northwest, Applegate Reservoir, OR; Libby Reservoir, MT and Dworshak Reservoir, ID, experienced a few unusable beaches and boat ramps. Extensions were made to boat ramps at Libby. Lucky Peak Reservoir, ID, lost recreational facilities a month earlier than usual due to the drought. Recreational boaters on the Columbia below Bonneville Dam were advised to take special precautions due to low flows.

In North Dakota, state and Congressional interests expressed concern regarding future recreational access impacts on tourism and the economy. In meetings with the North Dakota Game and Fish Department, the governor and the public, information regarding boat ramps and water levels was provided. Corps-operated boat ramps would be extended where possible.

The Southeast suffered the most severe impacts to recreation. Throughout the area, swimming, boating and water skiing were limited by low water and exposed or near-surface hazards. Unsightly beaches and overall unappealing aesthetics for homes and resorts along the shore had an adverse impact on visitation and facilities use. At Lake Lanier, near Atlanta, all 17 public beaches were unusable for swimmers, 28 of 57 boat ramps were closed, and 1,620 (24%) private boat docks were unusable, as were 1,310 (19%) marina boat slips in September. Economic losses for the recreation and resort industry were in the millions of dollars. The beach at Carter's Lake, GA, was closed from July 8 through 17 due to several cases of shigellosis reported there.

In all affected areas across the country, the public was kept informed of changing conditions and availability of facilities at recreation areas through more frequent press releases, TV and print media coverage, pamphlets, brochures and posted notices on project bulletin boards. In the Savannah area, a drought hotline was established for residents of the Southeast which provided up-to-date messages on conditions at lake projects on the Savannah River including current pool levels, number of operating boat ramps, and safety alerts. Buoys marking new hazards, and warning signs were set in place when necessary. Safety campaigns were also widely used.

From the end of June through the beginning of August, lockages for recreation craft were limited to two-hour intervals on the inland waterways of the upper Ohio River Basin. This limitation was implemented to conserve water. Some of the recreation facilities were closed at 7 of the 34 lakes in the Huntington area. The lakes most impacted were those used in augmenting downstream flow for water quality. In

Kentucky, one public beach at Carr Fork Lake and one at Rough River Lake were rendered unusable because of low water. Otherwise, there were minimal adverse impacts on recreation during the summer recreation season in the Ohio River Basin.

In the fall, however, there was a problem that highlighted the difficulties in operating a multi-purpose reservoir project when there are conflicting demands for a relatively small quantity of water. The white water rafting season usually starts in West Virginia in the Ohio River Basin in September after the Labor Day holiday. White water rafting is made possible by releases from the Summersville Lake into the Gauley River and from the Bluestone Dam into the New River. White water rafting and kayaking on the Gauley River in 1987 was provided on 21 days and attracted 47,000 people generating $20 million dollars for hotels, restaurants and other businesses in the surrounding area. In 1988, only 8 days of white water rafting could be provided on the Gauley below Summersville Lake. The lake pool was 50% of normal. It was necessary to conserve supplies to insure sufficient water for Kanawha River instream flows for fish and wildlife, and for industry and wastewater assimilation in Charleston, WV.

LESSONS LEARNED AND RECOMMENDATIONS

The following are summaries of lessons learned and recommendations selected from field-office reports. Selection was based on the predominance of a common theme.

1. Clarification of authorities, guidelines and procedures for emergency water supply assistance would be helpful.

The Corps as a whole had limited experience with widespread drought problems prior to 1988, and authorities for emergency water supply assistance had never undergone such a practical field test. During 1988, in most instances, resource management for water supply was accomplished under normal project authorities. Direct emergency water supply assistance is generally restricted to drilling wells on a cost reimbursable basis, and hauling or piping water.

There were some expectations in some areas of the country that the Corps could do more. In terms of these expectations, policies and authorities for emergency assistance seemed limited. These implied shortcomings pertained particularly to the plight of ranchers and farmers in the northern plains states who were ineligible for assistance. Complicating matters for these farmers and ranchers, was a perceived lack of correlation in authorities of the U.S. Department of Agriculture and the Corps. There was also concern expressed regarding limits to addressing contaminated water supplies.

Guidelines in Corps Engineer Regulation (ER) 500-1-1 for classifying an area as drought distressed were found to be unclear for some situations. Also, procedures sometimes took too long. Better defined eligibility standards would help field offices identify those projects appropriate for Corps participation, and would help furnish a more timely response to applicants. They would, also, help in explaining to applicants why their requests for assistance had been denied.

Questions were also encountered on water rights (with regard to Native American and states' rights), sale of water from Corps lakes, development of charges for water to be sold, and procedures for repayment of government expenses for contract well-drilling. Detailed guidance and procedures needed for dealing with these issues were found to be inadequate for some circumstances.

It is recommended that ER 500-1-1, in conjunction with Public Law 84-99 as amended by Public Law 95-51, as well as programs of other Federal agencies, continue to be reviewed in light of field experiences. Clarifications of authorities, policies and procedures should continue to be made as necessary. Legislative initiatives may be appropriate for further clarification of emergency water supply authorities.

2. Coordinating plans of action with states, municipalities, industries and other Federal agencies is extremely valuable.

It was found, in many instances, that better coordination with other Federal agencies, and state, local and private interests could have prevented some frustrations and inefficiencies. The value of having coordinated drought

management plans in advance of the emergency was demonstrated.

Many field offices ultimately formed or participated in coordination groups. Through these groups, users' needs and ideas could be considered in devising action plans for regional drought response, Corps authorities and those of other government agencies could be explained and utilized appropriately in the plan, and data for operations during the drought could be exchanged. In this environment of cooperation, everyone could understand each other's strengths and limitations, and work together toward the same goal. Everyone could understand the trade-offs required to balance competing needs.

Such efforts let users not only understand the reasons for certain water management decisions, but encourage them to support those decisions. They also ensure that users know their interests are being heard. This atmosphere of confidence and trust naturally extends to the general public and their legislators. Rumors and uncertainties are minimized. Confrontation born of misunderstanding is avoided. Management plans made in such an environment ensure that control of the decision-making process during a crisis is not lost to less rational political or public relations influences.

Drought management also becomes more organized as agencies and individual interests become knowledgeable of each other's requirements. For example, state governments would know that communities and individuals seeking Federal assistance would have to demonstrate that all other possible resources had been investigated prior to application. They would no longer forward inappropriate requests. States might recognize the expediency for designating one office for drought coordination. Restrictions due to drought on such things as water use and bans on outdoor fires would be consistent in areas under state control and Federal agency control. Congressional interests could be kept informed with periodic fact sheets based on coordinated actions.

Management plans that include decisions for water releases are better when users have submitted data that show how their operations are impacted at different water levels. This is true for recreation, towing, shipping, and power industries, municipal and industrial water suppliers, and agricultural activities.

The Lower Mississippi River Committee and the River Industry Executive Task Force were two formal groups established in response to the 1988 drought to coordinate mitigation efforts for waterborne commerce. Numerous other groups were organized to coordinate with a broader range of users.

The value of disseminating coordinated, up-to-date information to the general public on the status of water resource projects during the drought was also demonstrated. Such efforts promoted public understanding of the relative severity of changing situations and of measures taken to deal with them.

It is recommended that Corps participation in coordination groups for drought management, as well as drought management planning, be encouraged. Drought management planning would be accomplished in accordance with plans for national water management during drought. Coordinating and reporting information on events and actions to the

public in a pro-active manner should also be encouraged.

3. There is some need for improved data to support water management decisions.

It was discovered that more information about how the shipping industry makes decisions to utilize the inland waterways, and how delays in materials reaching factories impact them, would have been helpful in making decisions regarding navigation.

The importance of having up-to-date reservoir control manuals and water control plans for each project for low-flow drought conditions was noted. Additionally, drought contingency plans for each project were thought to be valuable. Funding priority for such efforts should be established.

Some saw a need to develop a method for estimating low flows during drought based on ground water levels and a recession hydrograph. The percentage depletion in ground water supplies is more difficult to quantify than the percentage depletion in surface supplies. More research and more sophisticated measuring techniques are required to develop low-flow models to reproduce drought flows.

There were some indications that improved capability for collecting real-time water quality data would be very helpful in making water management decisions, such as the timing and volume of releases for instream flow augmentation.

It is recommended that new methodologies and data bases be developed as necessary to improve the decision-making process during drought conditions.

4. Field offices would have benefitted from receiving periodic drought information reports from HQUSACE.

Field offices were required to submit periodic situation reports to HQUSACE to keep management informed of the drought activities nationwide and field responses. The field offices, though, never received any information back. As a result, they had a view of the drought limited by their own experiences and those of neighboring field offices.

Some feel it would have been advantageous to know if other field offices were experiencing similar problems, how they were handling them, and how policy was being implemented through HQUSACE. Information concerning actions taken by the Department of Agriculture (Agricultural Stabilization and Conservation Service, Farmers Home Administration, and Forest Service), Department of Interior (Bureau of Land Management, Bureau of Reclamation), Department of Commerce (Economic Development Administration) and Small Business Administration would have been helpful in directing local communities to other sources for Federal help.

It is recommended that information exchange among field offices be facilitated through periodic summaries of drought activities nationwide distributed from HQUSACE.

5. Requests for information on the drought situation by HQUSACE were too frequent.

Requests by various elements at HQUSACE for information from field offices regarding drought activities were numerous and sometimes uncoordinated. These requests, in addition to the requirement to submit daily situation reports to the Emergency Operations Center, proved to be burdensome for field offices responding to crises.

All inquiries of field offices by HQUSACE should be coordinated through the Emergency Operations Center.

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