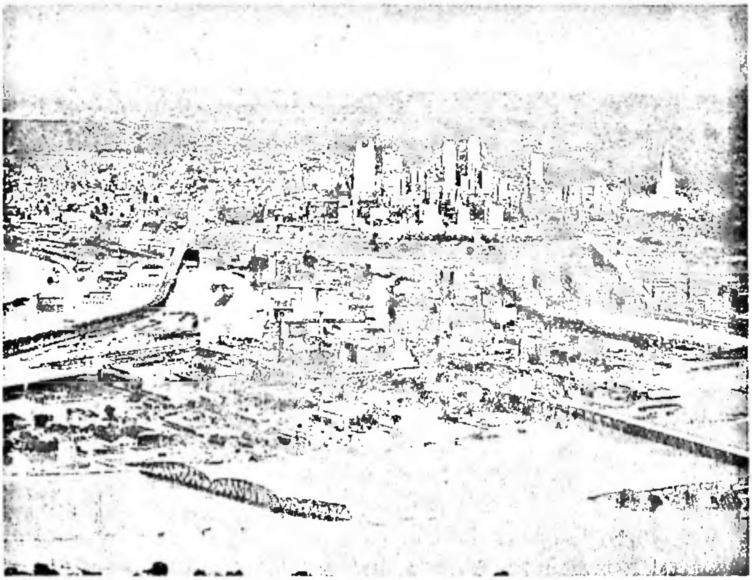
THE FLOOD PROBLEM IN FIRE PREVENTION AND PROTECTION



Kansas (Kaw) River, Flood of July, 1951. View Looking East Toward Central Industrial District, Kansas City, Missouri.

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PREFACE

This report was prepared by a special committee of the Advisory Engineering Council of the Committee on Fire Prevention and Engineering Standards. The Chairman was Eugene F. Gallagher, of the Ohio Inspection Bureau, Columbus, Ohio. To him is due the credit of collecting the data and preparing the report. Acknowledgement is made of the cooperation of the various regional organizations of the capital stock fire insurance industry, the U. S. Army Engineers, the U. S. Weather Bureau, the Cincinnati Gas and Electric Company, the officials of the various cities and towns in the path of the floods, and many others who have given valuable aid and counsel.

FOREWORD

Floods have ever presented a problem in connection with fire prevention and fire protection. While it is not the intent here to offer a complete solution to that problem, it is thought that, at least, there may be made available for common benefit the experience gained during the past several years when floods of unprecedented height occurred in various parts of the country.

It is not necessary to give any detailed account of past floods in any specific city or town. That information has previously been made available through many media, including the reports of various insurance service organizations, governmental agencies and professional associations. The bibliography may be of assistance to any who would pursue the general subject in some technical detail.

It is hoped that in addition to such other use as it may have, this discussion of the flood problem will be of some service to those in the various offices of insurance service organizations who may be called upon to face a flood emergency and who may find useful some reference on the subject.

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GENERAL

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In the following pages will be found a general discussion of floods including something of their history, their frequency and magnitude, their control, and other phases pertinent to the entire subject. From this discussion and from consideration of various technical reports issued by interested branches of the United States Government and by certain technical associations, the following conclusions may be drawn:

1. **Floods are not increasing in size and frequency.** This conclusion may seem entirely erroneous in view of the fact that all flood records were broken in 1936 and 1937. But these events must be looked upon as "freaks" in the orderly compilation of data and records. Excluding them for the sake of comparison with previous periods indicates that no appreciable change is taking place in either the frequency or size of floods.

2. **Floods are increasing in importance.** Thus far in the development of river basins, conditions have been such that there is an ever increasing potential damage due to floods. A flood which, 20 years ago, was an inconvenience is, today, in some localities, a disaster. This is the result of the increasing occupation of river banks and river valleys by towns and cities, industrial plants, bridges, railroads and highways.

3. **It is reasonable to believe that greater floods will be experienced.** Practically all students of the subject, as well as the experts who have prepared various reports issued under government supervision, agree that, in so far as available records indicate, the maximum floods have not occurred. Much more adverse synchronization of circumstances than has been experienced is quite plausible.

4. **Flood forecasting should be decidedly improved.** This will result from increased activity and the acquisition of new and modern equipment by the Weather Bureau.

History:

The story of floods, were it to be in any sense complete, would begin with the earliest days of man's history and would continue, an unfinished saga, until the last chapter in the world's existence had been written. There would be much in the story that would be fascinating. In fact, the few chapters which have been enacted thus far hold much of interest, depicting, as they do, man's courage and persistent determination to rise above the recurring tragedy of death, and disease, and desolation.

There are no authentic or systematic records of discharge on any river in any country extending back beyond 50 or 60 years. There are available, however, records of outstanding river heights on several rivers in Europe and Asia extending back many centuries. This is true of several French rivers where the records go back into the sixth and seventh centuries. Records of even greater length have been kept in Mesopotamia, India and China. By far the oldest record obtainable is found in the neighborhood of the second Nile cataract in upper Egypt. Here, some of the inscriptions date back to 1800 B.C., indicating that river heights and floods were ever a significant factor in man's progress. The longest continuous record of river gages is found at the Roda gage on the Nile at Cairo. This record covers 13 centuries. One fact of particular interest, which seems to be established by a study of these records, is that in magnitude, frequency, and irregularity of occurrence, floods have shown no changed characteristics down through the years.

With reference to stream flow in this country there are, of course, no records of appreciable antiquity. It is true that on one gage (at Hartford, Conn.) records have been kept of river heights for about 300 years, and at some other points for some 200 years, but these can hardly be translated into discharge with any degree of satisfaction. However, gage heights, alone, form an interesting comparison of river behavior of yesterday and today.

In considering the record of floods it should be remembered that their destructiveness is not confined to large rivers alone. There are few rivers or streams that are not, at times, flowing beyond their channel capacities. Even small streams, subject to very sudden rise, may be productive of great damage, but this is usually concentrated within a relatively small area. These smaller streams, which are apt to rise so rapidly, may often claim more lives than do the more extensive floods which rise more slowly on the larger rivers. Naturally the total amount of potential destruction is dependent upon the size of the river and its drainage area and upon the value of the property subject to inundation by its overflow.

The Mississippi River: The Mississippi, with its tributaries, constitutes the most important and most destructive river system in the United States. History relates that it was first seen by white man in 1542, at which time DeSoto stood upon its banks apparently unimpressed by what he had seen.

At any rate, the description his companions carried back failed to incite sufficient interest or curiosity to cause any other white man to visit the river for about 130 years. Almost another 100 years passed before the river valley had a white population worth considering. It was to be expected that the banks of the rivers would be particularly attractive to the settlers. Rivers were the line of least resistance to the unexplored sections of the country. They provided transportation and power. Soil along the river banks was the most fertile for agricultural purposes. Tradition tells that the Indians warned the white men that the river rose at times to great heights and spread out, in its lower reaches, to cover many miles. They looked askance as the white man built his homes and his towns on the very banks. Inevitably, these new settlements were devastated by the floods, against which the white man had been warned, and invariably he rebuilt his homes and stores hopeful that never again would the waters rise so high.

Although history records a great number of floods of considerable magnitude in the Mississippi, those prior to 1826 must be looked upon as more or less unauthentic. It is known that floods of major importance occurred in 1718 and in 1735—the latter breaking through levees and doing considerable damage. The valley was again visited by unusual floods in 1770, in 1782, and by an exceptionally high flood in 1785. The year 1791 saw a major flood at New Orleans followed by the floods of 1796 and 1799. Natchez was seriously damaged in 1809 and the valley in general was flooded at intervals of about three years down until 1828. A series of floods is recorded as starting again in 1844 and continuing almost annually until 1859.

In 1879 the Mississippi River Commission was created and from that date more definite information on floods became available. This commission lists nine major floods, memorable among which is the flood of 1913 which originated in the swollen waters of the Ohio and its tributaries involving immense losses in the vicinity of Dayton, Ohio, and even up the Scioto River to Columbus. In 1927 occurred the most disastrous flood in the lower Mississippi resulting in more than 200 breaks in the levees and in the loss of about 250 lives.

To a certain extent, the floods in the lower Mississippi reflect high waters in the Ohio. This is not invariably true, however, because high waters in the lower reaches may be due to debouchment from the upper Mississippi or the Missouri or, indeed, from other tributaries which flow into the Mississippi farther down stream.

The Ohio River: Floods in the Ohio are described as early as 1762 in a letter written by Col. Henry Boquet who was the English commandant at Fort Pitt. His letter indicates that the water reached a height equivalent to 41 feet on the Pittsburgh gage. During the past 62 years there have been 23 severe floods in the Ohio Valley. Among the earlier floods, for which authentic data are available, should be noted the flood of 1884 which set a record not equaled in the greater part of the valley until 1937. In the order of their size come next the floods of March, 1913, February, 1883, January, 1907, February, 1832, January, 1913, and March, 1907. It will be observed from this short list of floods that, in several instances, major floods occurred twice in the same year.

New England Floods: New England can likewise point to an unfortunate history of high water and serious flood damage extending over a long period of years. Records on the Kennebec start in 1770 and tell of much damage caused by 20 major floods, the flood of 1936 being the highest. Starting in 1846 there are recorded 11 severe floods on the Penobscot, the highest occurring in 1923. Similar accounts are available for the Androscogin, the Saco, the Merrimack, the Thames, the Connecticut and others. The city of Lowell, Mass., has suffered many floods, but none within the last 200 years has been as high as the one of 1936. The history of floods at Hartford, Conn., is particularly interesting because there is probably no place in the United States where longer or more complete records are available. In fact, there is a record of a great flood at this location as early as 1639. Here again the flood of 1936 exceeded all previous heights.

The history of floods might be prolonged indefinitely and might include occurrences in Texas, in New York, in California or in about any other state in the country. However, in the foregoing are mentioned the principal areas of flood in the United States. An expansion of the history would seem to serve but little purpose. If it is of any value it lies principally in the fact that from these events of the past some conclusions may be drawn justifiably, albeit with the possibility of considerable error, with reference to the future.

Causes:

Disastrous floods are invariably the result of excessive rainfall, rapid melting of accumulated snow, failure of reservoirs, forming and breaking of ice jams, or the breaking of levees. Frequently floods result from two or more of the ordinary causes acting in conjunction. The great flood of 1884 in the Ohio and Mississippi is an excellent example of the results of rainfall and melting snow. More recently there is to be noted the New England floods of 1936, resulting from the same combination.

Floods caused by ice jams, dam failures, or broken levees are usually of comparatively small significance. Apparently contradicting this statement will be recalled the Johnstown Flood in 1889 in which over 2,200 persons lost their lives. Tragic as was this disaster it was, from a property standpoint, not one of the country's great floods. The total loss to property was about 2 per cent of that in the 1937 Ohio Valley Flood and, indeed, was only about one-third as great as the flood of 1936 in Johnstown itself. Disasters following ice obstructions, dam failures, high tides and gales impress themselves upon the public mind because, in many instances, the unusual nature of the occurrences results in their being extensively publicized and perhaps overemphasized in importance.

All major floods have been caused by an excess of rain, although, as mentioned previously, this has, in some instances, been greatly augmented by snow lying on the ground at the time warm rains occurred. Floods of this type are apt to be recurring because, indefinite as it may be, there is some semblance of consistency in meteorological phenomena, and heavy rains are to be regularly expected within certain rather generally defined areas.

The Ohio River Basin is so located geographically that various flood-producing factors have a better chance of acting over that basin than over any other part of the great interior drainage system of the United States. The great rain-producing storms of this section are of the southwestern type. They move almost invariably along a path from Texas to New England. The Ohio River basin is directly in the path of these storms. The northern part of the basin is so situated as to receive rainfall from storms which move across the continent from West to East over the Great Lakes. As a result this northern section sometimes receives rainfall from two sources in quick succession or practically at the same time. The topography of the basin is well adapted to flood causation. The northern and eastern parts of the basin are rugged with precipitous slopes, often covered with snow. Rain falling on this accumulated snow results in rates of runoff far in excess of that which could be produced by the rain itself.

New England is practically in the same line of storm travel and may expect heavy rains under normal meteorological conditions in early spring. When rains are abnormal, or when snowfall has been excessive prior to rains, or when other factors act in coordination, floods are a natural result.

Frequency of Floods:

The frequency with which floods of certain magnitude are likely to be experienced is a very important consideration in connection with any analysis of the flood situation. This can, of course, but be an estimate based upon the experience of past gage heights and discharges. Although a number of formulae have been developed to translate past records into predictions of probable frequency with which similar occurences may be reasonably expected in the future, all of these are, of necessity, empirical and produce what can hardly be looked upon as other than a serious attempt to form a careful estimate.

There has been no flood during the last 300 years at Hartford, Conn., which reached the height of the flood in 1936. There is no reason to believe that this height will be equaled until after another 300 years or more have rolled on. On the other hand, there is no very valid reason to feel certain that it will not be repeated within the next year or two. Flood events which are not the absolute maximum lend themselves more readily to an empirical analysis of probable frequency based upon past river behavior. It may be of interest to include the frequency expectancy of certain river heights on the Ohio at Pittsburgh and at Cincinnati. These are expressed as floods which may be expected to occur once in a stated number of years.

Pittsburgh

25′ (flood stage) equaled or exceeded almost annually

30′	equaled	or	exceeded	once	in	3	years
35′	"	"	"	"	"	19	"
40′	"	"	"	"	"	100	"
45′	"	"	"	"	"	500	"

Cincinnati

52′ (flood stage) equaled or exceeded once in 2 years

57′	equaled	or	exceeded	once	in	5	years
62′	"	"	"	"	"	13	"
67′	"	"	"	"	"	24	"
72′	"	"	"	"	"	100	"
77′	"	"	"	"	"	500	"

No great reliance or inordinate feeling of security can be based upon the results of such computations as these, however. Even though it could be definitely established that a given flood height could be reached only once in 100 years, there is no reason to believe that the next year is not the one in which that probability will be realized. In this connection, it is of interest to record that in 1935 there was included in the Report of the Mississippi River Commission to the Chief of Engineers, U. S. Army, a statement that a flood on the Ohio of the height of 78 feet on the gage at Dam No. 37 (near Cincinnati) could not be expected to occur "more than once in perhaps 500 to 1,000 years." That extreme height had never been reached before to the knowledge of man. On January 25, 1937 the gage at Dam No. 37 stood at 78.8 feet.

Magnitude:

It would be of tremendous importance, economically, to know what the absolute maximum flood at any location could be. This again, can be estimated after a careful analysis of many factors, but it cannot be determined as a certainty. The usual estimate is made by assuming a synchronization of various adverse factors which have happened independently in the past but which have not been concurrent or timed in such a way as to produce the maximum flood. It is the practice, therefore, in estimating the absolute maximum flood which can occur in a given river basin, to assume that certain storms which actually occurred were shifted a few miles in a direction which would produce maximum run-off, or to assume that certain rains were delayed a week or two, or, perhaps, fell a week or two before they actually did. A maximum blanket of snow may be considered as covering the ground in the drainage area. Ice may be assumed to break-up at a time when it will combine with flood waters and increase their height. An interesting example of the possibilities of maximum floods is found with reference to Pittsburgh in a study made by E. K. Morse and Harold A. Thomas, both members of the American Society of Civil Engineers, and residents of that city. On February 28th, 1936, there was a river height of 29.2 feet on the Pittsburgh gage. On March 18th the river was again in flood and was at a stage of 46 feet. It is estimated that if these two floods were combined the stage would have been 54 feet, with enough ice in the head waters to form heavy gorges. It would reasonably be expected to overturn bridges, after piling up behind them, diverting water through the "Golden Triangle" at unbelievable heights. It is difficult to conceive how much damage might be done to old buildings and indeed to the new skyscrapers by the impact of large cakes of ice moving down stream at a velocity of from 8 feet to 12 feet per second. Most of the older buildings would quickly collapse and, in turn, menace all other property nearby. The possibility is no fantastic figment of the imagination, but is based upon a synchronization of events which have already occurred independently. Similar alarming maximum possible flood conditions are found in many other parts of the country.

Flood Control:

Recurring floods with their attendant damage soon aroused man's ingenuity. The progressive development of the valleys required that he devise some means to keep the flood waters within bounds. This work, started over 200 years ago, is still in progress. As early as 1718 the French on the lower Mississippi were engaged in constructing levees to afford some protection to their property. In 1816 there was published a discussion of the advisability of constructing the Bonnet-Carre Spillway to provide protection for the city of New Orleans—a project which was finally completed in 1935—and used successfully in 1937. The Federal Government was petitioned for aid following the Mississippi floods of 1849, and in 1850 passed the Swamp Land Act which is probably the first time the government took an active part in the problem.

Following the Civil War the government took a more prominent role in this work and in 1878 provided $1,000,000 to improve navigation in the Mississippi. This work could be so advantageously coordinated with flood protection that there was established the Mississippi River Commission in 1879, which has subsequently played such an important part in the development of protective works and river improvement.

Within recent years millions have been spent by the Federal Government, the states, and the municipalities to effect some degree of protection against floods. This work has been rather generally conducted throughout the country. One of the first federal grants outside of the Mississippi was in connection with a $65,000,000 project in Los Angeles County, California, which was commenced in 1915.

Of great significance in a consideration of the present problem is the Flood Control Act of 1936. By that legislation, for the first time in history, a Federal policy with respect to the country at large is adopted. This is referred to as the "Omnibus Act" and provides for flood control projects in 46 major basins. The estimated total cost of the projects authorized is approximately $397,000,000. The most justifiable and meritorious projects, as developed by exhaustive study by engineers and specialists, are included for initial execution. Ultimately, of course, each project will be analyzed from the economic standpoint of cost and contemplated benefit.

For every locality involved in the recent floods and for many other places where the danger of floods exists, extensive flood control plans have been developed. Much time may elapse before these planned works are completed.

Too much reliance, however, must not be placed upon flood control plans even when completed. Some localities will, in the light of past experience, be practically immune with flood control features in operation. It will be recalled that the wall at Cairo saved that city in 1937. Other localities will benefit but little until an entire coordinated program is executed. The

United States Army Engineers recommend 45 additional reservoirs, estimated to cost $246,000,000, for the protection of the Ohio Valley. The Engineers state that, had these reservoirs been in existence and advantageously operated, they would have reduced the crest of the 1937 flood at Cincinnati about 4 feet and at Louisville about 2 feet. With these comparatively slight decreases in crest there would still have been most serious floods in those cities. Flood protection plans for the Ohio, of necessity, contemplate levees and walls in addition to the construction of the reservoirs referred to.

Possibly more progress in flood control work will be made as a result of an act passed by Congress in 1938. Prior to the passage of that act the Federal Government was prohibited from expending any money for the construction of flood protection projects until the local agency, whether state, municipality or other political subdivision, had arranged to furnish without cost to the Government the necessary lands and rights of way. Naturally, this was a deterring factor in those cases where reservoirs and dams in one section would be required to protect property in some other locality or, perhaps, in some other state. The act passed in 1938 provides that the entire expense of projects of this nature shall be borne by the Federal Government.

Purely local problems within a municipality present many complex phases. The citizens may reasonably hesitate to place upon themselves an expense burden of considerable magnitude merely in order to enhance the value of some river front property.

Where only comparatively small areas of an entire city are subject to floods, the question is invariably raised "Why are these sections occupied?" Indeed, in the consideration of the Omnibus Flood Control plan by the government there are certain small places where abandonment and removal are recommended. In other localities, however, such a course is hardly feasible. In fact, people cannot be dissuaded from living in the path of danger. Earthquakes do not deter people from building a new and larger city at the same location with the knowledge that no man-made protection could hold them safe from a recurrence of the disaster. Human nature is still the same — flood ravaged cities are rebuilt and will continue to be.

It will be found, furthermore, that returning to former homes or the location of former homes is not so much a matter of choice as it seems. Many of the industrial properties are, for rather valid reasons, located near the river. Workers live near these plants because they can do so more economically than to live where transportation and higher rents must be considered. There is but little possibility that these comparatively small flooded areas of certain cities will ever be completely abandoned. On the contrary, the steady increase of values in flood areas will probably continue.

A campaign of education should, however, eliminate the location of essential industries, water pumping stations, telephone exchanges, hospitals, penitentiaries and similar properties in the path of any conceivable flood waters. The lesson taught by floods of the past must be heeded. The persistence with which properties are located in sections where they should not be cannot but give rise to the same trouble that exists in foreign countries. Rome, Paris, London and Moscow, for example, have worked intermittently for centuries on their flood problems and have not to this day succeeded in conquering them.

Flood Forecasting:

One of the most important and practical means of reducing damage from a flood is knowledge beforehand that the flood is coming and that it will reach a certain height. Armed with this knowledge those whose property is subject to flood do what they can to protect it. Stock and equipment is moved to higher floors in the building or moved to higher ground. Temporary bulkheads to prevent the entry of water to certain vulnerable sections of the property may be installed. Many steps may be taken by individuals to safeguard their property and by public officials to safeguard the property of all.

Flood forecasting on a systematic basis apparently began in France in 1854. The extent of the network of stations used at that time is not known nor is it known from available literature what degree of success was attained in making predictions. In any event, there has been no interruption in this forecasting service since its beginning 84 years ago. Similar work was undertaken in Italy and Bohemia in 1866 and was inaugurated in this country in 1871.

The United States Weather Bureau uses two distinct methods in forecasting floods. The older and more refined method is based on gage relations and, in some instances, from discharge data. The other method is forecasting largely or altogether from reports of rain that has fallen or is expected to fall in the period under consideration.

Forecasts of expected stages in down-river areas are based almost invariably upon gage relations up-stream. Of course, in some cases it is necessary to give weight to intervening rains. It is obvious that the farther a section of a river is removed from its source waters the greater the time range that is possible in making forecasts. Predictions based upon gage relations have been made with a more or less degree of satisfaction for some 65 years. Ordinarily the term of forecasts ranges from two to three days in the upper valleys to as much as from three to four weeks in the lower Mississippi.

Gage relations as a basis for flood forecasting do not, however, form practical bases for use in the head waters of a stream or in a basin into which flow numerous small source streams. This is true of much of the country east of the Appalachian Mountains. To be effective in such areas, forecasting must be based upon knowledge of rainfall both as to amount and intensity and upon its geographic distribution. This method of forecasting, referred to as the Unit-Hydrograph Method, is a recent development. Briefly, it depends upon the rapid collection of rainfall data in the basin under consideration, correlating this with a factor of discharge or run-off. It has been found that the discharge from a relatively small watershed may be an index to surface conditions over much larger areas. Small basins having this characteristic will be equipped with automatic stage recorders and facilities set up to transmit the record of flow promptly to the forecasting centers. Thus the "index" watersheds will provide, in the early hours of a storm, an indication of what its actual run-off co-efficient is to be. Of course, this co-efficient will vary from day to day and from year to year. Frozen ground saturated soil, snow-covered areas, dry dusty conditions will all have a material effect upon the amount of rainfall that will find its way into the stream as run-off. Once the run-off co-efficient is established the expected crest can be predicted with a considerable degree of accuracy, although it is, of course, impossible to formulate the ultimate peak crest until the rain ends.

Inadequate or erroneous estimates as to probable flood crests are ofttimes worse than useless and may contribute materially to the total damage resulting from a flood. It is conservatively stated that the flood losses throughout the nation for the past 35 years are about two billion dollars. It is estimated that this loss could have been reduced at least one-fourth had an adequate system of flood forecasting been in operation on all the principal rivers. This savings is only incidental to the saving in loss of life and human misery which accompanies all major floods.

Considerable criticism has been directed at the United States Weather Bureau for its failure to forecast with any degree of accuracy the recent unprecedented floods. This is particularly true of the 1936 flood at Pittsburgh. In that flood the Pittsburgh office of the Weather Bureau issued, at 8:00 A. M., on March 17th, a prediction for the forenoon of March

18th of 33 feet. On March 18th at 8:00 A. M. it had reached 42 feet and 43.6 feet was predicted as the ultimate crest. By 9:00 P. M. that same day it had actually reached 46 feet. It is stated that had an accurate 24-hour notice been received, one single department store would have averted a direct loss of over $750,000. The blame for this unfortunate situation is placed upon the fact that the United States Weather Bureau did not receive adequate weather reports and rainfall data from its various local observation stations.

In Cincinnati, in 1937, the residents were inadvertently lulled into a false sense of security by forecasts which did not predict the river heights several days in advance as was usually the custom. In fact, on January 21st at 7:00 A. M., the Weather Bureau bulletin stated that it was impossible to make any further accurate forecasts and that the crest might reach 66 feet. On January 22nd with a stage of 71.3 feet, it was predicted that the river would rise two or three feet more. On January 24th the forecast was for 75 feet the following day, but on the following day it was 80 feet, from which point it began to recede. It is acknowledged that more accurate and earlier forecasts would have saved millions of dollars in Cincinnati.

With reference to the criticisms which have been aimed at the Weather Bureau, it is necessary, from a sense of fairness, to recall that the two cases specifically cited presented most difficult problems. As has been stated in the Pittsburgh area, the central office was unable to secure adequate data from the observation stations. In part this situation is due to the fact that the Weather Bureau has been operating on a reduced appropriation necessitating the curtailment of a number of observation stations. Furthermore, although the need has been recognized, there has not been provided sufficient equipment and stations in the Pittsburgh area to permit accurate forecasting, under conditions of heavy rainfall in the small basins uniting to form the Ohio at that point. The Cincinnati situation was rendered particularly difficult because, although up-river gage heights could be translated into corresponding expectancies at Cincinnati, there was an unusually heavy rainfall in the immediate valley of the Ohio itself. This increment could not be accurately weighted with the equipment and data available to the present Weather Bureau operations in that district.

Mention of the activities of the Weather Bureau would be grossly incomplete if it failed to include some statement relative to the progress which that Bureau is making in weather observation and in the collection of data upon which to base forecasts. Rainfall records have, for the most part, been merely a figure representing the total amount of rain which fell in a certain locality in a period of 24 hours. This is of but little value in connection with watersheds having concentration periods of but two or three hours. It is essential to know not only how much rain fell in 24 hours, but also the maximum intensity of its fall. To provide for this deficiency a number of recording rainfall gages are being located in certain strategic watersheds. Steps will be taken to see that during critical storm periods the data from these gages are transmitted hourly to the forecasting center.

New recording stream flow gaging stations are being installed, particularly in the region of Pittsburgh where flood forecasting must be rapid and accurate to prevent enormous losses.

The Weather Bureau is making use of the latest developments in transmission facilities. Of particular interest is a recently developed telephonic stage transmitter which utilizes a standard telephone. A device actuated by the ringing circuit raises the receiver of the telephone at the gaging station throughout a period sufficiently long to encompass the cycle of stage signals.

Since the World War quite definite progress has been made in other phases of weather forecasting. Prior to that time methods were largely empirical and were based almost exclusively upon surface conditions and clouds. In more recent years with the increase in the number of observations made by airplane, it has been possible to obtain the characteristic properties with respect to temperature, humidity, and pressure of the masses of air which overlie great regions of our country from time to time. Various data obtainable from such airplane observation permit the Weather Bureau to ascertain weather disturbances at their very inception. Thunderstorms can be forecast accurately and observers assisted in determining not only the speed of movement of a disturbance, but also whether it will increase or decrease in intensity. Recently rapid developments have been made in the use of the radiometeorograph which, attached to a balloon and sending back signals of pressure, temperature and humidity, ascends to heights well above those obtainable by airplanes. All of this will undoubtedly result in marked improvement in forecasts of all types.

Because accurate flood forecasting is of such importance in any consideration of the general subject of floods, it may be of interest to note that the Weather Bureau, in order to improve this service, is proceeding along the following lines as rapidly as funds permit:

1. The establishment of more and better placed rainfall stations, especially in the head water regions.

2. The installation of an adequate network of recording rain gages to enable the forecaster to know the intensity of rainfall. At present most of the gages are merely of the eye-reading type indicating accumulative rainfall without respect to intensities.

3. Survey of the amount and condition of snow in the mountains.

4. Arangements for a more reliable transmission of rainfall and river stage data. In the Eastern floods of March, 1936 the Weather Bureau places part of the responsibility for lack of accuracy in flood warnings upon failure of wire communications. Radio is being considered for this purpose.

5. Reorganization of the country into eight districts, each under the supervision of a capable hydrologic engineer.

Miscellaneous Factors Affecting Floods:

Several programs being sponsored and prosecuted by the Federal Government are of such a nature that they have a bearing on the flood situation. While the War Department functioning through the U. S. Army Engineers is responsible for flood control on the major streams, the Department of Agriculture is responsible for this work on the watersheds. In conducting this work the Department of Agriculture coordinates its forestry work, soil conservation work, the work of the Bureau of Biological Survey, the economic work of the Bureau of Agricultural Economics, the engineering work of the Bureau of Agricultural Engineering, and so on. It will suffice for the purpose of this paper to make brief mention of some of the work of this department pertaining to the flood problem.

Under the Soil Conservation Service a comprehensive study of erosion has been made. It has been found, among other things, that the plowing of the land has speeded up run-off of water so that it is about nine times as rapid as were vegetation and grasses to remain untouched. By cooperation with the farmers on such matters as contour cultivation rather than up and down the slope furrowing, terracing where necessary to prevent erosion by rapid run-off, and by retiring certain areas from active cultivation permanently to vegetation, such as grass, trees or shrubs, definite progress is being made in decreasing run-off in some of the head water areas.

Proceeding on the basis that the control of water begins at or near the place where it falls, the Division of Forestry is conducting reforestation in certain localities where denuded slopes and drainage areas contribute materially to floods.

especially in the comparatively small streams and brooks which cause great damage and which make up in numbers throughout the nation what they may lack in size or spectacular effect. On the basis of data now available the Department of Agriculture has stated that the following conclusions seem amply justified:

Reforestation will

1. Reduce the quantity and rate of run-off from a drainage area during the times of flood crises by

    (a) Increasing the rate of infiltration into the soil.
    (b) Increasing the water-holding capacity of the soil.
    (c) Mechanically retarding run-off.
    (d) Retarding the rate of snow melt.

2. Through increased absorption, increase ground water supply and regularize stream flow.

3. Reduce rate of deposition of erosional debris in waterways, thus lengthening the effective life of down-stream control measures, such as levees, reservoirs, etc.

4. Prevent shoaling of streams through silt deposition, thus aiding in the reduction of flood crests.

All of this work is to be considered as assisting and reinforcing control work on larger rivers. It is by no means a substitute therefor. It is recalled that great floods occurred hundreds of years ago when most of the drainage area of rivers was "forest primeval."

The Biological Survey serves this broad question of flood control principally by coordinating its functions of the propagation of big game, migratory birds and water fowl with the official flood control agencies. The establishment of refuges for wild life, particularly those for migratory water fowl, requires the impounding of water to form reservoirs and marshes. These may be in many cases so selected that the most good from a flood control standpoint may accrue from them. Incidentally, the conservation of fish and game may be materially aided by the method pursued in operating certain flood control works.

The Bureau of Agricultural Economics studies the economic soundness of the various flood modifying plans before soliciting actively the cooperation of the farmer. Flood considerations may require a change in the type of farming, cropping, etc., and the question as to the effect of such change on farm income is naturally a most important factor in securing the cooperation of the farmer.

These so-called miscellaneous factors may be expected to have but little immediate effect on the flood problem as it presents itself with reference to the major rivers of the nation.

II.

MEETING THE FLOOD SITUATION

The following discussion concerns itself with steps which may be taken to mitigate damage from floods and to provide a degree of protection against fire during flood periods. Economic considerations may indicate the advisability of determining the maximum flood for which preparation should be made. This is largely an individual problem which must be answered for each municipality and indeed for each property which may be affected. Whether to design for a flood which may be reasonably expected once in fifty years, or whether to design for a river stage somewhat in excess of the maximum of record, necessarily depends upon many factors, including the value of the property involved and the expense of providing flood protection. Desirable as it may be, it is not always feasible to protect property against a flood which may be expected at most infrequent intervals.

RESPONSIBILITY OF THE COMMUNITY

The greatest share of responsibility for minimizing the loss of life and property from floods rests directly with the municipal government. Obviously, it is incumbent upon the municipality to see that certain essential properties are located well above any expected flood height. Fire alarm headquarters, police department, radio and communication headquarters and similar vitally important features of municipal administration should be so situated that they can function unimpaired during any expected flood. In addition to the necessity of seeing that municipally owned property is not located where it is subject to flood damage, the city has a definite obligation to its citizens. This obligation may advantageously be considered first, with respect to planning to prevent future flood damage, and second, with respect to the functioning of the various departments of municipal government and administration during a flood.

Designing and Planning

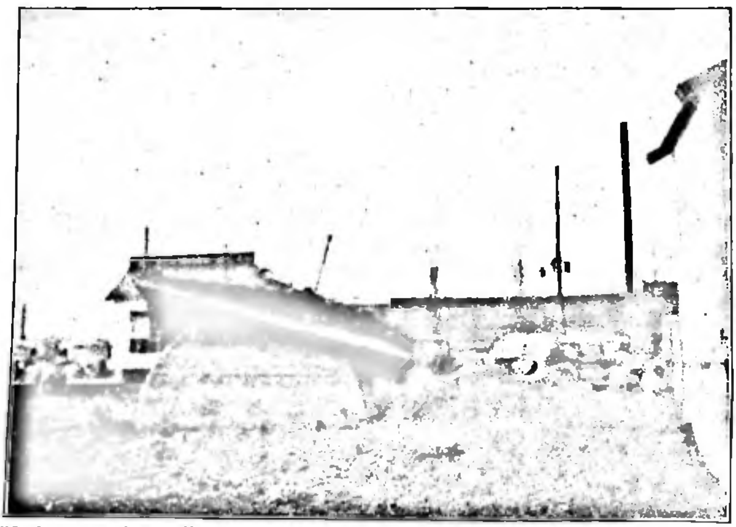
Zoning—It seems elementary that by the enactment of proper zoning ordinances the type of property which may occupy lowlands subject to inundation should be limited. If economic considerations would permit, the ideal situation would result if all such areas subject to flood could be utilized as recreation centers or parkways which would enhance the beauty of the city and contribute materially to the welfare of its citizens during normal periods, and which would result in a minimum of loss during periods of inundation. Such an arrangement, however, is somewhat Utopian inasmuch as certain industries have definite and perhaps valid reasons for locating on the river bank. It is the duty of the municipality, however, to forbid, by the enactment of suitable ordinances, certain types of property from locating where floods are a menace. Certainly there is no justification for permitting hospitals, penitentiaries, children's homes and similar institutions to be located where the lives of those who inhabit them are endangered by high water. Certain areas may well be made unavailable for dwelling purposes. If lowlands not protected by reliable dikes or levees must be occupied they should be restricted to certain industries and private enterprises, the nature of which creates no hazard to other nearby properties during time of flood.

It is recognized that the abandonment of an established section of a community presents many tremendous problems and may impose a considerable burden upon the municipality, but yet the benefits to be gained are obvious and from an economic standpoint will, many times, justify the act. Several cities are aware of the desirability of removing valuable and susceptible properties from flood-subject areas, and have taken preliminary steps to accomplish this, realizing that this results not only in minimizing the likelihood of severe property damage but, what is more important, results in removing from danger the lives of those who might otherwise be trapped by a sudden rise of water.

Where topography is such that certain sections of a city may be isolated and inaccessible during periods of high water, it is essential that in planning street improvements due consideration be given to the desirability of elevating main avenues into such areas. Bridges should be built to withstand maximum flood heights and should be so designed as to offer the least possible obstruction to water flow. It is important that these sections, not actually inundated but surrounded by water, be made accessible so that food and supplies are available and so that fire protection can be maintained.

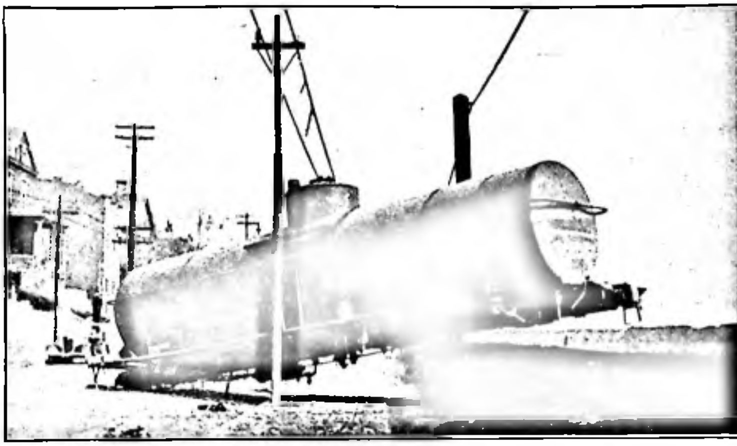
Flammable Liquid Storage—The ever-increasing use of the internal combustion engine in almost every phase of modern civilization has resulted in the storage of tremendous quantities of oil and gasoline in cities and towns. Much of this storage may be found in the low lands subject to flood. In Cincinnati alone there was stored in the flood area 8,600,000 gallons of gasoline and oil at bulk stations, 750,000 gallons of gasoline in underground tanks at filling stations, and appreciable quantities of gasoline and oil at industrial operations.

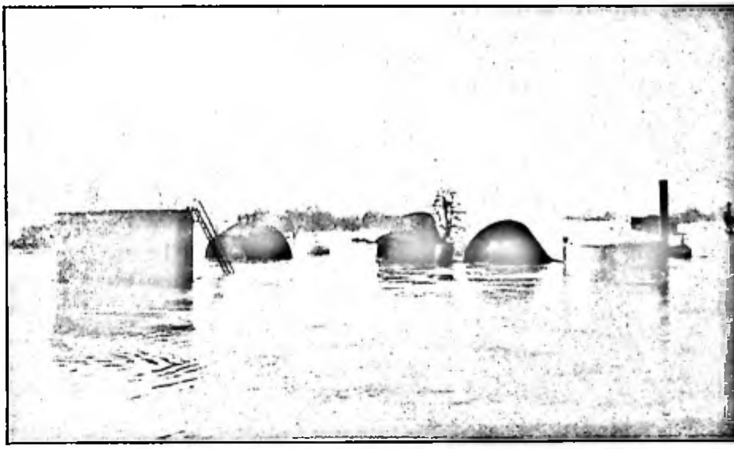
Experience has demonstrated most convincingly the extreme hazard of locating oil industries or operations requiring the storage of oil in lowlands subject to inundation. Hundreds of tanks containing flammable liquids have been subject to floods within recent years. Many of these were comparatively undamaged and retained the liquid which was in them. Others, however, floated away or were lifted off of their foundations, rupturing pipe connections and spilling their contents into the flood waters. A history of large fires during floods is predominantly a recounting of losses due to this circumstance. The fires at Pittsburgh in 1936 and in Springfield, Mass., that same year, a fire at Louisville and the most serious Mill Creek conflagration in Cincinnati in 1937 should preclude the need of any further demonstration of the hazard attendant upon oil storage. If a municipality cannot prohibit the storage of oil in flood-subject areas, then its duty to its citizens demands the adoption of city ordinances providing for the safeguarding of such oil tanks as must be located in those areas which will be subject to high water. The National Board of Fire Underwriters, cooperating through representation on a joint committee with the American Petroleum Institute and the International Association of Fire Chiefs, developed regulations which, if followed, will provide suitable safeguards for oil storage. Every municipality subject to flood should make mandatory the requirements contained in the Regulations of the National Board of Fire Underwriters on Containers for



Underground gasoline tank under 6-inch concrete slab upheaved by flood.

Flammable Liquids (NBFU Pamphlet No. 30) or in a special pamphlet issued by the National Board of Fire Underwriters entitled "Recommended Safeguards for Flammable Liquids Storage Tanks in Regions Subject to Floods."


Tank car floated from tracks 20 feet below wall on right.


Foating oil tanks create serious fire hazards during floods.

Water Supply—An uninterrupted supply of water for sanitary and fire defense purposes is of paramount importance in any community. In those communities where the service is furnished by the municipality the responsibility for the continuity of supply is a direct obligation of the city administration. In those cases where this essential service is rendered by private enterprise, franchises and service agreements are invariably such that the municipality cannot escape responsibility for the existence of systems which cannot function during floods. As a matter of fact, experience indicates that, if anything, private enterprise is more prompt and ready to make those corrections in existing systems which will insure continuity of service than are the municipalities themselves.

The fundamentals of design of a suitable waterworks system including the pumping station, filtration plant, storage reservoirs and distribution, are relatively simple. The most desirable arrangement locates the pumping station well above any expected high water. It is particularly essential that pressure pumps supplying clear water to city mains, and the filtration plants, and settling basins, be so located. The task of cleaning filter beds which have been contaminated by flood waters is one that requires considerable time during which potable water cannot be furnished the community.

It may be necessary to place the low-lift primary pumps at a lower level. If low-lift pumps are located below flood level the site should, of course, be protected by suitable walls or dikes of sufficient height to withhold water from the building. Motor-driven pumps are manufactured which are admirably suited for low-lift purposes and which may be operated entirely submerged in water. In many instances these may be used to advantage for low-lift purposes where it is impracticable to protect equipment against inundation.

Adequate provision should be incorporated in the design of steam power waterworks for a fuel supply sufficient to operate the plant for the duration of any expected flood, and coal handling apparatus should be such that it will not be interfered with by high water. If power is electric every precaution should be taken to see that there will be no failure during the emergency. Dual sources of supply should be available and current should be transmitted to the waterworks over dual transmission lines so designed that essential transformers, switches, and similar equipment are located above flood waters. If there is any reasonable doubt as to the continuity of electric service the pumping station should be provided with emergency generating equipment operated by steam or other suitable motive power.

There may be situations where the use of portable gasoline pumps for emergency purposes will be found advantageous in water pumping stations. It is true that in the case of large systems these pumps cannot begin to supply the demand, but they may be able to maintain pressure on the system which is of definite value when emergency reservoir supplies are made available only for short periods during the day. It is important to remember that whatever emergency equipment is provided should be given good maintenance at all times. Too many times emergency equipment is allowed to deteriorate merely because it is not in regular use, and then is not available for service when it is so greatly needed.

Consideration should be given to the advisability of providing chlorinating apparatus for use in those cities where water supplies may be interrupted and possibly contaminated by floods. Even though such apparatus is not normally used, it will be of definite service following a flood when health considerations make it necessary to chlorinate the water.

Water supply systems should be designed so that the pumping capacity is to be available during any period of flood, and any storage reservoirs in the design should be considered merely as adjuncts and not as a principal source of supply to be used while inadequately protected pumping stations are out of service.

In the design of the distribution system cognizance should be taken of the fact that certain sections of the areas served will be inundated and that there may exist in these areas a great number of broken pipes and mains. It is essential, therefore, to locate valves which will sectionalize such areas to prevent the wastage of huge quantities of water. The use of bridges which may be damaged by high water should be avoided as supports for water mains which cross a river.

The task of providing a complete water supply system designed to withstand floods is one which cannot be accomplished overnight, and it must be borne in mind that many communities have considerable sums of money invested in the existing vulnerable systems. At least, until such time as an opportunity is afforded to provide a suitable system which can withstand flood conditions, important buildings may be protected by flood walls or dikes. In some cases it may be necessary to provide watertight bulkheads for doors and windows and to see that any other openings are suitably caulked. This is an uncertain arrangement, which, although suitable for an emergency, should not be looked upon in any sense as a permanent solution to the problem. Frequently a pumping station bulkheaded in this manner will have exterior walls which are not sufficiently strong to withstand the water pressure against them. The limit to which a waterworks plant can be barricaded depends upon many conditions, including the design of the buildings and the porosity and water transmission capacity of the soil on which the structures are built. It is necessary to take special precautions against floating by filling all underground storage tanks, as well as those aboveground which are below flood level. Concrete floors may be weighted by using pig lead, sand bags, or other satisfactory heavy material. When pumping stations are to be bulkheaded it is necessary to see that all pipe holes carried through foundation walls and other similar openings are effectively closed. It is almost impossible to caulk pipe holes from the inside and, consequently, this must be provided for in normal times and not delayed until a flood is imminent. Effectively sealing a building requires that all abandoned pipe lines be sealed watertight and that sewer lines or drains be constructed of cast-iron pipe with tested joints and suitable valves. It will be necessary to provide sufficient auxiliary pumping equipment to discharge such leakage as finds its way into the plant. As a rule the portable type gasoline-engine-driven centrifugal ditch pumps are satisfactory for this work.

It is well to remember that steam power pumps can ordinarily be put back into service after inundation more rapidly than can those relying upon special electric motors for power.

Electric Power Service—Electric generating stations, because of their requirement of huge quantities of water for condensing purposes, will invariably be located on the very bank of the river. It is impracticable to ask that they be located on high ground where it would be necessary to pump condensing water to a considerable height. However, it is possible to construct power houses so that they may continue operation even though entirely surrounded by water, and most of the large utility companies have taken steps to floodproof those plants which have in past floods been thrown out of service. This may be accomplished by constructing suitable flood walls around all essential equipment, thus making the plant virtually watertight to a point above any expected flood height. To do this requires massive construction and weighting to prevent any tendency to float when the structure is surrounded. For example, the new floodproof condenser pit at one of the plants in Cincinnati has concrete walls 6 feet thick. Generators are at an elevation well above any previously reached river stage. Switching apparatus, house service equipment, and boilers are all so protected or elevated that they will be immune from flood damage. Similar steps should be insisted upon in the case of any plant subject to interruption by high water. It is also essential to see that ample fuel will be available for use during the flood siege.

Courtesy, Cincinnati Gas and Electric Co. *© M. Parks Watson, Cincinnati.*

"Columbia" Power Plant near Cincinnati. Out of service during 1937 flood but now protected against river stage 7½ feet higher than 1937 crest.

To insure the delivery of energy to the various points of consumption, all transformers, switches, and similar equipment must be elevated. Particular attention should be directed to the location of any underground transformer vaults on the distribution system to insure that these are not located where they will be filled with water, unless the equipment is of the special type which will not be affected by submersion in water. Important transmission lines should be so designed and constructed that they are afforded protection against flood damage.

The company or department furnishing electric service to a community should have established well in advance of any flood a regular program of action to be followed when certain flood heights are predicted. The use of a card index system makes comparatively easy the location of certain meters and equipment which should be removed in advance of the rising waters. Systems of this kind are successfully used by public utilities in several of the flood-subject cities.

Gas Service—It is important that gas service be continued during the period of a flood because of the demand which will be made upon it for heating and cooking in those sections of the city not affected. Artificial gas plants should be located above flood levels, as should also the gas holders. Of course, extensive existing structures which it is not feasible to abandon should be afforded protection by flood walls or dikes.

Courtesy, Cincinnati Gas and Electric Co. *© M. Parks Watson, Cincinnati*

"West End" Power Plant, Cincinnati. Out of service during 1937 flood; now protected against river stage 7½ feet higher than 1937 crest.

Natural gas systems should be so arranged that essential regulator stations, valve houses, etc., will be located at safe elevations.

Gas distribution systems should be sufficiently valved to permit shutting off those sections of a city which may be flooded, thus preventing the escape of gas from broken mains with the attendant life, fire, and explosion hazard. A complete program of action should be formulated in advance of any flood, and meters which should be removed at certain river stages listed in readily accessible form.

Telephone Service—Telephone service is vitally important during time of emergency. Here the solution is similar to that applied to electric power service; namely, the elevation or adequate protection of all equipment essential to operation.

Emergency Codes—The adoption of a predetermined plan of civic administration during the emergency of flood should be accomplished in every city where this damage threatens. When a flood really approaches there will be many things which must be done; many actions which must be taken and many decisions which must be made, and there will be but little time to consider them. The regular routine of normal government is too cumbersome and moves too slowly to meet the situation. Certain officials must be given extraordinary authority; there must be complete and rapid correlation of all municipal departments to avoid duplication of effort when no effort can be wasted and to avoid confusion in the protection of life and property. Liaison must be established upon an efficient and workable basis between the many activities of the city itself and the other agencies called into service during the emergency.

Obviously, all this may be better accomplished if some well considered plan is available for use when the emergency arises. Several cities have adopted such emergency provisions. Oklahoma City, aware of the possibility of a severe conflagration due to the existing oil and gas hazard, has outlined a code to be followed in case of disaster. Los Angeles, mindful of the earthquake hazard, has adopted such a code which functioned effectively and proved of definite assistance during the flood of 1938.

An emergency code should be drawn so as to provide the best means to meet the many situations presented by a disaster. One of the prime requisites for efficient handling of disaster is to keep the general public from becoming panic stricken. A means towards this end is to keep the public services as normal as possible. This may best be accomplished by grouping the control of water, electricity, gas, and transportation facilities under one head.

A proposed emergency code for the city of Cincinnati constitutes perhaps the most recent thought on this subject. It represents, for the most part, the procedure followed by the existing civic administration in Cincinnati during the flood of 1937. This code has a great many excellent features and may well be studied by any community, even where the occurrence of disaster is more remote than it is in those cities located subject to recurrent floods. For that reason the proposed Cincinnati Code is included in this treatment of the flood subject.

Cincinnati has a city manager form of government but the code, with minor revisions, would be equally suitable for any other form of municipal administration. Attention is called to the fact that the code provides for the making available of necessary equipment. boats, ropes, etc. Other features provide for exchange of information concerning missing persons. Rehabilitation control is provided for and sanitary aspects of the situation are adequately covered. Arrangements are made to provide first-aid and medical assistance, clothing and food. All cities are prepared to meet these necessities in some manner or other, but manifestly this can be done with a great deal more efficiency and less duplication of effort if the entire plan is predetermined and given authenticity by official adoption.

The Emergency Code prepared for the city of Cincinnati will be found in Appendix C.

During the Flood

Consideration has been given to the steps which a municipality should take during normal times so that when the flood threatens it will find itself in the best possible position to cope with rising waters. Safety to life and property will not be guaranteed by these preparations. Much will depend upon the manner in which the city actually meets the flood. Almost invariably when a flood impends there will be an official warning issued by the Weather Bureau giving the expected height which the waters will reach and the expected time of the crest. It is now that the defense plan of the city must begin to function speedily and efficiently. Official warnings must be issued through the medium of press and radio. The city must virtually prepare itself for a siege. Experience has shown that such preparations should contemplate a river stage which may be somewhat higher than the actual figure predicted. Unforeseen concentration of rainfall may make even the careful calculations of the Weather Bureau experts erroneous.

Police Department—The police department must prepare for any rescue work which may be necessary, seeing to it that boats, boots, and other essential equipment is available. Certain sections of the city must be evacuated and any orders issued to that effect must be enforced immediately. Traffic may need to be rerouted to make it possible to move personal belongings from the areas which will be flooded. Special parking regulations may need to be put into effect at once to keep clear for emergency important thoroughfares. If the expected flood is likely to be of unusual proportions and the situation require the assistance of the military, such as the militia, coast guard, or similar agencies, the work of correlating the duties of these organizations should be undertaken at once.

The police department must be prepared to assist the fire department in exerting police power to secure any necessary safeguards, particularly assisting to enforce the orders of the fire department relative to the steps to be taken in minimizing the hazard from oil storage tanks which will be subject to flood. Arrangements should be made to patrol regularly the flooded districts in boats for the purpose of preventing looting and also to enforce any rules designed to safeguard life and property such as rules prohibiting smoking in any areas where gasoline vapors or gas leaking from broken mains or other hazards exist.

Fire Department—The fire department will be called upon to face unusual handicaps in its effort to provide fire protection for the city during the time of high water. When the flood warning is received and the probable extent of the inundated area determined, steps must be taken to move out of the area equipment which would otherwise be rendered useless by high water. Certain fire stations must be temporarily abandoned and the equipment located where it will afford the best possible protection for the affected areas. Fire alarm boxes which are likely to be under water should be removed and the areas from which this service has been discontinued constantly patrolled with the realization that fires may start and, because of the prevailing excitement and individual concern of those evacuating the area, be not promptly reported. This patrol service should be maintained until the regular alarm system is again operative, preferably by the use of power boats when the water has risen if the current is not too strong to make this possible. Boats should be provided with some means of signaling an alarm when a fire is discovered. This may be accomplished by a special type of siren or by small portable radio transmitting sets. Boats should be provided with chemical extinguishers in the hope that small fires which have been discovered and reported to headquarters may be extinguished in their incipiency.

The extreme hazard presented by oil and gasoline tanks in flooded areas demands that the fire department supervise the investigation of the situation immediately upon receipt of the flood warning. This is particularly imperative in those cities which have not adopted and enforced a suitable ordinance governing the location and construction of oil storage tanks. It is necessary to check every filling station, oil distributing station, refinery, or industrial operation employing oil storage located in the expected flood areas to see that every reasonable safeguard is taken. It will also be necessary to look into the situation at those properties which are heated by fuel oil and which may have appreciable quantities in storage. All tanks which are not properly safeguarded against flotation, even when empty, should be completely filled before the waters rise. Aboveground tanks may be filled with the liquid they contain if the expected flood crest will not be sufficient to float the tanks when filled with the flammable liquid. Underground tanks and others which will be largely submerged at the expected flood crest should be filled with water thus providing as much total weight as possible to combat buoyancy. After tanks have been filled the vent, fill, and discharge pipes should be sealed shut. In an emergency this may be accomplished with the use of a suitable plug covered and sealed with cup grease. Care should be taken in filling oil storage tanks to see that all open flames in the immediate vicinity are extinguished, thus minimizing the hazard which results from discharging flammable vapors from the vent pipe. Practically all of the major fire losses during recent floods have been the direct result of ruptured oil and gasoline tanks, and too much emphasis cannot be placed upon the absolute necessity of seeing that this hazard is safeguarded in every reasonable respect.

The fire department may find it advisable to suggest that oil refineries and bulk stations of the various oil companies pool their surplus supply of foam powder, foam generators and similar appliances at some central location where it will be accessible to the fire department in case of emergency. The opportunity for the individual plant to use foam at the time it is flooded may not be available, but with the entire surplus supply pooled and accessible to the fire department, some effective fire defenses may be possible.

In preparing to afford effective protection to the inundated areas, the fire department should have available such special equipment as may be of assistance in reaching fires in properties in such areas. Pumping equipment may be mounted in barges and arrangements made to move the barges by power boat. It is usually better, however, to equip several small power boats with pumps sufficient to furnish at least one good fire stream. Many difficulties will be encountered in maneuvering large barges, particularly if the current is swift and if overhead wires interfere. It is well to see that the boats are equipped with spray nozzles of a type particularly effective in combating oil or gasoline fires. Ordinarily, it will be found advantageous to use 1½-inch hose on the boats as this is much more easily handled under the adverse conditions obtaining than is the larger hose. In Pittsburgh consideration is being given to providing a barge on wheels equipped with a fire pump. Such a barge could be pulled to the water's edge and then, after it is floated, towed to the scene of the fire.

It has been found advantageous in hose stream towns to equip certain strategic hydrants with a length of hose attached to a float or otherwise arranged so that it terminates above the water. A hydrant can usually be opened under water, but it is not comparatively easy to attach hose to it.

In order to make as much use of regular equipment as possible it is advisable to "sound" the streets to determine to what extent apparatus may be taken into inundated areas where, if necessary, suction may be taken from the flood water. Ignition systems of apparatus should be waterproofed as far as possible. The foregoing outlines, in general, the steps which should be taken to afford as effective protection as possible to the inundated areas.

While requiring a great deal of preparation and entailing many hardships on the part of the firemen who may be called to combat fires in the flooded sections, the problem is by no means as serious, where public water supply is maintained, as is presented by a situation where water supply for the entire city is put out of service. An entire municipality devoid of its normal protection and practically helpless in the face of any serious fire certainly challenges the resourcefulness and ingenuity of the fire department. That these situations did exist and were almost invariably faced without despair but with a determined effort to carry on as well as possible, is indeed a tribute to the spirit and intelligence of the municipal fire departments.

Similar situations may, unfortunately, arise in the future. For that reason it is well to consider some of the emergency plans and methods adopted by fire departments during the recent floods. Their use proved to be effective once and may be the means of saving untold life and property again.

Because of the seriousness of the situation, rigid rules of fire prevention must be promulgated and strictly enforced. Now, if ever, everything possible must be done to prevent a fire. While the resources of the fire department will be severely taxed during the emergency, constant surveillance to minimize fire hazard may be undertaken by other volunteer organizations under the supervision of the fire chief.

If a fire does break out the problem of prime importance, of course, is to have some supply of water available. Small chemical lines may prove entirely inadequate and water must be relied upon. It is in solving this problem that the greatest resourcefulness has been used.

It is essential to have pumpers or suitable pumping equipment available. Therefore, such municipalities as normally rely upon direct pressure in city mains must take steps to provide pumpers when there is any likelihood of water supply failure. In many instances it has been possible to secure these from nearby cities for use during the emergency.

The fire department of any city where the regular water supply may be threatened by flood should have in permanent form, kept constantly corrected and readily available, a list of all emergency sources of water. These include private cisterns, swimming pools in clubs, hotels, etc., ponds, lakes, and during the flood, basements which may be flooded even though located in a district not actually inundated. A list should be maintained of all private fire pumps in industrial and mercantile establishments if the pumps have their own suction reservoirs. With this information the fire department will be able, in advance of any fire, to know just where the nearest source of supply for pumper suction is located. Water in a swimming pool of a city club, for instance, may, if the attack has been planned, be used effectively in combating a fire which may occur anywhere within a considerable area nearby.

Tank trucks such as those used by oil companies and having capacities of from 800 to 1,500 gallons, may be filled with water and one or more located in each fire station. Thus, when the alarm is received, the department will be able to respond with its own water supply, meager it is true, but ofttimes sufficient to extinguish the fire to which it has been called. Of course, additional tank trucks of water can be dispatched speedily to the scene of the fire when necessary. In all of this work, radio communication is decidedly helpful. Police cruisers receiving notice of a fire can direct to it other tank trucks which may be in use furnishing water for domestic purposes.

Special couplings should be provided so that in certain cases where it might seem advisable, connections can be made to a sprinkler drain thus drawing water from the gravity tank on the sprinkler system to supply pumpers or to fill the tank truck when a nearby fire threatens. This should be resorted to only after due consideration of the advisability of leaving helpless a sprinklered property in an attempt to save a nearby building. At times the alternative of not taking water from the gravity tank may result in the fire getting beyond control and possibly involving the sprinklered property and many others.

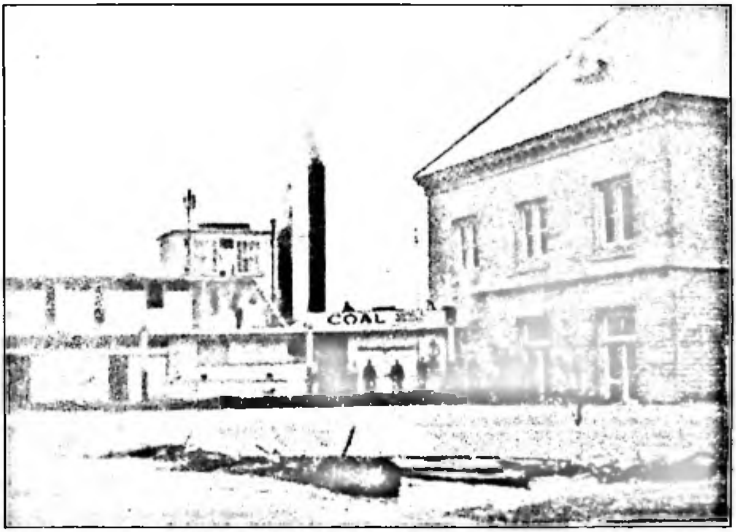
If the city has a separate high pressure water system not interconnected with the regular domestic supply, this may be made available for use if a pumper taking suction from the flood waters can be connected to it.

Manholes in the section of the city not inundated may be partly filled with backwater, and this should be investigated so that in case of necessity they may be used for pumper supply.

At times when the source of water supply is quite remote from the scene of the fire it may be feasible to connect several pumpers in tandem. This expediency was resorted to successfully in one notable instance during the 1937 flood at Cincinnati in a fire which involved the Riverview Apartments. Several pumpers were used taking suction from the discharge line of the pumper ahead of them, and in this manner water sufficient to extinguish the fire was conveyed for a distance of 5,000 feet.

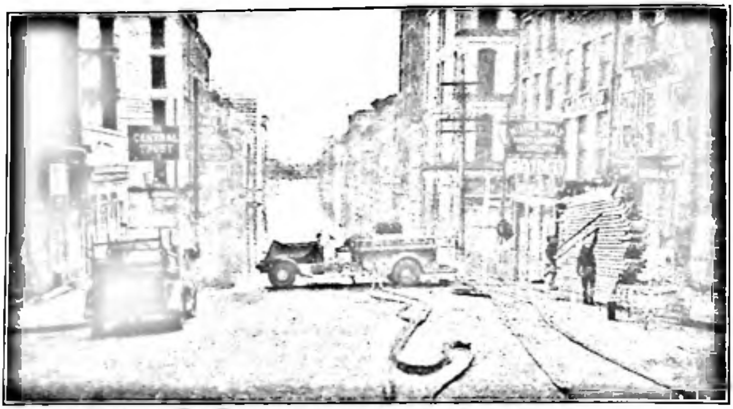
It will be found advantageous for the fire department to place large chemical extinguishers on wheels in certain properties where fire might readily result in serious loss of life. It is recommended that this practice be followed in connection with hospitals, children's homes, and similar institutions. Such extinguishers are for the use of the fire department and may form a valuable expediency during the time when regular water supply is not available.

Water Supply—If a city has installed its waterworks so that the pumping equipment, filtration plant and other essentials of the system are immune from damage by flood, the task of the waterworks department will consist of but litttle more than taking reasonable precautions to see that ample fuel is on hand, power equipment is in good order, chemicals and supplies are available, and to make certain that all reservoirs are filled. The department should stand in readiness to close the necessary valves to prevent excessive wastage if, during the flood, mains in inundated sections be broken, and the loss of water is sufficiently serious to justify depriv-



Courtesy, Louisville Waterworks.
River steamboat furnishing emergency steam supply to operate Louisville water pumping station. (1937)

ing such sprinklered properties as may be in service in the flood section of this source of supply. Unfortunately, however, at the present time those cities having water supply systems which can continue to function normally in the face of a flood of excessive height are by far the exception.



Courtesy, Cincinnati Fire Department.

Cincinnati fire department pumper at water's edge ready to supply fire main if alarm received. (1937)

Where water pumping stations are vulnerable to floods, such emergency action as may be necessary to protect the station must be taken immediately. This may involve bricking up door and window openings or providing other suitable watertight bulkheads, making certain that pipe openings, floor drains, sewers, etc., are properly blocked off to prevent the inflow of water. Suitable sump pumps must be placed in readiness to keep the plant as dry as possible. If there is danger of floating, the floor must be weighted with heavy material. If there is a likelihood that water will make it impossible to handle fuel and other supplies in the regular manner, special provision must be made to take care of this feature.

It is ordinarily advisable after storage reservoirs have been filled, to isolate them from the distribution system so that if the worst comes, at least that much water will have been conserved. It is recommended that wash water tanks be filled and held in reserve so that if filters become contaminated, means will be available to clean them without delay after water has receded.

Several ingenious methods have been employed in certain individual pumping stations in an attempt to continue service. In several the boilers are at a lower elevation than the pumping floor, and bulkheading or sandbagging merely the boiler room section has enabled the station to hold on for a while longer than otherwise would be possible. In other instances, certain essential machinery at lower elevations has been protected by a hastily constructed cofferdam. As a most interesting example of resourcefulness, reference is made to the efforts of the Louisville Water Company to continue to supply water during the 1937 flood. After making every effort to continue pumping, this had to be abandoned when the boiler house bulkhead let go, making it impossible to keep up steam pressure. The last of the steam was used to operate the crane to lift certain essential electric motors above the operating floor and above what was hoped would be the ultimate crest. It was decided to attempt to operate the steam pumps by obtaining steam from a steamboat which could be moored near the plant. The boat was secured and connected to the steam pump by flexible steam hose which was obtained from the railroad shops at Louisville. After working the best part of a day, steam was supplied to a 24 m.g.d. pump, although considerable difficulty was experienced when some of the plank flooring of one of the lower balconies floated in the spokes of the flywheel. However, outside of breaking the planks into small pieces and damaging the guard rails, this did

Courtesy, Cincinnati Fire Department.

Water station, Cincinnati, during period when pumping station was flooded. (1937)

not result seriously. The flexible steam hose was a constant source of danger and interruption. Meanwhile, however, the pump continued to operate, except when minor unavoidable interruptions occurred, and the river continued to rise. At its crest there was 4½ feet of water over the operating floor, with the result that the main crank shaft bearing of the 24 m.g.d. pump had over a foot of water above the bearing caps. This means that the main bearings of the pump were without oil, but, fortunately, they continued to operate without difficulty with nothing more than water lubrication and cooling. Later, oil was actually applied to the bearings while still under water by the use of long feed pipes, which provided enough static head of oil to overcome the water pressure. The task of maintaining water service under such difficulties seems to demonstrate the thought that there is really nothing that cannot be done if the proper effort be devoted to it.

If water continues to rise to a point where a bulkheaded pumping station is in danger of collapse because of external pressure, or if the leakage of water into the station becomes excessive and this no longer can be controlled, it will be necessary to abandon pumping operations. When it is finally decided to abandon a steam operated plant, the pumps should be shut down and the valves left in such a way as to cause the least possible delay in putting the pumps back into operation. Even in steam operated plants there will be found some electrical equipment including small motors, switches, and transformers. These should be removed and placed above high water. Should there be turbine-driven centrifugal equipment, the reduction gears should be disassembled and removed to a dry place. Cranes should be available to lift heavy electrical equipment such as motors and generators, because such equipment is particularly susceptible to water damage and it may require considerable time to place it in operative condition after the flood. If there is any danger of freezing weather during the time the plant is to be abandoned, care should be taken to drain, in so far as possible, essential piping within the station so that this will not be found broken when an attempt is made to resume operations. The proper detailed steps to be taken in the abandonment of any plant will be an individual problem, and the procedure to be followed should by all means be predetermined and available for use when the emergency arises.

It will now be necessary to investigate every possible means available for furnishing to the city at least some water for drinking and cooking purposes. The local situation will determine the emergency steps to be taken. It may be possible to pump into the city mains by private fire pumps, industrial pumps or by the use of fire department pumpers, water which may be obtainable from suitable private supplies, from industries, or institutions. Where cities are located adjacent it may be possible to connect hydrants on the ends of mains of the contiguous cities to hydrants on the ends of mains in the flooded city. Fire department pumps may be used to boost the pressure from one town to the other, although unless this emergency has been considered in the design of the distribu-

Courtesy, Cincinnati Fire Department.

Old steam pumper which supplied water to two Cincinnati suburbs. (1937)

tion system, it will usually be found that the small sized mains in the outskirts of the two cities will make it almost impossible to furnish enough supply to meet the requirements. It is possible to use several fire department pumpers in tandem in order to convey water a considerable distance, thus furnishing a partial supply for storage reservoirs or for distribution systems. At times hose lines may be laid across bridges spanning a river between two towns, one of which has not been involved in the flood.

As indicated earlier, any storage reservoir or tanks should have been filled when there was the slightest possibility of its being necessary to abandon the pumping station. Such storage facilities should have been isolated, thus making available such water as is contained in them. Unless such storage reservoirs are exceptionally large in comparison to the distribution system, or unless emergency pumps can maintain some pressure on the system, it is usually inadvisable to attempt to furnish water, even for a short time each day, by opening the valve between such storage and the distribution system because during the time the water is turned off, and in spite of the fact that the inundated sections may have been shut off by proper valving, there will be so much wastage in the lower sections of the city that the system will be emptied and much of the water from storage will be lost in filling the distribution system before it can be put to any useful purpose. For this reason it will perhaps be advisable to operate a fleet of trucks equipped with sterilized containers for the purpose of conveying potable water to certain convenient points in the city, from which it may be secured by the citizens. It is well to have a regular route and to cover the city twice a day at stated intervals. The use of a bell or special siren may serve some purpose in notifying the people of a certain district that water is available. Of course, if the supply is meager it will be necessary to limit the amount which will be furnished to each family. During some floods water for all purposes has been conveyed in large tanks, such as those which were obtained by dismantling railroad tank cars, and in some instances every conceivable container, such as whiskey barrels, were stationed at schools, refugee centers and other advantageous points from which water could be distributed. It is advisable to chlorinate this water, treat it with hypo-chloride of lime or to use other suitable purification methods. It is imperative to caution all people to boil water before use, and these warnings may be prominently posted at every distribution center and conveyed by means of radio and press notices. The services of Boy Scouts and similar organizations may be used to advantage in notifying individual householders of the impending shut-off of water supply and in furnishing information as to where water will be available.

The situation with respect to emergency supply is somewhat different in every locality and in every city. In meeting these individual problems those charged with the responsibility of furnishing water have indeed done well. Careful consideration of the problem of obtaining emergency supplies in advance of the existence of any emergency should be of immeasurable help in meeting such situations in the future.

Electric Power Service—The problem of maintaining in operation electric generating stations, whether privately or municipally owned, where the design is not such that they can withstand an expected flood crest, is very similar to that of water pumping stations. Emergency bulkheads may be erected, windows and doors bricked up to the necessary height and other similar steps taken in an effort to withhold flood waters. Meanwhile, plans should be made as to the best procedure to follow if the generating station must be abandoned. It may be possible to elevate above the expected crest certain house service machinery and equipment, thus facilitating the resumption of operations following the flood in the event that the main generators themselves are not involved.

Fortunately, in most of the larger cities, interconnection facilities, particularly in the case of privately owned plants, will supply at least enough energy to care for the absolute necessities of the city. Usually it will be necessary to enforce, with the assistance of the police department and other authorized organizations, a drastically curtailed use of current. It is often necessary to declare an emergency holiday for mercantile and industrial activities, and to use such meager supply of power as may be available for operating essential pumps, furnishing energy for light and power to hospitals and institutions, and possibly a maximum of one or two lights in each household.

Heating systems which depend upon electric controls or electric motors for pumping oil or operating stokers may have to be abandoned except in those buildings where heat is an absolute necessity, or where some other motive power is available.

Where there are no interconnection facilities, the problem is even more acute. It is possible that small increments of energy may be obtained from private plants at either industrial or large mercantile establishments. This may be sufficient to energize fire alarm systems, radio stations and certain other vitally important services.

Due to the imperative necessity of restoring the electric service as soon as possible after the water recedes, those responsible should anticipate essential equipment which will be required and take immediate steps to see that this will be available from the manufacturers or from other sources.

Gas Service—The use of bulkheads and cofferdams may make it possible to continue to supply gas after the plant is threatened by the flood, the situation again being similar to that obtaining in connection with waterworks.

Men should be readily available to close valves controlling any mains which may be broken during the flood. If possible, means should be employed to shut off gas service in all properties which the expected river stage indicates will be under water. Meters should be removed from all such properties so that the task of resuming service will not be delayed by the necessity of repairing or renewing meters damaged by water.

ation should be met by the provision of special private protective features, such as some means of storing water so that it will be available to supply hose lines during flood periods, and also by the installation of suitable chemical extinguishers, preferably of the type on wheels, when conditions are such that these may be readily handled throughout the premises.

Large industrial properties should be provided with one or more boats. These may be much needed and can hardly be secured after the flood has created a demand for all available boats in the community.

It may be feasible in the case of properties of large value, to construct flood walls or dikes to divert water from the premises. In other instances it will be practical to have available permanent bulkheads for door and window openings. Where appearance is of importance, effective bulkheads may be constructed as rolling steel curtains concealed in the reveal of the wall above large show windows of department stores, etc., so that they may be lowered and caulked when the necessity arises.

Sprinklered Properties—All of the foregoing comments relative to plans designed to minimize flood damage to properties in general are equally applicable to properties equipped with automatic sprinklers. Sprinklered properties present some additional individual features, however, by the very virtue of the fact that such protection against fire has been provided. As a class, the properties contemplate high concentration of value and from the underwriter's standpoint are given special consideration in more liberal underwriting. The cost of fire insurance upon such properties is materially less than in the case of similar properties not so protected, and it is but reasonable to expect that in the design of sprinkler installations the flood question will be fully considered and such special features incorporated as will insure the utmost reliability of protection.

With this thought in mind, certain features should be incorporated in the design of sprinkler systems in all properties subject to recurring flood. It is especially important to maintain sprinkler protection during times of flood when this is at all possible in view of the fact that public protection, if available at all, is usually at its lowest point of efficiency. In view of the possibility that city water may be shut off in flood areas, it is particularly important that a reliable secondary source of supply be provided for properties so located. Experience indicates that gravity tanks are the most reliable secondary supply under flood conditions and that steam fire pumps and electrically-driven fire pumps are next in order of reliability.

In general there are a few fundamentals of design and arrangement in sprinkler layouts which will assist in maintaining service under the adverse conditions presented by floods. Following are the more important of these:

All valves should be so located that they are accessible during the period of high water. This may require, in some instances, dual control valves; that is, the outside post indicator valve together with a gate valve located above high water. It may be possible to provide post indicator valves with suitable extension stems that can be put in place in advance of a flood and which may be quite useful if means can be taken to properly support the extension and protect it against floating debris. All dry valves should be located well above expected high water levels.

When valves are elevated in accordance with these suggestions it is important to see that the risers are propery boxed and protected against damage by floating debris, upheaved floors, etc., in the inundated section of the building. Precautions should be taken to protect the risers of dry pipe systems from freezing.

In the layout of sprinkler piping it is well to supply the basement sprinklers, and those on any other floor subject to flood, by lines which drop down from a control valve on the floor above, thus making it possible to turn off these sections of equipment from the floor above.

Alarms and alarm equipment should be located above the high water level, and any lines to supply lower elevations should be taken off above the alarm apparatus. Central station supervisory equipment on sprinkler systems should be located above any expected flood level. This is only practicable where the control valves are above the flood level. If post indicator valves have supervisory equipment a separate circuit should be provided, thus preventing the interruption of alarm service on the inside valves.

Air compressors should be located well above any expected high water level, and this same precaution should be taken with reference to fire pumps and their power supply. Special caution should be used to see that any circuits furnishing electric current are provided with every reasonable safeguard against interruption.

Consideration should be given to the installation of dry pipe systems in certain normally heated areas of high value when conditions may make it impossible to maintain heat during high water.

During the Flood

It is essential that those entrusted with the management of large and valuable property have authentic and advance notice of impending floods at the earliest possible moment. Attention is directed to the fact that the United States Weather Bureau is prepared to telegraph, collect, any company or individual who has made satisfactory arrangements to have such notification. The arrangement should be made with the local Weather Bureau office in the city or district in which the property is located, it being the usual practice to designate the expected flood stage which is of concern to the individual, it being understood that when this stage is expected to be reached or exceeded, notification will be made. This plan may be particularly useful to certain large interests which have important branches located in districts subject to flood and may wish to furnish special supervision to them when floods threaten.

Property in General—Having received notice it becomes the duty of those in charge of property to see that every possible step is taken to minimize damage from the impending flood. Of course, this can be accomplished with a great deal more ease and efficiency if previous considerations, as outlined earlier in this discussion, have been given to those features which may tend to lessen the probable damage. Investigation must be made at once to see that all damageable stock is moved to locations well above the expected high water level. Record storage vaults or safes should be made as watertight as possible. A liberal application of cup grease around door cracks and similar openings will usually be effective. Such temporary bulkheads as may be needed must be put in place. Windows should be boarded up to minimize breakage. If boilers are so located that they will be inundated, fires should be drawn and the boilers allowed to cool. Oil tanks must be checked to see that they are filled either with oil or oil and water so that the likelihood of their floating will be removed. Fill, vent and gage pipes must be sealed. If any tanks containing flammable liquids are so located that they are particularly subject to damage by debris and ice which may be carried by the current, attempt should be made to protect them against impact which might rupture them and liberate the oil. Careful check should be made to see that any gravity tank or other water storage facilities are properly filled so that in the event the city water fails, this supply will be available. A thorough check should be made to see that any chemicals or other material which may become hazardous when wet are above the expected crest. Provision should be made to shut off gas and electricity in any buildings which will be inundated. An effort should be made at once to have moved from railroad sidings any cars containing supplies or finished material which may be damaged by the rising waters. Any tank cars containing flammable liquids should be removed from the flood area. Care should be taken to see that ample fuel and supplies are on hand so that power and heat can be furnished if, otherwise, the boilers are not put out of service. Where possible, electrical apparatus should be elevated above expected high water and highly damageable parts of machinery disassembled and removed to a place of safety. A careful and thorough check should be made of all private fire protection equipment to see that this is properly located, so that it will not be inundated, and is in good operating condition. If the probable failure of regular sources of heat or light will make it essential to provide temporary means, the temporary devices should be secured and installed with due respect to fire hazard. During the period of flood, unusual precaution should be taken to prevent fire. Extra watchmen should be provided to patrol premises, smoking should be prohibited, and every other possible means taken to eliminate any hazard which might result in fire at a time when normal protection cannot be relied upon.

Sprinklered Properties—In addition to all the foregoing, special thought must be given to emergency steps to take in order to maintain sprinkler protection in properties which are affected by floods. The most serious situation will arise when the flood occurs at a time when freezing weather may be encountered, particularly if it is impossible to maintain heat throughout the property. Even with dry systems there are certain vulnerable points which must be protected against freezing. When it is likely that heat cannot be supplied in the regular manner, arrangements should be made to provide emergency heat for dry pipe enclosures, gravity tank risers, and similar essential points. This can usually be done with the use of Underwriters' Laboratories listed portable kerosene heaters suitable for the purpose, but it is essential that special precautions be taken in the use of such temporary measures to see that they do not create an appreciable fire hazard.

Sometimes the failure of the heating plant may result from the inability of the public water supply to function. If a gravity tank is available careful consideration should be given to the advisability of draining some water from it for use in the boilers. Needless to say, the use of such water should be limited to the quantity necessary to prevent freezing in the areas protected. In some heating plants the failure of electric power may be a serious matter, particularly if the devices are fired by fuel oil or by stokers. It may be possible to remove the stokers and hand-fire heating boilers and it has been found feasible, in some past instances, to operate stokers by means of a small portable internal combustion engine. Oil burners have been successfully operated during an emergency by small gasoline washing machine motors.

In the event of the failure of power supply, it will be impossible to furnish air for dry pipe systems in the regular manner. In this event, arrangements should be made for the acquisition of a portable air compressor or, as a final emergency step, provision should be made to use commercial cylinders of certain inert gases such as carbon dioxide and nitrogen. The judicious use of this method may supply sufficient pressure to replace the small amount of leakage in a normal dry pipe system. If the danger of freezing is remote and satisfactory air pressure cannot be maintained, operating the system wet may be resorted to as an expediency.

Every effort must be made to maintain water supplies for sprinkler protection, and this may become quite a problem when the regular supply fails. If the failure is due to a ruptured pipe on the premises, this may advantageously be overcome by the use of fire hose connected to the sprinkler system and to the source of supply ahead of the break. If the city supply is shut off, temporary emergency connections may be possible with some nearby property having a private source of supply at least sufficient for some degree of sprinkler protection. It may be possible to provide temporary pumps for furnishing supply to sprinkler systems.

In spite of all the efforts which may be made, it may be advisable ultimately to shut off and drain the sprinkler equipment. This may be true when a system is operated wet and danger of freezing is imminent. It must be borne in mind that the severe freezing of a complete system such as might take place in a protracted cold spell following a flood would indeed present a serious rehabilitation problem. It would mean that the property would be without protection at a time when every possible effort was being made to resume operation and, consequently, when hazards would be even greater than normal. When competent help is available and when the location of valves is such that the system may be rapidly drained, it will be possible to postpone this action until there is conclusive evidence that the danger of freezing is real. In some instances it has been deemed desirable to place pans of water at various parts of the property protected by sprinklers and to observe closely whether or not there is any tendency to freeze. Of course, at the first signs of the formation of ice the sprinkler system must be shut off and quickly drained.

It is usually advisable to shut off the sprinklers when the design of the system is such that rising waters preclude the possibility of reaching control valves. Upheaved or collapsed floors or floating debris may rupture the sprinkler piping on the lower level and deplete such water supply as would otherwise be available.

It is well to shut off sprinklers in small outside lumber sheds and similar buildings which are likely to be floated from their foundations by flood waters, thus conserving water supply which would otherwise be wasted.

Where there is a private supply which is in excess of the requirements for the property and the water has the approval of the public health authorities, special arrangements may be made to augment the city supply from such private source.

III.

REHABILITATION.

After the flood waters have finally receded, people who have lived in the flooded area will want to return to their homes. Those who were engaged in business or manufacturing housed in buildings in the flooded area will be anxious to return to them and resume operations at once. Such persons will give little o. , o thought of ascertaining whether or not their damaged property is safe for occupation. They have been awaiting the recession of the water while housed, perhaps, in some refugee center, and have been gravely concerned as to the havoc which the flood might wreak upon their property. Now that it is possible, it is but human nature for them to want to rush in almost before the water has run out of their houses. The city faces a grave obligation to prohibit this uncontrolled rehabilitation until some assurance can be obtained that buildings are safe for occupation.

The municipality is faced with the responsibility of investigating thoroughly all buildings which were subject to the flood. In larger cities this task will undoubtedly fall to the Commissioner of Buildings, or comparable official, who may deputize such qualified individuals or organizations as may be needed to complete the work expediently and capably.

Property in General:

In general, it will be necessary to inspect flood damaged buildings to determine, first of all, if they are structurally safe for use. Weakened or settled foundations or walls may render them hazardous in view of possible collapse of the entire structure. Old brick buildings having weak lime mortar joints are apt to be structurally unsound, particularly if the flood had been of considerable duration. It will be found true in general that the duration of the inundation will have a definite effect upon the damage suffered by certain types of construction. Some buildings which will withstand a flood of a day or two without any major structural damage will be found unsafe following a flood which involves abnormal river stages for a week or more. Buildings which are found so severely damaged that they offer but little opportunity to make satisfactory repairs, and which by virtue of their weakened condition endanger life and nearby property, should be condemned by the city or state authorities. A building so condemned should be torn down as soon as possible.

Buildings which have been in the flood areas but which are not damaged to the extent where they are considered structurally dangerous for occupation, must be considered from the standpoint of sanitation. Conditions such as result from the spread of sewage and filth by flood waters may render the property decidedly hazardous to health. Such buildings should be declared unfit for occupancy and the owners or tenants should not be allowed to move back into them until they have been properly cleaned up and disinfected.

Building inspection should contemplate careful investigation of the condition of chimneys and flues. Any that are cracked or otherwise unsafe should be condemned for use until repaired.

In designating those buildings which are condemned and those which are unfit for occupancy, it will be found advantageous to use prominently displayed placards attached to the building. This will be of assistance to the police department in enforcing the official orders with respect to the use of such buildings.

The use of temporary heating arrangements in hastening the drying out of buildings presents a great many hazards unless the arrangement is properly safeguarded. It is recommended that the city authorities enforce rigid rules regarding the use of heaters in flood-damaged buildings. A suggested set of rules covering this situation follows:

1. Stoves, furnaces, salamanders or other temporary heating devices for drying out buildings shall not be used unless suitable water supply is available and the building is accessible to the fire department.

2. No such heaters shall be used until after the building has been proven free of gas pockets, or oil or gasoline fumes.

3. Wood, kindling, or refuse shall not be used as fuel.

4. Salamanders or heaters not safely connected to flues shall be fired only with coke or gas. Ventilate building to avoid possibility of carbon monoxide gas.

5. No fire should be kindled in any salamander or flueless heater inside of building. To avoid flames or sparks in the building start the fire outside the building so as to have only a coke fire when the salamander or heater is brought inside.

6. No salamander shall be used unless it has legs at least 14 inches high and has a baffle plate beneath.

7. Metal or asbestos board shields or canopies shall be suspended over salamanders or flueless heaters.

8. No salamander or heater shall be set on a wooden floor unless it is covered as follows: If heaters or salamanders have legs not less than 14 inches high the floor should be covered with not less than 4 inches of hollow tile, brick or sand

extending at least 2 feet beyond the sides of the heater. If heaters have legs less than 14 inches high the floor should be covered by not less than 8 inches of hollow tile laid over heavy sheet metal or asbestos.

9. Ordinary heating stoves of domestic type having legs not less than 4 inches high may be set over a base of 4 inches of brick, tile, cement, or sand.

The city, particularly if it is a comparatively small one, will find that there will be a great many requests for the fire department to pump out basements following the recession of the flood. Fire department pumpers should never be used for this purpose. There have been any number of instances where pumpers were seriously damaged. Gravel, cinders, and miscellaneous debris and mud may permanently impair the efficiency of the pumper. In one town the suction lift of the pumper was reduced 25 per cent after extensive use in pumping out basements. Another municipality was forced to purchase a new pumper to replace one ruined in that manner. It was surprising to note, following the flood of 1937, how many communities were content to deplete seriously their fire protection in the work of rehabilitation. Several instances were found where the only piece of apparatus in a town was in constant use for four or five days pumping out basements and in one case the apparatus was loaned to a manufacturing plant for general clean-up service. It is not uncommon to find that good fire hose is being used to flush streets, clean out mud from buildings, etc. Such hose is all too often left mudcaked and in poor condition. The desire to rehabilitate property as rapidly as possible is an entirely understandable one, but certainly any community should hesitate to impair its fire protection at the time when the hazards attendant upon rehabilitation are greatest, due to drying out buildings with temporary heating appliances and due to the uncertain safety of electrical wiring. Old hose, unsuited for fire department use, may well be used to flush streets and clean up generally, and small portable gasoline engined pumps will afford a satisfactory method of dewatering basements.

In pumping out basements, caution should be exercised to see that the water level in them is not reduced too rapidly. The approximate level of ground water should be determined and the water level in the basement kept at about the same height. Too rapid dewatering of the basement of a large department store following the 1937 flood caused excessive external pressure from ground water which was still far above its normal height, with the result that the foundation shifted, necessitating the expenditure of thousands of dollars to prevent the ultimate weakening of the structure.

In the rehabilitation of industrial property, the problem of cleaning up and drying out the premises is similar in all essentials to that in connection with other types of property. Buildings should, of course, be checked to determine if they are structurally safe and those not found to be so repaired or removed. Mud and silt should be washed from all machinery and the machinery well greased to prevent rust. Bearings should be taken apart and thoroughly cleaned before being operated.

The reconditioning of electrical wiring and equipment presents a special problem and will be discussed later under the heading "Electrical Wiring and Equipment."

Sprinklered Properties:

In addition to all the problems of the rehabilitation of property in general, it is necessary to consider, in the case of sprinklered properties, the re-establishment of sprinkler protection. This should be the first concern of anyone entrusted with the management of property where the sprinkler system is not in operation following a flood. There will be a great number of other features demanding attention, but probably none as important as the restoration of protection. Unusual hazards resulting from attempts to hasten the drying out process and to resume operation as soon as possible make it imperative to have the best possible protection available. Neglect in the restoration of protection may result in losing by fire what remains of the property after the flood.

The following order of procedure is recommended for the restoration of sprinkler service:

1. Restore water supplies. Clean any pump suction wells or intakes which may have become silted or clogged by debris. If wet system be certain that sufficient heat can be provided to prevent freezing.

2. Submerged fire pump and compressor motors, controllers and switches should be removed at once and sent to a competent electrical repairman for drying out and reconditioning before they are put back in service. Repairmen should be impressed with the importance of restoring this electrical equipment ahead of ordinary industrial equipment.

3. Submerged pumps and air compressors should be examined, cleaned and reconditioned.

4. Sprinkler equipment which has been submerged should be checked. Some of this may have been damaged by floating objects or by collapse or settling of floors.

5. Silt-covered sprinklers should be thoroughly cleaned.

6. Dry pipe valves should be thoroughly cleaned and restored to service. Restore to service the heating devices of

dry pipe valve cabinets, repairing these cabinets if necessary. If temporary heaters are necessary see that they are safe.

7. If elevated tanks have been drained and their foundations have been subjected to the flood, they should not be filled until a thorough check has been made to detect any structural weakness.

8. Riser control valves should be opened, after making sure that drain valves are properly closed.

9. After water pressure has been applied to underground mains or systems, check should be made for leaks or breaks.

10. Extreme care should be used in connection with any temporary or makeshift heating arrangements for drying out buildings or equipment.

Restoration of Public Utility Services:

Water Supply—Of paramount importance is the speedy restoration of water to a municipality in which the waterworks was unable to function because of the flood. A desire to provide fire protection for valuable property is one consideration which urges every possible effort in again supplying the distribution system, but a sane regard for the health of those using the water for domestic purposes demands certain safeguards.

Dewatering and cleaning the pumping station itself is a process similar to that necessary in any industrial property. The length of time required to place pumps in operation will depend upon the type of equipment installed. Steam reciprocating pumps and their auxiliary equipment present the simplest problem since they require very little extensive cleaning and may, in fact, be operated entirely under water if this be necessary. Steam turbine equipment, however, requires very careful cleaning especially of oil lines, bearings, oil coolers, and reduction gears if these have been submerged. Satisfactory cleaning has been accomplished with kerosene rag swabs and live steam.

An electrically operated pumping station presents the most serious problem of all if steps were not taken before the flood to protect the major equipment such as the motors driving pumps, motor generator sets and transformers. If these have not been kept dry it will be a time-consuming task to get them ready for operation. It may be expedient to secure replacement equipment as a temporary measure. In one small town a gasoline tractor was successfully used to operate the pump while the regular electric motor was being dried out and repaired.

Filter plants may present some difficulty when it is attempted to return them to service. Pumpage will be increased greatly due to many broken service connections throughout the community, leaks in mains, and the excessive use of water for cleaning. With turbid water to begin with and an unusually high filtration rate, chemical treatment must be closely watched. If the operation of hydraulic valves, chlorinator jets and the washing of filters depends upon pressure from the distribution system, it may be necessary to partly close nearby valves so that sufficient pressure is built up in the vicinity of the plant. If the distribution system is practically empty when the pumping station resumes operation, partly closing such valves will be the only means of securing the necessary operating pressures at the plant.

The restoration of service in the distribution system entails considerable work. During the time operations have been suspended it is quite possible that outside water has entered the system through breaks. When service is resumed this untreated and possibly polluted water will be forced to other parts of the distribution system. It is essential, therefore, that all consumers be notified of the importance of boiling water before use. It will be necessary to chlorinate water going into the distribution system and to maintain a constant test of the purity of water, taking samples from various points in the distribution system, including some at the extreme outer limits. The requirement that all water be boiled should not be removed until chlorinated water has been obtained in the samples taken at the most remote parts of the distribution system.

Due to the large amount of water which will be used for household cleaning purposes following the resumption of service, it may be several days before pressure in the system reaches normal. Until pressures have reached what is approximately normal the city street department and those having private fire protection should be asked to cooperate in curtailing the use of large hose for cleaning streets and buildings.

Electric Service—The restoration of electric service, whether it be the problem presented at the generating station, at the private industrial power house, or on the consumer's premises, presents some special requirements. The rehabilitation of power houses, with the exception of steps which must be taken to restore electrical equipment, is comparable with the rehabilitation of other industrial properties. A discussion of some of the special features in connection with electrical installations will be found under "Electrical Equipment" which appears later in this section.

Gas Service—The rehabilitation of the gas plant itself will present but little that is not to be encountered in the rehabilitation of industrial plants in general. It is a tremendous task, however, to restore service to individual localities or properties. As a rule, inundated mains will be found effectively stopped by the water even though through some inadvertancy they were not shut off. The water being at a higher pressure than that obtaining on gas distribution systems, automatically shuts off the gas when it finds its way into the pipes. Before starting to restore gas service to flooded areas, all control valves should be rechecked to see that the gas is actually shut off. It is then necessary to clean all the lines of mud and silt and to dry them thoroughly. This is most successfully accomplished by blowing compressed air through them. Care should be taken to see that all valves which connect the particular mains being cleaned with the rest of the distribution system are in good condition so that no air will leak past them. If any doubt exists relative to their tightness, it is better to disconnect the mains completely before cleaning them since most gas is explosive over a wide range of air and gas mixtures. Meanwhile, consumers' meters are replaced. When everything is in readiness, extreme caution must be taken to see that the consumer is notified and that all gas utilization appliances are shut off within the consumer's property. Service may then be restored, but the piping system on the consumer's premises must be carefully checked for leaks which may have developed during the flood. If the test dial on the meter indicates leaking gas, the leak should be searched for either by listening for the hissing sound, by passing the hand over the piping, or by applying a solution of soap and water to the exterior of the piping system. Never should an attempt be made to detect the location of a leak by the use of an open flame.

Electrical Equipment:

Wiring—It can be stated in general that no system of electrical wiring can be accepted as free from damage by submersion in water unless the devices and fittings are constructed to withstand such conditions. At the present time, material is manufacured which is adaptable for marine work and would be considered watertight. However, to wire premises generally with that type of material would increase the installation cost to an unreasonable figure.

Experience gained from an investigation of many thousands of electrical installations which have been flooded indicates that the extent of damage is dependent upon the type of wiring or equipment and, to some degree, upon the length of time which the equipment is submerged. It must be borne in mind that when a flood covers a territory it brings with it many different materials and chemicals in suspension. Flood waters may contain appreciable proportions of gasoline, kerosene, and other petroleum products. In addition, they may contain traces of many various chemicals, all of which may have some deleterious effect upon insulation.

Experience shows that the systems which contain the smallest amount of moisture-holding materials dry out more rapidly and are, therefore, more easily restored to service with the least degree of hazard to life and property. Open rubber covered wire on porcelain knobs or cleats comes in that category.

It may be of interest to consider certain types of wiring and equipment with respect to the condition in which they were found following inundation. Conduit, electric metallic tubing, or surface raceways and some of the other raceways, such as under-floor conduit, unless installed so as to drain, will pocket moisture in the low places and cause a gradual deterioration of the insulation on the conductors.

Conduit systems that were submerged contained quite a quantity of silt which was mixed with oil and gasoline and various forms of chemicals. The silt also was found to contain some particles of metal which were probably picked up from the street. Many of these installations showed by actual Megger tests that the insulation value of the conductors within the conduit was below a safe requirement. In fact, some conduit installations tested showed insulation values ranging from 20,000 ohms to 200,000 ohms. Where such installations were submerged for some period of time the insulation, if rubber covered, had a tendency to swell due to the deterioration of the rubber surrounding the conductor. It was further found that in some instances, especially near outlet, junction, and pull boxes, the enamel or galvanizing had been removed due to thread cutting and consequently oxidation had set in to a point where a considerable deposit was noticeable at bushings and locknuts. If permitted to remain in that condition there was no question but that after a period of time the metal would have materially decreased in thickness and the effectiveness of grounding decreased.

Metallic armored cable, especially of the type having a paper wrap, was materially affected. The paper had a tendency to soak up considerable water and naturally swell. It was almost impossible to dry out this cable. If the water surrounding the cable contained acid it had a tendency to set up a corrosive effect which, of course, would affect the value of the armor as a current carrying medium for grounding purposes and also increase the liability of an insulation failure.

Most cartridge fuses examined were unfit for use as the fiber casings had absorbed much water and therefore were swollen and distorted. Such distortion had an effect upon the calibration of the fuses and such fuses were usually unfit for use due to the fact that the contact between the ferrules or to the blades and the clips of the fuse holder was such as to cause a resistance due to improper contact.

Enclosed switches were found to be in a defective condition as the fiber connecting bars were distorted due to moisture absorption. In consequence the blades were not in a proper alignment, and this affected the current carrying capacity.

Relays, contactors and equipment of a similar nature in which fiber insulating bars were used were also unfit for use because the alignment of the armatures, etc., had been seriously affected.

Metal portions of cutout bases showed the effects of the flood and corrosion was in evidence on these parts. In fact, some of them were unfit for further service because the effective break distance had been reduced to a point where a current leak was possible. In those bases where fiber washers were used, the fiber washer constituted a direct current path rather than an insulation. Many of the cutout bases were so covered with silt or mud that a cleansing was almost impossible.

Many motors showed the effects of gasoline and oil on the insulation, the varnish being dissolved. In such cases a drying out process was not adequate to place them again in an operative condition.

Electrical refrigerators, radio sets, washing machines, and other electrical appliances and devices which were inundated and which contained small motors, contactors, etc., were severely damaged and necessitated complete overhauling.

Metal-shell paper-lined sockets and switches which were submerged were almost all unfit for use because the lining was swollen and the metal parts corroded.

Panelboards, etc., which contained cutout bases, circuit breakers, etc., showed various degrees of damage.

Gas tube sign transformers and accessories, unless especially made for outdoor use, were more or less damaged.

Faced with impaired electrical equipment it is necessary that some procedure be established for making it reasonably safe and useful or else for requiring a complete rewiring. In many cases the damage can be repaired by taking proper means to clean and dry the equipment.

Rigid conduit installations which have been submerged invariably contain mud, silt and small particles of material carried into them by the water. Wires should be withdrawn and the conduit swabbed out. The conduit may then be dried with air at ambient temperature. Warm air should not be used as subsequent cooling of the conduit will produce condensation.

Metallic armored cable unless having a paper wrap may dry out and still be serviceable. The system should be tested for leakage to ground and if not testing satisfactorily should be replaced by new material. This same procedure should be followed in connection with other types of wiring and any installation found unsatisfactory upon test replaced by new wiring.

It would be most desirable to require a thorough inspection of all wiring before current is supplied. Practical considerations make such a procedure impossible in the average large city. Thousands of properties are involved and the task of making a complete investigation of the wiring in each would require much time during which the occupants would be deprived of service. Temporary light would, of necessity, be used during this period and the occupants would avail themselves of every conceivable device to provide it. Candles, gasoline and kerosene lamps, and lanterns would all be used in great numbers by people entirely unfamiliar with their use. These are the considerations which make it advisable to effect some compromise in the attempt to secure the absolute maximum of safety in electrical installations immediately following a flood.

A compromise, at least pending an opportunity to make a thorough inspection of all affected wiring, may provide for the utility, the electrical department of the city, or an authorized organization to check the main line and branch fuses, replacing them at the time the meter is replaced. The capacity of these fuses must not exceed the safe carrying capacity of the conductor, and in ordinary branch lighting circuits must not be in excess of 15 amperes. Of course, only listed fuses are to be used. When these fuses do not hold, service is to be disconnected and not to be supplied until proper inspection can be made and the difficulty remedied.

In some cases where only the lower floors were flooded and it is especially desired to supply current to the floors above which were not involved, it will be found feasible to disconnect all wiring in the section which was flooded and, by means of a temporary service connection, supply current to that portion of the wiring which was not affected.

In the case of industrial services, these may be restored as soon as transformers and service equipment are in operative condition. Proper fuses are to be installed with the understanding that in case these do not hold the service is to be disconnected and the owner notified that correction is needed.

Service is to be disconnected in any building designated as condemned.

Arrangements should be made to have someone on duty twenty-four hours a day to serve as a clearing house between those who require the services of electrical contractors and the available contractors.

It is pertinent to note that, in so far as can be determined, there has been no unusual number of fires resulting from the use of electricity in flood damaged buildings where the practice of proper fusing has been followed. Proper over-current protection has apparently served to effect reasonable safety and to justify the resumption of service after a flood, even though a complete examination has been impossible.

The use of wiring in flood damaged buildings prior to a complete examination should be considered only as an expediency. As soon as the opportunity is available a complete check should be made and the necessary corrections effected.

Motors, Generators, etc.—Restoring motors and generators as well as certain other types of equipment requires a continued drying with the use of heat. This process may prove hazardous if care be not used in its execution. Experience recounts several instances where fires, some of considerable consequence, have resulted from the use of too high temperatures, improperly constructed temporary drying enclosures and failure to supervise properly the work. The amount of equipment requiring drying following a flood is enormous and the natural tendency to ignore discretion and to speed up the process at the sacrifice of safety should be avoided.

The drying of equipment which has been damaged by water should be undertaken only under competent electrical supervision. Where skilled men are not available and the equipment is comparatively small, it is preferable to send the apparatus to a concern experienced in this work.

In general, the damage done by water will vary with the type and age of the equipment. New types of motors are less susceptible to water damage due to improved impregnating process for making insulation moisture resistant. Old, poorly maintained motors which have seen hard service are dried out with more difficulty and the results may, in some cases, be unsatisfactory.

Before drying motors or generators they should first be disassembled and thoroughly cleaned with a water jet. Bearings should be cleaned with water and with carbon tetrachloride and all traces of mud removed.

The most effective way to dry small equipment is in a vacuum oven. While these are not always available it has been found comparatively easy to make them out of cast-iron pipe. One utility was very successful in constructing an oven of this type by bolting steel plates at the end of a 15-foot section 35 inches in diameter. Strip heaters were fastened to the outside of the pipe and then the entire pipe covered with non-combustible insulation. Thermo-couples were provided inside the pipe with the conductors emerging through regular automobile engine spark plugs. Vacuum pumps were used to exhaust the air and a temperature of from 100° to 110° C. was maintained during the drying period.

If it is impractical to provide a vacuum oven, equipment may successfully be dried in atmospheric ovens at temperatures not exceeding 120° C. These ovens may be of temporary construction preferably with an asbestos board or some other non-combustible insulating material. The enclosure may be heated by electric heaters so arranged that they are not in contact with any combustible material, or by steam coils safely installed. It may be found convenient to use coffee roasters, dry cleaning dryers, Japan ovens and similar devices for atmospheric drying of small equipment.

Certain large electrical equipment such as spare rotors for large generators may be dried by passing current through the windings. This requires competent supervision to see that voltage is kept low enough so that the insulation of the windings will not be broken down. The danger in this method lies in the possibility of using too high a voltage at first, in consequence of which the insulation may be ruined. It is recommended, therefore, that where it is at all possible some safely arranged method of using external heat be resorted to.

IV.

SERVICES OF ORGANIZATIONS.

Activities of Insurance Service Organizations:

It is through its service organizations, individually and jointly, that the business of Fire Insurance plays an active and important role in the great recurring drama of the flood. Perhaps there will be found no better exemplification of how organizations formed primarily to serve the interests of the insurance business have become quasi-public in their nature than consideration of their activities during a time of emergency. Property owners through years of contact have come to look upon the rating and inspection bureaus and upon similar service organizations as authentic sources of help. City officials, fire chiefs, superintendents of waterworks and other department heads have come to realize that through its service organizations the fire insurance business can be counted upon to bring judgment and a nation-wide experience in facing, with them, the unusual and difficult problems raised by the flood. As a consequence it will be found in recent great floods that company organizations were called upon to serve the public in many ways.

Fortunately there is never any conflict in serving the best interests of the public and in serving the best interests of the insurance business. Consequently, in performing the signal services which many boards and bureaus and associations are called upon to render during times of disaster, it is reassuring to know that they are doing the utmost for their companies.

It is difficult to outline the duties of insurance service organizations insofar as their functions in flood areas are concerned. Of course, the underwriter rightfully expects them to be alert constantly in seeing that fire protection is not needlessly impaired and that property is not needlessly endangered. Because of underwriting practices the most concern during times of flood will probably be evinced in connection with sprinklered properties. Here the insurance company has concentrated a great deal of liability on the assumption that adequate sprinkler protection will obtain constantly. When the continuance of that protection is seriously threatened it is but natural for the underwriter to become apprehensive. One of the important functions, therefore, is for the bureau to render such service as it can to the end that protection is maintained.

This work may well be planned in advance of the flood. The bureau should make a study of the flood situation in every sprinklered property located in communities subject to floods which it may handle in the regular conduct of its work. If the property be located above any reasonably conceivable high water level, the study may consist merely of indicating in the bureau records the steps which could best be taken to maintain service in the event of failure of regular city water supply (if a factor in the risk under consideration), the failure of electric service and of gas supply. An emergency program should be discussed with the property owner and an outline of the suggested method placed in the file for use if it ever becomes necessary.

A much more thorough study should be made of those properties so located that they are actually subject to flood damage. All important valves, pumps, compressors and similar essential apparatus should be correlated with river stages. Data should be secured indicating at what river height the heating plant can no longer operate and at what stage electric power will no longer be available. All of this information may well be entered on cards and so filed that at any expected river stage the bureau can tell just what properties will be threatened or impaired and what specific features will be vulnerable. For example, a certain property may be located near a river which has a normal stage not exceeding 15 feet. A study of the situation, with due respect to relative elevations and past experience, indicates that post indicator valves will be completely submerged at a river stage of 25 feet and that the boilers can no longer operate at a stage of 29 feet. The weather bureau warns of an impending flood which will reach a crest of 30 feet. Reference to the card file indicates back of the "30 feet" guide a number of properties which will be affected by such a flood. A review of the data shows that the property in question is without basement and has a sprinkler drain at an elevation equivalent to a river stage of 32 feet. The owner is reached at once and it is decided to provide temporary extension stems for the post indicator valves and to leave the equipment in service. If the expected crest is reached and the boiler plant cannot be satisfactorily bulkheaded it will still be possible to shut off and drain the sprinkler equipment if freezing temperatures threaten.

Other properties which the records show will be affected by the expected stage should be reviewed in a similar manner and the most advisable procedure—one which should preferably have been outlined when the property was studied at some previous time—discussed at once with the property owner and put into action. This system will insure the maximum of service and assistance to the property owner and to the insurance companies.

During the flood the demands which will be made upon the local offices of insurance service organizations will make it necessary to augment the force. In those cases where the service organization's office in the community or in the vicinity is a regional one the management will undoubtedly transfer to the flood district all available men from other territories. Where the office of the organization is the only one of a board or bureau it may be necessary to secure, temporarily, experienced and capable assistance from other organizations. Arrangements must be made to secure such special equipment as may be needed, including flashlights, boots, etc.

Throughout the period of the flood, the service organizations must be constantly in readiness to answer requests for assistance and advice. Much resourcefulness must be used in an effort to maintain protection where at all possible. When sprinkler systems are reported to be low in air pressure and there is danger of the dry valve tripping because the air compressor regularly used cannot be operated, the bureau may be in a position to send to the property a portable compressor mounted on a truck. It may be possible to have sprinkler pipes, which have been broken by floating debris, plugged so that protection is available to other sections of the property. Possibly a system threatened by freezing and with drain inaccessible may be drained by removing a head at a low point. In New England one of the inspectors had a boat carried over the top of a building and lowered into a flooded areaway where he broke a window, rowed in and plugged a sprinkler pipe which had been broken, thus permitting the restoration of service. In another instance a break in a main under 12 feet of water prevented protection being maintained in a plant. The services of a diver were obtained and the divisional valve closed, enabling protection to be restored to most of the property.

By constantly checking sprinklered properties the service organization may be of inestimable help in conserving water which may be so needed for fire protection. If water supply is to be cut off and electric service discontinued, properties may be checked to see that automatic fire pumps devoid of their suction are cut out. Steps may be taken to see that city gates on multi-source equipment are shut in order to avoid the possibility of leakage through check valves. Advice relative to emergency heating arrangements may be given in many specific cases where the absence of heat would mean that protection could no longer be maintained.

It must not be supposed that sprinklered properties are the only class which require attention by the companies' organizations. However, the class does afford the greatest opportunity for intelligent supervision during the actual period of the flood.

In most instances there will be operating within a district several service organizations. These may include the rating bureau, the inspection bureau (when a separate organization), associations specializing in the handling of sprinklered properties, engineers of the National Board of Fire Underwriters, associations of company men (field men), and similar groups, all working in the interests of the fire insurance business. It is important that the work of all of these representatives be correlated to avoid duplication of effort and the rendering of divergent advices to the public. An agreement must be reached as to which office will be responsible for the consolidated efforts of all the fire insurance organizations and that authority recognized by all participating in the work. Usually the local rating office, due to the general nature of its work, has established itself in the confidence of the public to a greater extent than have other organizations with a more limited scope in so far as local contacts are concerned. For that reason, it will usually be advisable to place in the hands of the rating office the supervision of all service work.

During the flood there should be maintained the closest cooperation with the city officials. The organizations should offer to help the various departments of municipalities in every way possible. Opportunities will be presented to suggest warnings of a fire preventive nature which may be broadcast and published in the local newspapers, and the service organizations should be of every assistance in drafting such warnings and other emergency regulations. Close contact should be maintained with those in charge of public water supplies and public fire protection and every effort made to assist in maintaining these at their highest possible efficiency. It is important to contact smaller towns as well as larger cities to assist where possible in insuring the resumption of normal public protection.

Experienced men should be furnished to make inspections of refugee centers which may be housing hundreds of those driven from their homes by the flood. It may be found that buildings converted to this use are entirely unsuited for such occupancy being provided with inadequate egress facilities and unsafe temporary heating and lighting arrangements. Cooperation with the city should be secured in safeguarding all buildings in which refugees may be housed or fed.

One of the important details to be performed during the period of flood is to keep the fire insurance companies informed as to general conditions in the flood area and, where possible, as to the situation with respect to the larger individual properties within the area. It has been found possible during the past floods, and where the office of the service organization was not actually in the flooded area, to publish daily bulletins, mailing these to all interested companies. These bulletins give the most recent official information as to conditions in general, outline the status of sprinkler protection in the various sprinklered properties affected by the flood and, on the whole, constitute a means of reporting promptly and effectively to the fire insurance companies the seriousness of the flood and the success with which the service organization is protecting their interests. The execution of this work will ofttimes require considerable ingenuity and entails a great deal of difficulty. Many times it will be necessary to report conditions by phone or telegraph to the central office of the service organization, at which point the material can be made ready for mailing to the interested companies.

The great bulk of the work of the service organizations will come after the flood waters have receded and rehabilitation is under way. To begin with, there will be the necessity of checking all sprinklered properties which were involved in the flood for the purpose of seeing that service is restored as promptly and completely as possible. It will be necessary to keep in close touch with the waterworks departments of the various communities within the affected district to urge that, where this service was impaired, it be restored to its normal efficiency with no loss of time.

One of the largest tasks confronting those insurance service organizations maintaining electrical departments is the inspection of wiring in the many buildings which were damaged by flood. This is a tremendous task and doing it in a thorough manner will consume considerable time and will require the services of many capable electrical inspectors.

Such reports as are published by the National Board of Fire Underwriters and by other organizations covering the fire defenses of municipalities, should include a resume of the flood situation as it affects the individual city or town. Various reporting organizations throughout the country which issue underwriting reports upon individual properties should include information relative to the flood feature, giving the river stage at which the property is affected and the frequency of occurrence of this river stage in the past.

Service organizations of the fire insurance companies have rendered in the past, and are prepared to in the future, practically all of the services which have been suggested. That they have performed the tasks well is evidenced by the place they occupy in the regard of the public in those localities where emergencies have arisen.

Activities of Other Organizations:

No consideration of the flood problem in general should fail to mention the great services rendered by the many organizations cooperating in the tremendous task of bringing some semblance of order out of chaos and of administering to the needs of those made destitute by the emergency. The work of these other organizations does not ordinarily so closely parallel the work of the insurance organizations as to require correlation, although in the common endeavor to be of service there will be times when the paths will cross. Needless to say, the insurance service organizations should give complete cooperation and render all possible assistance to these other organizations.

Chief among the organizations of mercy and relief will be found the American Red Cross. This organization begins activity as soon as disaster threatens. With the first United States Weather Bureau warning, chapters throughout the danger zone are instructed to relay the alarms to families whose property will be endangered and to assist in carrying out evacuation if necessary. Experienced disaster relief workers will be provided to help the local chapter. All available boats will be secured and placed in rescue service. Food and clothing supplies in towns and cities will be augmented by carloads of donated and purchased goods consigned to centrally located warehouses. As soon as possible, crowded conditions in refugee centers will be relieved by the establishment of tent cities. These are well ordered, clean, placed on high ground with good drainage, and most of them will be provided with wooden floors. The Red Cross will avail itself of the assistance of the U. S. Public Health Service in maintaining proper sanitary conditions in relief centers. When local hospitals do not have sufficient room, emergency hospitals will be established. With the assistance of the U. S. Public Health Service, special laboratory equipment will be made available and will be particularly useful in "typing" classifications of pneumonia that develop. Physicians and nurses will be furnished to care for the needs of refugees and others in the disaster zone. Leaders of the Red Cross will meet in daily conference with the leaders of other organizations working in the disaster district including the regular Army, Navy, Coast Guard, U. S. Public Health Service, the Weather Bureau, and other organizations of the municipal, state, and federal government, thus insuring a complete synchronization of effort.

In the Ohio and Mississippi Rivers flood in 1937 alone the Red Cross found 139,000 families who required emergency relief. In addition to requiring emergency relief, 97,000 of these families required substantial rehabilitation assistance.

The Public Health Service of the United States renders decidedly valuable services during time of flood. In addition to cooperating with the American Red Cross, it furnished essential vaccines and other biologics to combat the spread of communicable disease within the flood areas. During emergencies the office at Washington is open twenty-four hours a day to receive orders for needed medical supplies, to see that these are filled and delivered with the greatest possible speed and with no waste through duplication of orders. In addition to assisting in the rendering of medical service, United States Public Health Service also renders expert advice and cooperation in the reconditioning of water supply systems including emergency chlorination; the cleaning and disinfection of private water supplies; the sanitation of milk pasteurization plants; maintenance and repair of sewerage systems including the flushing of sewer lines and the rehabilitation of sewage treatment works; the establishment of temporary facilities for water supply and refuse disposal in cities and small communities; directing sanitation in refugee centers and camps; the general disposal of garbage refuse, dead animals, spoiled foods and other decomposable organic matter; general clean-up including flushing of streets and the removal of debris and mud and pumping out basements and cellars when necessary as a sanitary measure. It is largely due to the efforts of this work under the Surgeon General of the United States that, in spite of the unprecedented hazards to public health as a result of floods, there has, within recent years, been no marked increase in communicable diseases among flood sufferers.

It is impossible to include in a writing of this kind any record of the services of many other organizations, all of which furnish immeasurable assistance in time of flood. It is recalled at once that such services are rendered by the Salvation Army, American Legion, Volunteers of America, and many local church and similar organizations. The National Guard of various states were of great assistance in guarding flooded districts, keeping unauthorized persons out of danger zones and preventing sightseers interfering with the necessary rehabilitation work. Working with the police department the National Guard was undoubtedly of great assistance in preventing looting from homes and stores abandoned during the flood. The work of rescue carried on by the U. S. Coast Guard was noteworthy. A book could be written covering nothing more than the activities of the U. S. Army Engineers in combating flood situations on the navigable streams. This organization is responsible primarily for the protection of United States property, the collection and dissemination of river information and the rendering of all possible assistance to communities and relief agencies whenever requested. It was largely due to their efforts that certain isolated communities along flooded rivers received necessary food, clothing, and medical supplies during the past Ohio River emergency. No consideration of flood disasters would be complete if it failed to take into account the unusually valuable support rendered by the press and radio. Newspapers devoted their front pages to appeals for help and for conveying to the public warnings and precautions which must be heeded in order to safeguard life and property as much as possible. Radio stations in many instances proved to be the only direct link between disaster and the public. During the recent floods, radio was everywhere: on the water; in automobiles and airplanes; in isolated studios; in fire departments; in the offices of insurance service organizations; connected to fire pumpers stationed at some temporary point of supply; and, in general, furnishing the much needed communications which otherwise would not exist in the flooded areas.

V.

BIBLIOGRAPHY.

The following is by no means a complete bibliography, but it does include specific mention of a number of authentic discussions of the subject of floods. Numerous additional references will be found in the general and periodical indices of any well-equipped reference library.

Various publications of the U. S. Geological Survey known as Water Supply Papers. There are 22 of these publications in all to date covering various floods.

U. S. Geological Survey, Water Supply Paper 771—"Floods in the United States—Magnitude and Frequency." Includes various formulae for determining run-off and expected frequency. Includes gage records by year of practically all gaging points in the United States.

U. S. Geological Survey, Water Supply Papers 798—"Floods of March, 1936—New England Rivers."

Journal of American Waterworks Association, September, 1937—Numerous articles dealing specifically with the problems of public waterworks during flood periods.

May, 1937 issue of "Civil Engineering." A discussion of past floods and flood control projects.

March, 1937 Proceedings of American Society of Civil Engineers. A symposium of various authorities on the physical and economical aspects of flood control, flood forecasting, etc.

Committee on Flood Control, HR Document No. 1, 75th Congress—"Comprehensive Flood Control Plan for Ohio and Lower Mississippi Rivers."

Hearings Before House Committee on Flood Control, 75th Congress, June, 1937.

HR Document 306, "Ohio River."

"The Master Plan" by Edward M. Bassett, 1938, Russell Sage Foundation.

"Can Zoning End 'Caveat Emptor'?", Pennsylvania State Planning Board Bulletin, September, 1937.

"A Common-Sense View of the Flood Problem," Division of State Planning, New York.

"Drainage Basin Committee's Reports for the Ohio Basins," U. S. Government Printing Office, December, 1937.

Floods in the United States, January and February, 1937, published by the U. S. Department of Agriculture, Weather Bureau, in Monthly Weather Review, Vol. 65.

The Floods of March, 1936 in Pennsylvania published by the Commonwealth of Pennsylvania, Department of Forests and Waters and prepared in cooperation with the U. S. Geological Survey.

Reconditioning Flood Damaged Electrical Equipment, Publication No. F-13, Edison Electric Institute.

"Flood Plain Zoning and Evacuation" by H. C. Klein, April, 1939 Quarterly, National Fire Protection Association.

Resolution of the National Fire Protection Association on Flood Plain Zoning and Flood Plain Evacuation, Proceedings of Annual Meeting, May, 1939.

For a more complete bibliography the reader is referred to Water Supply Paper No. 771, Geological Survey, United States Department of the Interior, in which will be found 207 specific references to books and articles on the subject.

ADDENDUM — 1951.

U. S. Geological Survey, Water Supply Paper 967—Notable Local Floods in 1939.

U. S. Geological Survey, Water Supply Paper 997—Floods in Colorado.

U. S. Geological Survey, Water Supply Paper 1046—Texas Floods of 1940.

U. S. Geological Survey, Water Supply Paper 1066—Floods of August, 1940 in the Southeastern States.

U. S. Geological Survey, Water Supply Paper 1080—Floods of May-June, 1948 in Columbia River Basin.

U. S. Corps of Engineers, Army, Annual Reports of 1940 to 1949.

APPENDIX A.

RESUME OF RECENT GREAT FLOODS

In the following pages are included abstracted accounts of three of the recent floods, all of them larger and more destructive than any previous floods within the period of authentic record.

Many other floods have occurred and, as a matter of fact, are occurring even as this is being written. The public recalls the great floods of 1927, 1913, and even 1884. Smaller floods, not as great in extent as these outstanding ones but just as disastrous in the limited areas, which they affect, are occurring almost every month. In 1935 there was a flood at Houston, Texas; in 1936 in Virginia; in 1938 in Los Angeles, and so on. In a recent statement made by Merrill Bernard, Chief of the Division of Rivers and Floods, U. S. Weather Bureau, it is shown that during the past 168 months in which records were kept there were only 15 in which no loss of life or property resulting from floods was reported.

FLOODS OF NEW ENGLAND—1936

Meteorologically, circumstances preceding floods of March, 1936 on the New England rivers were such as to presage stages and discharges of extraordinary height and volume. Ground in the drainage areas had frozen before it had been covered with the winter's accumulation of snow. The preceding winter had been marked with unusually low temperatures which had prevailed without the intervention of thaws up until as late as March 9th. This situation was most favorable for abnormal runoff, all that was needed being some warm weather and a downpour of rain. Unfortunately, these are just the events which occurred. On March 9th the weather became unseasonably warm, continuing so during the remainder of the month. An intense rain storm started on March 11th continuing through the 13th, and adding its increment to the unusually large amount of water held in storage in the drainage basins in the form of snow and ice. These rains accelerated the thawing and produced flood conditions over practically all of the area of New England except in the extreme northern parts. The first storm was followed by a severe downpour on March 17th which was generally much larger and produced more serious flood consequences.

The flood resulting from the first rain storm was marked by the breaking up of heavy ice. This heavy ice which had formed over long reaches of the streams during the extended period of sub-freezing weather was, for the most part, thicker and stronger than that usually obtaining at this time of year. The first few thawing days had failed to have much effect upon this ice, but the heavy rains, which were accompanied by warm temperatures, and aggravated by the rapid runoff of the drainage areas, resulted in an immense volume of water finding its way into the ice blocked channels of the rivers. Ice jams occurred at many places.

While the rivers were still carrying the burden of this ice, melted snow and rain, the second storm occurred pouring extraordinary volumes of water into river systems which were already flowing beyond capacity. The resulting floods fortunately did not entail any great loss of life, but property damage was estimated at more than $70,000,000. Advance forecasts were unusually accurate and this factor was of material assistance in keeping the loss of life at the minimum as well as making it possible to effect some material reduction in the property loss.

The 1936 flood in New England was greater than any previous flood on record. It is a fact, however, that on certain medium and small watersheds, flows were greater in 1927. While the flood of 1927 resulted in only about one-half the property loss which occurred in 1936, it took a much greater toll of life due principally to the excessively high velocities which were developed in rivers with steep slopes such as the White and Winooski. In many instances the peaks occurred at night and found the inhabitants entirely unprepared, with the result that many were trapped in their homes without chance of escape. In Vermont alone 87 lives were lost. The greatest loss of life and property occurred in the Winooski Valley.

The meteorological conditions which caused the New England floods of 1936 were widespread and also produced extreme floods as far south as the Potomac River and as far west as the Allegheny and Monongahela Rivers at Pittsburgh. Heavy losses were sustained in New York State and in Pennsylvania.

In New England, flooding was general in all the principal drainage areas, except in the northerly and easterly portions of Maine. It was heaviest in the valleys of the two principal rivers, the Connecticut and the Merrimack, with their populous cities. About 90 per cent of the loss occurred in nine river basins, comprising these two and also the following in descending order of the total damages:

Thames
Androscoggin
Blackstone
Kennebec
Saco
Housatonic
Penobscot

It is difficult to describe the flooding as it affected any single river and its tributaries, but it is of value to consider the effects of the flood in certain of the principal cities involved.

Springfield and Hartford, located on the lower middle reaches of the Connecticut River, were affected principally by slowly rising flood waters rather than by the swift currents of the flood that affected properties in the upper portions of the river valley and the tributary streams. In the Merrimack River, the power of the current during the flood was notable in its effects at Manchester and Nashua, as well as to a lesser extent in the cities of Lowell, Lawrence, and Haverhill.

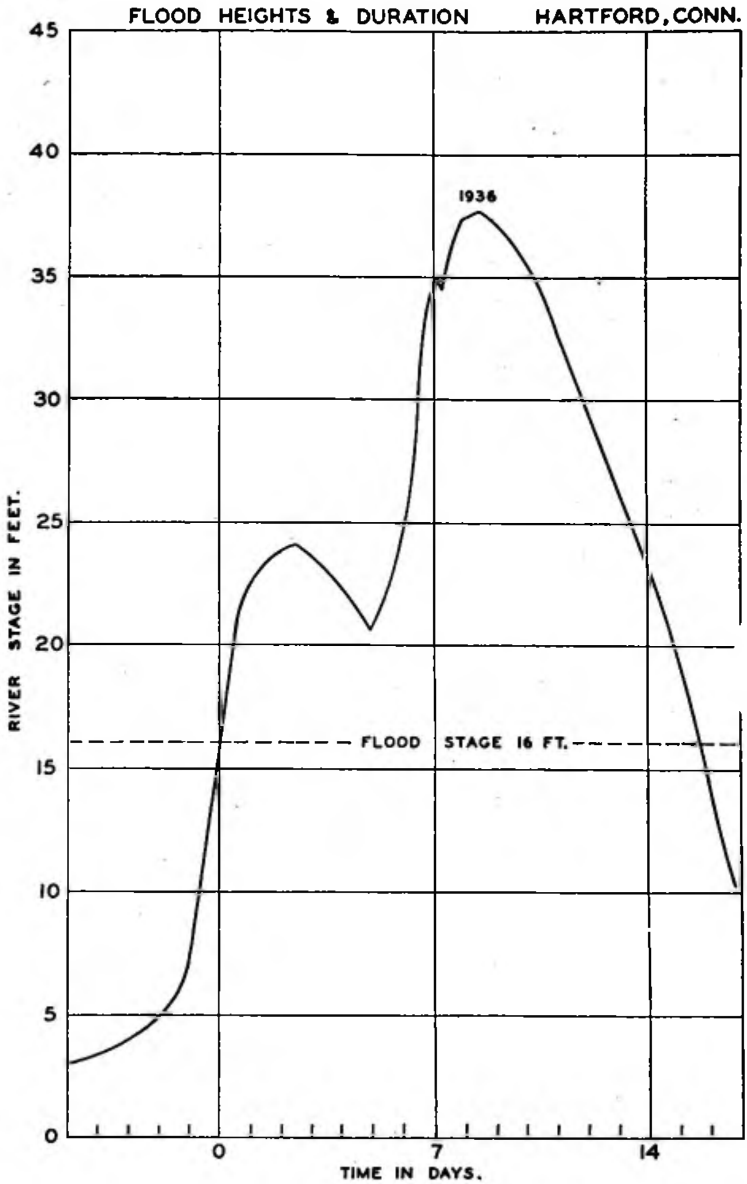
Hartford, Conn.

This city was more severely damaged by this flood than from any previous one. The flood waters covered about one-fifth of the area and reached a crest of 37.5 feet above the low water mark, exceeding previous records.

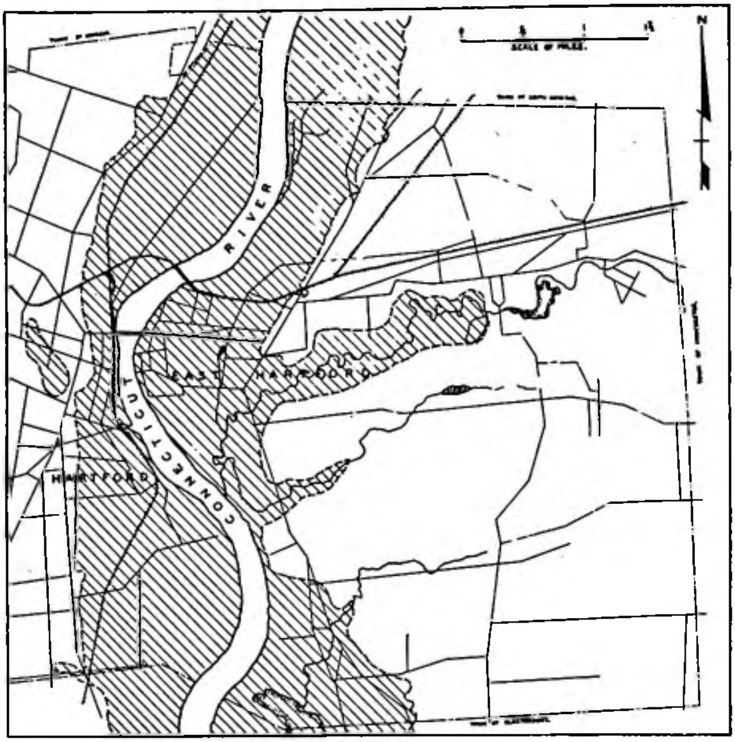
Fortunately, most of the large manufacturing plants in the Hartford area are so located that they were not damaged by the flood. However, a lower portion of the city does contain several large industrial plants. Although this section is protected by a high dike, the water reached such an unprecedented height that it flowed over the top of the dike and flooded the entire area. Here some of the greatest damage was encountered. Water reached a depth of 20 feet or well above second floor level at one large plant.

Even when the river receded it left the high water in this section and the dike finally had to be cut to release the waters so salvage and rehabilitation work could be started.

Breaks occurred in the city water mains within the diked area and some of the sprinkler systems in the plants in this section were broken. These breaks caused a heavy loss of city water and finally the water department practically closed the main valve supplying this area. A man was stationed to open the valve wide in case of an emergency. Some water was allowed to flow through the mains maintaining sufficient



FLOOD HEIGHTS & DURATION
HARTFORD, CONN.
1936
FLOOD STAGE 16 FT.
RIVER STAGE IN FEET.
45
40
35
30
25
20
15
10
5
0
0
7
14
TIME IN DAYS.



Map of Hartford, Conn. and vicinity showing inundated area March, 1936.

pressure to prevent non-potable flood waters from entering the system through the breaks. This, undoubtedly, prevented contamination of the water supply.

Not only were the sprinklered manufacturing plants severely hit by the flood, but also many mercantile establishments. In some cases, goods were moved to locations not affected and damage thus avoided. However, in other cases store owners suffered a complete loss of their goods.

Hundreds of dwellings and tenements had to be vacated as flood waters reached to the second story in many cases. This meant the providing of temporary housing facilities for hundreds of families who lost practically all their household goods.

The City Gas Company was able generally to maintain gas lines in commission, although in some instances the gas supply had to be shut off in certain sections due to breaks and excessive leakage.

The local power company maintained its central power distributing station until nearly the height of the flood when it became inundated and was put out of commission. The city was then left without electric lights and power until flood waters receded sufficiently to permit temporary connections to be made and power supplied.

Telephone service was placed on an emergency basis when regular power failed. Portable generators and emergency batteries were then brought into use and supplied current until the restoration of local power facilities.

The freight houses and yard were flooded and so fast was the rise of water when it reached this location that it was not possible to move the loaded freight cars to higher ground. The contents of these cars caught in the flood were, in many cases, a total loss.

Springfield, Mass.

In Springfield and West Springfield, conditions were extremely serious. Many industrial and mercantile properties suffered heavy damage in the lower section of the city. A break in one of the city water mains left part of the flooded area without protection for several days.

At one plant rising waters forced oil from underground fuel oil tanks to the surface. This floating oil came in contact with hot furnaces in the metalworking section and ignited. The resulting fire was very stubborn, but due to the excellent work of the fire department laboring under great difficulties, it was prevented from spreading to nearby buildings. Two city fire stations had to be abandoned during the height of the flood, the apparatus being moved to higher ground. The fire alarm system was out of commission in parts of the flooded area and these sections were patrolled by fire department members and naval reserves in boats. In plants under American District Telegraph supervision where service lines were out of commission, hourly patrols to the district were maintained by the A. D. T. Company.

Lowell, Mass.

This city was seriously affected, many of the manufacturing plants sustaining considerable damage.

Several of the large industrial plants normally obtain water supply for fire protection from connection to a private system. A large reservoir and numerous pumps taking suction from the river furnished the water supply for this system. During the flood a break in a main at one of these plants caused the private reservoir to be drained and as most of the pumps were out of commission, this group of mills was temporarily without a satisfactory supply for fire protection. The valve controlling the broken line was under several feet of water and could not be reached until a diver was called on to shut it off. The few private pumps that were still available then began the work of refilling the reservoir and were later assisted in this work by a city fire department pumper. With this reservoir again filled and the private system in commission, the threat of a serious fire in these valuable industrial plants was greatly reduced.

Although the city water department pumps and filter beds were flooded, it was possible to avoid a shortage of water through the use of connections to water systems in adjoining towns. The water department then installed chlorinators and as soon as flood waters receded sufficiently their pumps were started and water supply in the reservoirs replenished.

Undoubtedly, a great deal more serious flood damage would have resulted had it not been for the operation of an old canal gate often referred to in Lowell as "Francis' Folly." James B. Francis laid out the system of locks and canals in 1848 at which time he sent engineers up the Merrimack River to interview old farmers in an effort to learn how high flood waters had ever risen in the past. He suspected that sometime in the future a similar flood might occur. To protect the city against this he built, at the entrance of the canal at Lowell, a big timber gate 12 inches thick with stone walls having grooves into which the gate was arranged to drop. This gate was suspended by a wrought iron shackle so that it was ready for any emergency. The people of Lowell ridiculed the idea, but four years later, in 1852, a flood reached sufficient proportions to warrant closing the gate and this saved the city from inundation. The gate was then hoisted again, a new shackle put on and a sledge hammer and cold chisel placed nearby for some future emergency. Here these remained throughout the years from 1852 until March, 1936. As the flood waters passed all previous records, men were sent up to the gate, the link was cut and the gate again dropped, shutting off the waters and saving much of the city from serious damage.

Lawrence, Mass.

This city was extensively damaged when the Merrimack River reached heights above any previous river stages ever recorded. The water supply was seriously impaired as the pumping station and filter beds were inundated. The emergency connections made to water supply systems of adjoining towns augmented the supply but did not prove sufficient to care for the demand. When the flood receded from the filter beds at the pumping station these were found to be covered with several feet of silt and mud, and it involved a tremendous amount of work to clean them and prepare them for service.

General.

Fire protection systems in hundreds of industrial plants were impaired by breaks. In the majority of these cases, emergency repairs were made under the supervision of fire insurance representatives.

In addition to the damage caused by flood waters themselves, there were certain marked instances in this flood where damage was caused largely by the force of ice with which most of the rivers were filled. Perhaps the most striking example of this was at Scotland, Conn., where a brick hydro-electric plant with reinforced concrete floors was destroyed by ice piled up to such an extent that it went over and around the dam and down through the roof of the power station.

In general, the brief preceding accounts of situations in some of the larger cities in New England which were involved in the 1936 flood, could be repeated for many more localities in this section of the country. In many places were pumping stations, filter beds, and reservoirs put out of commission and city mains unable to supply water which was much needed for fire protection and sanitary purposes. Many ingenious methods were utilized in meeting such emergencies.

UPPER OHIO VALLEY FLOOD—1936

The flood of March, 1936 reached the highest stages ever recorded in the upper Ohio Valley, although this flood was by no means as severe as others which have been experienced on the Ohio below the Huntington district. It is estimated by the U. S. Army engineers that the flood damage in the Pittsburgh district (which extends as far down river as Moundsville, W. Va.) was $199,000,000 in 1936, as compared with an estimated damage of only $6,800,000 in 1937.

Pittsburgh.

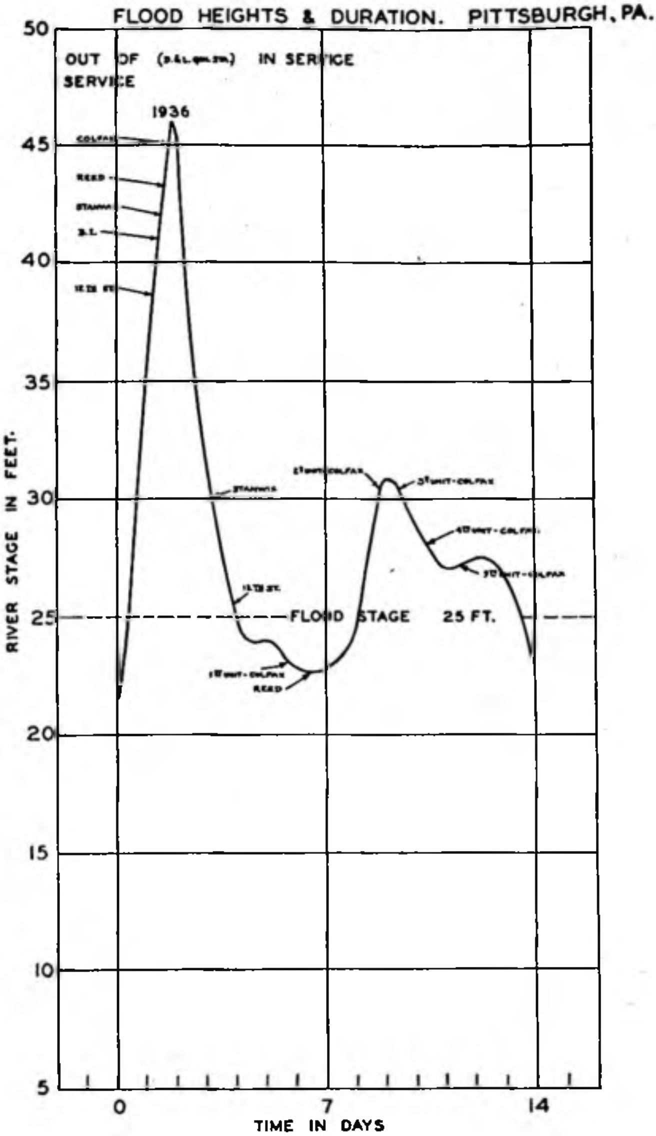
This city, situated at the point where the Allegheny and Monongahela Rivers converge to form the Ohio, has ever been subject to flood. A gage of 25 feet is considered flood stage, and it is almost an annual occurrence for low lying areas within the city to be inundated.

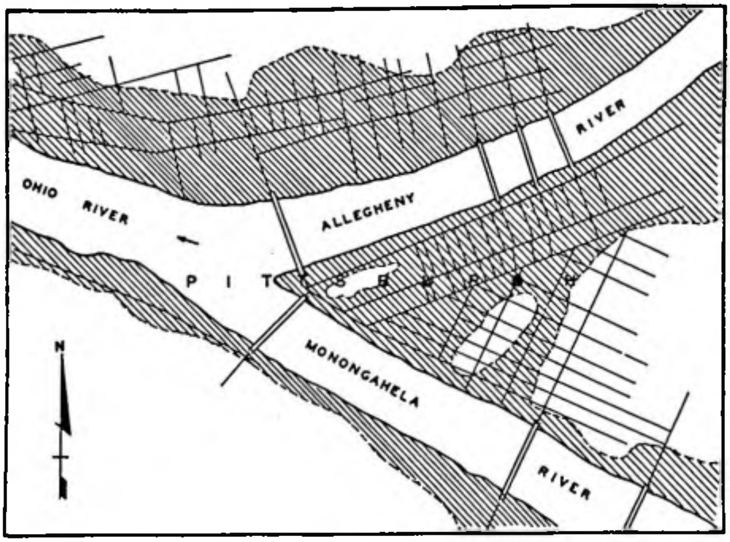
The head waters of the Allegheny are in the Allegheny Mountains in Pennsylvania and New York states. The Monongahela River has its sources in the Allegheny and Appalachian Mountains in northwestern Maryland and northeastern West Virginia. The Allegheny flows southerly and the Monongahela northerly, both skirting the western foothills of the mountain ranges. Although both of these rivers rise among the foothills they are different in characteristics. The Monongahela is a relatively mild river even when it is in flood, whereas the Alleghany is treacherous, subject to rapid rise and washouts, and offers a constant threat of flood.

Unusually severe weather prevailed during the winter of 1935-1936. Snow fell intermittently with the result that up to the last week of February there was about 5 feet of snow on the mountains. A thaw in February melted much of this snow and also caused the heavy ice which was in the rivers to break up, producing a flood crest at Pittsburgh of 29.2 feet. It was a most fortunate circumstance that some of the snow and ice went out with this minor flood instead of remaining to add its increment to the major flood which occurred on March 18th.

The rivers were high during the early part of March, and on March 16th rain began to fall in the areas draining into the Monongahela and Alleghany systems. Precipitation on March 17th and 18th was as much as 3.79 inches on the watersheds of the two rivers which conflow to form the Ohio. The crest of the Monongahela reached Pittsburgh at 6:00 P. M. on March 18th and that of the Alleghany three hours later. The ultimate crest reached was 46 feet, or 21 feet above flood stage. The resulting damage in Pittsburgh and, in fact, in the entire Pittsburgh district was enormous.

When the rivers began to rise on the morning of March 17th, reaching the flood stage at 25 feet at about 8:30 A. M., the Weather Bureau was making a careful study of the situation along the various rivers in an effort to give proper warning. Even late Tuesday afternoon it was predicted that 35 feet would be the likely maximum. Had this assumption been correct comparatively little damage would have been done but, unfortunately, the rise did not even hesitate at 35 feet, passing that point at a little after 10:00 P. M. Tuesday, March 17th, at a rate of rise of 0.8 feet per hour and continuing that rapid rise until nearly noon on Wednesday when the speed of rise decreased somewhat but continued until it reached a maximum of 46.2 between 7:00 and 10:00 P. M. It is quite possible that had proper warning of the ultimate level been given, power companies could have taken necessary steps to have insured continuity of service and water pumping stations could have continued to operate. Be that as it may, the city was not warned in time and the water did leave Pittsburgh and its environs without light, telephone or telegraph service, and in many portions without water or heat. The Pennsylvania Railroad line to Columbus, Ohio, was the only rail link with the outside world.


FLOOD HEIGHTS & DURATION. PITTSBURGH, PA.
OUT OF SERVICE
IN SERVICE
1936
FLOOD STAGE 25 FT.
RIVER STAGE IN FEET.
TIME IN DAYS
50
45
40
35
30
25
20
15
10
5
0
7
14



Map of Pittsburgh, Pa. and vicinity showing inundated area March, 1936.

As early as 8:00 on the morning of March 18th it had been necessary to shut down the pumping station of the South Pittsburgh Water Company which supplied a population of about one quarter of a million, including a portion of Pittsburgh and practically all the boroughs south of the Monongahela River. There was practically no reservoir capacity in this system, and, consequently, by 2:00 that afternoon this area was entirely without water for sanitary purposes or fire protection. By noon of this same day practically all the other pumping stations were out of service, and it was a question whether or not they would be restored before the supplies remaining in the reservoir were entirely exhausted. Some sections located on high levels were immediately without water. At 4:00 on Wednesday afternoon the water crippled the last of the Duquesne Light Company's power stations, and the city and practically all of Beaver and Alleghany Counties were without electric service. The telephone company, the telegraph companies, and the fire department alarm systems were thrown upon reserve storage batteries.

At the height of the flood the greater part of the total area of the "Golden Triangle," which constitutes the heart of the city's office and mercantile section, was inundated. The congested area comprises 79 blocks and some 53 of these were partly or entirely under water, some to a depth in excess of 10 feet.

Firemen went on 24-hour duty. Appeals were broadcast for large supplies of chemicals, including extinguishers and their charges. A motorcycle patrol was organized for the districts where fire alarm boxes had been damaged. A number of fires occurred, four of major proportions, two involving floating oil and gasoline on the water, presenting a most difficult problem for the fire department.

Although the electric power stations in the Pittsburgh district were all out of service by 4:00 P. M. on Wednesday, March 18th, tie-ins with the West Penn Power Company and other public utilities made service for certain essential operations available almost continuously. Hospitals and pumping stations had electric service by Thursday, March 19th, but most of the buildings and residences and industrial plants in the district were without current for several days during which it was necessary to resort to emergency lighting methods. Practically full electric service was available by March 28th.

In Pittsburgh proper the reservoir supplied all portions with water except those supplied by the South Pittsburgh Water Company and a few very high points, and there was some 38,000,000 gallons of water remaining in the reservoir when the pumping plants resumed operation. The Pennsylvania Water Company which serves the eastern section of Pittsburgh and boroughs lying east of the city was able to supply most of its customers from the reservoir. In other boroughs, including Homestead and Shaler Township and Etna, Sharpsburgh and Aspinwall, water was rationed and available only at certain periods in the day. At McKeesport and Coraopolis small reserves were held as a precaution against fire, McKeesport retaining 5,000,000 gallons and Coraopolis 1,000,000 gallons. Since the distribution systems in these two localities were practically drained it is doubtful if any good purpose was served by reserving these quantities of water, inasmuch as there was no way to direct it to the vicinity of the fire and it would have been spread over the entire distribution system leaving very little available at any one particular point.

All pumping stations in the district had resumed operations by March 23rd. The cities and towns in the upper Ohio Valley cleaned their streets of the accumulation of household furniture, pianos, and other once-prized possessions, shoveled the mud from the buildings, and courageously removed the visible and tangible effects of the most disastrous flood they had ever experienced.

THE OHIO VALLEY FLOOD OF 1937

The Ohio Valley Flood of 1937 produced the highest crests within the knowledge of man, at all points on the Ohio River from Huntington, W. Va., to its junction with the Mississippi. It produced the greatest amount of loss, both direct and indirect, of any flood ever experienced by the nation.

This flood was caused by a prolonged period of excessive rainfall beginning on December 26, 1936 and not terminating until January 25, 1937. The most unusual meteorological conditions which prevailed during that time resulted in a weighted mean depth of precipitation over the entire Ohio basin of 11.2 inches, approximately as much as normally occurs during the three months of January, February and March combined. Unusual as conditions were they could have been worse had the Atlantic high pressure area remained in position longer, or had it moved westward, or had the resulting low pressure area along the line of air mass discontinuity been more intense. When predictions reached record stages there was a drop of temperature and a snowfall in certain parts of the basin which gave promise of reduced run-offs. Then on January 23rd an unexpected storm developed over northern Alabama, a storm which swept north and northeast over the Ohio basin precipitating heavy warm rains which carried the previous snowfall into the already record flood of the Ohio.

The result was disastrous. Weather Bureau reports of expected stages had been pushed progressively higher, but with the advent of the storm from Alabama it was almost impossible to hazard a guess as to where the crest would be. In 48 hours the gage at Cincinnati, which was already some 2 feet higher than any previous recorded stage, climbed 7 feet. A stretch of river nearly 500 miles long crested almost at the same time.

Pittsburgh.

Pittsburgh was flooded but by no means as seriously as it had been the year previously. As the waters swept down the river they inundated Wheeling Island, but this was more or less a regular occurrence and it caused no unusual suffering. Parkersburg was flooded, but this city had likewise experienced higher floods previously. Below Parkersburg conditions became more acute.

Huntington.

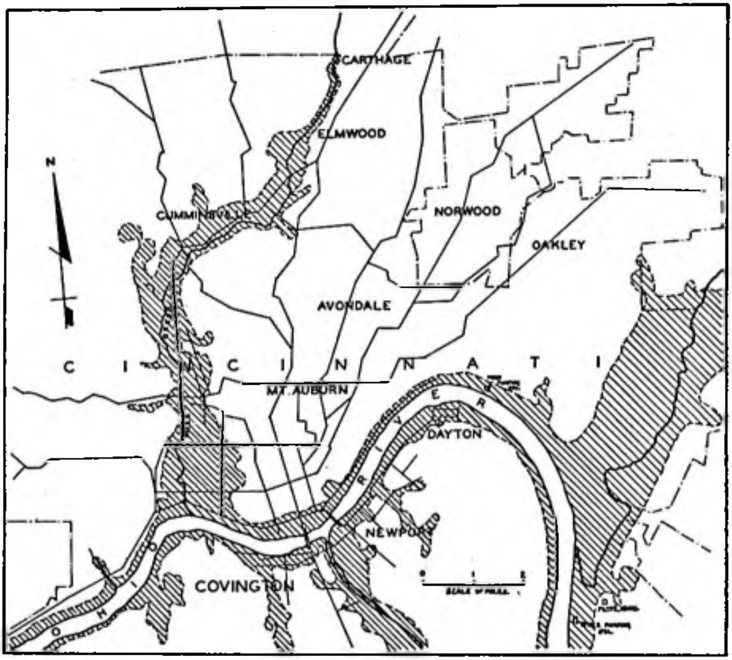
Huntington, West Virginia, was flooded worse than ever before in its history. The waterworks pumping station was out of service a little more than three days and normal pressure was not available for a period of about ten days. Five of the eight fire stations were inundated from 5 feet to 14 feet, the equipment being moved to higher ground. Fire alarm system was in service except for alarm boxes actually under water, although automatic central station sprinkler alarms were not functioning. The town was about 55 per cent under water, including the entire business section and a good part of the residential district. The river on the principal business streets had flooded business houses and stores to about the first floor ceiling. In many parts of the city electricity and gas were off for an extended period and for several days it was impossible for railroads to operate. The city was under a constant threat of fire from gasoline from various filling stations and distributing points. One serious fire from gasoline floating on the water resulted when an occupant of a rescue boat threw a match overboard, three of those in the boat being burned to death and several houses being destroyed.

Portsmouth.

Proceeding downstream, the water topped the Portsmouth flood wall, which had been built following the 1913 flood and which was now found to be about 10 feet below the crest. When the continuous rains made it evident that the flood wall would not afford the ultimate security for which it was designed, the population was moved from the low sections of the town and the sewer valves opened in order to prevent damage to which the wall might be subject if it were overtopped. Here protection facilities were seriously impaired, although there was a minimum of 2,000,000 gallons of water in the reservoirs when the waterworks pumping station resumed operation. All but one of the fire department houses were flooded and the fire alarm system entirely out of commission.

Cincinnati.

The metropolis of Cincinnati is situated, for the most part, on hills and the greater part of its area is not subject to direct damage by flood. Immediately across the river, not so fortunately located, are the towns of Covington, Newport and Dayton, and other suburban areas in northern Kentucky. The population of Cincinnati has always considered a stage of 71 feet, which was experienced in 1884, as the absolute maximum height to which the river could rise. The great flood of 1913 fell 2 feet short of reaching that mark. Waterworks and power plants were built with a 4-foot margin of safety above the 1884 mark and the citizens felt secure with this leeway. Although the Army Engineers, in their prosecution of some academic problems relative to floods in the Cincinnati area, considered a project flood of 83 feet, this was looked upon as an absurdly high figure. The early stages of the 1937 flood seemed to substantiate this belief of the citizens because shortly after the crest had passed the previous high the weather turned cold and the rain turned to a heavy blanket of snow with but little run-off. While at this point the city had been considerably damaged, there were still available heat and light and water and some railroad transportation.

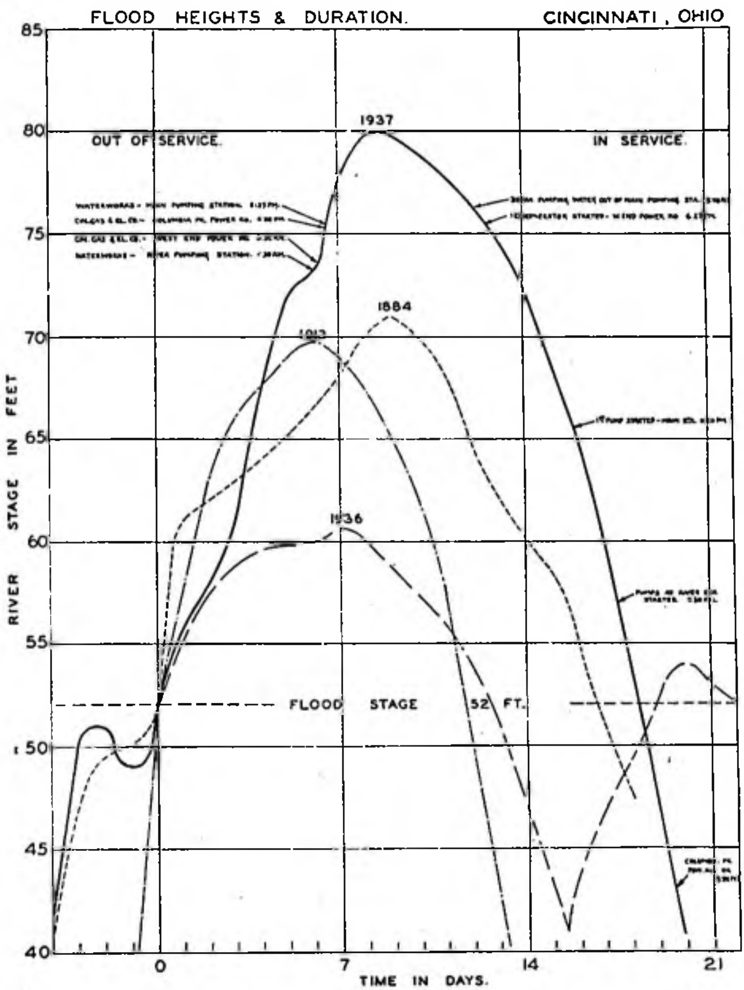


Map of Cincinnati, Ohio and vicinity showing inundated area, January, 1937.

Then came the famous "Black Sunday," a day upon which the snow changed to a warm rain and this, together with the snow already fallen, ran rapidly into the swollen waters. The water rose at a rate of 0.3 foot per hour. Power was no longer available. Waterworks ceased operation and water was rationed. The entire city was placed on an emergency basis under a one-man rule of the city manager.

Due to lack of water, public fire protection throughout the entire city of Cincinnati was seriously impaired. Fire alarm systems were out of service in and near the flooded areas. Here gasoline floating on the water likewise produced a severe hazard and resulted in one fire which caused a loss of $1,225,000. The most serious damage by flood in this city occurred in the highly developed Mill Creek industrial district. Property on the Ohio River front is, for the most part, of considerably lower value than that which was involved in the lowlands bordering on Mill Creek.

One ameliorating factor in connection with the cities on the Ohio River from Cincinnati upstream is the topography



which invariably permits access to higher ground from the rear. Thus the problems of communication, supplies and evacuation are comparatively simple. The situation from Cincinnati to the mouth of the river at Cairo, however, is entirely different. Many towns in this section are built on low bluffs immediately on the water front, but behind these town sites are still lower lands through which the main arteries of transportation approach the river. As a consequence, these approaches become inundated before the towns themselves are flooded. In many cases telephone and telegraph lines are swept away and communities find themselves totally dependent on outside aid for evacuation and supplies. In many instances, particularly in the smaller towns, no communications could be obtained until the towns were contacted by river patrols.

Louisville.

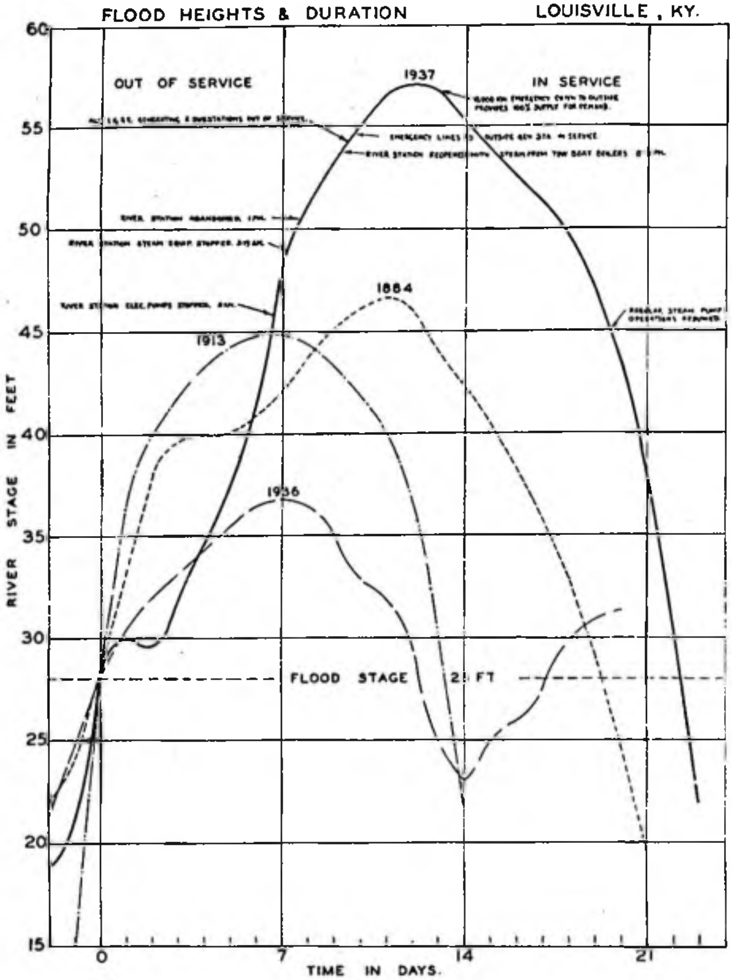
As the waters continued their rush downstream, they produced deplorable conditions in many of the smaller communities. Lawrenceburg and Aurora, Indiana, and Carrollton, Kentucky, found themselves under many feet of water, but it was downstream farther at the large city of Louisville, Ky., where the flood wreaked its greatest havoc in a locality of marked vulnerability. This city, which has a population of approximately 330,000, is, like other towns on the lower Ohio, situated on a small bluff which in past floods was high enough

Courtesy, U. S. Army Engineers, Louisville, Ky.

Ohio River Flood Crest, January 27, 1937. Upper gage 57.1.
View north showing central business area, Louisville, Ky.

to protect it against serious consequences. This time, however, about 70 per cent of the total area of the city was covered with water, including a considerable part of the business and industrial sections. Serious damage was also suffered by certain suburban communities in Indiana, including Jeffersonville, New Albany and Clarksville. The crest here was 11 feet higher than had ever been experienced. About 200,000 of the residents of this city had to be moved or taken from their homes, a tremendous task requiring assistance from many organizations and agencies. While the pumping station was seriously handicapped, emergency operations on a curtailed basis were made possible by use of steam boilers on a boat which was moored near the pumping station. A small amount of water was rationed each day. Fire defenses were materially weakened, it being impossible to reach most of the property because of the flood waters, added to which must be considered the fact that fire and police alarms were seriously impaired.

Map of Louisville, Ky. and vicinity showing inundated area January, 1937



Evansville.

Next on its rampage downstream, the river reached Evansville, Indiana, where again it exceeded all previous records and inundated nearly half the city. At least half the population of this city suffered direct flood loss and the city was under military rule for 23 days. Normal waterworks service was interrupted on January 26th and was not fully restored until February 2nd. Most of the fire alarm system was kept in service and fire apparatus was available. The use of pumps on small boats was of considerable value in affording protection.

Paducah.

The next city of appreciable size in the path of the flood waters was Paducah, Ky. This city was perhaps more completely damaged than any other city approaching its size in the entire valley, about 90 per cent of the city being inundated. The waterworks was obliged to shut down on January 24th and the pumps were not started again until February 18th. The fire department was in unusually dire straits during the disaster, the former chief having been killed at a fire just a few days before the water rose. So completely flooded was the city that the only available place a piece of fire apparatus could be kept was in a cemetery. Fire alarm system was inoperative and telephone service was seriously curtailed.

Cairo.

Flood waters then descended and entered upon what has been referred to as the "Siege of Cairo." This city is located in a most vulnerable position at the junction of the Ohio and Mississippi Rivers, and being built upon low ground relies for its protection upon a flood wall which has been designed to withstand a stage of 60 feet. To prevent water from exceeding this height there had been provided the New Madrid-Bird's Point floodway, a diversion channel in the Mississippi below Cairo which it was hoped would prevent excessive river heights immediately above it. Anxiously the people watched the waters rise beyond the point at which the floodway was designed to function. The Army Engineers realizing the necessity of opening the floodway, tried every way to convince the people living in it to leave the danger zone, but eventually were obliged to dynamite the levee without knowing whether or not all of the inhabitants had left. Fortunately none was trapped in the floodway and the wall at Cairo withstood the attack.

The unprecedented flood waters, with flattened crest, flowed down the Mississippi from Cairo producing high water at many points but doing no appreciable damage. If left uncontrolled, there would have been produced a discomforting gage height at New Orleans, but by means of the operation of the Bonnet-Carre spillway, which had never before functioned to divert flood waters, the crest at New Orleans was held at 0.7-foot lower than the undesirable 20-foot mark.

Thus the great flood of 1937 found its way into the Gulf, leaving behind direct damages estimated by the United States Army Engineers as totalling $411,200,000 and with indirect damages due to loss of business, rehabilitation expenses, etc., estimated as being of equal magnitude.

APPENDIX B.

UNDERWRITING EXPERIENCE.

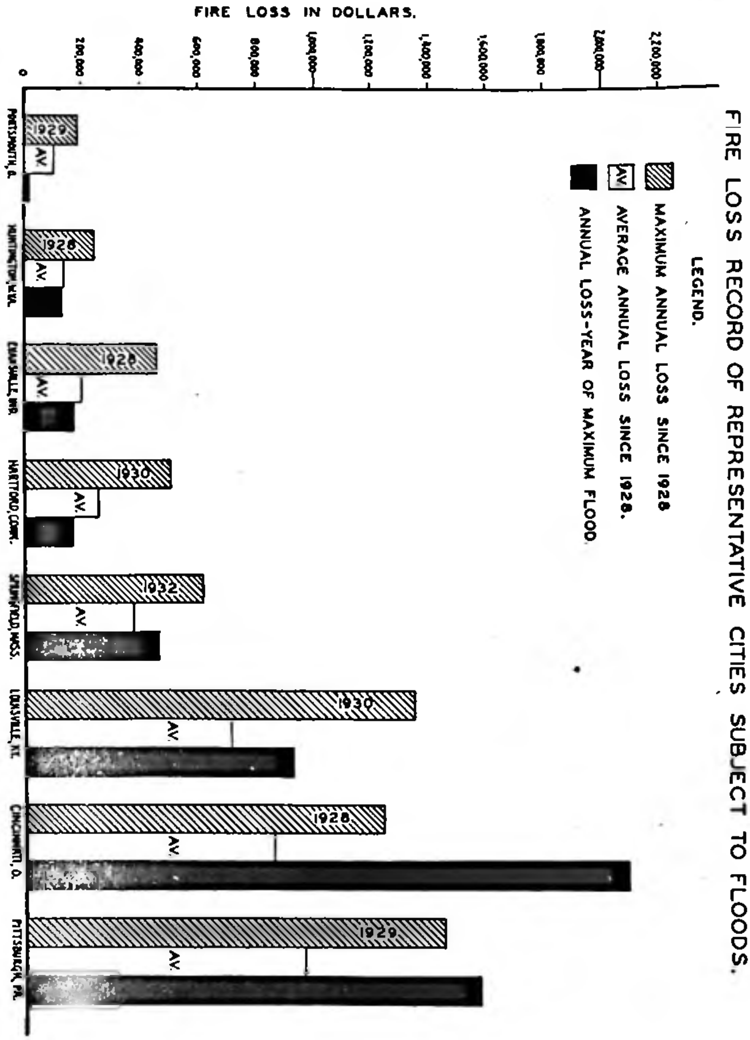
Experience in General:

Since the direct hazards to life of high water, epidemics, etc., are somewhat beyond his province, the practical fire protection engineer will, in any consideration of the flood problem, devote his principal attention to ascertaining whether these catastrophes have produced anything seriously abnormal from a fire loss standpoint. It would seem reasonable to expect a definite increase in losses. Protection, both public and private, is at a minimum; oils and gasoline may be floating on the surface of the water in the very midst of congested values; makeshift and comparatively hazardous heating and lighting arrangements are used in the drying out process; industrial operations are resumed with as little delay as possible and without normal safeguards; and electricity may be unavailable with the result that candles and gasoline and kerosene lamps are used by persons unfamiliar with their hazards. All these conditions are ominously favorable to the origin and spread of fire.

The fire protection engineer is by no means alone when he realizes, with apprehension, the serious threat of fire which inevitably accompanies every flood. Fire at such a time is more than ever to be feared. In his attention to the many emergency situations which arise there is every possibility that man may overlook this enemy which is more sinister even than the waters which imperil him and his property.

An effort to substantiate the premise that floods produce particularly adverse fire loss experience is met with but questionably convincing success. In fact, if the losses as reported by the fire departments of several representative cities definitely subject to floods be reviewed, it will be found that in some instances fire losses for the year in which the last major flood occurred are actually less than the ten-year annual average. The following figures may be of interest:

City	Annual Average Beginning 1928	Maximum Annual Loss	Annual Loss Year of Maximum Flood
Portsmouth, Ohio	$ 92,864	$ 185,320—(1929)	$ 14,768—(1937)
Huntington, W. Va.	130,098	242,795—(1928)	128,059—(1937)
Evansville, Ind.	199,718	462,999—(1928)	166,528—(1937)
Hartford, Conn.	259,710	506,236—(1930)	165,434—(1936)
Springfield, Mass.	368,027	621,873—(1932)	432,885—(1936)
Louisville, Ky.	717,395	1,333,971—(1930)	928,728—(1937)
Cincinnati, Ohio	864,769	1,250,328—(1928)	2,106,733—(1937)
Pittsburgh, Pa.	967,672	1,461,334—(1929)	1,575,176—(1936)



It will be noted that only two cities, Cincinnati and Pittsburgh, have had their worst experience over a ten-year period during the year of major floods. It should be considered that in Cincinnati, one loss during the flood, the so-called Mill Creek Conflagration, amounted to approximately $1,225,000. It will be seen that there is nothing in the general experience in Cincinnati, discounting this one major catastrophe, which would justify any marked pessimistic viewpoint. In Pittsburgh, one loss at the Waverly Oil Works is estimated at $550,000. These outstanding losses in Cincinnati and Pittsburgh were the direct result of the floods as were several other large individual losses, such as the loss to the Moore Drop Forging Company at Springfield, Mass., which accounted for the greatest part of the entire 1936 loss in that city.

Various deductions may be made from the experience of these cities, but it does not seem out of order to consider that those having the most adverse experience suffered one outstanding fire loss during the period of inundation. Each of these abnormal losses (which are abstracted individually in a subsequent section of this study) was directly attributable to oil and gasoline tanks from which liquid was released by flood waters. Discounting these major catastrophes there seems to be but little in the general experience to cause the fire protection engineer great concern, but he must never lose sight of the fact that tremendous potentialities of fire do exist during flood periods. Fate may not always be so kind.

It is of interest to consider the fire department experience during the actual period of inundation. To ascertain this, information was secured from the fire chiefs of a number of cities which experienced severe floods within recent years. An effort was made to determine whether or not during the flood period there was any abnormal increase in the number of fire alarms received. The following tabulation indicates the experience:

City	Relative Number of Alarms During Flood Period
Hartford, Conn.	Increase
Evansville, Ind.	Average
Lowell, Mass.	Average
Haverhill, Mass.	Less than average
Holyoke, Mass.	Average
Lawrence, Mass.	Average
Huntington, W. Va.	Increase
Cincinnati, Ohio	Considerable increase
Louisville, Ky.	Less than average
Springfield, Mass.	Average
Pittsburgh, Pa.	Considerable increase
Ironton, Ohio	Considerable increase

The foregoing tabulation shows that in only five of twelve cities did the fire department receive more alarms during the period of flood than the average received during the same period in a normal year. There may be some merit to the thought that during the time of emergency, such as is presented by a flood, people are unusually cautious, being aware of the lack of protection and the dire results which might be expected to follow a fire.

As an aftermath of a flood, frequent fires in the flooded areas might reasonably be expected. Electrical wiring has been water-soaked and its insulation weakened. In some sections rehabilitation may be a slow and discouraging process. Certainly the flood-scarred remains of property in many instances offers but little incentive for its protection or preservation. Proposed zoning ordinances may threaten to change entirely the character of a district. Dwellings may be permanently gone, leaving no trade for the mercantile establishments in certain areas. Such a set of circumstances constitutes an almost ideal breeding place for moral hazard and incendiarism.

Information was secured from the records in the fire departments in these same twelve cities relative to the fire losses in property which was damaged by flood. The purpose was to ascertain if experience has indicated any adverse loss record since the flood in those sections of the city where property actually suffered severe damage. It is pertinent to note that in no single instance do the fire department records show an increased number of fires in the sections which were flooded.

If there is any optimistic deduction to be made from the record of fires during floods, the fire protection engineer will undoubtedly be inclined to discount it by a realization of the dire possibilities that exist. There is no very good reason, other than the capricious fortunes of chance, that entire blocks of some of the larger cities were not completely destroyed by fire. Water supply was not always available and, in spite of their courage and resourcefulness, the fire departments could have but found themselves helpless had a fire of serious proportions developed in one of the many congested high-value districts.

OUTSTANDING INDIVIDUAL LOSSES

Almost every flood has had in connection with it one or two outstanding fire losses; losses in which the flood itself was a factor of vital significance. Attempting to recount most of these would be an arduous task and one of questionable value. Yet, there may be something of value in a consideration of abstract accounts of some of the most interesting of these losses in which floods played an important part, either in the origin or spread of fire or in the serious handicaps they imposed upon efforts to extinguish it.

Cincinnati, Ohio, 1937, Riverview Apartments — This fire occurred at the time when water was being rationed and was caused by the use of candles for temporary light. Since it was inadvisable to drain the reservoir supplying the section of the city in which the structure was located, some other means of supplying water had to be found. The Riverview Apartments, a good-sized modern fireproof structure, is located on a high hill overlooking the river. The terrain ends quite abruptly, producing a rather precipitous drop of several hundred feet to the river. Along the sides of this hill and at different levels are several roadways running parallel to the river. Pumpers were stationed on each of these roadways; hose was dropped down the hillside to the roadways below, and from there in relays to the river bank. Pumpers at the different roadway levels operated in tandem pushed water from the discharge of one pump to the suction intake of the next and so on to the fire. In order to obtain the proper picture it is well to note that approximately one mile of fire hose was laid in order to supply the necessary water. The fire was successfully extinguished.

Cincinnati, Ohio, 1937, Mill Creek Valley—This fire, which reached conflagration proportions, occurred in the Mill Creek Valley at a time when this section was inundated by flood waters. The cause of the fire has not been definitely determined, but from all accounts it resulted from a live wire which fell into the gasoline-covered flood waters. The fire involved industrials, both sprinklered and unsprinklered, mercantiles and dwellings and threatened an entire section of the valley. The area in which the fire occurred was hardly a congested one; nevertheless, there was heavy loss to several properties because flaming gasoline, released from tilted storage tanks, was floating on the water covering several city blocks.

Firemen were seriously handicapped in combating the fire, not only because of the existence of flood waters, but principally because of the flaming gasoline which covered such a large area that it made the task decidedly perilous. However, after four hours, during which time spray nozzles manned by men in boats were used, the fire was brought under control and confined to the vicinity of the Standard Oil Company's distributing station where it was finally extinguished late the following day.

The fire occurred on January 24th, but events directly affecting it date back to the 21st when employees of the Standard Oil Company were engaged in emptying the large gasoline storage tanks which it appeared would soon be surrounded by the rising waters. They expected to continue this work the following day, but on the next morning shortly after midnight a fire occurred in the B. & O. roundhouse located immediately across Spring Grove Avenue and several hundred feet from the gasoline tanks. Because of this fire it was deemed inadvisable to resume emptying the tanks. Meanwhile the water was rising with such rapidity that it was not long until the plant was entirely surrounded. Soon the tanks were floating, releasing gasoline from broken connections. All day Saturday, January 23rd, gasoline vapors were so noticeable and the odor so pronounced in the Crosley main plant located nearby that it was suggested that the main line electric switch be pulled in that property. This was not done, however, but employees exercised the greatest precaution against fire. Sunday morning, January 24th, a flash occurred on Johnson Street along which power transmission lines are carried. Flames immediately spread so rapidly that a general alarm was given all employees to vacate the Crosley plant. When the flames reached the gasoline tanks there was a series of explosions which continued for some time. In all, 250 firemen answered the alarm, and although the men available were placed at strategic points, it was soon apparent that there was a shortage of man power to cope with the fire raging at that time. Assistance was rendered by short-term workhouse prisoners from the institution located nearby. Water was approximately 10 feet deep, and it was necessary for the firemen to struggle against great odds presented by the rain, water, and flaming gasoline. Hose and equipment became most cumbersome and could be moved only with considerable difficulty when it became necessary to shift the attack. The total loss from this conflagration was estimated at $1,225,000 and may be directly attributed to the presence of gasoline on the water's surface.

Hamilton, Ohio, 1913, Champion Coated Paper Co.—The flood of March, 1913 wreaked its greatest havoc in the state of Ohio, the city of Hamilton being particularly unfortunate. The Champion Coated Paper Company, which was of substantial combustible construction with brick walls, was located on the west bank of the Miami River opposite the business section of the city.

Dangerous conditions were first apparent at the plant on Tuesday, March 25th. Water backed up through the sewers in one of the beater buildings. There was a large quantity of lime in casks stored in this basement. Fire started in one of the casks due to the slaking of lime and was extinguished by men with shovels who scooped up water from the floor. Later, a second fire started and was fought with hose streams until the rising water compelled the men to abandon this attack. The flood completed the work of extinguishment without any appreciable fire damage to the building.

Water continued to rise until it reached a depth of 15 feet above the floor of the coating mill. At about midnight on Thursday, March 27th, fire was seen in a general storage building in which was kept the main stock of chemicals. While it cannot be irrefutably stated, all evidence substantiates the belief that the reaction between the water and the chemicals started this fire.

The fire had its origin practically at the time of the maximum height of the flood. All ordinary means of fire protection were crippled. The fire pump was under about 20 feet of water and all boiler fires had been extinguished.

During the progress of the fire, which lasted for hours, efforts were made to fight it at certain sections where access was possible. A bucket brigade made use of water and wet clay. Wet felts were hung on walls of the store house to protect the windows. These attempts, however, were not of much avail. Finally the flood receded and water fell below the boiler grates. Although some uncertainty was felt as to the amount of water in the boilers, particularly in view of the fact that the feed pumps could not be started immediately, nevertheless, steam pressure was gradually raised by using resin in the boilers for fuel. The fire pump was then started with two hose streams and fire was more successfully attacked. Much of the plant fire equipment had been washed away. In an effort to secure some assistance an appeal was sent to the town of Oxford, twelve miles distant. The fire department of that town responded and with their help the fire was finally brought under control.

Springfield, Mass., 1936, Moore Drop Forging Co.—Sections of this plant involved in the fire which occurred during the 1936 flood include an incombustible (all steel) building occupied for drop forging and containing the usual hammers, punches, and furnaces. This building communicated with an ordinary frame joisted storage shed. The storage shed was completely sprinklered and the major portion of the incombustible forge shop was likewise so protected. Contents in the forge shop were almost entirely incombustible. Furnaces, some fifty in number, were fired with fuel oil pumped from tanks buried nearby.

Work in the forge shop was discontinued when flood waters, presaging the worst flood in 300 years, began to enter the street near the plant. Water began to seep into the forge shop about midnight. At 5:00 A. M. on the following day a dike broke resulting in a sudden rise of water to a 3-foot level. Water is thought to have entered the fuel oil tanks, replacing the oil which floated on the surface, finally coming in contact with the still hot fire boxes of the furnaces. The oil became ignited in the forge shop and flashed over the entire area. Flood waters rose rapidly, reaching a height of 7½ feet in the plant. The intense heat of the burning oil at this elevation soon wrecked steel truss members, and in a short time the roof, shafting, and overhead equipment tumbled into the water.

The Springfield fire department responded to the alarm but was seriously handicapped, being obliged to use a hydrant some 500 feet distant and carry a hose line by boat to the vicinity of the fire. Firemen were undoubtedly a factor in preventing spread of this fire to other buildings. The loss in the forge shop and the storage shed was practically total, the fire eventually burning itself out. There is no evidence that operation of the sprinklers had any effect in the sections involved, although sprinklers throughout the exposed buildings apparently functioned, assisting in preventing the spread of fire to other sections. Some sprinklers were still operating 48 hours after the fire, it being impossible to reach the control valve which was under several feet of water. The loss is estimated at about $400,000.

Louisville, Ky., 1937, Louisville Varnish Co. — The fire which involved this sprinklered brick joisted varnish factory apparently started when naphtha tanks in a covered concrete pit were lifted by flood waters, breaking piping connections and releasing naphtha. The building and a brick wall enclosing the property were so arranged that they formed a yard enclosure which confined the floating naphtha. Vapors were ignited in some manner which caused a flash over the plant opening many sprinkler heads. City water was shut off at this time, and the 20,000-gallon gravity tank was quickly drained. The fire soon involved other volatile liquids and enveloped the entire property.

The fire department responded but could not get within two blocks of the plant and made no effort to extinguish the fire. At that time the entire city was in the direst straits of an emergency and energies of the fire department and other municipal departments were engaged primarily in rescue work, in consequence of which this fire, large though it was, was looked upon merely as another incident of the flood. Varnish drums continued to burst after the fire started, and in some sections of the plant fires were still burning when the water receded ten days later. The estimated loss was $265,000.

Huntington, W. Va., 1937, Gasoline Fire—During the time the flood was near its crest, gasoline from an overturned tank accumulated on top of the water. Rescue work was being carried on in the vicinity and a woman who was in one of the rescue boats lighted a cigarette and then tossed the match overboard. Gasoline vapors flashed, resulting in the death of three persons and serious burns to four others. The fire continued for about an hour, destroying a filling station and involving two small frame dwellings.

Warren, Mass., 1936, Ohio Carpet Co.—A fire, presumably originating from the spontaneous ignition of low grade carpet yarn stored in the basement, destroyed this four-story brick building during the flood of 1936. The property was protected by sprinklers, but only a weak primary source of supply was available, the secondary being out of service due to the flood. The fire was not promptly discovered and had apparently burned for some time under the bagged wool shoddy which probably contained some oil and was out of reach of the first sprinklers to operate. By the time the fire department arrived the fire had reached the looms on the second floor. A pumper was so located that it could take suction from the tail race, but it was of no avail. Outside help was summoned, but flooded and muddy roads delayed seriously the arrival of additional pumpers. The plant was totally destroyed. The fact that the secondary supply, which was normally from two steam-driven fire pumps, was out of service because of the flooded boiler room was undoubtedly a factor of importance in the failure to prevent total loss of this property.

Holyoke, Mass., 1936, Chemical Paper Mfg. Co.—A carload of lime was stored in a small one-story brick building. Flood water reaching the lime caused sufficient heat to fuse four sprinkler heads. Sprinklers were shut off and the lime cooled by a chemical line used by the public fire department. Loss was confined to the slaking of the lime and to slight damage to an adjoining roof through which the fire department cut a hole in order to reach the inside of the building where lime was stored. This small loss is probably typical of many similar occurrences which were not specifically reported.

Pittsburgh, Pa., 1936, Waverly Oil Works—This fire was caused directly by flood waters of the Alleghany River. Early Wednesday morning, March 18th, water covered the plant premises to a depth of about 4 feet. It seems most likely that this caused the flotation of certain tanks with the subsequent rupture of the piping and the discharge of oil and gasoline. It is supposed that a short circuit in a switch at the boiler house ignited the floating oils. At the time the fire started the river was rising at the rate of about 0.7-foot per hour and was rapidly inundating the entire refinery. When the fire department arrived several tanks in the vicinity of the boiler house were burning freely and large quantities of burning oil were floating over the entire area. Apparently the fire was beyond control from the very start, the firemen being unable to penetrate more than a short distance into the plant yard due to the depth of water and the floating oil. Fire burned steadily from Wednesday morning until Saturday, during which time from ten to eighteen hose streams were in constant use. The fire spread throughout the entire plant causing a loss of practically 75 per cent of the value of all oils and gasoline in storage, and 60 per cent of the entire building, tank and machinery value. Losses amounting to about $200,000 were suffered by adjoining properties as a result of burning oil being carried into these on top of the flood waters. There was no loss of life, although several firemen were seriously injured. The loss is estimated at $550,000.

SPRINKLER LEAKAGE EXPERIENCE

The loss from sprinkler leakage directly attributable to floods is not as great as might be supposed. This is accounted for in large part by the fact that major floods have, in recent years, not been accompanied by severe weather, and temperatures have not dropped to a point which might result in severe damage to such sprinkler equipment as had not been drained. It is reasonable to expect that a protracted period of low temperatures, starting when flood waters are at or near their crest, would be productive of great sprinkler leakage damage.

A great many sprinkler lines were broken and a great many heads knocked off by floating material, but the water from the ruptured sprinkler lines did no damage not already caused by flood waters. The wetting of certain materials, such as paper carton stock, resulted in swelling which broke sprinkler lines with but small sprinkler leakage loss. At a paper company in Holyoke, Mass., employees moving stock to prevent its damage by flood knocked off a sprinkler head which caused a loss of approximately $300. At a manufacturing plant in Springfield, Mass., a gasoline lantern was hung on the sprinkler piping during some flood emergency work, and the resulting sprinkler leakage loss amounted to approximately $1,000. These losses are mentioned merely because they are indicative of the average small loss which has occurred.

The one outstanding sprinkler leakage loss due to floods occurred at the Hampden Grinding Wheel Company, Springfield, Mass., during the flood of 1936. In this property oil-fired kilns were in operation when flood waters finally came into contact with them. At that time the temperature in one kiln was approximately 2,000 degrees F., and the others were operating at approximately 1,000 degrees F. Flood waters coming in contact with the practically incandescent mass of material in the kilns blew a 30-inch cast-iron manhole cover off the top of one of them, releasing a large volume of steam and also liberating the heat which was in the kiln itself. Several heads in the immediate vicinity of the kiln opened, but the large volume of steam penetrated all sections of the plant, opening heads in the elevator shaft and on the second floor near vertical openings until a total of 23 had been operated by the liberated steam. The watchman was unable to reach the control valves, both those in the building and on the premises outside being submerged. As a result the 23 sprinklers operated at from 130 pounds to 145 pounds pressure for approximately 76 hours. The loss was large, involving considerable damage to finished grinding wheels, moulding material, motors, belting, wood pulleys, etc.

APPENDIX C.

EMERGENCY CODE ORGANIZATION CHART

Prepared for

CITY OF CINCINNATI

EMERGENCY COUNCIL
Mayor, Chairman

City Manager	Red Cross Repr.
City Solicitor	Citizen
Dir. of Safety	Citizen

EXECUTIVE BOARD
City Manager, Chairman

City Com. Chairmen	Red Cross Com. Chairmen

CITY COMMITTEES	PRIVATE AGENCIES (Other than Red Cross)	RED CROSS COMMITTEES
—CODE INFORMATION		RESCUE—
—COMMUNICATION		MEDICAL AID—
—PUBLIC UTILITIES		SHELTER—
—LAW AND ORDER		FOOD—
—FIRE		CLOTHING—
—WATER		TRANSPORTATION—
—STREETS AND HIGHWAYS		FINANCE—
—BUILDING INSPECTION		REHABILITATION—
—PUBLIC HEALTH AND SANITATION		
—REGISTRATION AND INFORMATION		

EMERGENCY CODE

Prepared for

CITY OF CINCINNATI

Purpose

This Code is formulated to provide a co-ordinated organization which will meet effectively the needs of the people of Cincinnati arising from the occurrence of a major physical emergency, whether by flood, fire, earthquake, tornado, civil commotion, or any circumstances threatening to result immediately in any such emergency.

Organization

There is hereby created an Emergency Council, which will be the supreme authority for this Plan, subordinate only to the constituted authorities of government—city, state, and federal. The personnel of the Emergency Council shall be composed of seven members: the Mayor, City Manager, City Solicitor, Director of Safety, Chairman of Hamilton County Red Cross Chapter, and two citizens to be appointed by the City Manager.

The duties of the city government during times of emergency are to be regarded as merely a "stepping up" of its normal duties. The Mayor shall be the Chairman of the Emergency Council. The City Manager, as executive and co-ordinating officer, shall be the chairman of the Executive Board. He shall also act as Chairman of the Emergency Council in the absence of the Mayor.

The Emergency Council shall be the policy-forming body of the organization. Its policies shall be executed and administered through the City Manager, as Chairman of the Executive Board.

Members of the Emergency Council shall be members ex-officio of the Executive Board. Other members of the Executive Board shall be the chairmen or alternates of all City and Red Cross Committees.

The Chairmen of the *City Committee* shall be:

Committee on Code Information
Director, Municipal Reference Bureau

Committee on Communication......Director, Dept. of Safety

Committee on Public Utilities
Director, Dept. of Public Utilities

Committee on Law and Order......Chief of the Police Force

Committee on Fire..................Chief of the Fire Force

Committee on Water..............Supt. of the Water Works

Committee on Streets and Highways
Director, Dept. of Public Works

Committee on Building Inspection......Comm. of Buildings
Committee on Public Health & Sanitation..Comm. of Health
Comittee on Registration and Information
Chief, Division of Public Welfare

The Chairmen of the *Red Cross Committee* shall be:

Committee on Rescue ....
Committee on Medical Aid ....
Committee on Shelter ....
Committee on Food ....
Committee on Clothing ....
Committee on Transportation ....
Committee on Finance ....
Committee on Rehabilitation ....

It shall be the duty of the Executive Board to administer all public service affairs during the emergency period in strict accordance with the policies of the Emergency Council.

Committee Personnel

Members of the City Committees shall consist of the regular employees of the city departments having committee functions. Both chairmen and members of the Red Cross Committees shall be appointed by the Chairman of the Hamilton County Red Cross Chapter.

Headquarters

The headquarters of the Emergency Council, as well as that of the Executive Board, shall be within the City Manager's office in the City Hall. In case the City Hall is unavailable for occupancy or use, the City Manager shall designate the location for headquarters.

The headquarters for each City Committee shall be the normal headquarters of the city department assuming that committee's function. For purposes of administering its committee function, the city department shall utilize, whenever possible, its normal stations and districts. Whenever the regular facilities of any city department are unavailable for occupancy or use, the director or supervisor with the approval of the City Manager, shall establish temporary headquarters.

Headquarters of all Red Cross committees shall be determined by the Chairman of the Hamilton County Red Cross Chapter.

Private Agencies

Private agencies desiring to volunteer services for emergency work shall register their intentions with the Chairman of the Executive Board (City Manager), who shall, at his discretion, assign such agencies to the proper committees.

EXECUTION

Declaring the Emergency

The existence of the emergency shall be determined and shall be so declared by the City Manager. It shall be confirmed by proclamation of the City Council as soon thereafter as possible. The effective date of the emergency, both as to its beginning, extent, and termination shall be as determined and declared by the City Manager.

Mobilization

The City Manager shall put this Emergency Plan into operation in the manner which he deems most effective for coping with the particular emergency involved. In all cases, however, the City Manager, as Chairman of the Executive Board, shall advise all Committee Chairmen when to start and cease operations by written declarations of the beginning and termination of the emergency.

Flexibility of Emergency Plan

When, in the opinion of the City Manager, any provision of this emergency preparedness plan shall be insufficient to meet any phase of the emergency, it shall be his duty to assign all the forces under his command in such manner as, in his opinion, will best serve the public need; provided, however, that under no conditions shall the City Manager authorize or condone violation of any federal law, state law, or ordinance of the City of Cincinnati. It is understood that in administering public services as specified in this Code, the City Manager and the Emergency Council will confine their authority to the legal boundaries of the City of Cincinnati.

Meetings

The City Manager shall call a combined annual meeting of the Emergency Council and Executive Board during the month of January. The purpose of this meeting shall be to further the coordination of activities included in this Emergency Plan, instruct the members concerning their respective functions, study the effectiveness of, and develop new policies and activities for, the Emergency Plan.

The Emergency Council and Executive Board shall also assemble for special meetings whenever summoned by the City Manager.

Pubilicity and Records

All persons, committees, and agencies shall forward emergency information to the Chairman of the Executive Board who shall have sole control over its publication.

Whenever practical, records shall be kept in detail of all operations and performances. Each Committee Chairman shall maintain a file of such records for submission to the Executive Board.

The Executive Board shall submit detailed reports to the Emergency Council promptly after each emergency. These reports shall include such items as a description of the work performed by each committee, difficulties encountered in their performance, and methods used in overcoming these difficulties. These reports are to be submitted in a manner most suitable for the Council's use in studying the effectiveness of the entire Emergency Plan, and for making suitable revisions thereof.

Passes

The City Manager shall have passes prepared in the form of identification cards for issuance to those persons whose official duties will necessitate their entering the affected area or passing through police lines. Such passes shall be issued as necessary by the Chief of Police, effective for the duration of each emergency.

Compensation

No compensation shall be paid for any emergency service rendered under this Emergency Plan. This provision does not apply, of course, to regular salaries of employees of the City Government, Red Cross, or other participating agencies. No one is authorized to incur any expenditure or indebtedness except as may be provided through the regular channels of the participating agencies, or as specifically authorized by the Emergency Council.

CITY COMMITTEES

COMMITTEE ON CODE INFORMATION

Chairman: Director of the Municipal Reference Bureau

Responsible for disseminating information of the contents and purposes of the Emergency Code.

COMMITTEE ON COMMUNICATION

Chairman: Director of the City Department of Safety

Responsible for planning and maintaining a centralized system of communication, utilizing the police radio station or some other means for the unified control and clearance of all emergency action. Inasmuch as it is the responsibility of all city committees to broaden their normal duties to meet emergency requirements, it is necessary to clear all emergency orders through one central point to avoid duplication of their effort by Red Cross Committees and private agencies.

COMMITTEE ON PUBLIC UTILITIES

Chairman: Director, City Department of Public Utilities

Responsible for maintaining such public services as telephone, electricity, gas, and such other services and commodities which on account of the emergency may be affected with a public interest.

Responsible for providing adequate public transportation facilities during period of the emergency by organizing the facilities of all public carriers such as railroads, street cars, busses, taxicabs, and airplanes.

COMMITTEE ON LAW AND ORDER

Chairman: Chief of the Police Force

Responsible for maintaining law and order; and protecting all public facilities, including public utilities, public buildings, highways and bridges; and in assisting the Fire and other committees in rescue work.

Duties:

1. Co-ordinate all public service units such as the Fire Force, U. S. Army, Reserve military forces, etc., to assist the Police Force in the performance of its duties during the emergency.
2. Provide and store in suitable locations an adequate supply of city-owned equipment for emergency use, such as boats, boots, ropes, etc. Cooperate with the Fire Force in the planning and performance of this duty.

COMMITTEE ON FIRE

Chairman: Chief of the Fire Force

Responsible for combating fire hazards and fires; also for rescuing and aiding disaster sufferers.

Duties:

1. Maintain records of all water supplies available in the Cincinnati region for fire fighting purposes; also, records of all fire fighting equipment, both private and public, in the Cincinnati region.
2. Commandeer and take entire charge of storage and movement of all dangerous materials, such as inflammables, explosives, chemicals, etc., not only for public safety, but also for direct use in demolition emergency measures.

3. Cooperate with the Police Force in maintaining law and order; also in management of emergency equipment.

COMMITTEE ON WATER

Chairman: Superintendent of the City Water Works

Responsible for the maintenance of water service for public consumption.

Duties:

1. Maintain records of all available equipment and sources of water supply in the Cincinnati region.
2. Arrange and plan water distribution system so that maximum public service can be maintained during the emergency.
3. Cooperate with the Law and Order Committee for protection of the public water supply facilities.

COMMITTEE ON STREETS AND HIGHWAYS

Chairman: Director of the Department of Public Works

Responsible for maintaining streets, highways, and sewers in suitable condition for public use; also responsible for the construction of temporary streets and roads as may be required for the public use during the emergency.

COMMITTEE ON BUILDING INSPECTION

Chairman: Commissioner of Buildings

Responsible for safety, sanitation, fire prevention and general welfare in connection with buildings and premises through enforcement of the Building Code.

Duties:

1. The Commissioner of Buildings shall assign all personnel at his disposal in such manner as in his opinion will best serve the emergency. He shall co-ordinate all available resources for building inspection and other related activities necessitated by the emergency.
2. Inspection reports shall be made on the progress and extent of the emergency with special reference to buildings and premises affected. Such reports shall be part of the regular building inspection records and be at the disposal of the Committee with all other available material.
3. The general co-ordination of police, fire and building inspections of the Department of Safety with the other departments of Health, Public Works, Utili-

ties, Law, etc., shall continue until changed by the officials in charge of the respective departments or by the City Manager.

COMMITTEE ON PUBLIC HEALTH AND SANITATION

Chairman: City Commissioner of Health

Responsible for all matters pertaining to public health control, such as the sanitary inspection and conditioning of buildings, the sanitation of concentration camps, and the burial of the dead.

Duties:

1. Prevent the spread of contagious diseases during emergencies.
2. In flood emergencies, placard all flooded houses as unfit for habitation. After flood recedes and houses have been approved structurally by the Building Inspection Committee, supervise the removal of debris and mud, and the spraying of interiors with disinfectants.
3. By co-ordination of Department of Health personnel and Red Cross Committees, supervise and conduct all required medical examinations and treatments.
4. Make plans for the identification and burial of the dead.

COMMITTEE ON REGISTRATION AND INFORMATION

Chairman: Chief of Division of Public Welfare

Responsible for the registration of all families applying for relief, and for answering inquiries of relatives and friends of the emergency sufferers and other persons seeking information.

Duties:

1. Make advance plans for the efficient handling of registration for relief control.
2. Establish information bureaus for such purposes as:
   (a) Answering telegrams and other inquiries about the dead and injured and the whereabouts of survivors.
   (b) Assisting in reuniting families separated by the emergency.
   (c) Serving as a means of contact between people in the emergency area and their friends and relatives outside.

(d) Answering general questions concerning the emergency work and directing inquirers to the proper committee or official.
(e) Maintenance of a list of hospital patients. identified dead, and missing persons.
(f) Registering of survivors—giving their location, destination, condition, and immediate plans.
(g) Registering of personnel employed in relief operations, with telephone numbers and other necessary information.

RED CROSS COMMITTEES

COMMITTEE ON RESCUE

Chairman: (To be named)

Responsible for cooperating with the Fire, Law and Order, and Transportation Committees in the rescuing of people and animals from places of danger.

Duties:

1. Be acquainted with the location and nature of rescue and first-aid equipment.
2. Have a thorough knowledge of life saving and first-aid methods.
3. Be prepared to go into action at a moment's notice—day or night.

COMMITTEE ON MEDICAL AID

Chairman: (To be named)

Responsible for organizing and directing the Red Cross medical relief activities in the emergency area; and for cooperating with local physicians in providing the medical care of individuals suffering from the effects of the emergency.

Duties:

1. Determine the available medical, hospital, and nursing resources of the county.
2. Cooperate with the Public Health and Sanitation Committee to avoid duplication of effort and to secure coordinated action.
3. Work out plans with the Red Cross Transportation Committee and also the Public Health and Sanitation and Public Utilities Committees for the necessary moving of medical supplies by boat, auto, truck, train, or airplane.

COMMITTEE ON SHELTER

Chairman: (To be named)

Responsible for providing housing facilities for emergency sufferers.

Duties:

1. Determine available housing facilities including auditoriums, schools, armories, hotels, rooming houses, etc.
2. Secure the cooperation from owners of such buildings before the emergency.
3. Estimate the number of refugees that can be housed in each building.
4. Inventory the available cots and blankets.
5. Make plans for housing refugees in tents on public tracts of land such as parks.
   (a) Inventory all materials, tools, tents, fencing, fuel, etc.
   (b) Prepare plans for arrangement of camps, including building locations, sanitation and drainage facilities, etc.
   (c) Cooperate with the City Committees on Public Health and Sanitation, Streets and Highways, Public Utilities, Law and Order, and Fire, in the preparation of these plans.

COMMITTEE ON FOOD

Chairman: (To be named)

Responsible for providing food for emergency sufferers and relief workers.

Duties:

1. Determine food resources within the community, including:
   (a) Best available sources of supply.
   (b) Agreements with merchants.
   (c) Information from merchants concerning types of essential food supplies dealt in and approximate quantities usually carried in stock.
2. Make advance plans for the preparation and serving of foods to emergency sufferers and relief workers.
3. Cooperate with the Shelter Committee in planning canteen quarters, camp kitchens, etc.

COMMITTEE ON CLOTHING

Chairman: (To be named)

Responsible for providing clothing for emergency sufferers.

Duties:

1. Determine market sources of suitable clothing supplies.
2. Make plans for the collection, handling, and distribution of donated clothing.

COMMITTEE ON TRANSPORTATION

Chairman: (To be named)

Responsible for cooperating with the Law and Order, and Fire Committees to provide emergency transportation service as may be beyond the capacity of the regular public vehicles such as patrols, ambulances, boats, etc. Such transportation may include the movement of emergency sufferers, relief workers, household goods, materials and supplies.

COMMITTEE ON FINANCE

Chairman: (To be named)

Responsible for raising relief funds and disseminating information in regard to relief requirements.

Duties:

1. If the Chapter has insufficient funds to meet estimated financial needs, the Committee shall raise a relief fund by personal solicitation, supported by the press, radio, public speakers, and letters of appeal.

COMMITTEE ON REHABILITATION

Chairman: (To be named)

Responsible for cooperating with City Committee on Registration and information, City and County Welfare authorities and private social agencies for investigating and relieving family and individual needs resulting from the emergency.

THE FLOOD PROBLEM SUPPLEMENTAL REPORT

1951

Acknowledgment is made of the cooperation of the various regional organizations of the capital stock fire insurance industry, and the U. S. Corps of Engineers, Army, and others who have given valuable assistance in the preparation of this supplemental report.

Report compiled by Engineer Edward L. Zeltner

GENERAL

Purpose: The purpose of this report is to serve as a supplement to our report on "The Flood Problem in Fire Prevention and Protection," issued in 1939. This latter report presents general information and a comprehensive overall picture of the general flood problem from the standpoint of fire protection and fire prevention. It should be of interest and continue to serve a useful purpose to those analyzing problems arising out of flood conditions.

During the eleven years, since its publication, many disastrous floods have occurred and will continue to plague numerous areas throughout the nation. A few of the more notable floods are: Flood of May, 1949 in Fort Worth, Texas; Floods of August, 1940 in the Southeastern States; Floods of March-July, 1947 in the Missouri River Basin; Floods of May-June, 1948 in the Columbia River Basin; Floods of December, 1948 in the Connecticut River Valley; Floods of May-July, 1950 in the Kansas District which includes the States of Kansas, Nebraska, Missouri and Iowa; and the recent Flood of mid July, 1951 in the Kansas and Missouri valleys.

It is apparent that many of the floods occurring in the past eleven years, have caused greater damage and life losses than the floods that occurred in the years prior to 1938. This is the result of the increasing occupation of the river banks and river valleys by towns and cities, industrial plants, bridges, highways and other diversified facilities, and for the production of agricultural products. It must be recognized that this growth and expansion, during these years which included the period of World War II, has been extraordinarily rapid and very extensive. Then, too, in many cases, flood waters have risen to levels exceeding all previous recorded maximum stages, with the result that flood waters overflowed the levees, dikes and flood walls where so provided but which were not designed for such unprecedented high water levels. Much damage has also resulted from the failure of locally built levees and flood walls. Property located in or near the river banks and valleys of rivers and streams will always be subject to flood damage.

It was not until the passing, by congress, of the Flood Control Act of 1936, that flood control work was established on a nation-wide basis. By supplemental Flood Control Acts passed by Congress in the subsequent years, flood protection work has become a major public works activity.

The Federal flood control problem is of such magnitude that many years will be required to study all the areas throughout the nation that are subject to floods, and large funds are needed, to carry out the various flood protection projects that may be authorized by Congress from time to time. It must be recognized that the general flood control program is little more than 10 years old as of 1950. It is administered by the U. S. Corps of Engineers and under the supervision of the Deputy Chief of Civil Works for Flood Control. During this period the U. S. Corps of Engineers has made extensive studies of flood conditions and voluminous data has been collected with respect to the problem of flood control. Many flood control dams and impounding reservoirs have been constructed and brought into operation at various localities, and at times of floods in these respective areas, have proved to be most valuable in preventing additional damage. It should be noted that a number of these flood protection facilities serve multiple purposes, i.e., they are also utilized, wherever feasible, for the generation of electricity, irrigation of agricultural lands, prevention of soil erosion, etc.

To show the progress made by our government in its endeavor to provide flood protection, this can be presented, at best, by the following extracts taken from a recent report of the Corps of Engineers, which was submitted to the U. S. Senate and printed, in full, in the Congressional Record—Senate of August 15, 1951.

Quote

4. Flood damages which can be evaluated in monetary terms do not measure the total impact of floods upon the national economy, but they are the best indication of the magnitude and distribution of the flood problem. The Corps of Engineers, under congressional directives, has studied this problem in practically every major river basin of the country and on many smaller streams. As a result of these studies estimates have been made of the flood damage, both direct and indirect, which would occur, based on the degree of river valley development prevailing generally at this time, and assuming that no flood-control works were in existence.

8. Accomplishments: (a) In order to determine the effectiveness of the flood-control program the Corps of Engineers has compiled records of actual flood damage that have been prevented by flood-control works now in operation; and of other benefits of these projects. A field appraisal of accomplishments of flood-control projects to June 30, 1950, shows the following pertinent facts:

(1) These works afford flood protection to 861 cities and towns with an aggregate population in the protected

areas of 3,034,000. Populations indirectly affected by the protective works are of course much greater.

(2) These works afford flood protection in varying degrees to over 26,000,000 acres of agricultural lands. The degree of protection varies as follows:

	Acres
Full protection—against the maximum flood of record	17,200,000
Good protection—against all floods up to and including those of 10 years frequency	5,200,000
Partial protection—reduction of flooding to permit higher agricultural use	3,600,000
TOTAL	26,000,000

(b) The benefits of flood-control projects complete or in operation on June 30, 1950, may be summarized as follows:

BENEFITS ACCUMULATED TO JUNE 30, 1950
(Millions of dollars)

	Flood damage prevented	*Increased land use*	*Other benefits*	*Total*
Flood control, general	738	145	57	940
Mississippi River and tributaries	5,372	(*)	463	5,845
Total	6,110	145	520	6,775

* No estimate.

CURRENT ESTIMATE OF AVERAGE ANNUAL BENEFITS
(Millions of dollars)

	Flood damage prevented	*Increased land use*	*Other benefits*	*Total*
Flood control, general	86	17	16	119
Mississippi River and tributaries	221	(*)	58	279
Total	307	17	74	398

* No estimate.

Unquote

Flood Forecasting: With respect to the U. S. Weather Bureau flood forecasting service, it can be stated that with the present extensive radio communication systems and other improved Weather Bureau reporting facilities provided, that more accurate and earlier forecasts can now be made. This permits advanced precautionary measures to be taken by the public in protecting buildings and contents, water works pumping stations, public utilities, and in establishing other safeguards. In a Des Moines, Iowa, report of the June, 1947 flood, it was stated that "the accuracy with which the local meteorologist forecast the time and crests for the Des Moines and Raccoon Rivers was invaluable in preparation for the emergency."

Flammable Liquid Storage:—Oil storage tanks, located in areas subject to inundation, continue to present an extreme fire hazard. A general review of the floods occurring in the past ten years, show many cases in which oil storage tanks, in the flooded areas, are still being floated away, or lifted off of their foundations, rupturing pipe lines, and discharging their contents on the flood waters.

The extensive use of butane and propane gas for domestic and industrial purposes throughout the country, has resulted in a rapid expansion of the liquefied petroleum gas industry. Tanks of 30,000 gallons capacity, storing such gases, have been installed in flood-subject areas of some cities and towns.

The introduction of these tanks together with oil storage tanks in districts subject to floods creates an extraordinary high hazard. Unless proper safeguards are provided for oil and liquefied petroleum gas storages, serious disasters are highly probable during flood conditions.

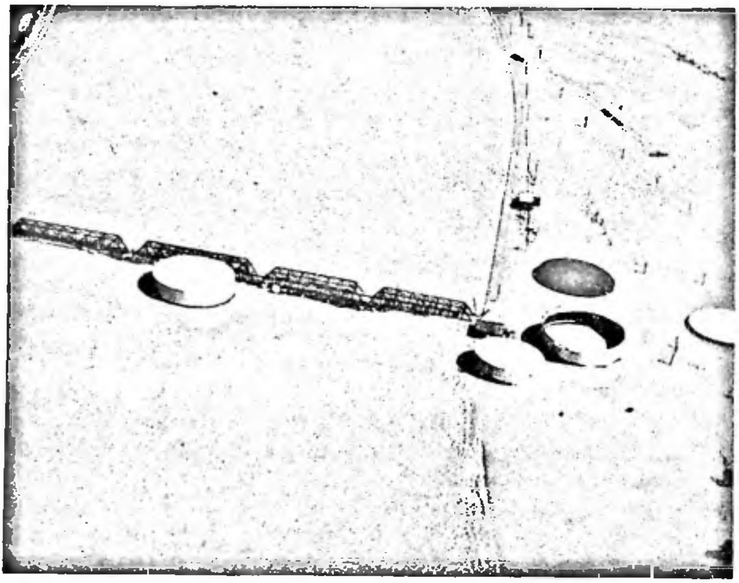
During the recent Kansas-Missouri flood in July, 1951, a large area in Kansas City, Kansas, was seriously endangered by floating gasoline discharged from ruptured oil tanks and pipe lines. Immediate precautionary measures taken by local authorities undoubtedly prevented a major disaster. On the Kansas City, Missouri side of the river, however, gasoline floating on the flood waters caused a serious conflagration which is described on Page 126 of this report.

The following extracts are taken from a Preliminary Report by the Kansas State Fire Marshal covering a survey on bulk oil storage stations located in the areas affected by the July, 1951 floods. The cities and towns covered in his report are on the tributaries of the Missouri River, and on the Neosho and Cottonwood Rivers which are tributaries of the Arkansas River.

"In the 21 cities and towns surveyed, each contained from 1 to 10 bulk oil storage plants, or a total of 62 in number. The total number of storage containers in the 62 plants affected was 391; of the latter, 125 tanks were damaged or moved from their foundation but did not move from the premises; 47 moved or floated from the premises. Of approximately 3,150,000 gallons of flammable liquids stored in the tanks, about 290,000 gallons of flammable liquids were lost.

"As a matter of record it should be mentioned that many of the storage facilities were not filled to capacity. Also some stored liquid has been moved when the operator realized his station would be flooded. Some operators prevented the loss of liquid and damage to storage facilities by removing the flammable liquid and filling the container with water or adding water to fill a partially filled container.

"It was quite apparent that the most destructive damage to buildings and properties of all types was sustained in areas where a swift current was flowing. This cause for excessive damage also applied to flammable liquid storage containers.



Aerial view in Argentine District, Kansas City, Kansas.
55,000 barrel oil tank endangering bridge; Flood of July, 1951.

"Evidence is ample to indicate that storage containers in the path of a rapid current were damaged or carried away with the resulting loss of contents. However, the rapidly flowing current also created a turbulence that so completely mixed the spilling flammable liquid with large volumes of water that the evaporation of the flammable liquid was retarded and therefore greatly minimized the hazard due to lack of concentrated clouds of combustible vapor in a given area."

Repeating from the 1939 Report of the Flood Problem in Fire Prevention and Protection as follows: Every municipality subject to flood should make mandatory the requirements contained in the National Board of Fire Underwriters Standards for the Installation of Containers for Storage, Handling and Use of Flammable Liquids, Pamphlet No. 30, which contains Recommended Safeguards and Safe Practices for the Protection of Tanks Containing Flammable Liquids in Locations That May be Flooded.

RESUME OF RECENT NOTABLE FLOODS

In the following pages are included abstracted accounts of several recent floods.

FLOOD OF KANSAS RIVER AND TRIBUTARIES — JULY, 1951

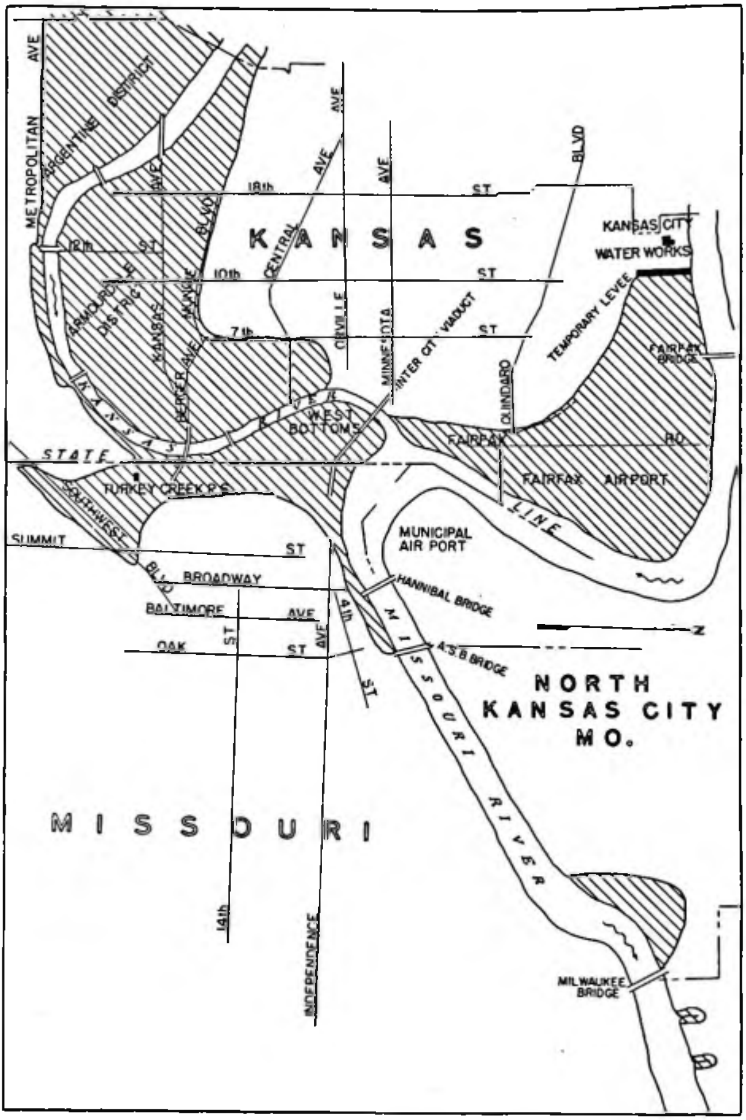
Kansas City, Kansas—Kansas City, Missouri—Heavy rains in the early part of July 1951, principally in the central and east portions of Kansas, sent a large volume of water down the Kansas (Kaw) River. Reports showed that on July 12, the river stage was 39.9 feet, rising to stage 41 feet on July 13, and that flood waters reached a crest of about 51.28 feet on July 14. Stages are those recorded at the U. S. Corps of Engineers gauge on the 23rd Street Bridge, Kansas City, Kansas, which was the only gauge in operation in the area on the Kansas River. This gauge was installed two years ago so no exact comparison with the 1903 flood level can be made, but a fair estimate is that the July, 1951 crest was 5 feet higher than that of 1903.

Along the river banks are earth levees or concrete flood walls designed for protection up to 1903 flood levels. On the Kansas side, the river breached the south levee and poured into the Argentine District; it went through the levee protecting the west side of Armourdale; and broke through the Santa Fe Railroad gate in the west flood wall of the Central Industrial District. The river rose so high that instead of following its usual course, it cut through Armourdale and the Central Industrial District to the Missouri River, actually discharging over the floodwall protecting the north side of the Central Industrial District, into the Missouri River.

The Kansas City, Kansas, water plant is located within the floodwall and levee system which protects the Fairfax Industrial District. An emergency dike, erected by several thousand volunteers, prevented water which flooded the Fairfax District from reaching the plant. Four fire stations were flooded and all apparatus was moved to other stations on higher ground. There are no fire alarm boxes in Kansas City, Kansas. Fire alarms are received and transmitted by telephone with subsequent broadcast through the police radio. Approximately 8,100 telephones in the flooded areas were out of service, and of these, 4000 were under water.

Kansas River Flood, July, 1951. Stockyards District. View taken in Easterly direction from Kansas City, Kansas.

The floating oil hazard, quite common during flood conditions, was most pronounced at the height of the flood. A number of flammable liquid storage tanks were lifted from their foundations and others floated some distance from their origin with most of their contents leaking out. It was estimated that 30 acres of the Fairfax District in Kansas City, Kansas, was covered with gasoline floating on the water when



Courtesy, Kansas Inspection Bureau and Missouri Inspection Bureau.

Map of the Cities of Kansas City, Kansas and Missouri showing inundated areas July, 1951.

the water leveled off in that area. The various local and state authorities and others cooperated in taking immediate precautionary action and were successful in avoiding a major disaster. In this same district, two of six 30,000 gallon propane tanks tilted but they were promptly shored up and prevented from toppling from their supports.

Thousands of dwellings were seriously damaged and over 3000 families made homeless. Heavy damage resulted in the industrial and business areas. Direct loss has been roughly estimated at over $750,000,000.

The area of Kansas City, Missouri, involved in the July 13, 1951 flood was relatively small. However, this area, as shown on the map, contained a high concentration of business and industrial values and the principal pumping station which normally supplied about two-thirds of the water used by the city. The flood water, following a break in the dike system, quickly filled the area on the city side of the Missouri River floodwall. The water reached a depth of 10 feet in the pumping station which was out of service for about five days. Three fire stations located in the flooded area had to be abandoned and apparatus moved to higher ground.

The flood conditions involved many buildings and bulk oil storage tanks in a congested industrial district located in the vicinity of the Southwest Boulevard and the Kansas-Missouri State lines. A fire was started by one of the floating oil tanks when, according to reports, it struck a high tension power line and burst into flame. Fed by the oil slicks on the surface of the flood waters, the fire spread rapidly until it reached conflagration proportions. The fire department had difficulty in getting water to the burning area due to the total flooding of the area to an average depth of nine feet, and lack of water in the city mains. The fire burned over an area equivalent to six to eight ordinary city blocks; it is estimated that the total fire loss might reach five million dollars.

This conflagration on the Missouri side of the river also spread to the Kansas side but here the fire was confined to an oil bulk station near the State line; the fire loss is estimated to be about $32,000. In Kansas City, Kansas, a fire also occurred in a flooded business area; it was caused by or resulted from an explosion at a gasoline filling station. Several structures were damaged and the fire loss was estimated to be about $55,000.

Topeka, Kansas—This city suffered its most damaging flood since 1903 when the Kansas River broke through the earth dike on July 11, 1951 at a stage of about 30 feet; maximum stage reached 36.4 feet. Previous floods and their stages are as follows: 1844, 42.2 ft.; May 30, 1903, 32.7 ft.; June 9, 1908, 28 ft.; June 5, 1935, 27.65 ft.

Many industrial plants and warehouses as well as dwellings and mercantiles sustained considerable damages. It is estimated that more than one third of the population were driven from their homes and that the loss may be over $100,000,000. Efforts on the part of many volunteers in sandbagging and keeping the dikes intact prevented inundation of the pumping station.

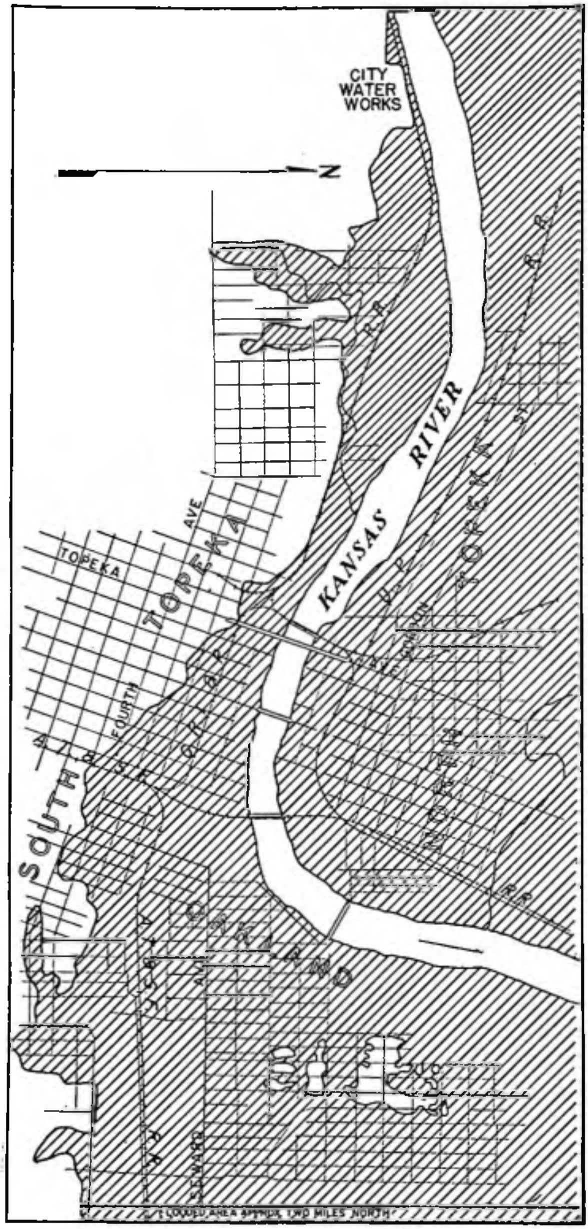
Three of the seven fire stations were flooded, but apparatus was removed to other stations. The fire alarm system was out of commission in parts of the flooded area. With all apparatus equipped with two-way radio the department operated efficiently through its own broadcasting station.

At one gasoline bulk plant one gasoline storage tank was overturned; when coming in contact with a hot wire, it exploded and burned vigorously above the flood waters, and burning debris floated down stream into a large lumber yard and a flour mill district. Fire companies, operating from a bridge, were able to extinguish the floating burning debris as it passed under the bridge.

A section of a high pressure natural gas main was lost when the bridge, supporting it, was washed away. The main was valved off; no fires were caused by gas in the flooded area.

* * *

Many other smaller cities and towns, located on the Kansas (Kaw) River, Neosho River and other tributaries which rose to unprecedented heights in July, 1951 and causing the worst flood in their history, sustained moderate to considerable damage. The areas inundated were mostly residential in character, some farms and small mercantiles. Many families were made homeless. In most cases, the local water supplies were either partially or totally put out of service for one or more days. There were no fires reported during the duration of the flood. A number of incidents were reported in which one or more aboveground oil storage tanks had settled or were in leaning condition due to washing away of the foundations. In one locality, seven butane tanks were washed from their respective masonry foundations resulting in damage to piping. Fortunately, no fires occurred in these areas during this critical period.



Courtesy, Kansas Inspection Bureau.

Map of Topeka, Kansas, showing inundated area July, 1951.

DES MOINES RIVER VALLEY FLOODS — IOWA AND NEBRASKA — JUNE, 1947 AND APRIL, 1951

During most of the month of June, 1947, rainfall covering about two thirds of the State of Iowa ranged from 4 to 10 inches in excess of the normal rainfall of 4 inches for the entire month.

Due to the heavy rains in the valley of the Des Moines River and its tributary, the Raccoon River, the City of Ottumwa, on June 6, experienced one of its most disastrous floods. The flood reached a stage approximately three feet higher than the highest previous flood which occurred in 1903. The business district was under 2 feet of water and 4000 people were evacuated.

Electric power and public water supply services were completely disrupted for two days. Only a meagre reserve of water for domestic consumption was available. The city officials put into operation prearranged plans which have been prepared for such an emergency. The river rose so rapidly that all services of power failed; the pumping station as well as the entire city was without power or light. The power failure was caused by a break in the foundation wall of the public utility generating station, resulting in a flooded basement. The source of outside power was also lost when the flood caused a pole in the principal transmission line into the city to fall into a tree. The pump motors and electric controls were raised above the flood water in the pumping station, which reached a depth of 24.5 inches above the pump room floor. The flood water also covered the reservoir and filters. As the water receded sand bag walls were built around two motor bases, the motors reconnected, and two pumps put into operation when power was restored. Water, with little sediment, was taken from a large concrete reservoir which provided for normal consumption for 48 hours. Restoration of the filter plant was made as rapidly as possible.

A south side fire station was flooded but men and apparatus were moved to dry ground on the south side of the city which was completely isolated. No fire alarms were received during the height of the flood. Telephone service, though never completely disrupted, was maintained with portable generators providing the power for operation.

This City of Ottumwa, experienced two subsequent floods, one on June 15 and another on June 28; a total of three within one month. The city prepared for the last two flood assaults by sand bagging at strategic points and prevented further damages.

The City of Fort Dodge was hit by the flood on June 22; a flood crest of 17.91 feet was reached, which is the highest stage ever recorded. Much of the narrow industrial area located north of Central Avenue between the river and the bluff was under water and inaccessible to the fire department. The water works pumping station located in this area, was not flooded, although water was 4 to 6 feet deep in the surrounding streets. The electrical generating station ceased operations, due to some auxiliary equipment and cables being under water for about 48 hours, leaving the city without electric service. One aboveground gasoline tank tilted sufficiently to rupture piping connections and permitted several thousand gallons of gasoline to escape. Backwaters held this gasoline in the area creating a constant threat of fire for several hours. Fortunately no fires occurred during the critical period of the flood.

During the latter part of June, 1947, the City of Des Moines, receiving an accurate forecast from the local U. S. Weather Bureau meteorologist as to the time and crests of the Des Moines and Raccoon Rivers, immediately prepared, in advance, for the highest crest of the Des Moines River since the record flood of 1903. Inundated areas inaccessible to fire department response consisted mainly of low grade residential districts in river bottom land and a few small industrial plants. All the earth levees through the main sections of the city withstood the flood waters fairly well with one exception. A levee break did occur at one location inundating a residential area of approximately 25 blocks. All utilities remained intact, and fire department service was generally normal throughout the flood period, although the waterworks plant and power plant were isolated by flood water. The waterworks plant withstood a severe flood which occurred earlier on June 13.

During the June, 1947 floods, two dike breaks occurred on the Salt Creek adjacent to Ashland, Nebraska and 35 homes in the low lands were flooded. This was the highest water level in 39 years. A flash flood occurred in the Cambridge, Nebraska, area causing the death of 15 persons and property damage estimated near a million dollars. Flash floods affected many other towns in Nebraska and Iowa. On June 24 one third of the City of Columbus, Nebraska, was under water and the new Republican River bridge was badly damaged by the flood. An estimate of 200 million dollars was made by U. S. Corps of Engineers as the loss suffered due to floods in the spring of 1947.

No fires occurred in the areas during the flood periods.

Mississippi River Area Floods—Eastern Iowa—April, 1951. The rapid thawing of an extremely heavy snow fall, accelerated by general rains in the upper regions of the Mississippi River, produced flood conditions during April, 1951, along Eastern Iowa, reputed to be the worst in 70 years. Cities most affected by the flood include Dubuque, Clinton, Davenport and Muscatine; Burlington, Ft. Madison and Keokuk were affected to a lesser degree.

In Dubuque, an area of approximately 132 blocks was inundated. Many mercantiles and manufacturing plants, in the flooded area, were inaccessible to public fire protection. The waterworks plant and public utilities remained in full operation. At Clinton a crest of 20.6 feet was reached on April 23. About 30 blocks were covered with flood waters. Davenport anticipated a crest, as forecasted by the Weather Bureau, of 19.0 feet. Approximately 30 blocks, mostly residential in character, were affected by the flood. The tanks at bulk gasoline storage plants in the flooded area at Dubuque, and the tanks of several large oil farms located up the river from Davenport, in Bettendorf, were filled with either flammable liquids or water as a precautionary measure against possible floatation.

* * *

A flood wall and levees have been built along the river bank at Omaha, Nebraska, and this immediate area has not suffered any damage in any recent year from high water in the Missouri River. Several dams have been built along the Republic River and this should reduce the frequency of floods which in the past have caused very serious damage in southwest Nebraska.

* * *

FLOODS OF SOUTHEASTERN STATES — AUGUST, 1940

During August, 1940 the Southeastern States experienced two major floods. The first flood resulted from the hurricane of August 10-17. As the hurricane abated, torrential rains ensued producing flash floods. The streams swelled very rapidly and flood stages exceeded all those previously known in western North Carolina, except the floods of July, 1916 on some streams. The area affected was extensive, extending along numerous rivers and streams from the mountains to the coast. North Carolina was most affected by the storm and resulting flood. Considerable loss of life and heavy damage to structures and contents, highways, railroads, public utilities, and crops resulted. At a gaging station at Wilkesboro, North Carolina, the flood reached a stage of 37.6 feet, 3.1 feet higher than that of July, 1916 flood.

In the town of North Wilkesboro, North Carolina, located in the fork of the Yadkin and Reddies rivers, the industrial area and the mercantile district suffered heavy damage from inundation and many persons rendered homeless. The water supply works was rendered inoperative; broken service connections, resulting from the collapse of buildings, depleted the elevated storages, and the principal portion of the town, including the mercantile district and manufacturing areas, was without water supply for fire protection for about 4 days. The fire department equipment was unimpaired, however, the absence of water in the distribution system rendered operations ineffective except for booster and small stream appliances and the drafting of flood waters to supply the pumper. The fire alarms were received by telephone, since this service was not interrupted. However, the fire department siren was inoperative for 18 hours due to the loss of the power supply. Two serious fires, during the flood period and resulting in practically total losses, occurred in industrial plants. One fire involved the Home Chair Company plant and although this plant was practically a total loss, the fire department responded and, with the pumper taking suction from flood water, prevented the spread of fire to adjoining properties. The other fire, of undetermined origin, involved the International Shoe Company's tannery and extract plant. This plant was completely surrounded by water, thus preventing the response of the fire department. The principal buildings were destroyed. The total loss of both fires was estimated to be about $1,000,000. Two other fires, of a minor nature, occurred in dwellings but were extinguished by the fire department with small stream appliances.

Roanoke Rapids, a town of 10,000 population, suffered severely from the flood waters of the Roanoke River. Other floods occurred in 1877 and 1912; however, records indicate that this was the worst flood experienced in the history of the town. Extensive damage was suffered in the industrial area along the river. In this area, there were located the generating plant of the electric company and the raw water pumping station of the town; they were severely damaged and inundated to a depth of 12 to 15 feet. The fire department operations were hampered in flooded areas. A small fire occurred in a paper plant, but was extinguished by firemen who reached the plant in boats.

Many other towns and communities in North Carolina, too numerous to mention, experienced minor to severe flood damages; public fire defenses were temporarily impaired due to flooded pumping stations, washed out gravity supply mains and power failures. Few to no fires occurred. One incidence was reported of floating oil storage tanks. At Williamston, North Carolina, two tanks floated from their foundations, and other tanks at the bulk plant were sufficiently filled to prevent any damage from floating; no fires occurred from this condition.

The second flood resulted from a local storm of August 28-31, 1940, which covered a much smaller area in Western North Carolina and Eastern Tennessee.

The August, 1940 floods on many streams in South Carolina and Georgia were severe but in general did not exceed previous known floods. Considerable damage and loss of life was sustained in the vicinity of Charleston, S. C., and Savannah, Ga. In Virginia, many cities and towns along the James River and the tributaries were affected by the storms and ensuing floods. In many instances, water supplies and public utilities were interrupted, and industrial districts, and parts of business and residential areas covered by flood waters. Greatest damage sustained to crops in low-land areas and in destruction of highways, bridges and railroad properties. No fires were reported occurring at any place during the flood conditions, nor was there any record of oil tanks rupturing or floating from their foundations.

The damage and losses arising from the floods of August, 1940 were estimated by the U. S. Corps of Engineers at over 30 million dollars.

* * *

FLOOD IN FORT WORTH, TEXAS — 1949

This city sustained considerable damage in May, 1949 when a heavy rain, totalling approximately 10 inches, caused the worst flood ever experienced in this area. The city was without water for domestic use for about 3 days, and without water for fire protection in the business district for one day, when a small quantity was made available from the Dual system (not potable). The Holly Pump Station, located on low ground near the channel of the Clear Fork of the Trinity River, is protected from high water by a levee on the west side of the plant. Before construction of an emergency flood gate was completed in one of the low places of the levee, flood waters overflowed the levees and entered the plant. More severe flooding would have occurred had not a flood control levee on the opposite side of the river broken in several places and thus relieved the pressure on the levee protecting the water plant. The station was evacuated. Water continued to flow into the low land surrounding the pump station until the ground upon which the plant is located was approximately 3 feet under water. This condition flooded filters, clear wells, boilers and pumps.

During the period the water system was out of operation, the fire department was restricted to the use of booster tanks, drafting from swollen streams and rivers and refilling booster tanks from tank trucks loaded with water which were spotted around the city. Two fires occurred during the interruption of the water supply. One involved a laundry building and the other a venetian blind factory. The total loss was estimated to be about $45,000. The fire alarm system was only slightly affected by the flood. Steps have been taken by the city whereby the levees will be raised an additional 4 feet, making their tops approximately 3 feet above any water level previously encountered.

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COLUMBIA RIVER BASIN FLOODS—MAY-JUNE, 1948

The May-June, 1948 floods were the greatest in magnitude of discharge since 1894 and most disastrous in the history of the Columbia River Basin. The floods involved areas in the States of Washington, Montana, Idaho and Oregon. Records of peak stage in the vicinity of The Dalles, Oregon, have been kept since 1858. Major floods have occurred in 1862, 1876, 1894 and 1948. The flood of 1849, of which there is no authentic record, was reported to have been 5 feet higher than that of 1862. The greatest of these five floods was that of 1894.

The 1948 flood was caused by a sequence of temperatures conducive to production of a flood from snow-melt. Temperatures during April and part of May were subnormal thus retarding the melting of the snows in the high mountains. About May 16 temperatures rose above normal producing conditions most favorable for a major flood. In Montana warm weather and heavy rains produced peak flows as early as May 23.

Flood damage in Montana was great but would have been even greater had it not been for the fact that the country is rather thinly settled. The greatest flood damage occurred in the Columbia River below The Dalles. However, heavy damages were sustained in many areas of all four States.

Damage to highways and railroads was widespread. In the State of Washington mainly residential and farm properties were affected. In Vancouver, shipyards and airports were flooded, the flood stage reached 30.2 feet. At The Dalles, Oregon, the river broke through a levee, flooding the lower section of the town. Mass evacuation from the residential areas along both sides of the lower Columbia River prevented any loss of life. Dikes failed in Woodland and the town's business district was covered with flood water 2 to 8 feet in depth.

The Willamette River in Portland, Oregon, backed up by the Columbia River, reached a stage of 29.95 feet on June 1. It then receded slowly but only to renew its rise again, and a second crest of 29.975 feet was reached on June 14.

The flood waters inundated Portland's east side business district and the Union Pacific railroad yards. The entire wholesale district was under 6 to 10 feet of water. One radio station was flooded and had to cease broadcasting operations. A break in the dike of Multnomah County drainage district released flood waters which spread over a large area, flooding Portland's airport and the adjacent military airport. Portland's airport was out of service for a period of 3 months. An item of interest stated that the U. S. Corps of Engineers had saved a $43,000,000 aluminum plant at Troutdale, Oregon, by dumping 29,000 cubic feet of gravel across Columbia River Slough near Portland.

The greatest single disaster of the flood occurred at Vanport, Oregon. The city, developed during World War II as a housing project, was located in low ground area between the north city limits of Portland and the Columbia River and within dike protection. The population was estimated to be 20,000. On May 30, a railroad fill, which served as the west dike for the district, failed under a head of not more than 8 feet. A wall of water poured through the break with such rapidity that few of the residents escaped with more than the clothing they were wearing. Within two hours, 10 to 20 feet of water inundated the entire area; the city was completely destroyed. Reports indicated at least 20 persons lost their lives. The disaster occurred on a Sunday when many people were absent or using the 3-day holiday to move out of danger. The homes of over 18,000 persons were destroyed. The total loss including buildings and personal property was estimated to be about $22,000,000.

The Kootenai River in northern part of Idaho flooded a section of the mercantile district of Bonners Ferry. A water supply main to the town was broken; pumpage was immediately provided to the extent of 1000 gallons per minute so that the fire protection system was maintained while drinking water was hauled in for a considerable time. Oil tanks in the lower section of the town were floated but local residents provided a current by a cut in the dike which carried the floating oil slick away and no fires occurred.

Considering the flood conditions as a whole, but excluding the destruction of Vanport, Oregon, few water supply systems were seriously affected.

No serious power shortages resulted except for temporary disruption of service in some areas. Telephone communications were disrupted in many sections when pole lines were blown down by high winds or damaged by the flood. A cable across the Columbia River broke between Portland and Vancouver. No serious fires were reported, and no hazardous situations created from floating or ruptured gas and oil storage tanks.

The following data and loss information on the Columbia River Flood of May-June, 1948 is taken from the Report of the Portland District, Oregon, U. S. Corps of Engineers.

> "**Residential** damage classification applies to properties used primarily as homes, not including residences on farms or in areas devoted entirely to farming. The residential damages listed in this report are those to properties in urban and village areas, including multiple-unit apartments and other purely residential developments.
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> "**Commercial** damage classification includes organizations dealing with distribution and storage of goods, either wholesale or retail. If the same company was engaged both in processing and distribution of goods, as was the case in many small woodworking and retail building supply combinations or combinations of seed and grain and stock feed processing, the major source of income was used to determine whether the enterprise should be classed as commercial or industrial. The major losses consisted of damage to buildings, deterioration of stocks of goods, costs of providing alternate storage outside the flood plain, losses due to inability to supply established markets, and costs of obtaining alternate sources of goods or methods of supplying the trade. Heavy damages were suffered at those cold storage warehouses where refrigerating equipment was installed in basements below flood levels. Large amounts of perishable foods were moved to other storage places. Storage facilities along the waterfront used for grain, oil, lumber, and other commodities also suffered severely. Many companies went to great expense in moving goods, finding alternate sources of supply or modes of delivery, and similar activities.
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> "**Industrial** damage classification included the lumbering and paper making enterprises, aluminum plants and many other diversified manufacturing occupancies.
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> "**Utilities** damage classification includes the telephone, electric and gas services. (The greatest concentration of utility damages was in Vanport City, Oregon, where telephone, electric and gas service as well as the telephone exchange and the electric substation, was completely destroyed.) Many power lines were seriously damaged, substations inundated, and other damage was done.

"**Municipal and Public** properties classification include municipal buildings, schools, churches, and other nonprofit public and semi-public structures, and to municipally owned sewers, water systems, sidewalks, parks, and similar properties; extra costs of policing, fire protection, local sandbagging, and other temporary flood control measures undertaken by municipalities.

"**Transportation** facilities classification includes generally railroad properties, highways, bridges, airports, river traffic and facilities, etc. Damage to transportation facilities are shown in the table.

"**Agricultural** damages include loss of buildings (barns and farm houses) and farm equipment, farm improvements, orchards, loss of crops, fences, etc. Pastures, meadows, grain, orchards, nursery stock and hundreds of gardens belonging to suburbanites were damaged by the flood. In addition to damages from actual flooding, losses resulted from emergency expenditures over extensive areas to effect evacuation in anticipation of possible inundation. Evacuation entailed removal, feeding, and housing of cattle outside the flood plain, abandonment of farm operations, and personal inconvenience and expense.

"**Summary of direct and indirect losses.**—Throughout the appraisals and enumeration of losses, all physical losses were considered as direct damages. All other losses, which in many cases involved both capital and operative expenditures, were considered as indirect. On these bases, indirect losses amounted to about 33 per cent of the total losses. However, all items of indirect losses were the direct result of the flood. A summary of direct and indirect losses is shown below.

Types of Damage	*Direct*	*Losses Indirect*	*Total*
Agricultural	$13,353,000	$ 1,281,000	$14,634,000
Residential	24,913,000	401,000	25,314,000
Commercial	3,685,000	3,082,000	6,767,000
Industrial	6,385,000	15,556,000	21,941,000
Utilities	999,000	744,000	1,743,000
Public properties	3,594,000	678,000	4,272,000
Transportation	5,381,000	4,001,000	9,382,000
Flood control (1)	2,145,000	2,946,000	5,091,000
Public aid and relief (2)	—	1,201,000	1,201,000
Total	$60,455,000	$29,890,000	$90,345,000

(1) Includes damages to flood-control structures and emergency expenditures for flood fighting.

(2) Covers only immediate emergency expense. Other items of public aid, such as expenditures for rehabilitation are included with agricultural, residential, and commercial losses."

For complete details regarding the method of loss compilations by the Corps of Engineers, reference should be made to the Report on Flood of May-June, 1948, Columbia River and Tributaries, prepared by Portland District, Corps of Engineers, July 1, 1949.

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MISCELLANEOUS FLOOD SITUATIONS

Since 1937 flood walls and other flood protection facilities installed along the Ohio River have furnished adequate protection, as of 1951, for many of the larger Ohio communities.

Along the Ohio River, in West Virginia, the Cities of Huntington and Parkersburg are protected by flood walls. No damage or loss of protection facilities has resulted in these cities since the flood of 1938. In Wheeling, which is without flood protection, the flood stage of 36 feet has been exceeded eight times since 1938. Two dwelling house fires occurred, one in 1942 and one in 1947; firemen were hampered, in each case, by high waters. Losses amounted to $8,000 and $5,000, respectively.

In the New England States it would appear that the flood control projects initiated after the 1938 flood have prevented any serious damages to communities along the Connecticut River. On the Hoosic River, which empties into the Hudson River, a serious flood occurred on December 31, 1948; a dry cleaning plant, located on the river bank at North Adams, Massachusetts, was undermined by the flood waters, and it collapsed, into the river; no fire ensued. On the same date, flood waters of the Housatonic River inundated the boiler room of a large paper mill located at Lee, Massachusetts. At Rutland, Vermont on June 3, 1947, due to heavy rainfalls, a dam in East Creek above the reservoir which supplies water to the city was washed out. The flood waters washed out the supply mains from the reservoir leaving the city without any water supply. Until emergency measures were set in operation, no water was available for a period of 24 hours. Flood waters, carried down the creek, inundated many homes and places of business in the low lands, and washed out the gas manufacturing plant and transformers supplying electricity to the city. No fires of consequence occurred during the flood period. The loss, however, to the city and to property owners whose buildings were damaged, was very heavy.

Along the Tennessee River, in Tennessee, it appears that no areas have experienced any serious floods in recent years. The Cumberland River has caused some trouble in Nashville, Tennessee, floods having occurred in 1943, 1945, 1946, 1948 and 1950. They were minor in nature and no serious damage was reported.