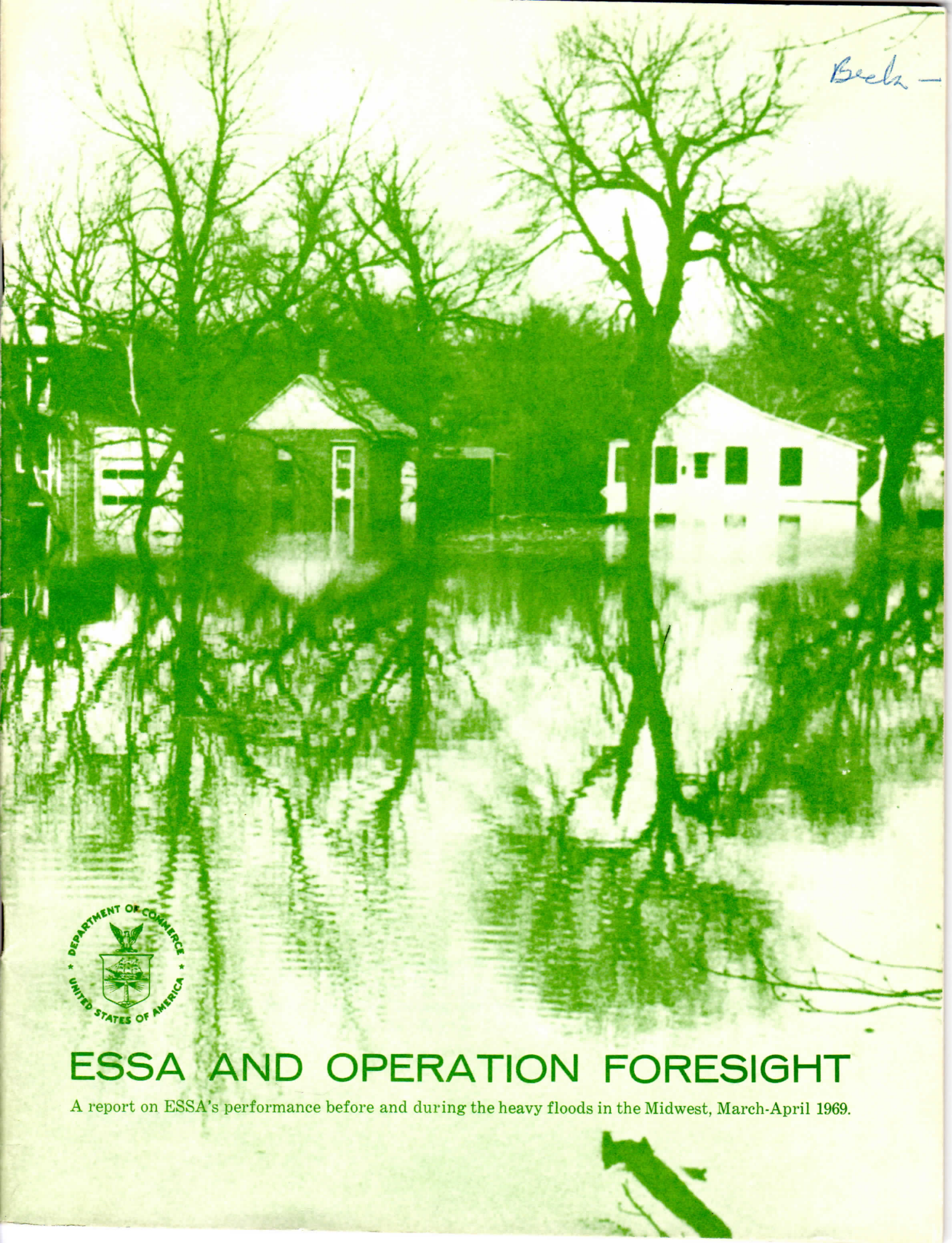

ESSA AND OPERATION FORESIGHT

A report on ESSA's performance before and during the heavy floods in the Midwest, March-April 1969.

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U. S. DEPARTMENT OF COMMERCE
Maurice H. Stans, Secretary
Environmental Science Services Administration
Robert M. White, Administrator

Washington, D. C.
May 1969
ESSA/PI690030

FOREWORD

On April 15, 1969, I requested Donald F. Moore, Assistant Administrator for Plans and Programs, Environmental Science Services Administration, to undertake, as a matter of priority, a survey of how ESSA's River and Flood Forecast and Warning Service performed during the disastrous flood situation that was occurring in the Midwest. Specifically, I asked for a review of the effectiveness of our forecasts and warnings prior to and during the disaster. I was particularly interested in any deficiencies that might have existed and asked for recommendations whereby our service might be further improved.

The enclosed report by Mr. Moore and his group presents their findings on the flood forecasting service during the midwestern snowmelt floods and the present capabilities and limitations of that service. The general conclusion of the survey group—that the service performed in an outstanding manner which made possible unparalleled large-scale and most effective Federal, State, and local preparedness measures to meet a major natural disaster—is a tribute to the diligence and dedication of personnel involved.

Robert M. White
Administrator
Environmental Science Services
Administration

PREFACE

The survey team included Robert Beck, Office of the Federal Coordinator for Meteorological Services and Supporting Research, ESSA; Herbert Lieb, Deputy Director, Public Information, ESSA; Arthur Hosick, User Services Representative, Weather Bureau Central Region in Kansas City, Mo.; and the undersigned. The team assembled at Kansas City on Monday, April 21, and spent the first three days reviewing information available at Weather Bureau Central Region Headquarters regarding the Midwest snowmelt flood situation and planning the field visits that followed. The team was divided into two groups with Mr. Beck and myself visiting the eastern half of the flood area and Mr. Hosick and Mr. Lieb the western half. The two groups met in Minneapolis for a joint visit prior to returning to Kansas City.

During the course of the field visits by the survey team, an attempt was made to visit Weather Bureau River District Offices (RDO), State and local Civil Defense Directors, U. S. Army Corps of Engineers Division and District Offices, Weather Bureau offices in the disaster area not having an RDO function, and towns and cities particularly affected by the flooding. Attachment A to the report gives the itinerary of the two survey teams and the names and titles of the principals interviewed.

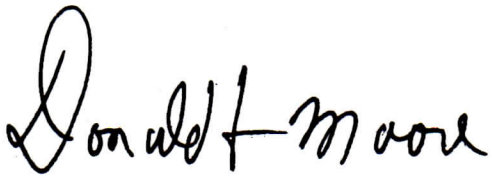
At the outset, it was agreed that it would be necessary to place limits on the extent of this survey for reasons of time. The survey encompassed the major flood areas in the Midwest. These included the Mississippi and Missouri River basins, the Red River of the North, and the Souris (Mouse) River in North Dakota. The states involved were Minnesota, Wisconsin, Iowa, Nebraska, Illinois, and North and South Dakota. It is recognized that serious flooding has occurred and continues to occur this spring in other portions of the United States. It is anticipated that many of the conclusions and recommendations with respect to the Midwest flood situation will be applicable to areas outside the Midwest, particularly in the far West.

It is important to differentiate among the three principal types of floods that can be disastrous in the upper Midwest. They are: spring snowmelt floods, the source of the present disaster in the Midwest; floods that occur in spring and summer as a result of heavy and protracted rains; and flash floods, which are highly localized and occur with very little notice. This survey concerns only the first situation, the snowmelt condition that has created record floods this spring in the Midwest. Similar record flooding occurred in 1965 and 1952.

This survey was particularly interesting because it revealed how early recognition of a flood potential and accurate predictions well in advance of expected crest stages can make possible major preventive measures which can reduce damages significantly, save lives, reduce economic losses, and greatly reduce the human suffering and misery that follow disastrous floods.

The survey members were impressed by the tremendous cooperation that developed among Federal, State, and local authorities and the public when the possibility of a disaster was recognized and it was realized that time was available to do something about it. In the Midwest flood situation, all of the essential ingredients were there—early and accurate forecasts of the general flood potential, Federal funds available in advance of the floods for preventive measures (as opposed to being used for a cleanup operation after flooding occurs), and the cooperation and desire on everybody's part to avoid the avoidable.

The survey team is indebted to numerous individuals within ESSA, other Federal agencies, and State agencies for their contributions to this report. It is impossible to enumerate all of them, but particular credit should go to Roy Fox, Director of the Central Region, Weather Bureau, and his staff and to William E. Hiatt, Associate Director of the Weather Bureau for Hydrology, and his staff. The survey would have been inadequate, if not impossible, without their willing cooperation and assistance.



Donald F. Moore
Assistant Administrator for
Plans and Programs
Environmental Science Services
Administration

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Figure 1—"Heavy, Heavy Over Our Heads," editorial cartoon of February 6, 1969, Copyright St. Paul Dispatch, used with permission.

Chapter I
The Flood Threat

Well before there was a general concern for the 1969 potential for record snowmelt flooding, the States in the northern border of the Midwest had another emergency on their hands—snow in record quantities. The accompanying cartoon from the St. Paul *Dispatch* (Fig. 1) is a humorous portrayal of what was a very serious emergency for the State of Minnesota. Cumulative economic losses directly related to the snow emergency alone have not been completely determined, but estimates are very high; for example, nearly every community and county government spent five and six times their normal budgets for snow removal. Because of the snow situation, several State governments had nearly exhausted emergency funds prior to the onset of flooding. In Minnesota and the Dakotas, the snow emergency and flood emergency overlapped for a period of time.

Continued heavy snows and low temperatures in December gave Weather Bureau personnel the first indication that flooding might assume serious proportions during the snowmelt period in 1969. On January 9, representatives of the Minnesota Civil Defense, ESSA Weather Bureau, Corps of Engineers, and Department of Military Affairs met in Minneapolis. At that time, Joseph H. Strub, Jr., Meteorologist in Charge of the Minneapolis, Minn., Weather Bureau Office, alerted the group to the possibility of serious flooding in the area served by his River District Office. (See Attachment B for a map depicting the River Forecast Center/River District Office organization of ESSA's River and Flood Forecast Service.) Weather Bureau personnel throughout the Midwest area shared Mr. Strub's concern for possible serious flooding.

The hard facts were revealed on February 1, when detailed observations of snow depths and the water equivalent of the snow on the ground were made over the whole area. The Des Moines *Register* of February 2, 1969, ran a major article on possible disastrous flooding. This article cited Weather Bureau officials as stating that there was a real potential for disastrous floods. Assessments were based on a four-State survey of snow and ice conditions in northern Iowa, southern Minnesota, western Wisconsin, and eastern South Dakota. The survey showed more water equivalent on the ground than during a similar period before the record Mississippi flooding of 1965. The snow survey was a cooperative project of the Weather Bureau, the Corps of Engineers, and the Geological Survey.

Many factors determine the extent of potential flooding. Chief among these are temperatures, snow depth and water equivalent of the snow, precipitation, river stages, and antecedent ground conditions. Knowledge of antecedent ground conditions is essential for runoff prediction and includes such things as the type of soil, its moisture content, and depth of frost. The three accompanying figures present the situation that obtained during the winter of 1968-1969. Figure 2 shows the departure of temperature from normal, Figure 3 the percentage of normal precipitation, and Figure 4 snow depth. These figures clearly show the reason for concern: precipitation had been high, temperatures low, and snow depth on the ground and water equivalent were far above normal over a wide area of the Midwest. Following an analysis of the special snow survey and related data by the Weather Bureau Kansas City River Forecast Center, Weather Bureau Headquarters in Washington, D. C., was advised of the situation and flood potential.

At that time, the River Forecast Center at Kansas City prepared its first official spring flood outlook. This outlook, issued on February 11, covered the Red River of the North and portions of the Missouri River and its tributaries. The outlook stated that a very serious

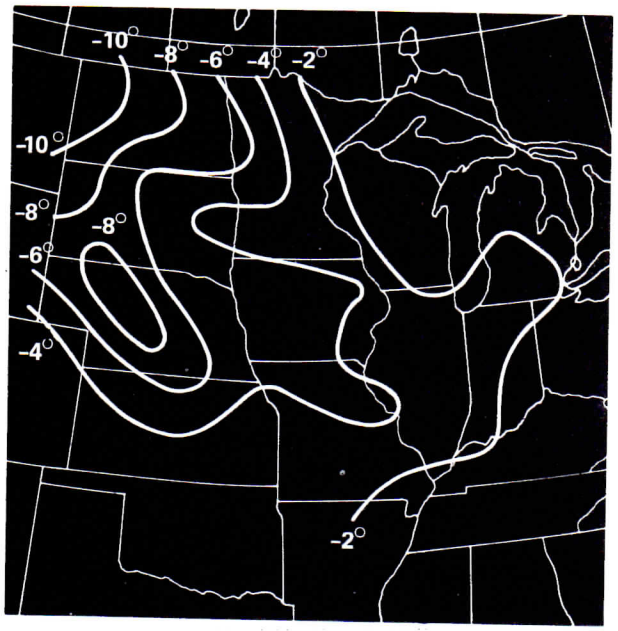
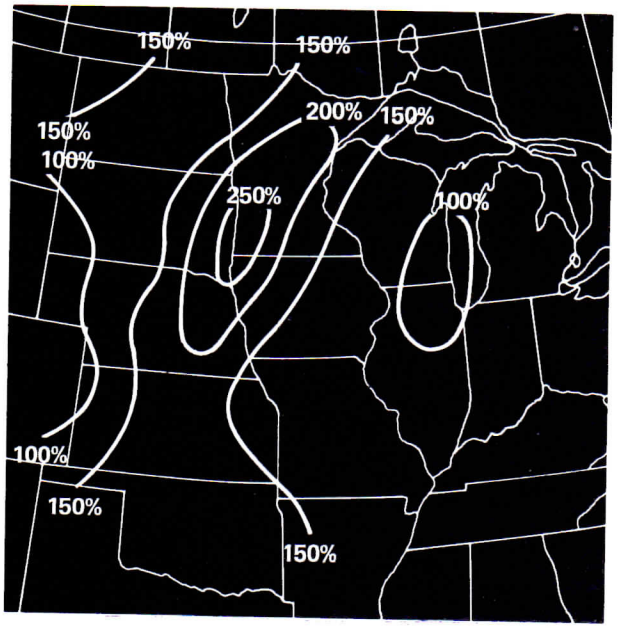


Figure 2 — Temperature Departures from Normal °F
December 68 - January 69



Note: The 150% of normal represents about 1 in 35 years.
The 250% of normal represents about 1 in 100+ years

Figure 3 — Percentage of Normal Precipitation Winter 68-69
(October 68 - February 69)

flood potential existed in these areas, and that conditions warrented preparation for major, damaging floods. As mentioned previously, the existence of a similar flood potential along the upper Mississippi and its tributaries had been brought to public attention as early as January 9 by the Weather Bureau's River District Office in Minneapolis, Minnesota. Starting on February 20, weekly flood potential statements were prepared by the Forecast Center at Kansas City for all affected areas and transmitted to River District Offices, news media, State and local officials, and Congressmen from the affected States.

On February 28, William E. Hiatt, Associate Director, Weather Bureau, Hydrology, briefed officials from many government agencies (Attachment C) on the flood threat. Mr. Hiatt was accompanied by Dr. Robert M. White, Administrator, ESSA, and the Director of the Weather Bureau, Dr. George P. Cressman. At this point, it was generally accepted that the spring flooding in the Midwest could very well assume disastrous proportions. Fortunately, early recognition of this situation at the highest levels of the Federal and State governments made it possible to launch *Operation Foresight* to avert or ameliorate the almost certain results of these floods. The actions that were taken at the Federal, State, and local levels are discussed in the next chapter.

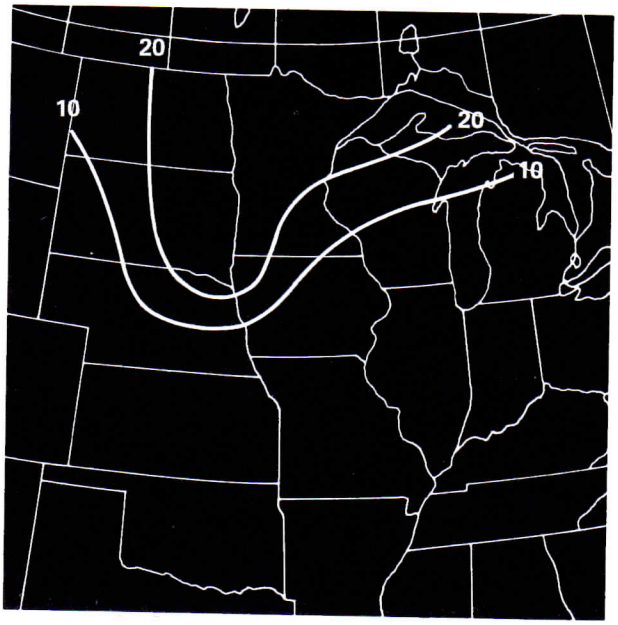


Figure 4 — Snow Depth March 10, 1969 (Inches)

Chapter II
Operation Foresight

In a White House press release on March 1 (Attachment C), President Nixon expressed his concern about the spring flood threat and ordered a major effort by Federal agencies to undertake all feasible preparations to reduce or alleviate the flood damage and suffering. He instructed George A. Lincoln, Director of the Office of Emergency Preparedness, to coordinate an extraordinary Federal planning and operational effort to supplement State and local resources. In a letter dated March 1, 1969 (Attachment D) Mr. Lincoln urged the Corps of Engineers to aggressively utilize available authorities under Public Law 99, 84th Congress, to meet the serious and imminent flood threat. These actions, resulting from the early warning of the flood potential by the ESSA Weather Bureau made possible preparedness activities on a scale never before attempted for anticipated flooding.

PL–99 funds had not been used in this way in the past. Liberalization permitted extensive preflood actions by the Corps of Engineers and improved the outlook for avoiding much of the damages that have occurred with similar flooding in past years. PL–99 funds were made available to protect public areas where local finances were inadequate. Aid was in the form of levee contracts, sandbags, polyethylene film, pumps, and lumber. Technical assistance was given to survey potential trouble spots and supervise contracts. To qualify for the use of PL–99 funds in this way, a community had to demonstrate that it had a feasible protection plan and could furnish the necessary right-of-ways and labor for the construction of levees.

The President's directive initiating *Operation Foresight* was greeted with enthusiasm and action at the State and local levels throughout the threatened areas. Actions taken by Federal, State, and local agencies in the areas concerned were extensive. A few of these actions are enumerated to illustrate the cooperation that was developed and the preparations that were possible:

Corps of Engineers—The majority of the organizational effort and work of preparing for the flood and instituting preventive measures fell to the Corps. With the release of more than $16 million of PL–99 funds, the Corps had the task of organizing State and local officials to get contracts underway and protective measures completed before the flooding occurred. The Corps carried out reconnaissance of rivers and streams to identify obstructions to free flow. It staffed information centers to expedite handling of very heavy volumes of requests for information and on-site technical assistance. Communications nets were strengthened with additional equipment, and a large number of engineers was transferred from other sections of the country to assist.

Office of Emergency Preparedness—The Denver and Battle Creek regions of the Office of Emergency Preparedness held numerous meetings jointly with other agencies, such as the American Red Cross, the Corps of Engineers, and ESSA Weather Bureau, to discuss emergency preparedness measures that could and should be taken to prepare for the potential flood threat.

American Red Cross—The ARC announced its plans for dealing with the flood emergency on March 11 and initiated many planning meetings with its State and local representatives to discuss means for handling its responsibilities during and after the flooding. The Red Cross' primary concern was in caring for people evacuated from their homes.

Department of Transportation—The *Coast Guard* made plans for, and subsequently provided, boats and helicopters for the evacuation of flood victims from unprotected areas. The *Federal Aviation Administration* made plans to

protect vital communications and air navigation aids.

The Department of Agriculture—USDA advised farmers to take necessary pre-emergency actions to minimize losses of livestock, machinery, and stored crops due to flooding. It also made plans to provide inspectors to supervise post-flood cleanup operations where food was concerned, such as grocery stores, restaurants, and food establishments.

State Actions—A number of States declared emergencies so that all State resources could be brought to bear in assisting local communities with their problems. County plans were prepared for providing essential public services during the emergencies. Numerous flood planning meetings were held at the local level, usually with the participation of Federal agencies such as the Weather Bureau and the Corps of Engineers. State National Guards committed heavy equipment for levee work, and Guard personnel were committed to emergency evacuation of personnel, security patrols of flooded areas, and manning of control points. State Highway Commissions made trucks available for evacuation of property and levee construction.

Local Actions—The activities at the local level are too numerous to mention. There were few cases noted in which public apathy, disbelief in the forecasts, or failure to take positive action allowed flooding that could and should have been avoided. On the positive side, local Civil Defense officials developed flood protection manuals and plans outlining how the community was to deal with the situation and established emergency operating centers as focal points for coordinating all actions within the community. Plans previously developed for other emergencies, such as nuclear attacks and tornadoes, facilitated action in the flood threat. The construction industry, through local Associated General Contractor chapters, acted in an advisory capacity based on their operation of Plan Bulldozer to provide sources of men, materials and equipment. Emergency plans had to be developed for levee construction or for raising existing levees where crests were expected to be above the level of permanent protection. Frequently, this involved local bond issues (and elections) to permit the community to obtain the right-of-way for the levee, a pre-requisite to receiving PL–99 assistance. Plans were made for obtaining labor (volunteer and paid) for levee construction and security patrols for levees once constructed. Plans also were made for providing essential care for those people forced to move from their homes. In many cases, typhoid innoculations were given to small children as a precautionary measure. Community planning and community action to deal with the flood emergency were unprecedented. Colonel George Orr, Civil Defense Director in Iowa, and State and county Civil Defense directors in the other affected States all stressed that the long leadtime of the warnings made it possible to organize and coordinate the activities of the many political jurisdictions involved in flood prevention.

In summary, *Operation Foresight* was a remarkable success and an outstanding example of the benefits to be derived from good warnings of natural disasters, effective organization, and cooperative efforts of Federal, State, and local authorities.

Chapter III
Preparedness Actions by ESSA

Many preparatory actions were taken within ESSA to enable it to deal more effectively with the developing situation. These included educating the users to the situation, improving our observations on an emergency basis, adding communications, augmenting staff, and obtaining added forecast support.

In the education area, one of the key events was the April 1 appearance of Mr. Hiatt on NBC's Today Show, where he discussed the situation on a nationwide popular television show. In addition, a five-minute flood safety film developed by the Red Cross in cooperation with ESSA a number of years ago was distributed widely throughout the threatened area. Copies of an ESSA publication entitled "Floods and Flood Warnings" were mailed in quantity to ESSA River District Offices throughout the flood area. This publication explains the different types of flooding, and the Weather Bureau's methods of river and flood forecasting. It also contains a very useful section on community action and another on individual safety rules before, during, and after flooding.

One of the major efforts of the Weather Bureau was in personal appearances throughout the flood areas to present on a firsthand basis the latest flood information available and to answer questions of concern to local authorities, news media, and the general public. *This effort was commendable in view of the pressing demands on the meteorologists in charge of these Weather Bureau offices, particularly during a disaster. Many more such meetings would have been desirable and undoubtedly would have been held had adequate staffing made this possible.*

In the observing area, programs were set in motion to obtain a better picture of the snow cover, the water equivalent of the snowpack, and the condition of the ground.

Arrangements were made with the Department of Defense to make available upon request reports from DOD weather radars in the area to alert the River Forecast Center to any heavy precipitation which might be occurring in areas where Weather Bureau radar coverage is inadequate. Fortunately, in this instance heavy precipitation during the critical snowmelt period played no significant role. DOD also cooperated in testing a new type of airborne radar for use as a possible means of determining the extent of the snowpack in the flood threatened area. The results of the experiment were negative, but it is worth noting because the effort was made and the cooperation by the military was commendable. The Army provided a helicopter airlift for Weather Bureau personnel making snow surveys. The helicopters made it possible to obtain improved visual estimates of snow depth and snow cover, the variability of snow cover and water content over small areas, an evaluation of melt areas, and the conditions of rivers and small streams.

Attempts were made to gain additional information on the extent and depth of the snowpack by photographic means. The 67th Tactical Reconnaissance Wing, USAF, and the 123rd Tactical Reconnaissance Wing (Idaho Air National Guard on Federal Active Duty) cooperated by providing reconnaissance photographs which proved to be useful. More useful photo reconnaissance products would have been realized, however, if better specification of the types of photography required were made. The National Environmental Satellite Center provided special enlarged satellite photographs of the snow-covered area and telephoned analyses of these to the River Forecast Center as they became available. These photographs provided useful information on the general extent of the snow cover. Comparison of photographs from day to day gave clear indications as to where the snowmelt was occurring. The photographs

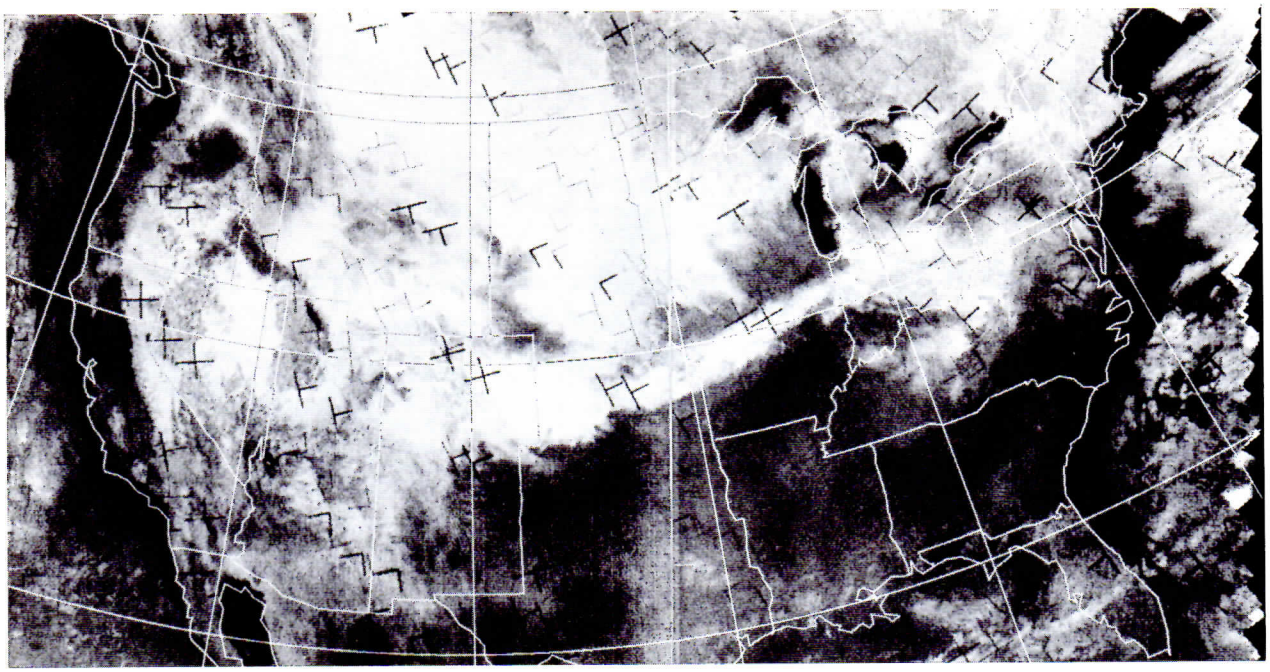
North Bridge linking Fargo and Moorehead, N.D., shown before rising Red River of the North made it impassable.
Fargo *Forum* photo

were also useful as a form of reconnaissance to help decide where additional ground observations were needed.

A major effort was mounted to augment the collection of the normal snow-depth measurements. As previously mentioned, a concentrated snow-depth and water-equivalent survey was carried out about February 1 as a cooperative effort of the Geological Survey, the Corps of Engineers, and ESSA. In addition, arrangements were made with existing cooperative observers for more frequent observations. County Civil Defense Directors were also requested to assist by obtaining special snow-depth measurements in their localities. Grave diggers cooperated by providing critical information as to the depth of the frost in the ground.

In the forecasting area, one of the major actions resulted from a meeting between personnel of the Office of Hydrology and the National Meteorological Center, Weather Bureau, to determine means of providing specialized weather forecasts to the Kansas City River Forecast Center on a continuing basis until the threat of flooding ceased. These forecasts took the form of daily four-day predictions of temperature and quantitative precipitation. They were transmitted to the River Forecast Center by a specially installed facsimile link. An evaluation of these forecast products provided by the National Meteorological Center is contained in Chapter IV. As indicated earlier, flood outlooks for the entire area of potential flooding were issued on a weekly basis by the River Forecast Center beginning on February 20.

Some special communications were installed

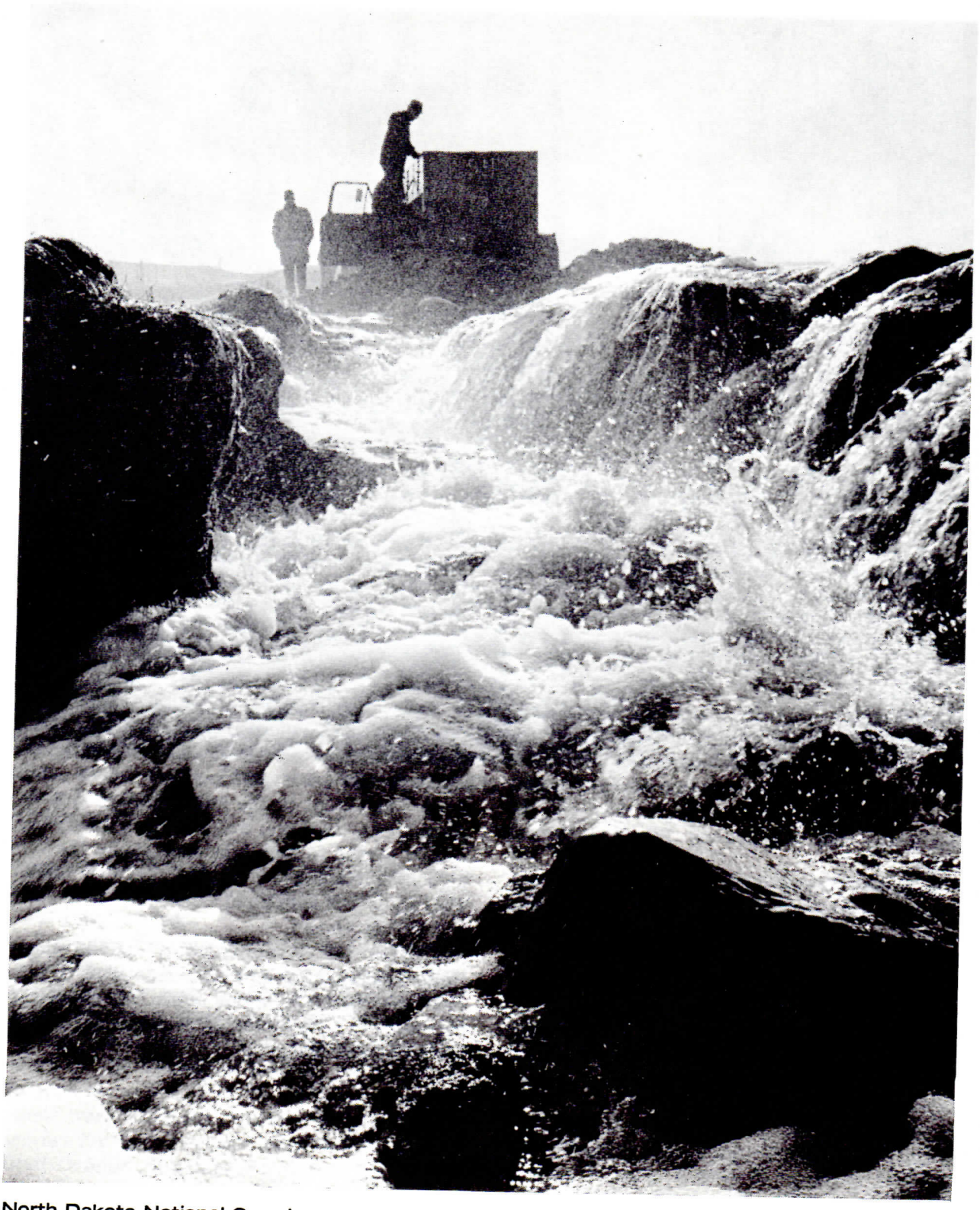


ESSA spacecraft photographs like this one were produced by programming a computer to select points of maximum darkness from 5 days' satellite data. The typically moving storm systems were thus screened out of the picture, except for some stationary cloudiness over the Atlantic. The rest of the country is shown cloud free, and the snowpack is clearly visible. The white swath from New Mexico into Indiana is new snow, dumped by a storm which passed during the 5-day period. Tees and crosses are fiducial marks from the satellite data.

by the Weather Bureau to deal with the emergency although there were some cases where added emergency communications would have been desirable, notably between emergency centers set up temporarily in a city to deal with the emergency and the nearest Weather Bureau office.

A modest amount of staff augmentation was provided to the River Forecast Center and the field stations to assist them during the flood emergency. The augmentation was of several types. The River Forecast Center was augmented by two hydrologists to help cope with the increased load. However, most of this added load had to be taken care of through overtime. A few people were made available to augment Weather Bureau offices, and a few additional substation network specialists were provided to aid in special surveys of snow and river conditions. The extent of the augmentation was not adequate to the need, and the flood emergency merely served to highlight once again, the thin personnel staffing at Weather Bureau offices. This subject is addressed separately later on in this survey report.

Finally, the Administrator, ESSA, made funds available through reprogramming to provide the Central Region with the flexibility necessary to meet increased demands during the period of emergency.



North Dakota National Guard crews work on a road washout near flooded Enderlin, where high water forced some 50 families from their homes.
Fargo *Forum* Photo by Colburn Hvidston III.

Chapter IV

Snowmelt Outlooks and Forecasts

ESSA's Kansas City River Forecast Center issued its first official spring flood outlook on February 11. This outlook was not distributed to the press, radio and television, but was mailed to the individual River District Offices. The next outlook, on February 20, marked the start of weekly outlooks released to the River District Offices, the press, radio, and television, State and local authorities, and members of Congress of the affected area.

Shortly after the overall 1969 flood potential became apparent, and before any specific stage forecasts were issued, the Regional Hydrologist conferred individually with principal engineers of the Omaha, St. Paul, Rock Island, and St. Louis Corps of Engineers Districts. Previous understandings were confirmed, and it was agreed that neither agency was in a position at that time to make a firm estimate of the flood potential. The Weather Bureau was encouraged to issue specific forecasts as early as possible.

With the exception of the statements made by Joseph H. Strub, Jr., Meteorologist in Charge at Minneapolis on January 9 and again on January 23, during meetings of the Minnesota Civil Defense, Weather Bureau, Corps of Engineers, and Minnesota Department of Military Affairs, there was no general ESSA issuance until February 20.

The team recognizes that there was an understandable reluctance to issue an outlook until the results of the special snow survey in early February confirmed that the situation was, in fact, extremely serious. Figures 5 and 6 illustrate just how serious the situation was and give a comparison of the water equivalent in the area just prior to the 1969 floods with that preceding the disastrous flood in 1965.

A. Outlooks, February 11-March 6

The February 20 outlook cited as the basis for the flood potential a widespread snowpack containing 8 to 10 inches of water equivalent at its center in the eastern Dakotas and Minnesota. Near-record to record flooding was indicated, even with no further precipitation, on the Red River of the North; upper Mississippi River tributaries in Minnesota, Wisconsin, and Iowa; and Missouri River tributaries in the eastern Dakotas, Iowa, and portions of Nebraska. Moderate-to-severe flooding was indicated for the remainder of the tributary streams with moderate-to-minor flooding along the main stems of the middle and lower Missouri and Mississippi Rivers. Normal or greater precipitation would increase the potential flooding to record and near-record levels throughout the area.

The February 27 outlook reaffirmed the seriousness of the flood potential, especially in light of significant amounts of precipitation over much of the snowpack area during the preceding week. It was noted that some snowmelt flooding had already started in Kansas and Nebraska, and that ice jams were causing higher than expected crests. The outlook ended by cautioning that it would be prudent to prepare for the most serious flooding possibilities indicated in the February 20 outlook.

The March 6 outlook continued to predict record or near-record flooding on main and tributary streams in the Dakotas, Minnesota, Iowa, Wisconsin, and portions of Nebraska, Kansas, and Missouri. Substantial amounts of precipitation fell during the preceding week over a large part of the threatened area, and observations of water content and soil condition reaffirmed the indicated high rates of runoff that would come when the snow melted.

B. The March 13 Outlook

On March 13, 1969, the Weather Bureau River Forecast Center, Kansas City, issued a complete, detailed snowmelt flood outlook for

Figure 5 — Water Equivalent of Snow Cover March 30, 1965
(Inches of Water)

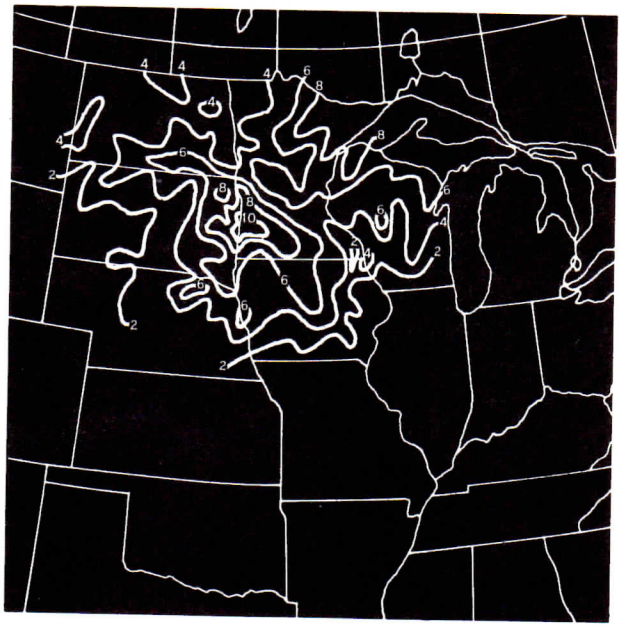


Figure 6 — Water Equivalent of Snow Cover March 14, 1969
(Inches of Water)

the area. This outlook consisted of crest stage values (two values were given—one for no further precipitation and one for normal precipitation) to be expected at some 225 points in the States of Montana, North Dakota, South Dakota, Minnesota, Wisconsin, Iowa, Nebraska, Kansas, Illinois, and Missouri. Record or near-record stages were predicted for over half of these points and major flooding was predicted for most of the remaining points. In general, the streams with the most serious flood potential were the Big Sioux, Little Sioux, James, Red, Minnesota, Upper Mississippi, and Upper Des Moines Rivers. Metropolitan areas in the paths of this potential flood, to mention only a few, were the Minnesota cities of Minneapolis, St. Paul, and Mankato; the quad cities of Moline and Rock Island, Illinois, and Bettendorf and Davenport, Iowa; Des Moines and Sioux City, Iowa; Sioux Falls, South Dakota; and Fargo and Grand Forks in North Dakota. More than 100 additional communities were in the flood path. In the aggregate, over a million residents of the area would be directly or indirectly affected.

Thirty days after this comprehensive outlook was issued by the Weather Bureau, an estimated 3,700 lineal miles of the rivers mentioned were simultaneously above flood stage. Crests had been passed at some points, and stages were rising at others. By April 16, most of the tributaries were receding; however, it would be many weeks before some of these rivers, especially the Red River, were back within their banks.

The early outlooks, and the crest forecasts of March 13, showed remarkable accuracy for all points where verification is possible. Forecast crests from the March 13 outlook and the actual crests which occurred at 51 representative points in the flood area are given in the accompanying table. Figure 7 is a scatter diagram of the forecast vs. observed crest levels for these 51 points. It is noteworthy that these crest forecasts are grouped about equally on both sides of a correct forecast represented by the diagonal line in Figure 7, indicating that the River Forecast Center was neither overly optimistic nor overly pessimistic about the expected conditions. Figure 7 also shows that the vast majority of the crest stages stand very close to the diagonal line, and that about 36 percent can be encompassed by a line representing a crest

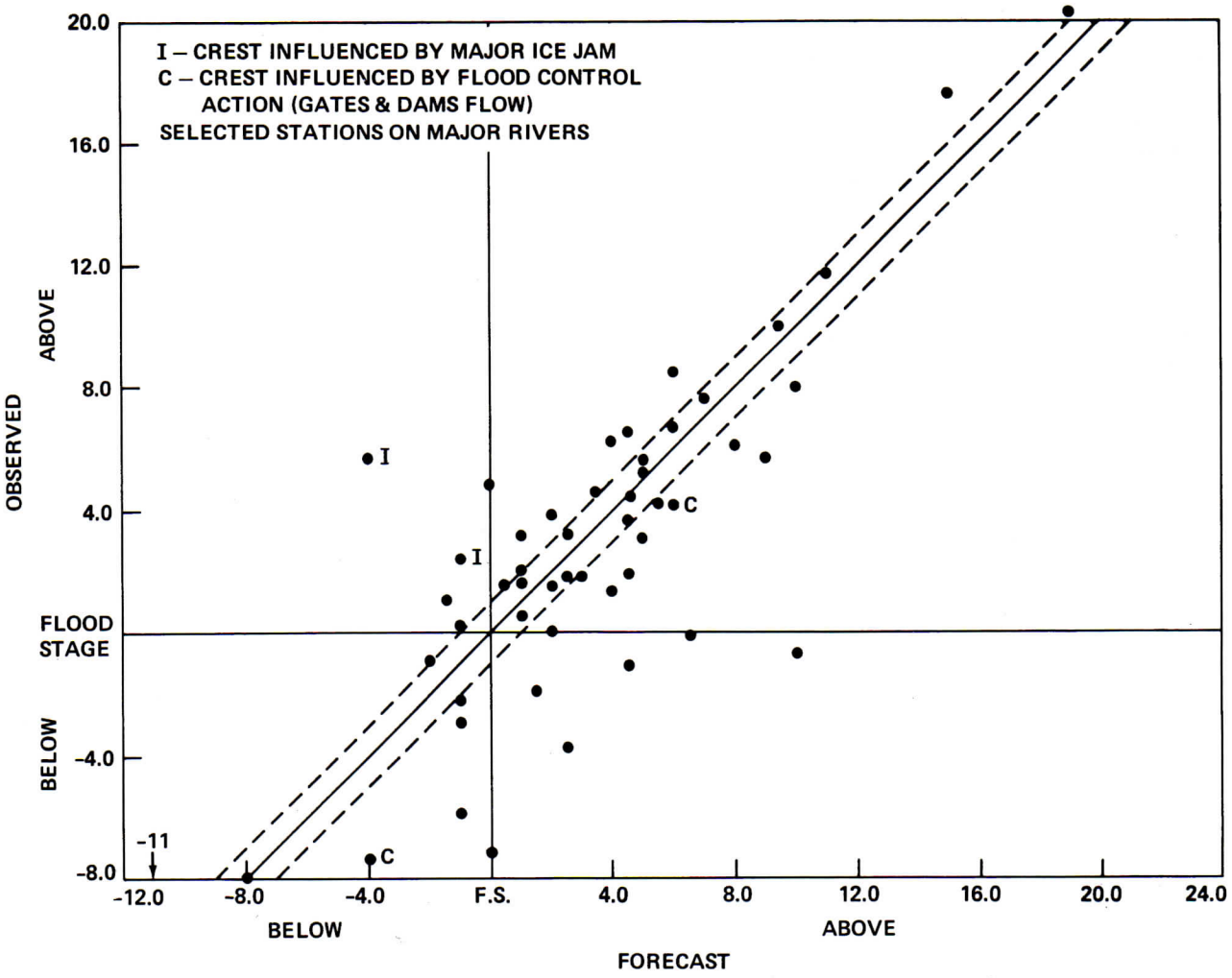


Figure 7 – Verification of March 13 Outlook (Stages Based on "No Precipitation")

stage within ±1.0 foot of the one that actually occurred.

Several of the more significant forecast errors warrant discussion. Ice jams caused crests well above those forecast at several points (indicated by "I" on Figure 7) but within the assumed values of crest variations given in the lead paragraph of the outlook. Crest values well below those forecast were observed along the Milk River in Montana, where expected flooding never materialized, and in portions of Nebraska, Iowa, and Wisconsin, where early, slow erosion of the snowpack was followed by hard freezes, permitting runoff to take place in two phases rather than one. Finally, flood control action—closing dams or opening diversion gates to avert disastrous flooding—affected some crest values (indicated by "C" in Figure 7).

Figure 8 is a second scatter diagram which shows the warning time provided by the March 13 forecast of expected crest, and is supplemented by Table I, which compares forecast and actual crests. It will be noted that the vast majority of the crests occurred in two groups: the first, one-to-two weeks after the March 13 issuance; the second, three-to-five weeks after that date. It is also important to note that the most serious flooding received the most advanced warning. This chart is also keyed to show where a flood stage was forecast to occur and did not, and conversely where one was not forecast and did occur. Again, it is noteworthy that the vast majority of the crests that were forecast above flood stage actually crested above flood stage.

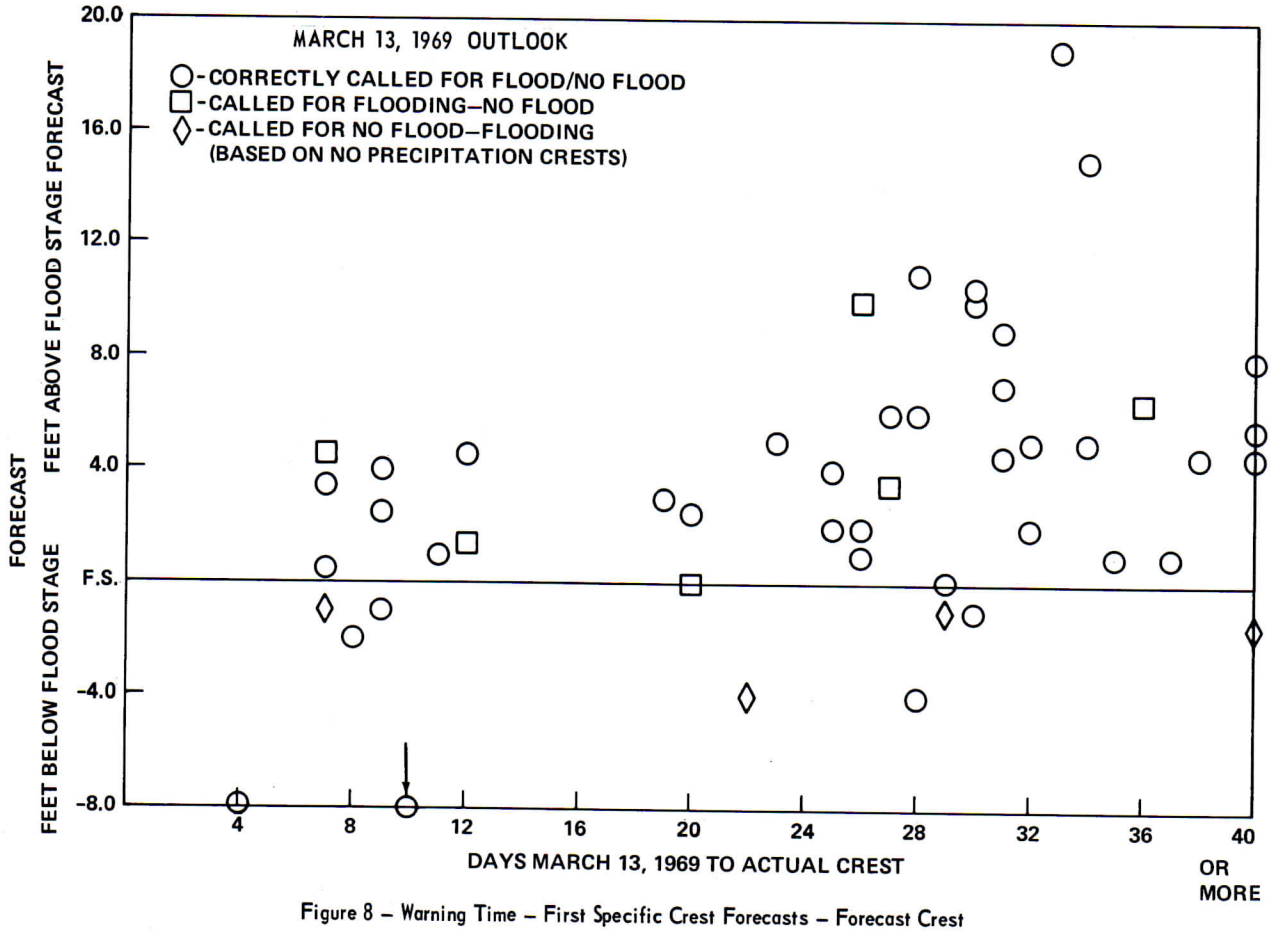


Figure 8 – Warning Time – First Specific Crest Forecasts – Forecast Crest Vs Days from March 13 to Actual Crest

These March 13 forecasts were verified and the details are shown, because they represented the single most important issuance of the River Forecast Center in the opinion of the survey team. They were the first forecasts with specific crest stages for the rivers in the flood area and provided Federal, State, and local authorities with the fundamental information they needed to determine the extent of the protection that would be required. These forecasts were updated from March 13 onward, until the river in question crested and then receded below flood stage. The survey team has reviewed all of these forecasts and has the detailed information with regard to each of them. Needless to say, considerable refinement in forecasts was possible as the weeks passed and the floods progressed to their peaks. Most of the revised key forecasts, and there were a large number of them, had a lead time of from one day to one week and verified within tenths of a foot. Considering that some of these rivers rose as much as 35 feet, this is phenomenal accuracy.

C. Special Case of the Souris River in North Dakota

Minot, North Dakota, on the Souris River, was one of the hardest hit communities in the Midwest flood area. More than 11,000 people were evacuated from their homes and were unable to return for over a month.

ESSA does not now provide river and flood services for the Souris River. The resources necessary to establish an adequate capability for forecasting this river basin have not been available.

The fact that ESSA did provide a minimal service in this critical area can be attributed to the alertness of people like Vern Hendrickson, MIC, Fargo; Keith Blessum, Field Aide, Fargo; Herman Stommel, MIC, Bismarck; Ray Jensen, State Climatologist for North Dakota; and Elroy Balke, Assistant Regional Hydrologist, Central Region. Through the efforts of these people, enough information was gathered and passed on to the Corps of Engineers and the Department of the Interior's Fish and Wildlife Service in the area to provide advance warning of the coming floods to the residents of Minot, North Dakota.

The pertinent events at Minot date from about March 6. On that date, Elroy Balke, Assistant Regional Hydrologist, Central Region, Weather Bureau, telephoned Mr. Stommel, MIC, Bismarck, to advise him of the serious flood potential in the Souris River Basin. Mr. Stommel released this information to the Governor of North Dakota and various news media the same day. The first flooding at Minot did not occur until April 10, over a month later, and was due primarily to a dike failure. The crest at that time was 17 feet. Flood stage at Minot is 14 feet. On April 12, Mr. Balke conferred with Mr. Tiemens, Corps of Engineers, at Minot and with the Fish and Wildlife Service, and agreement was reached to release a forecast of a second crest of 22 feet for Minot, with a crest date of about April 19. A joint release by the U.S. Army Corps of Engineers, the Bureau of Sport Fisheries and Wildlife Service, and the ESSA Weather Bureau on April 19 reported a crest on that date of slightly over 20 feet or about 6 feet above flood stage.

The following is a quote from a flood "special" on TV in North Dakota on April 17, 1969: "The Weather Bureau warned that near-record floods could be expected in the Red River Valley and eastern North Dakota and western Minnesota. It warned of moderate flooding on such western Missouri rivers and tributaries as the Cannon Ball, the Knife, and the Heart. It predicted probable flood forecasts with remarkable accuracy, but it is ironic that probable crests on the DuLac and Souris Rivers could not be predicted with equal accuracy. The Weather Bureau has never been given the responsibility for keeping records on these two rivers, an omission which public officials can probably be expected to look into in view of this year's flood situation. Actually, the Weather Bureau did go beyond its responsibility and issue warnings that flooding could be expected at Minot, even though lack of records made it difficult to come up with precise predictions but the warning did serve a purpose. They gave ample opportunity for preparation, and prepare North Dakotans did. Thanks to the warning, and to the preparation, the loss has been largely economic. There has been no report of loss of life, and human suffering has been held to a minimum."

The State of North Dakota is rightfully concerned over the fact that a record flood of disastrous proportions has occurred in an area of the State not covered by ESSA's River and Flood Forecast Service. The North Dakota State Water Commission has sent a letter to the Secretary of Commerce enclosing a resolution passed by that body regarding flood forecasting in the Souris River Basin. The resolution, signed by Governor William L. Guy (the Governor is Chairman of the Commission), notes the disastrous flooding in the Souris River Basin and requests the Department of Commerce to provide flood forecasting services. The resolution noted the "excellent services rendered the people in the Red River Valley through flood forecasting." A *prelim-*

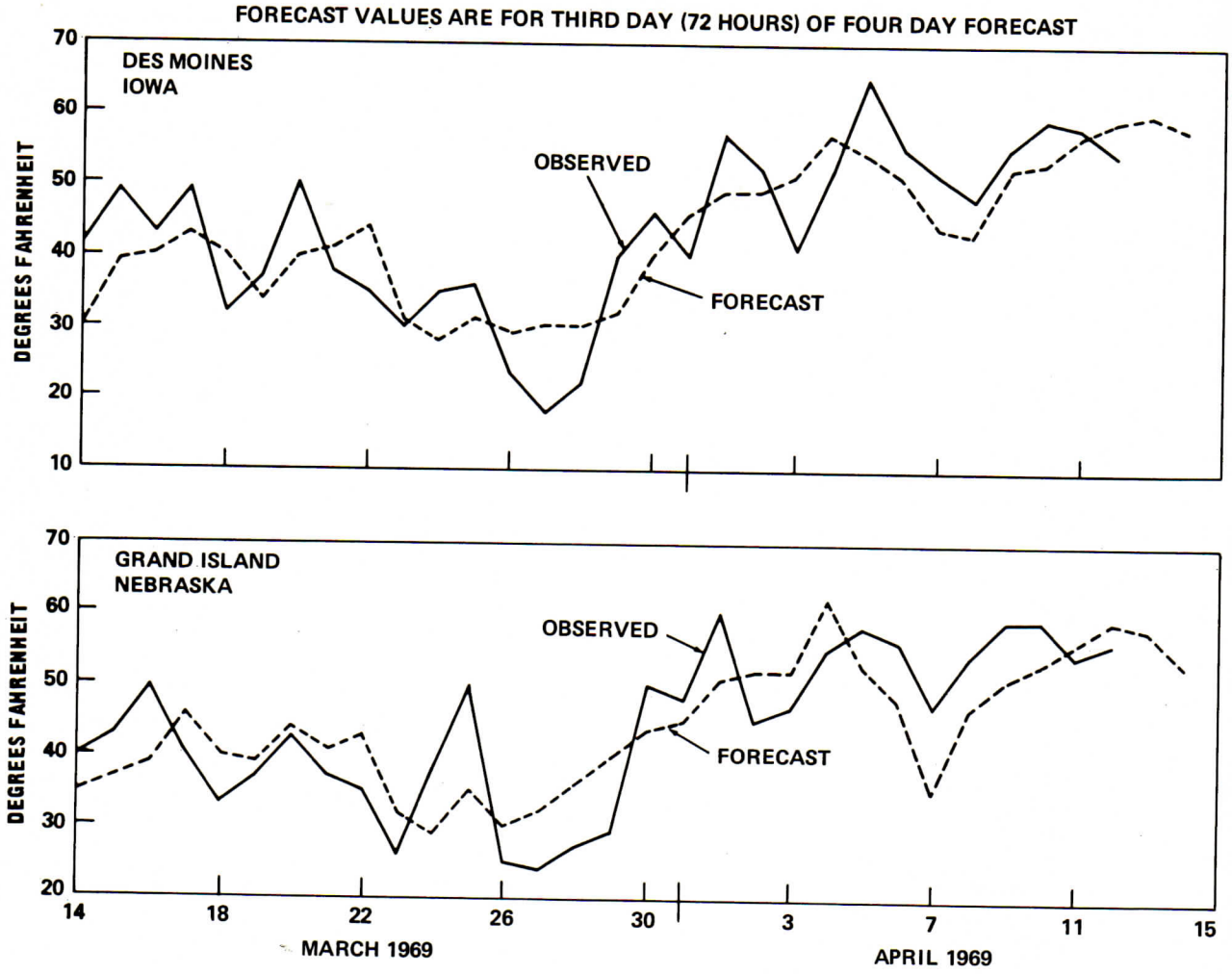


Figure 9a — Verification of Special Daily Mean Temperature Forecasts from NMC
(Data Supplied by Central Region Headquarters)

inary estimate of the costs to ESSA of taking such an action follows: a) $30,000 for the first year for establishment of a network of observations and development of forecast procedures; and b) $15,000 per year thereafter for support of the network and for forecast activities at the RFC.

In view of the seriousness of the flooding in the Minot area, and the concern of public officials in North Dakota, it would be advisable to undertake immediately, through reprogramming action, the establishment of routine service for the Souris River. ESSA should release a statement of its intentions through the Governor and the Congress as soon as possible.

The survey team's recommendations with respect to the Souris River are made with the full realization that there are other critical areas in the United States for which we do not now have a forecast capability. Some particular vulnerable areas include rivers in southern Michigan, northern Minnesota, and Colorado. Recognizing that it is difficult to assess the flood potential of rivers, it still would be desirable if the Director, Weather Bureau, were to list the major tributaries in the United States in order of their vulnerability to serious flooding for which ESSA does not now have a forecast capability. The list should be accompanied by an estimate of the resources necessary to develop a service for each river.

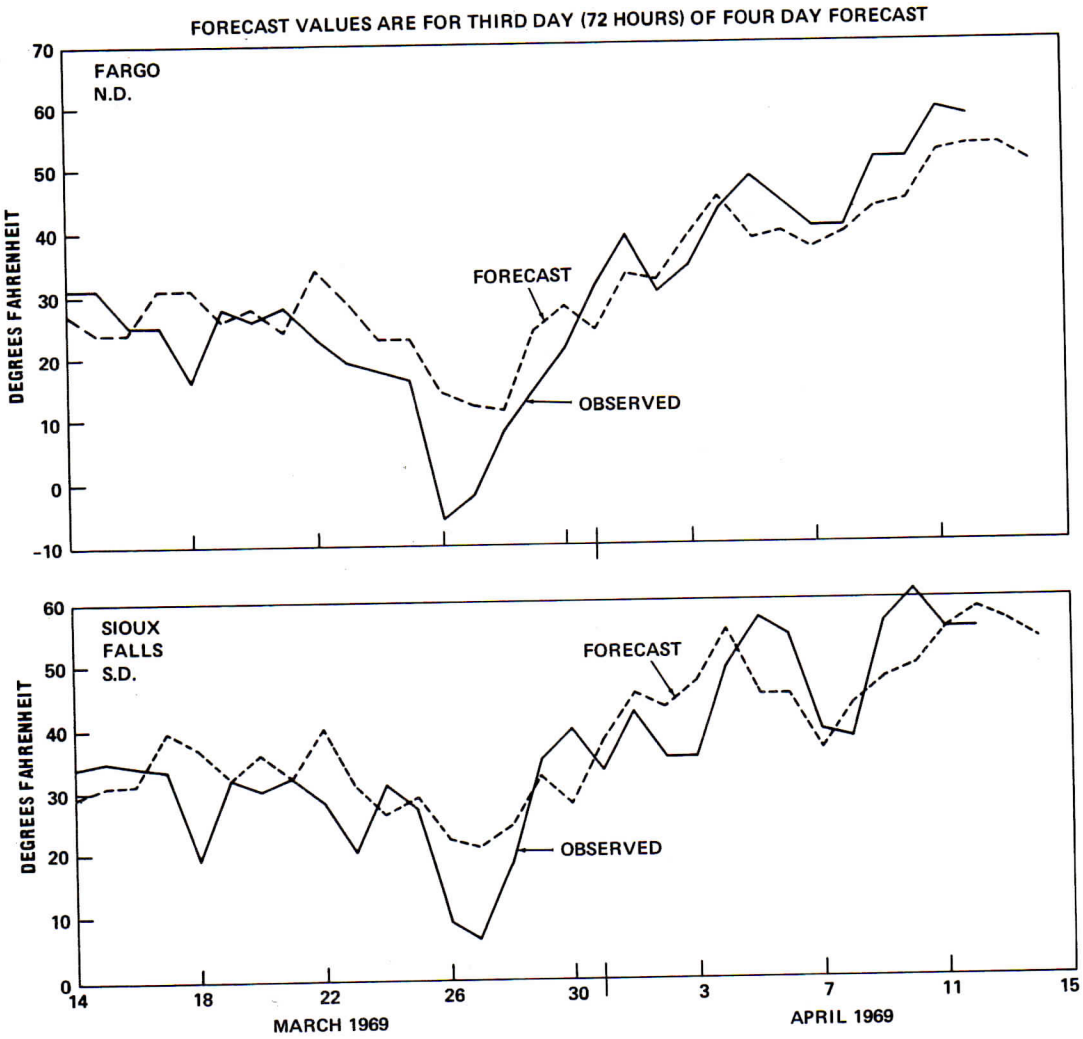


Figure 9b – Verification of Special Daily Mean Temperature Forecasts From NMC
(Data Supplied by Central Region Headquarters)

D. Special Products Provided by the National Meteorological Center

As mentioned in Chapter III, one of the preparatory actions taken within ESSA was to arrange for special daily issuance by the National Meteorological Center of four-day predictions of temperature and quantitative precipitation. Advance knowledge of these two parameters was absolutely vital to accurate crest predictions. Initially, the River Forecast Center staff used the temperature forecasts as they were received from the National Meteorological Center. As they became familiar with the product, they found that it was good with respect to areas without snow cover, but because it did not adequately take into consideration areas with snow cover, it was necessary to temper somewhat the forecasts for such areas. Temperature ceased to be a factor in the flood forecasts in mid-April, and the NMC forecasts of this element were terminated at that time. The quantitative precipitation forecasts were furnished and used until May 5. Attached are Figures 9 and 10 showing how the two products from NMC verified during the period in which they were used.

Figure 9 shows the mean daily temperature forecast for the third day of the four-day forecast period, plotted against the observed mean daily average temperature for Des

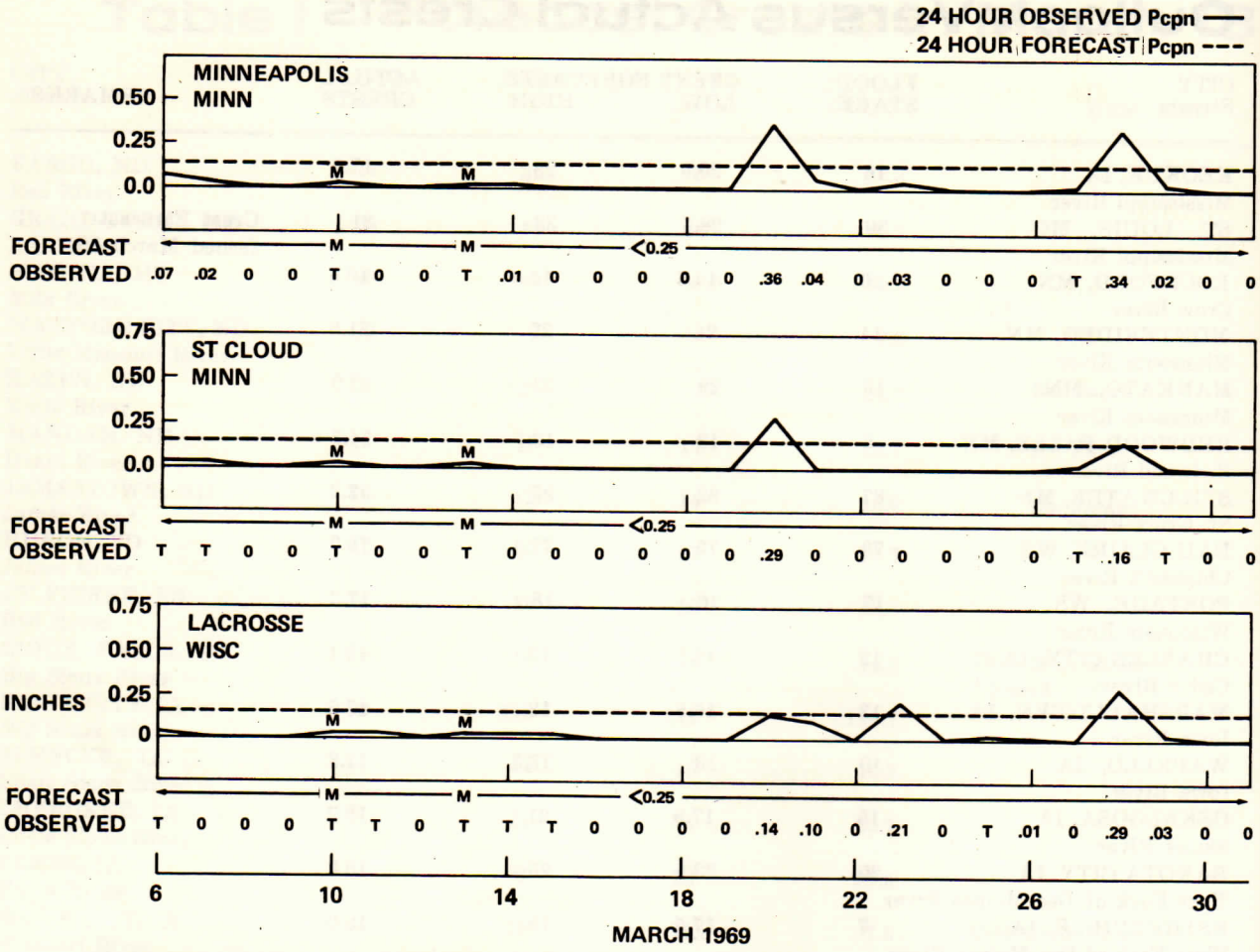
Table I — Forecast Crests In March 13

CITY Stream	FLOOD STAGE	CREST FORECASTS LOW	HIGH	ACTUAL CRESTS	REMARKS
FARGO, ND Red River	17	36	38	37.3	
GRAND FORKS, ND Red River	28	43	46	45.7	
NASHUA, MT Milk River	20	30	31.5	19.3	
WATFORD CITY, ND Little Missouri River	20	9	12	8.0	
HAZEN, ND Knife River	21	23	25	24.9	Ice Jams
MANDAN, ND Heart River	17	13	17	22.7	Ice Jams
JAMESTOWN, ND James River	12	12	14	16.9	Ice Jams
HURON, SD James River	11	20	21	16.7	
FT PIERRE, SD Bad River	16	15	19	13.1	
SIOUX FALLS, SD Big Sioux River	10	16	18	14.2	Diversion Gates Opened
SIOUX CITY, IA Big Sioux River	99	110	112	110.7	
SPENCER, IA Little Sioux River	10	14	15	16.2	
CHEROKEE, IA Little Sioux River	17	24	25	23.7	
JAMES, IA Floyd River	16	21	22	21.6	
SIOUX CITY, IA Missouri River	16	12	15.5	7.5	Discharge From Gavin's Point Dam Reduced
OMAHA, NB Missouri River	19	18	22	16.8	
KANSAS CITY, MO Missouri River	22	21	27	16.1	
GLASGOW, MO Missouri River	25	26	30.5	25.5	
ST. CHARLES, MO Missouri River	25	26	30	27.9	
ST PAUL, NB North Loup River	5.5	6.5	7	7.5	
COLUMBUS, NB Loup River	10	10	12	13.4	Ice Jams
GRAND ISLAND, NB Platte River	3.5	4	5	5.1	
LACROSSE, WS Mississippi River	12	16.5	18	15.7	
DUBUQUE, IA Mississippi River	17	25	27.5	23.1	
DAVENPORT, IA Mississippi River	15	20.5	23.5	19.2	

Fifty-one Cities Selected to Give Representative Coverage of River Basins
Low Forecast Crests Based on "No Precipitation"
High Forecast Crests Based on "Normal Precipitation"

Outlook Versus Actual Crests

CITY Stream	FLOOD STAGE	CREST FORECASTS LOW	 HIGH	ACTUAL CRESTS	REMARKS
KEOKUK, IA Mississippi River	16	20.5	23	17.9	
ST. LOUIS, MO Mississippi River	30	28.5	33	31.1	Crest Forecast Issued March 20
ROCKFORD, MN Crow River	10	14.5	16.5	16.5	
MONTEVIDEO, MN Minnesota River	14	21	22	21.6	
MANKATO, MN Minnesota River	19	29	32	27.0	
REDWOOD FALLS, MN Redwood River	6	12	13	14.5	
STILLWATER, MN St. Croix River	87	92	95	92.2	
EAU CLAIRE, WS Chippewa River	73	75	77	73.0	
PORTAGE, WS Wisconsin River	17	16	18	17.2	
CHARLES CITY, IA Cedar River	12	13.5	17	10.1	
MARSHALLTOWN, IA Iowa River	13	16.5	18	17.6	
WAPELLO, IA Iowa River	10	13	16.5	11.8	
OSKALOOSA, IA Skunk River	15	17.5	21	18.2	
DAKOTA CITY, IA East Fork of Des Moines River	20	23.5	25	16.3	
ESTHERVILLE, IA West Fork of Des Moines River	7	17.5	19	18.0	
DES MOINES, IA Des Moines River	23	29.5	32	22.9	
OTTUMWA, IA Des Moines River	10	11	....	11.6	No High Crest Issued
VAN METER, IA Raccoon River	13	17.5	20.5	17.4	
GARBER, IA Turkey River	17	21.5	26.5	15.9	
LINCOLN, NB Salt Creek	20.5	12.5	16.5	12.5	
BLUE RAPIDS, KS Big Blue River	1101	1105	1113	1102.3	
PIERCE, NB North Fork of Elkhorn River	12	14.5	15.5	13.8	
WEST POINT, NB Elkhorn River	12	10	11	11.1	
WATERLOO, NB Elkhorn River	15	15	17	7.4	
FT RIPLEY, MN Mississippi River	10	15	16	13.1	
MINNEAPOLIS, MN Mississippi River	16	18	20.5	17.5	



OBSERVED TRACES TREATED AS≈.02

FORECAST VALUES INTERPOLATED FOR STATIONS FROM NMC GRAPHIC FORECAST.

FORECASTS VALUES ARE FROM THIRD DAY OF FORECAST. FOR EXAMPLE: VALUES FOR 7th TAKEN FROM FORECAST ISSUED MARCH 4.

FORECASTS FOR LESS THAN 0.25 INCHES (<0.25) FOR 24 HOURS PLOTTED AS 0.15.

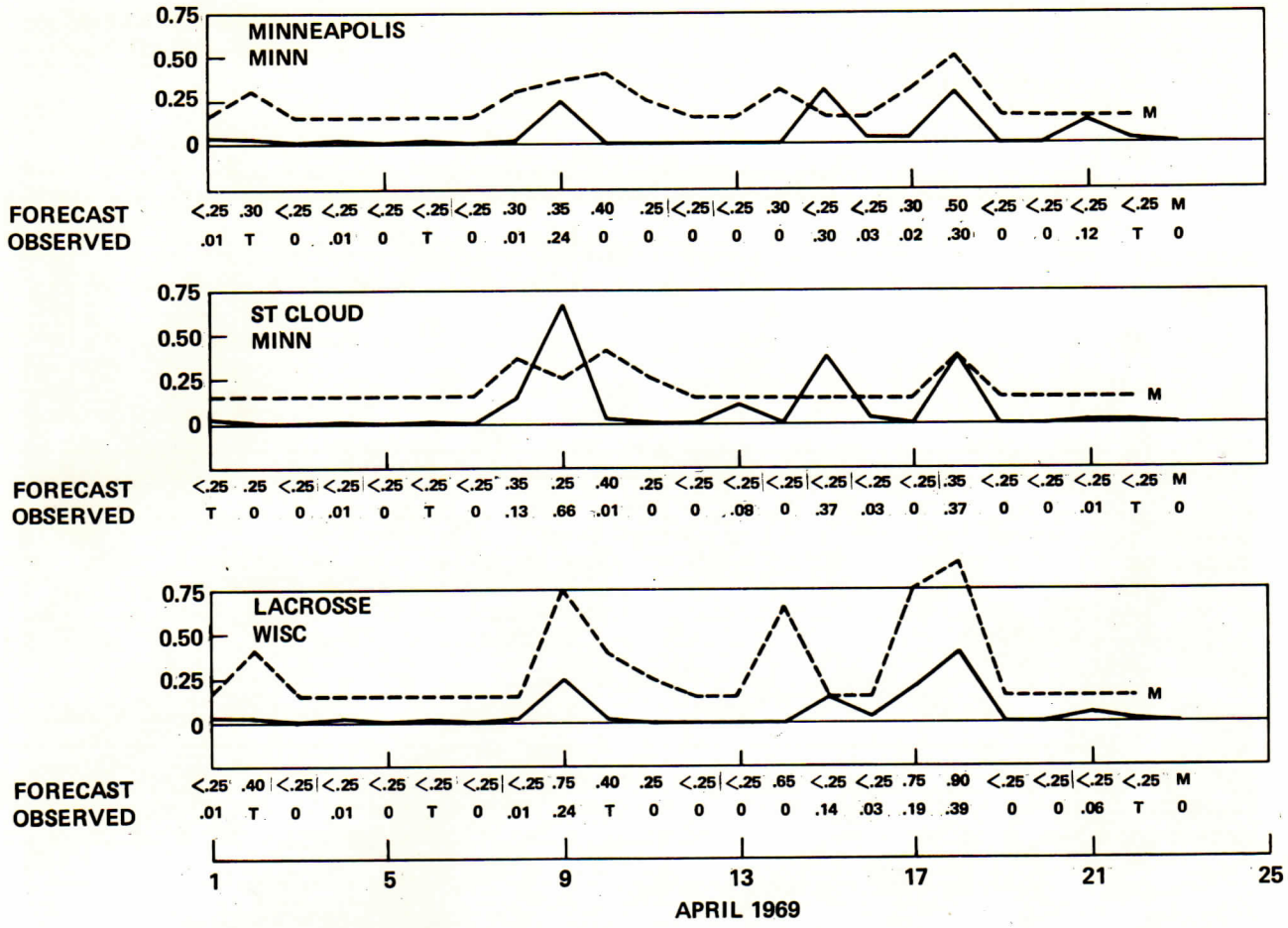
Figure 10a — Verification of Special QPF Forecasts from NMC (Data Supplied by Central Region Headquarters)

Moines, Iowa; Grand Island, Nebraska; Fargo, North Dakota; and Sioux Falls, South Dakota. Examination of the figure verifies the River Forecast Center's statement that the forecasts were good in areas without significant snow cover (Des Moines and Grand Island), but were somewhat too warm in areas having a heavy snow cover (Sioux Falls and Fargo until early April).

Figure 10, showing 24-hour quantitative precipitation forecasts (QPF) versus 24-hour observed precipitation for Minneapolis, St. Cloud, and La Crosse, is also based on the third day of the four-day forecast period. During March, the NMC QPF values did not indicate precipitation of 0.25 inch to 0.35 inch on the 20th and 28th, but otherwise quite accurately called for well-below-normal precipitation. During April, the QPF values were again quite good for Minneapolis and St. Cloud, but indicated significantly too much precipitation for La Crosse in terms of numbers of precipitation days and total amounts.

E. Summary

There is no question in the minds of the survey team that *ESSA's River and Flood Forecast Service did an outstanding job during the current Midwest flood emergency. Forecasts were issued well in advance in almost all cases*



See Figure 10a for Notes and Explanation

Figure 10b — Verification of Special QPF Forecasts from NMC
(Data Supplied By Central Region Headquarters)

and with an extraordinary degree of accuracy insofar as flood stage and crest heights were concerned.

The manner in which the forecasts were issued is commendable. From the very beginning, the outlooks and warnings were accompanied by clear statements of the assumptions on which they were based, and these assumptions were consistently restated during the period of the flooding. It was extremely important that Civil Defense, Corps of Engineers, and local authorities clearly understand these assumptions because, if they did not hold true, crest forecasts could be expected to depart markedly from actual conditions. The assumptions were: 1) melt proceeds at a moderate rate; 2) much slower melt rates would give lower crests and, conversely, much faster melt rates would give higher crests; 3) melting is not accompanied by rainfall (warm rains during the melt period would, of course, result in higher crests); 4) crests could be augmented from 3 to 5 feet by ice jams at those points frequently subjected to severe ice action.

These assumptions proved to be generally correct throughout the period of flooding, with the result that the crest forecasts were exceedingly good. The value of the flood forecast service of ESSA was stated and restated to the survey members many times by Corps of Engineers personnel, State Civil Defense Di-

"Kid power" was the Midwest's secret weapon against the 1969 Spring floods. Here, high school and college students sandbag the Northern State Power Company at Minot, N.D., to protect it from the raging Souris River.
American Red Cross photo by Jack Shere

rectors, local authorities, and field Weather Bureau personnel.

The members of the survey team are satisfied that the March 13 forecast served to alert the whole area to the seriousness of the situation and provided State, Federal, and local officials with the essential information on which to proceed with preparatory action. Because of the long lead time, some of these early actions took the form of stockpiling materials for emergency levees. Where there was little question that the predicted crests would be achieved, actual levee construction was initiated. Had the assumptions been wrong, in either direction, the many agencies taking preparatory actions would have adjusted their actions accordingly and would have had sufficient time to do so.

As a result of the performance of the River and Flood Forecast Service of ESSA during this 1969 snowmelt flood, there is a strong respect and trust on the part of the people involved in the quality of this service.

Chapter V
Floods of Record

The current Midwest snowmelt flood is compared in this chapter with similar record flooding that occurred in the same general area in 1952 and 1965. In all three cases, the major cause was snowmelt runoff.

In Table II, 46 points representative of the 225 included in the Kansas City River Forecast Center forecast of March 13 are compared with 1952 and 1965. The record year among the three is underlined. "X" in a year column indicates that flood stage was not reached in that particular year. "#" indicates that there was no gage installed at that location in 1952.

It is probably neither possible nor useful to draw a conclusion as to whether any given year represents an overall record with respect to flooding. Damage is certainly no criterion, because damage can be greatly reduced by permanent works of the Corps of Engineers (such as the six dams on the main stem of the Missouri River) and by temporary works made possible by accurate and timely ESSA forecasts of flood conditions. Both permanent and temporary works were major factors in reducing damages in the current flood. Water-equivalent of snow on the ground is probably as good a basis for comparison of potential flooding among record and near-record years. The comparison between 1965 and 1969 was given in Chapter IV in Figures 5 and 6.

Another approach is to consider the amount of water carried by each river. The U.S. Geological Survey is quoted as stating that in the Midwest flood areas some of the rivers were carrying two-and-one-half times the water they carried during the worst floods ever recorded in the Midwest in previous years.

For these reasons, it is not useful to attempt to make a judgment as to whether the 1969 floods were greater than those of either 1965 or 1952. There is no question in the minds of the survey team and of officials in the flooded areas that 1969 will go down as one of the record floods of the century. The crest stage information gives some idea of where records did occur in 1969 and in the other two record years shown. All of the record crests for the Missouri River occurred in 1952. The Missouri will probably never again have crests of these magnitudes at the points indicated because of the main-stem dams built since 1952 by the Corps of Engineers. In other areas, many record crests were set in 1969, and record crests are likely in future years.

From ESSA's standpoint, the most important fact is that Federal, State, and local officials were alerted to record and near-record floods over a vast area, and the subsequent flooding verified this forecast as remarkably accurate.

Red River flood waters force cattle to a tiny island of high ground near Bismarck, N.D.
Mandan *Morning Pioneer* photo

Table II — Crest Stage Comparisons of 1965 and 1952

	Flood Stage	Crests 1969	1965	1952
Red River				
Fargo, N. D.	17	**37.3**	30.5	34.7
Grand Forks, N. D.	28	**45.7**	44.9	**33.6**
Milk River				
Nashua, Mont.	20	X	20.0	**31.4**
Knife River				
Hazen, N. D.	21	24.9	X	**25.8**
Heart River				
Mandan, N. D.	17	22.7	X	**25.8**
James River				
Jamestown, N. D.	12	**16.9**	X	X
Huron, S. D.	11	**16.7**	X	15.2
Bad River				
Ft. Pierre, S. D.	16	X	X	**27.2**
Big Sioux River				
Sioux City, Ia.	99	**110.7**	X	#
Sioux Falls, S. D.	10	14.2	X	**14.5**
Little Sioux				
Spencer, Ia.	10	16.2	**17.2**	#
Cherokee, Ia.	17	23.7	**27.2**	X
Floyd River				
James, Ia.	16	**21.6**	20.2	20.3
Missouri River				
Sioux City, Ia.	16	X	X	**24.3**
Omaha, Neb.	19	X	X	**30.2**
Kansas City, Mo.	22	X	X	**30.6**
Glasgow, Mo.	25	25.5	X	**32.0**
St. Charles, Mo.	25	27.9	26.9	**31.8**
North Loup River				
St. Paul, Neb.	5.5	**7.5**	6.8	X
Loup River				
Columbus, Neb.	11	**13.4**	X	X
Platte River				
Grand Island, Neb.	3.5	**5.1**	X	4.7
Big Blue River				
Blue Rapids, Ks.	1101	1102.3	**1105.9**	X
North Fork, Elkhorn River				
Pierce, Neb.	12	**13.8**	X	#

X Below Flood Stage.
No gage installed in 1952 at this location.
The above locations are the same as those for which verifications were presented in Figures 7 and 8, except that locations which did not flood in any of the three years are not listed. The year having the highest stage is underscored.

of 1969 Flood with Record Flooding in the Same Area

	Flood Stage	Crests 1969	1965	1952
Mississippi River				
La Crosse, Wisc.	12	15.7	**17.9**	15.3
Dubuque, Ia.	17	23.1	**26.8**	22.7
Davenport, Ia.	15	19.2	**22.5**	18.6
Keokuk, Ia.	16	17.9	**22.1**	18.9
St. Louis, Mo.	30	31.1	X	**33.8**
Ft. Ripley, Minn.	10	13.1	**13.6**	12.2
Minneapolis, Minn.	16	17.5	16.6	**19.5**
Crow River				
Rockford, Minn.	10	16.5	**19.3**	16.2
Minnesota River				
Montevideo, Minn.	14	**21.6**	16.6	20.0
Mankato, Minn.	19	27.1	**29.1**	24.8
Redwood River				
Redwood Falls	6	14.6	**15.9**	11.8
St. Croix River				
Stillwater, Minn.	87	92.2	**94.1**	89.7
Chippewa River				
Eau Claire, Wisc.	773	773.0	X	X
Wisconsin River				
Portage, Wisc.	17	17.2	**18.4**	X
Cedar River				
Charles City, Ia.	12	X	**21.6**	#
Iowa River				
Marshalltown, Ia.	13	**17.6**	16.5	14.0
Wapello, Ia.	10	11.8	**17.3**	10.3
Skunk River				
Oskaloosa, Ia.	15	18.2	**19.9**	16.6
West Fork, Des Moines R.				
Estherville, Ia.	7	**18.0**	15.6	11.8
Des Moines River				
Des Moines, Ia.	23	X	**28.7**	X
Ottumwa, Ia.	10	11.6	**18.3**	10.3
Raccoon River				
Van Meter, Ia.	13	17.4	**18.2**	14.8
Elkhorn River				
Waterloo, Neb.	15	X	**15.5**	X

Dikes protect Fargo's City Hall as rising flood waters approach their highest point.
Fargo *Forum* photo by Jack Anderson

Chapter VI
Flood Damages and Cost Benefit Aspects of Preventive Measures

This chapter touches on preliminary and incomplete estimates of damages, economic losses, dislocations, and deaths attributable to the current flooding. It discusses in greater detail the preventive actions taken to avert or minimize these effects and provides some specific data regarding the benefit-to-cost ratio of taking preventive actions in advance of serious flooding.

A. Damages

The Corps of Engineers is compiling such information for submission to the Office of Emergency Preparedness, Executive Office of the President. Complete information could not be compiled at the time of this report because flooding still existed and some rivers would not be within their banks for several weeks.

It is possible, however, to get some general indication of the extent of damage, economic losses, dislocations, and deaths from preliminary reports of Federal and State agencies and newspaper accounts. Flood damage this spring is currently estimated by the Office of Emergency Preparedness to be more than $100 million. Damages in Minnesota alone were estimated to be over $70 million. North Dakota estimates $28 million thus far with $11 million in damages in the Minot area alone. Some of the major cities which suffered serious flooding included Moorhead, Minnesota; Minot, North Dakota; Sioux City, Iowa; Jackson, Minnesota; and Cherokee, Iowa. There were, of course, many others. In addition, more than a million acres of farmland have been inundated, with the result that crop planting will be delayed in many areas and may not be possible at all this year in others.

Preliminary figures provided by the American Red Cross indicate that more than 25,000 people have had to leave their homes. The Red Cross has served over 250,000 meals to displaced persons, rescue personnel, and people working on levees.

Loss of life in the flood area has been exceptionally light. The team was informed of ten deaths directly caused by the floods.

B. Preventive Measures Taken

Measures taken to prevent serious flooding are of two general types. The first involves permanent works, usually under the sponsorship of the Corps of Engineers, although State and local agencies, and even private individuals do some of this work. The main-stem dams and associated reservoirs on the Missouri River are the most striking example of permanent works that played a major role in this year's flooding. General Cannon, the Commander of the Omaha Division of the Corps of Engineers, advised members of the survey team that current estimates show that these dams held back about 6 million acre feet of water from snowmelt—water that would otherwise have moved down the Missouri in the form of flooding. The reservoirs created by these dams currently contain more water than they have ever held.

Throughout the area, one result of the 1969 flood is a revival of interest in long-range solutions to the flood problem. Many families had not recovered financially from the 1965 flood. According to the April 4, 1969, bulletin of the U.S. Corps of Engineers entitled *"Operation Foresight*—Preparing for Flood Emergencies," the Corps of Engineers operates six reservoirs in the head of the Mississippi River

which, although authorized to assist navigation, are now used for many purposes including flood control. However, the flood-control storage is limited, and the headwaters reservoirs had little effect on reducing flood flows except immediately downstream. The St. Paul District also reports that during the four years since the 1965 floods, the District completed levee and floodwall projects at South St. Paul, Winona, and Rushford, Minnesota and a reservoir on the Eaugalle River in Wisconsin.

As 1969 has shown dramatically, preventive measures of a temporary nature can play a major role in reducing flood damages, *when accurate predictions of flood conditions are made known well in advance of actual flooding.* ESSA's river and flood forecasting service met that need, and as a result temporary measures were very extensive and highly effective.

The following extract from the April 4, 1969, bulletin by the Corps of Engineers, summarizes very well the nature and extent of the preventive measures taken:

> "The Army's Corps of Engineers has obligated $11 million to date for 'Operation Foresight,' the major effort by Federal agencies launched by President Nixon on March 1 to reduce or alleviate threatened flood damage. The Corps' total program of committed, scheduled, or anticipated 'Foresight' activities is presently estimated at something over $15 million.
>
> "This Federal activity supplements a much greater effort undertaken by non-Federal interests. The role of the Corps of Engineers and other Federal agencies is basically to support activities initiated and largely carried out by States and communities. The entire program is coordinated by the Office of Emergency Preparedness. Most of the authority given them by Public Law 99, which authorizes the Corps to spend money for emergency flood-fighting activities.
>
> "More than 300 localities in 25 States are involved to date in the Army Engineers' part of the Emergency construction effort. In addition, scores of other communities have been advised or assisted by Army flood-fighting experts in the design or carrying-out of their own preparations. The great bulk of the activity—*almost $9 million* of the $11 million obligated to date—is in the northern Midwest, including the upper Mississippi River basin, the Red River of the North, and some tributaries of the Missouri.
>
> "*Some $4 million* are being invested by the Corps in about 100 miles of emergency levee that are being provided or strengthened in the upper Mississippi Valley. Inspection along the main river yesterday revealed the emergency levee work to be about 60 to 70 percent complete. Barring unexpectedly sudden flooding, this levee work should be finished in time to meet the threatened emergency.
>
> "Other kinds of activity carried out under 'Operation Foresight' include the removal of obstructions from channels; breaking up ice and log jams; flood-proofing riverbank facilities; checking the operability of old private dams; helping open inlets and outlets to natural lakes; establishing emergency operations centers; stockpiling and distributing sandbags, polyethylene sheets, lumber, radios, pumps, wire, and other flood-fighting supplies; setting up channels of communication with the Red Cross and other disaster-relief agencies; leasing heavy construction and earth-moving equipment, procuring hired labor for emergency work; and mobilizing experienced flood fighters from all parts of the country into the threatened area."

The Corps of Engineers also employed a technique designed to aid in ice removal. The following is a quote from a report by the St. Paul District of the Corps, dated 15 April 1969, subject *"Operation Foresight,* 1969," which states: "Dusting of ice with dark inert material was initiated in this district in 1966. The technique has proven generally effective in accelerating the weakening of ice sheets, thus aiding in ice removal." The Corps also employed other new techniques in flood protection such as: widespread use of plastic sandbags and plastic film to cover levees, application of urethane foam to temporary levee structures, and low-cost, high-volume irrigation pumps that can be used with farm tractors.

In addition to the major assistance provided under the direction of the Corps, considerable effort was devoted to preventive measures by State and local authorities and private indi-

viduals. These measures included moving property to high ground, and building individual levees to protect businesses and homes. One of the major efforts involved the use of boxcars to move grain from elevators in the path of the floods. The Department of Agriculture reported that 4.5 million bushels of grain (over $6 million worth) were removed from the plains of the Red River of the North between the Canadian border and Moorhead, Minn. All of this was accomplished through local advanced planning and the joint cooperation of Civil Defense, the Department of Agriculture, the Interstate Commerce Commission, and the railroads.

C. Benefit-to-Cost Ratio of Preventive Measures

Accurate and timely forecasts of impending flood situations do not, in themselves, produce any direct benefit; forecasting a flood won't prevent it from occurring. The value of such forecasts lies in the opportunities they provide for taking preventive measures to avoid the certain consequences of flooding. ESSA has demonstrated conclusively that accurate warnings are possible well in advance of serious flooding. It then remains necessary only to show that the benefits derived from taking preventive measures exceed the cost of such measures.

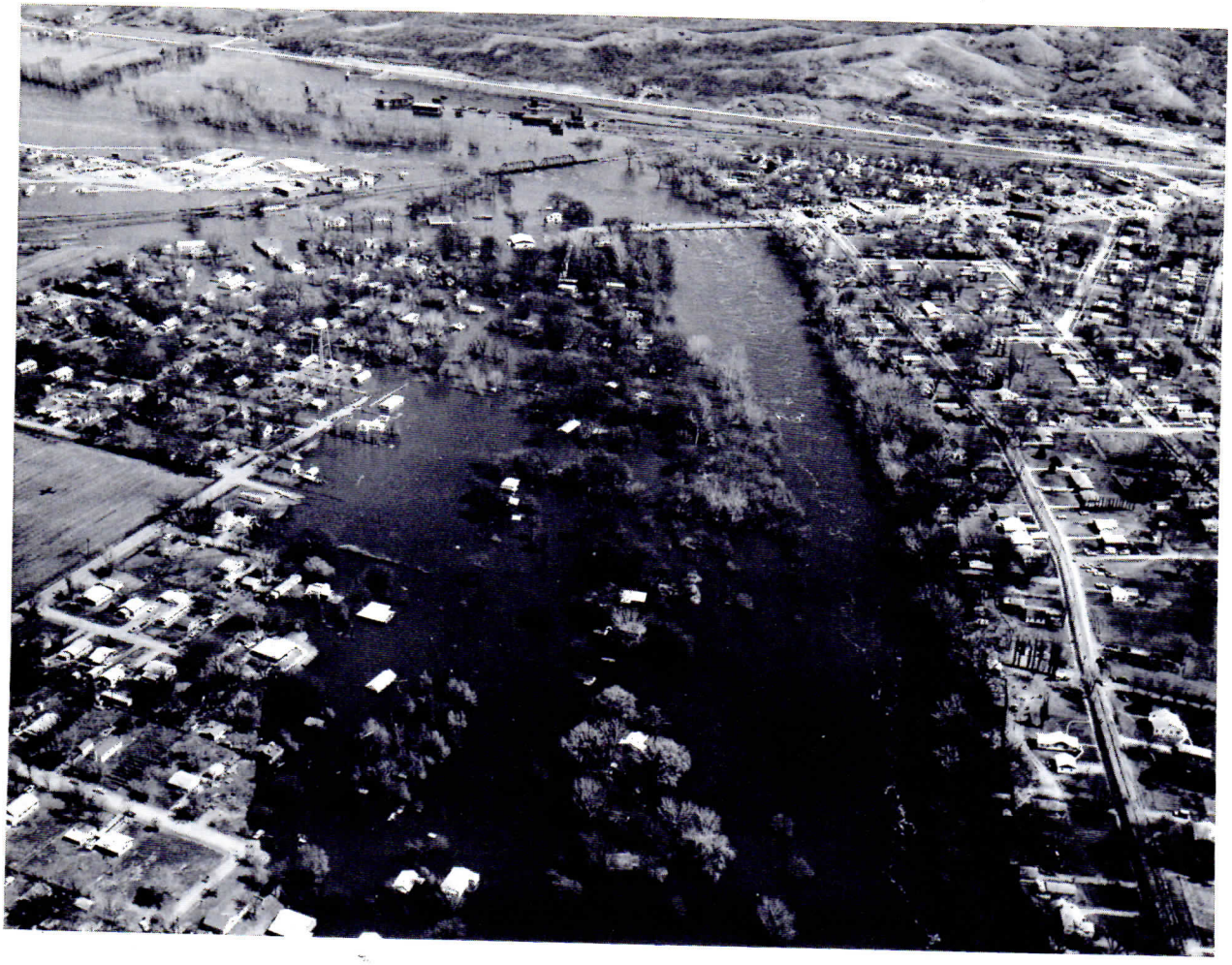
There are many illustrations in the current flood situation which prove conclusively that the benefit-to-cost ratio of preventive actions with respect to serious flooding is extremely favorable. The Corps of Engineers is amassing official figures that will answer this question in time for the Midwest flood area as a whole. It is, however, possible to provide some interim data illustrative of the benefit-to-cost ratios that have been obtained in the recent floods.

Major General Frederick J. Clarke, the Army's Deputy Chief of Engineers, stated on May 8 that *Operation Foresight* preparations had prevented an estimated $230 million in flood damages. Sixteen million dollars of PL–99 funds were made available under *Operation Foresight,* thus providing a benefit-to-cost ratio of more than 14 to 1. The State of Wisconsin is quoted in the newspapers as stating that early warnings and levee work, including $560,844 in aid from the Corps of Engineers, prevented $145 million in damage. Wisconsin spent an estimated $4 million of its own funds. The cost-to-benefit ratio based on these figures would be about 32 to 1. The Rock Island District of the Corps estimates that within its area an outlay of about $1,625,800 prevented damages approaching $46,360,000, a benefit-to-cost ratio of about 29 to 1.

The May 4 issue of the New York *Times* quotes officials of the Office of Emergency Preparedness, Executive Office of the President, as estimating that flood damage would have run three times or more the unofficial estimate of $100 million had it not been for the Government's preventive measures.

A very specific example of cost-to-benefit operating in reverse occurred in Cherokee, Iowa. Quoting from the April 9 bulletin of the U.S. Army Corps of Engineers: "At unprotected Cherokee, Iowa, 200 people have been evacuated as flood waters spread over 25 blocks and reached 4 feet deep around some homes. The National Guard troops are on duty there to prevent looting. The river is expected to remain in flood at Cherokee for several days (contacted on March 10, regarding a possible 'Operation Foresight' emergency dike, city officials reported that the necessary rights-of-way could not be obtained because too many private land owners were involved. The 'Operation Foresight' job would have cost an estimated $90,000.) Damage in the town to date is estimated at $285,000, with the river stage at 23.2 feet. If the river continues to rise to the 1965 stage of 27.2 feet, damage will reach an estimated $1,500,000." The river subsequently crested at 23.7 feet. Here is a specific case in which $90,000 would have protected a town from damages that did occur. The cost-to-benefit ratio would have been at least 3 to 1 and probably more.

In other examples, benefit-to-cost ratios cover a wide range.



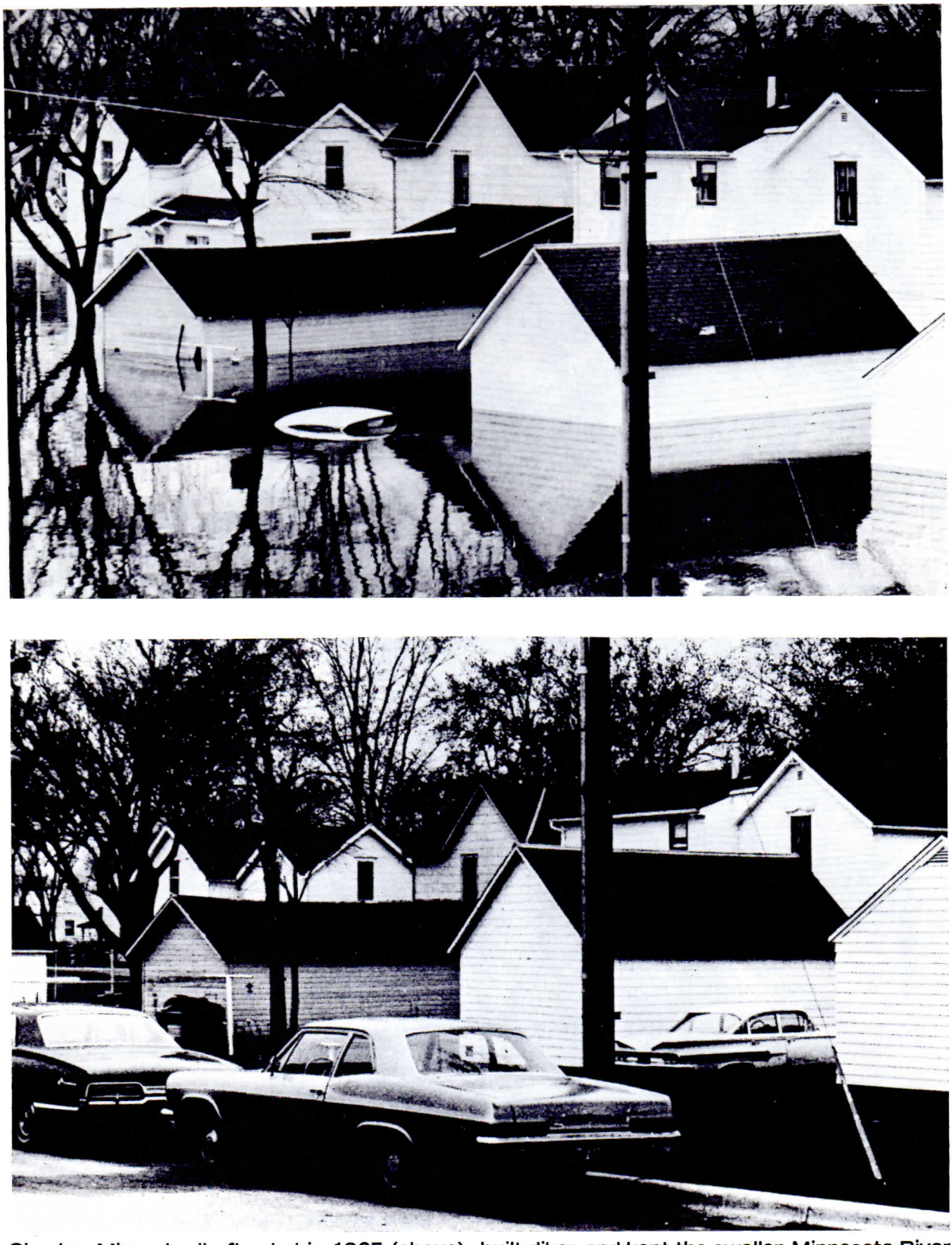
Emergency levee and sandbag levee preparations along the right bank kept the rising Big Sioux out of Riverside, S.D.; the unprotected North Sioux City shore at left was less fortunate.
U.S. Army Corps of Engineers photo by A. R. Salkin

There are undoubtedly *individual* cases where the cost of protection will exceed the benefits to be derived from the protection (*e.g.*, cost of protection will be greater than the cost of repairing the damages). The significant point is that, over a very large area, there are tremendous opportunities for preventive measures in advance of severe flooding which will yield extremely favorable benefit-to-cost ratios—if an adequate river and flood forecast service is available.

The members of the survey team saw many examples of the benefits of prevention during the course of their travels. In one notable instance, a town on one side of a river built a levee to protect itself from the forecast crest, while a town across the river took no action. The protected town was dry at crest stage; the other was completely under water.

The Minneapolis *Tribune* of April 17, 1969, ran a picture showing Chaska, Minnesota, during the 1965 flood and again during the 1969 flood. The crest stage in 1965 was 34.2 feet and in 1969, 32.4 feet. Flood stage is 18 feet. In 1969, Chaska was completely dry behind dikes, whereas it was completely under water in the 1965 picture.

One aspect of the 1969 flood protection measures is the possibility that some of the temporary levees constructed with PL–99 funds will be retained and improved. Thus, although costs are one-time, the benefits in terms of damages averted would continue to accrue.



Chaska, Minn., badly flooded in 1965 (above), built dikes and kept the swollen Minnesota River out of town in 1969 (below).
Minneapolis *Tribune* photo

Morale was high along the flooding rivers. Students from Breckenridge High School and Wahpeton State School of Science punted across a flooded street after saving another residence.
Fargo *Forum* photo

Chapter VII
Reaction to ESSA Services

The reaction to ESSA's River and Flood Forecast Service, prior to and during the emergency, has been generally quite favorable. Division and District Engineers of the Corps of Engineers, State Civil Defense Directors, Public Officials, and the media all spoke very favorably of ESSA's services. All agreed that the advanced warning and accurate forecasts had made possible an unprecedented level of preparation to meet a very serious flood situation. There are numerous quotes to substantiate this view. A few are listed below.

The *Kansas City Star*, April 29, 1969, said: "Never in fact had there been more adequate and certain forewarning of a flood. The deep winter snows, up to 90 inches in South Dakota, had carried a clear message to weathermen everywhere as the Spring thaw cleared. 'Operation Foresight' launched March 1 at a White House conference of agencies from several Federal departments undertook flood fighting preparation of a record scale. The Army Engineers obligated $15 million for such items as 100 miles of emergency levee in the upper Mississippi Valley, and this was but a part of widespread local efforts . . ."

In the Corps of Engineers bulletin of April 8, 1969, on *Operation Foresight,* the Army Deputy Chief of Engineers, Major General Frederick J. Clarke, is quoted as saying: "Probably there has never been a flood situation in which flood fighters were so on top of developments over a large area. Throughout the threatened area, emergency work done under 'Operation Foresight'—the program of Federal flood aid ordered by President Nixon—were proving their worth as stockpiled equipment and supplies are rushed immediately to threatened localities. Levees and other emergency works are being raised or strengthened on very short notice."

Time, April 25, 1969: "Yet, despite the seriousness of the floods, the total damage and injury and deaths could have been much worse had it not been for precautions taken by the U.S. Government and some individual communities. As early as last February, Weather Bureau experts predicted floods because of the massive Canadian snow packs dissolving with the Spring thaw. To try to protect at least some of the areas State and Federal Government agencies joined together to form 'Operation Foresight,' an $18 million emergency effort."

The following is an excerpt from an article in the May 4 issue of the New York *Times:*

> "A spokesman for the Office of Emergency Preparedness said that officials there believed that never before had there been such a big effort over such a short time in such a large area to combat floods before they happened.
> "River crests, monitored daily by the Environmental Science Services Administration's Weather Bureau, rose as high as predicted. The Mississippi River was as dangerous as expected, and predictions about the behavior of tributaries came out as forecast, according to the officials."

The survey team ranged all over the flood area, and talked with officials at all levels of government involved in the flood emergency. News releases were reviewed in every town visited. The team received favorable comment regarding ESSA's services prior to and during the flood emergency in all cases.

For isolated farms, swollen rivers became shallow inland seas as the Spring floods of 1969 spread over tens of thousands of square miles.
Fargo *Forum* photo by Colburn Hvidston III

Chapter VIII
Remedial Measures

As mentioned previously, the Weather Bureau's River Forecasting Service showed remarkable accuracy and performed admirably throughout the flood situation. There were no major maintenance problems or communication failures. The survey team, however, found areas in the system of observing, data collection, processing, dissemination, use of personnel and research and development that should be studied for possible refinements and improvements.

A. Observing

1. The Weather Bureau Manual requires that the MIC or his designated assistant make an annual visit to each substation network observer. The team found this to be a desirable, but unrealistic, requirement under the present and near-future manning levels. *These visits are necessary to assure that equipment is operating properly and observing techniques are being followed, but most Weather Bureau offices are fortunate if just the substation network specialists are able to meet the stated visit schedule.*
2. The semantics of reporting and forecasting river stages can be improved. It may have led to possible confusion, according to several of the State Civil Defense Division heads. It is not unusual to have two consecutive gages on the same river with stages and forecasts based on a different datum. For example, the flood stage at Marysville, Kansas, on the Big Blue River is 35 feet, and a few miles downstream at Blue Rapids it is 1101 feet. The survey team encountered the same difficulty. The reason for this problem is that most of the gages are based upon a zero datum level which is roughly the low water mark of the river. Some of the gages, however, use mean sea level as their zero level.

   George W. Orr, Director, Iowa Civil Defense Division, specifically requested that Federal agencies explore the possibility of setting a common datum for reporting river stages, establishing flood stages, and issuing stage forecasts. This request was made by others, and the survey team concurs.
3. In those cases where ESSA has installed river gages (approximately 300), some of them are of limited use until the Geological Survey determines the rate of flow for various river stages at the gages so that rating curves can be established and put into the forecast scheme (computer or manual). The cost of having the Geological Survey prepare a special rating curve is nominal. *Where this information is critical to the River Forecast Center, it should be requested.*
4. One of the major observation problems in river and flood forecasting is accurate snow sampling. Snow-depth varies markedly with terrain and wind conditions. In order to obtain an accurate mean snow-depth, a very conscientious observer must make a number of snow-depth measurements over a wide area. Even when the snow-depth has been accurately determined, it is not unusual for some observers to report the water-equivalent as a flat ratio—for example, 1 to 10—rather than to melt the snow sample to obtain the true water-equivalent, an

equivalent that can range anywhere from 1 to 30 in dry powder snow to nearly 1 to 1 in ice conditions. *This is an extremely difficult problem, and one that deserves considerable attention because of the critical nature of the water-equivalent data in snowmelt flood forecasting.*

5. Precipitation gage data comes from a variety of sources. ESSA is highly dependent upon networks of the Corps of Engineers, as well as on its own cooperative observers. *In a number of areas, the gage density is inadequate. As in the case of snow measurements, there is a strong need for improvements in the measurement and transmission of precipitation information. Automation is essential in this area, both from the standpoint of obtaining accurate, timely measurements and as a means of reducing manpower demands in the Weather Bureau offices where most of the data initially enters the system.*

6. Weather radars were not a critical factor during the current Midwest flooding, because heavy precipitation during the critical snowmelt period never played a major role. However, the situation could very well have been different. The excellent progress that is being made in ESSA in implementing the radar portion of the Natural Disaster Warning (NADWARN) Plan is commendable, and the *team urges that the complete Federal Plan be implemented as soon as practicable. This includes the remote scopes and emergency power.*

7. The Office of the Federal Coordinator for Meteorological Services, at the behest of the Weather Bureau obtained the support of the Department of Defense during the flooding emergency in making precipitation data available from Air Force Weather radars. The support of the Air Force was immediate, and a directive was sent by Headquarters, Air Weather Service, to its field stations to provide cooperation to ESSA Weather Bureau offices.

   All Federal resources should be immediately available to assist ESSA when any natural disaster threatens, and there should be no hesitancy on the part of the Weather Bureau to ask for such support at the local level when it is necessary. Similarly, ESSA should immediately respond to requests for assistance by the military weather services.

8. The members of the survey team were impressed with the degree of cooperation that exists between the Corps of Engineers, the Geological Survey, and ESSA in river and flood forecasting. In addition to the observations previously mentioned as being available from the Corps networks, ESSA makes extensive use of Geological Survey river gages. The Geological Survey's role in providing rate of flow data *vs.* stage heights for critical river gages is essential to the river and flood forecast program. Members of the team talked with Charles A. Collier, District Chief, Geological Survey, for the State of Minnesota, and obtained an extensive briefing on the Survey's normal operations and its stepped-up activities during record flooding. There was a strong willingness on Mr. Collier's part to cooperate with ESSA and, in fact, he had been working very closely with ESSA's Minneapolis River District Office to provide the latest rate-of-flow measurements obtained during the flood situation. The Corps of Engineers cooperates very closely with the River Forecast Center in its reservoir control operations. This is a two-way street: the Corps needs the forecasts prepared by the RFC, and the RFC needs to know the Corps' plans for controlling its reser-

voirs since they directly affect river stages.

B. Data Collection

1. Data from precipitation gages and river gages and snow-depth and water-equivalent measurements are collected in a variety of ways. *Much of the data is collected by individual telephone calls to Weather Bureau offices and some even collected by mail. This is a slow process and very expensive in terms of personnel time in a period when manpower is critical throughout ESSA. This area requires considerable study.* It is, of course, directly related to the previously mentioned observational program, and a general system study in the data-acquisition area appears badly needed.

   The ESSA Geostationary Operational Satellite (GOES, or prototype SMS) offers new opportunities to acquire rainfall and river stage data in near real-time from remote locations and from those that may be isolated by floods and therefore not normally operable at critical periods. A GOES system would permit the collection of data without relay and delay from hundreds of sites with direct readout via GOES to RFCs needing the information for use in the preparation of forecasts and warnings. Such a system would enable the Weather Bureau to establish reporting sites according to need rather than availability of observers, power, and communications. This would increase the overall service effectiveness through improved network alignment. Budget support of the GOES system has been requested starting in FY 1970. The initial phase of GOES data collection of rainfall and river stage data is planned for the Intermountain Region around Salt Lake City.

   One possible source of assistance does not appear to have been widely exploited. This has to do with the Civil Defense networks that exist in the United States. While these networks exist primarily for national emergencies and civil disorders, the majority of the time they are free and the team could think of no better use for them than assisting in the collection and dissemination of data with respect to natural disasters. More will be said of the capabilities of these State Civil Defense systems later on in this report.

C. Processing

1. The staffing of the River Forecast Center is as follows:

   1—GS–14
   2—GS–13's
   8—GS–12's
   1—GS–9 (vacant)
   1—GS–7
   1—GS–5 Secretary

   The Center has a very limited capability beyond a daytime operation five days a week. In addition, there is a lack of personnel at lower grades to do supporting work for the assigned hydrologists. As a result, highly paid personnel with short-supply skills are doing work that should be done by far lower grades; e.g., punching of data for computer input. The Center lacks flexibility for dealing with emergencies, particularly if they are of a protracted nature. There is a limit to how long personnel can be expected to work overtime.

   Faced with the likelihood that the 1969 snowmelt flood situation would be serious and protracted, an attempt was made to augment the RFC staff. Only a minimal augmentation was possible. This was due to the fact that there were no experienced hydrologists available who were familiar with

the forecast model used on the CDC 3100. The Center apparently felt that anybody else would not be of material assistance.

The survey team suggests that the Central Region examine the organization of the River Forecast Center to see whether some work could be assigned to lower grade personnel, who could be augmented in times of emergency. It is also recommended that the River Forecast Center go on a seven-day-a-week basis during the months of the year when any type of flooding is apt to occur. This should be done inasmuch as floods, like weather, do not operate on a 5-1/2-day week.

2. With the issuance of the March 13 outlook, the River Forecast Center began providing two crest outlooks: one based on water-equivalent existing as of March 8, the other based on augmentation of this water-equivalent by normal March precipitation. These two crest values were further qualified by the four basic assumptions mentioned in Chapter IV. *There was, therefore, a wide range of possible stages that could have resulted, only two of which were stated. This left the user, who must make some costly, difficult choices (stockpiling, levee construction, water control, etc.), to decide which stage he should protect against. ESSA knows something of the probability of each stage occurring, and it would seem desirable to study the feasibility of providing these probabilities to our users to help them in their decision making.* In the particular forecast mentioned on March 13th, one of the obvious questions raised by the Corps of Engineers was, "What happens if you get above normal March precipitation?" *The team feels that these probabilities would be extremely useful to State and Federal authorities, particularly to the Civil Defense authorities in the States and to the Corps of Engineers. It is suggested that the Weather Bureau study this matter.* The team notes that probabilities are being provided in connection with water supply forecasts to enable users "to make an intelligent assessment of the chance of realizing certain levels of water availability."

Some difficulty was noted in the production of the flood forecasts by the RFC, because its computer is shared with the National Severe Storms Forecast Center (NSSFC) at Kansas City. Not only do the two centers compete for time, but they are competing for time on an extremely slow computer system. To illustrate, the March 13 outlook required four hours of CDC–3100 running time, a long period in itself, but because of the waiting time in sharing it with the NSSFC, a total of 14 hours elapsed from the time the River Forecast Center began until the final stage of the forecast was produced. It is true that this represents an extreme case, because the March 13 forecasts were issued for 225 points. On a typical day when there is not much flooding, the CDC–3100 running time is about 70 minutes, and on a typical day when there is considerable flooding the time increases to 170 minutes. As stated before, the computer system is very slow. It has limited (16K) core memory, four slow-speed tape drives, and a 1000-line-per-minute printer. All input-output is on-line with most input by paper tape or card. The River Forecast Center does have access to a service bureau CDC–3200 at a cost of $260 per hour, with no data phone connection or terminal.

ESSA should as a matter of some urgency take steps to resolve the computer problem at Kansas City. Efforts

to optimize River Forecast Center programs and reduce running time should be accelerated. Current and future computer requirements at Kansas City should be established and a plan to meet these requirements prepared. Consideration should be given to upgrading the existing CDC–3100 system, installing a computer-to-computer link between Kansas City and Suitland, or use of service bureau computer capability in Kansas City.

D. Dissemination

1. In those States where the ESSA Weather Wire has been implemented and drops have been purchased by newspapers, radio, and TV stations, dissemination of forecasts and warnings to the media and hence to the public is excellent. Comments by several MIC's who have experienced the operation before and after ESSA Weather Wire speak very highly of this program. *There was, however, a uniform need expressed that the ESSA Weather Wire installation be accompanied with adequate personnel resources, as it does constitute a substantial added workload. There is no question that the ESSA Weather Wire should be completed throughout the United States as rapidly as resources permit.*

2. While the ESSA Weather Wire solves the problem for the media, the rapid collection and dissemination of serious, short-use information on natural disasters such as flash floods, tornadoes, etc., appear to be very strong candidates for handling by the State Civil Defense communications circuits. These circuits are part of a national system (NAWAS) established by the Office of Civil Defense (under the Secretary of the Army) to serve as a rapid means of communication down to the local level throughout the United States for national emergencies. They were not funded to handle natural disasters. *It has become increasingly apparent, however, that some States find them extremely useful for this purpose, particularly for tornado watches and warnings. Not only does this represent a very effective means for handling tornado watch and warning situations but it also provides an excellent way to exercise the system in peacetime. Several States mentioned that they feel that there is some question about its use for this purpose by the OCD. They do not believe they can obtain OCD funds for support of this type of activity.*

It is possible that there is some confusion with respect to this point. On May 1, 1957, the Office of Civil Defense Manual M–18–1, "Federal Civil Defense Administration Emergency Operation, Part 5—Warning," first contained authority for the States to use NAWAS for transmission of natural disaster information. As near as the Task Team could determine, this remains the case. It is true that OCD does not have legislative authority to expand NAWAS for natural disaster warning purposes since OCD's authority is for attack warning purposes only. OCD policy does, however, allow use of these facilities, once established, for transmission of natural disaster information.

E. Personnel

The shortage of ESSA personnel was never more apparent than during the current Midwest flood emergency. While large numbers of personnel were moved in by other Federal agencies to cope with this emergency, the augmentation within ESSA was modest. ESSA did not have the people to place in emergency operation centers to provide guidance and assistance on the critical weather factors involved.

F. Research and Development

The technique for predicting certain kinds of floods is reasonably well perfected. Given certain conditions with a reasonable degree of accuracy, such as temperature (actual and predicted), snow depth and water equivalent, precipitation (actual and predicted), river stages, rating curves, and antecedent runoff conditions (*e.g.*, frost depth, soil conditions, etc.), River Forecast Centers can provide predictions of substantial accuracy. *The most pressing problem lies in lead time, because the conditions causing a flood can be produced very shortly before the flood occurs. Serious considerations should be given to a shift in the emphasis in research and development in hydrology to the data acquisition problem.*

G. Other

The team recommends that the NAD-WARN Plan should be brought up to date and the possibility for an increased role for the State Civil Defense communications systems be considered. This plan would have to be developed in close cooperation with and agreement of the Office of Civil Defense and State offices of civil defense or emergency government.

The following is a quote from a report to the President of the Task Force on Federal Flood Control Policy issued August 10, 1966:

"The ESSA (Weather Bureau) has for many years compiled any flood damage data reported to it. Lacking facilities for appraising the reliability of the information submitted, or determining its completeness, or for filling in any gaps, the actual totals reported by the Bureau are known by it to include only a part of the flood damages suffered in the United States."

This report goes on to point out that the Corps of Engineers and Department of Agriculture also collect flood damage data. The report recommends that a new national program for collecting more useful flood damage data should be launched by the interested agencies including a continuing record and special appraisals in census years. It further recommends that the incomplete tabulation of the Weather Bureau be discontinued concurrently upon completion of a new national program and recommends the organization of that program. This recommendation of the Task Force on Federal Flood Control Policy has never been implemented and the survey team encountered the same unsatisfactory situation that was identified in 1966.

A lone rowboat and two passengers travel a Perley, Minn., street.
Fargo *Forum* photo by Colburn Hvidston III

Chapter IX

Summary and Recommendations

The spring flood of 1969 in the upper midwest part of the Nation will be remembered in parts of the area as the "flood of the century."

The floods caused an estimated $100 million in damage, killed ten people, and forced 25,000 to leave their homes.

While the damage was bad it could have been much worse. Precise and early flood forecasting permitted advance action that prevented an additional estimated $250 million in damage and there is little doubt that it saved lives and reduced human suffering to a minimum.

Spurred by the warning of snow-melt floods as early as January, communities began to plan and take action. President Nixon's order on March 1, 1969, to Federal agencies "to undertake all feasible preparations to reduce or alleviate the threatened flood damage" set in motion an unparalleled, coordinated Federal-State-local effort to combat a natural disaster—before it happened. The all-out effort was called *Operation Foresight.*

The existence within the Environmental Science Services Administration of an established system, tested and proven by tornadoes and winter storms, for dissemination of warnings was a very important factor in the effectiveness of the flood warning service. The warning system has been developed through the years by Weather Bureau officials working with Civil Defense officials, law enforcement agencies, news media, and many local, State, and Federal offices. An important part of the development of this system has been the high level of rapport and confidence which exists between Weather Bureau representatives and the local communities.

At the Weather Bureau, arrangements were made for special observations. Staffs of the River Forecast Center and Weather Bureau stations were augmented. The Weather Bureau's National Meteorological Center made special temperature and precipitation forecasts and ESSA's Satellite Center furnished special enlarged satellite photos of the snow-covered regions.

The early outlooks and the river crest forecasts issued by the Weather Bureau showed remarkable accuracy.

The correct evaluation of the flood potential and prediction of such a massive flood threat covering as this one did portions of seven States, will under the most ideal situation place a heavy burden on the Weather Bureau service system. It is significant, however, that the present system achieved results that would have been absolutely impossible 20 years and nearly impossible 10 years ago. The present river forecasting system has, during the past 20 years, evolved from a manually operated, decentralized, and fractionated system of river district offices. This system was without coherent and identifiable central authority and leadership in the late 1940's. The present sophisticated centralized prediction system utilizing modern electronic data processing techniques has evolved as a result of a calculated and planned attempt to improve these services. The most significant progress towards the attainment of this objective has been accomplished during the past 10 years. The report of the Task Force on Federal Flood Control Policy issued on August 10, 1966, stated that reliable, accurate and timely forecasts of floods and flood stages can be coupled with temporary evacuation to save lives and reduce property losses. Forecasting service provided primarily by the Environmental Science Services Administration and by others during the past has saved countless lives and dollars but there are

too many areas for which forecasts are not available and too many areas for which accurate and timely forecasts cannot now be provided. The Task Group recommended that an improved system for flood forecasting be developed by the Environmental Science Services Administration as a part of a disaster warning service. Specifically, the report recommended that means be provided the ESSA (Weather Bureau) to: automate reporting networks, take advantage of improved technology to keep abreast of changes in channel regime, extend the system, including flash flood forecasts to meet requirements in all areas of the Nation; provide prompt and reliable dissemination of forecasts through a nationwide warning communications system; provide assistance and cooperation with the Office of Emergency Planning and individuals, groups and communities in developing preparedness plans.

The survey team found that a great deal of progress has been made on these recommendations but that much remains to be done.

The following recommendations are made with a view to further improvements:

1. The matter of obtaining an adequate data base on a timely basis at a minimal manpower cost should be the subject of a systems study by ESSA and the Weather Bureau. Specifically:

   (a) The extremely difficult problems of obtaining accurate observations of mean snow-depth and water equivalent and soil conditions deserve considerable attention.

   (b) There is a strong need for improvements in measuring and transmitting precipitation information. Automation should be viewed as essential in this area to assure accurate, timely observations as well as a means of reducing manpower demands in Weather Bureau Offices.

2. The Weather Bureau should prepare a listing of the major streams in the United States for which there is not now a flood forecast capability. Further, this listing should be in order of vulnerability to serious flooding and should be accompanied by an estimate of the resources necessary to develop a service for each stream.

3. ESSA should undertake immediately, through reprogramming action, the establishment of routine Flood Forecast and Warning Service for the Souris River in North Dakota.

4. ESSA should explore the possibility of Federal agencies agreeing on a common datum for reporting river stages, establishing flood stages, and issuing stage forecasts.

5. The Federal Plan for Weather Radars and Remote Displays should be implemented as soon as practicable.

6. The Weather Bureau should examine its requirement that the MIC or his designated assistant make an annual visit to each substation network observer. This desirable practice should be weighed against the fact that most Weather Bureau offices visited are fortunate if the substation network specialists are able to maintain the stated visit schedule.

7. The organization and manning of the Kansas City River Forecast Center should be examined by the Weather Bureau Central Region to:

   (a) Determine if some work could be assigned to lower-grade personnel who could be effectively augmented during an emergency.

   (b) Place the Center on seven-day-a-week basis during those months when flooding is apt to occur.

8. ESSA should as a matter of some urgency take steps to resolve the computer problem at Kansas City. Specifically:

   (a) Efforts to optimize the RFC programs and reduce running time should be accelerated.

   (b) The current and future computer requirements at Kansas City should be established and a plan to meet these requirements submitted to ESSA.

9. The Weather Bureau should study the feasibility and usefulness of adding probability of occurrence of various forecast stages to forecasts provided to Federal and State authorities.

10. ESSA Weather Wire should be completed throughout the United States as rapidly as resources to install and operate it will permit.

11. ESSA should be represented at emergency centers established by Federal and State agencies to deal with natural disasters. Where staffing is at a critical level, as is presently the cast, a "hotline" should be established between the center and the nearest Weather Bureau Office as a minimum.

12. The current NADWARN Plan should be revised and reissued in close coordination with the Office of Civil Defense to bring it up to date and recognize the new and emerging capabilities of State Civil Defense communications systems and the possibility that these systems can become integral parts of the NADWARN system.

13. Appropriate steps should be taken to assure that all Federal resources will be immediately available when natural disasters threaten, and that there is no hesitancy on the part of Weather Bureau personnel to ask for such support when it is necessary.

Plans should be prepared in advance by the Weather Bureau outlining support needed (radar observations, snow depth measurements, aerial photos, airlift, etc.), the specific details as to what is required and the source of the support.

14. ESSA should press for implementation of the recommendation of the 1966 Task Force on Federal Flood Control Policy that a new national program for collecting more useful flood damage data be launched by interested agencies.

15. ESSA should place greater emphasis on the data acquisition problem in its research and development program in hydrology.

Attachment A

Field Locations and Key Personnel Contacted

Itinerary for Mr. Moore and Mr. Beck

April 23 and 24, 1969 (Wednesday-Thursday) Omaha, Nebraska

P.A.: Albert Bangert
Commanding Officer, Corps of Engineers, Missouri River Division: Brigadier General Craig Cannon

April 24 and 25, 1969 (Thursday-Friday) Des Moines, Iowa

MIC: Clarence E. Lamoureux
Director, Civil Defense Division, State of Iowa: George W. Orr

April 25, 1969 (Friday) Moline, Illinois

MIC: William A. Joern

April 28, 1969 (Monday) Madison, Wisconsin

MIC: William J. Rigney
Administrator, Division of Emergency Government, State of Wisconsin: Bruce Bishop

* *April 28 and 29, 1969 (Monday-Tuesday) Minneapolis, Minnesota*

MIC: Joseph H. Strub, Jr.
District Engineer, St. Paul District, Corps of Engineers: Colonel Richard J. Hess

Director, Department of Civil Defense, State of Minnesota: Mr. Phillip A. Iverson

District Chief, U.S. Geological Survey: Mr. Charles R. Collier

April 29, 1969 (Tuesday) Waterloo, Iowa

Duty Official, Weather Bureau Office: Mr. Edward Fencl

* Joined by Mr. Hosick and Mr. Lieb

Itinerary for Mr. Lieb and Mr. Hosick

April 24, 1969 (Thursday), Sioux City, Iowa

MIC: Paul Holcomb
Former MIC: Ivory Rennels
County Civil Defense Director: Tom Elliott
Editor-in-Chief, Sioux City *Journal*: Erwin Sias

April 24, 1969 (Thursday), Cherokee, Iowa

Managing Editor, Cherokee *Daily Times:* Frank Buckingham
General Manager, Radio Station KCHE: Kay Hutchinson

April 24, 1969 (Thursday), Sioux Falls, South Dakota

MIC: Ken Clark
County Civil Defense Director: Joe Vanderloo

April 25, 1969 (Friday), Bismarck, North Dakota

MIC: Herman Stommel
State Civil Defense Director: Nelson Stave
National Guard Commander: Colonel Herbert Mack
(Flood Coordinator)
Coordinator for State Civil Defense: General Leroy Landon

April 26, 1969 (Saturday), Minot, North Dakota

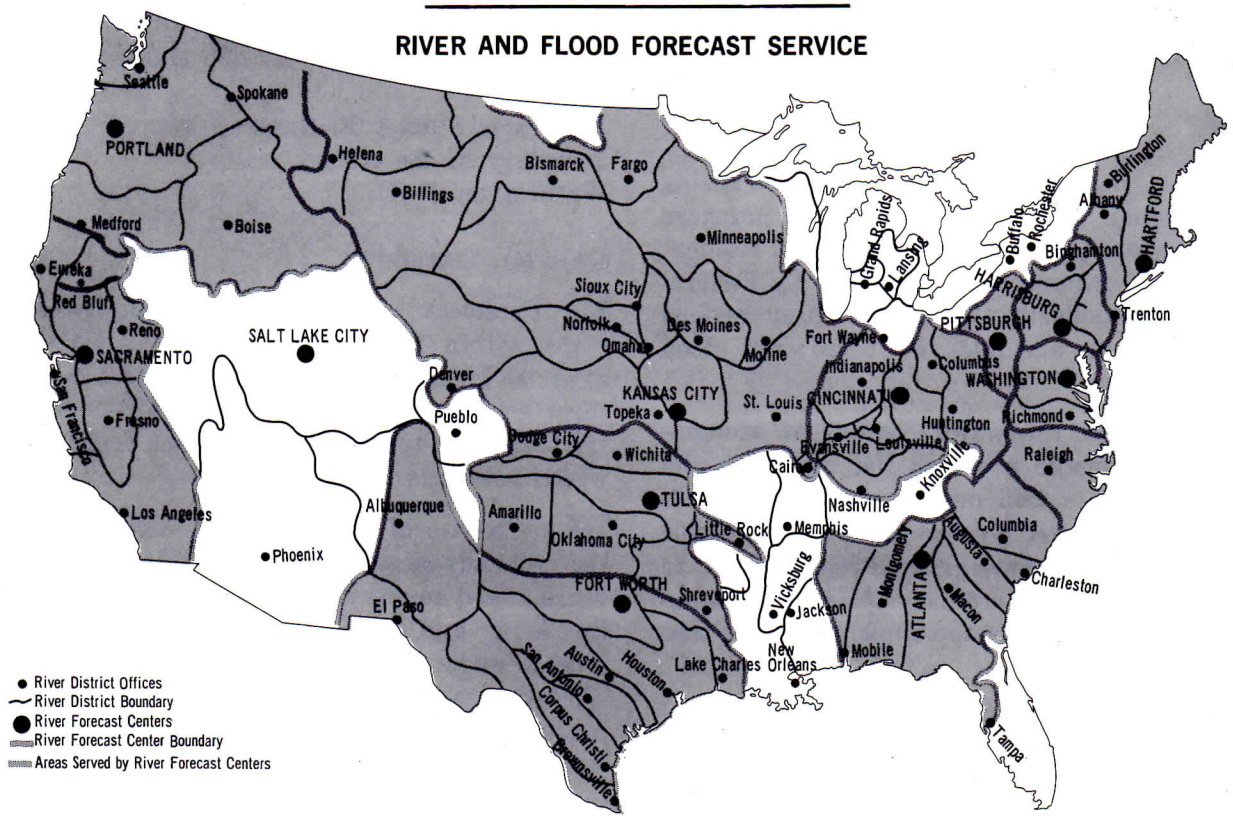
Corps of Engineers: Myron Tiemens
Publisher, Minot *Daily News*: Ray Dodson
OEP Representative: Jack Coulter

April 27, 1969 (Sunday), Fargo, North Dakota

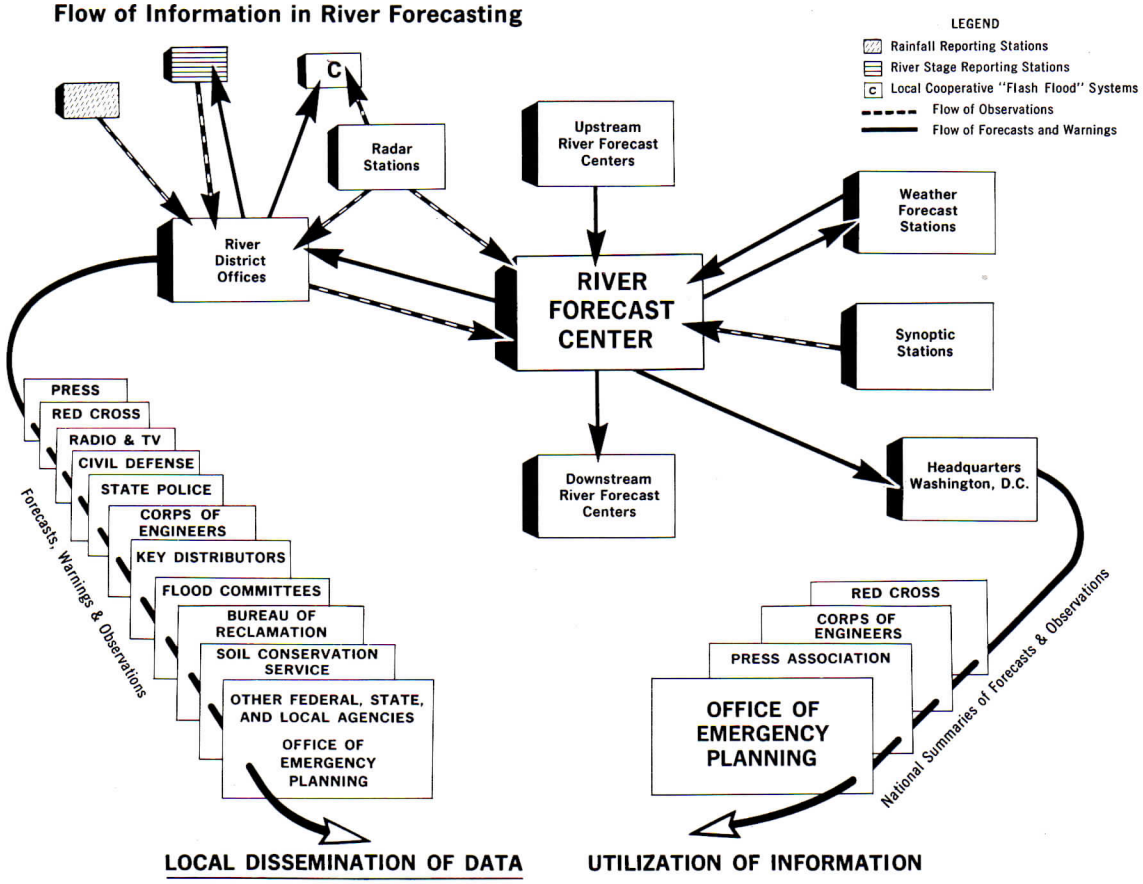
MIC: Vern Hendrickson
State Climatologist: Ray Jensen
Field Aide: Keith Blessum

Attachment B

RIVER AND FLOOD FORECAST SERVICE



Flow of Information in River Forecasting



Attachment C

March 1, 1969

THE WHITE HOUSE

Expressing his concern regarding the spring flood threat to many States in the northern and western parts of the Nation, President Nixon has ordered a major effort by Federal agencies to undertake all feasible preparations to reduce or alleviate the threatened flood damage.

Noting that the water content of accumulated snow in the northern tier of States and the Midwest is well over average, the President has instructed George A. Lincoln, director of the Office of Emergency Preparedness, to coordinate an extraordinary Federal planning and operational effort to supplement State and local resources.

The OEP is charged with marshaling Federal response to major disasters, such as floods or hurricanes.

The Secretary of the Army is being requested to make full use of available authority for employing the Corps of Engineers' capability for advance preparations and operations relating to flood emergency.

Members of an interagency group met for the first time last Friday. In addition to the Office of Emergency Preparedness and Governor Nils Boe, in charge of intergovernmental aspects of the Office of the Vice President, agencies represented were the Departments of Defense (including the Corps of Engineers), the Interior, Agriculture, Housing and Urban Development, and Transportation; the Environmental Science Services Administration (including the Weather Bureau), Small Business Administration, Interstate Commerce Commission, Bureau of the Budget, and American Red Cross.

The Office of Emergency Preparedness, Corps of Engineers, and most Federal agencies with disaster responsibilities work directly with State and local emergency officials through field offices.

Attachment D

March 1, 1969

Honorable Stanley R. Resor
Secretary of the Army
Washington, D. C.

Dear Mr. Secretary:

The President has directed that all feasible steps within the authorities of the Federal agencies be taken to prepare for floods which threaten to occur in various parts of the country because of the unusual snowpack conditions which now exist.

We are aware of the authorities and capabilities for advance preparation and operations during flood emergencies which are available to the Army and especially to the Corps of Engineers under PL 99, 84th Congress.
The aggressive use of these authorities under present conditions is urged. For example, it would appear that, within the time available to us, some work might be done on clearing obstructions to stream channels, and to repairing or constructing new levee sections where urgently needed.

I do understand that the Corps of Engineers is already alerted and is cooperating with the Office of Emergency Preparedness in disaster preparedness and in support of work it is called upon to do in connection with disaster declarations by the President.
We appreciate your cooperation in preparing to meet this serious and imminent threat with the resources at your disposal.

Sincerely,

G. A. Lincoln
Director