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FLOOD CONTROL IN THE MISSISSIPPI VALLEY

MESSAGE

FROM THE

PRESIDENT OF THE UNITED STATES

TRANSMITTING

LETTER FROM THE HON. DWIGHT F. DAVIS, SECRETARY OF WAR, TRANSMITTING WITH FAVORABLE RECOMMENDATION THE REPORT OF MAJ. GEN. EDGAR JADWIN, CHIEF OF ENGINEERS, CONTAINING THE PLAN OF THE ARMY ENGINEERS FOR FLOOD CONTROL OF THE MISSISSIPPI RIVER IN ITS ALLUVIAL VALLEY

DECEMBER 8, 1927.—Referred to the Committee on Flood Control and ordered to be printed with illustrations

To the Congress of the United States:

There is submitted herewith a letter from the Hon. Dwight F. Davis, Secretary of War, transmitting with favorable recommendation the report of Maj. Gen. Edgar Jadwin, Chief of Engineers, containing the plan of the Army Engineers for flood control of the Mississippi River in its alluvial valley.

In my message to the two Houses of Congress at the beginning of the first session of the Seventieth Congress, the flood-control problem of the lower Mississippi and the urgent necessity for its solution were outlined. The general duties and responsibilities of the Federal Government in connection therewith were therein discussed.

The total cost of the recommended project is $296,400,000, distributed over a period of 10 years. This large sum is manifestly justified by the necessities of the situation and the benefits that will result. In determining the distribution of the costs, there must be considered not only the people of the valley itself, who receive the major portion of the benefits, but also the great mass of taxpayers who suffer less directly from Mississippi River floods and upon whom most of the burden of Federal taxation falls. It is axiomatic that States and other local authorities should supply all land and assume

all pecuniary responsibility for damages that may result from the execution of the project. It would be revolutionary for the Federal Government to establish the precedent of buying part of the land upon which to build protective works to increase the value of the remainder. Similarly it would be very unwise for the United States in generously helping a section of the country to render itself liable for consequential damages. The Federal Treasury should bear the portion of the cost of engineering structures for flood control that is justified by the national aspects of the problem and the national benefits. It may even bear 80 per cent of such costs, but substantial local cooperation is essential to avoid waste. The portion this would leave to be borne locally for flood-control structures represents an expenditure of about $3 or 30 cents per year for 10 years for each acre in the alluvial valley to be protected every year from Mississippi River floods. The value per acre including railroads, towns, cities, and other improvements, is estimated at something over $200. It would seem that the States should share with the Federal Government the burden of assisting the levee districts and individual property owners, especially in view of the fact that the States benefit directly by the increased taxes from land made more valuable by reason of its protection.

The plan transmitted herewith is comprehensive and appeals to me as being adequate in its engineering. I concur in general in the conclusions and recommendations reached in the report, and suggest that appropriate legislation be enacted putting them into effect.

CALVIN COOLIDGE.

THE WHITE HOUSE,
December 8, 1927.

WAR DEPARTMENT,
WASHINGTON, D. C., *December 8, 1927.*

The PRESIDENT,
The White House.

DEAR MR. PRESIDENT: I have the honor to forward herewith the report of Maj. Gen. Edgar Jadwin, Chief of Engineers, giving the plan of the Army Engineers for flood control of the Mississippi River in its alluvial valley. The plan appears to be simple but comprehensive and is designed to take care of the maximum flood estimated by experts to be possible. The plan conforms to the natural tendencies of the river when in flood. The river is led rather than driven or forced. Navigation and channel stabilization in this reach of the river are also covered. The cost of structures, dredging and mapping is estimated at $296,400,000.

The flood of 1927 is understood to have caused the death of something less than 200 people, rendered over 700,000 temporarily homeless, and resulted in direct property damages estimated at over $200,000,000. A proper regard for the lives and interests of our fellow citizens in the valley requires that legislation be enacted to prevent the repetition of such a disaster not only from the standpoint of loss of life and damages already caused, but also to reduce the chance of an even greater disaster and unparallelled loss of life in the event of the failure of present structures near more thickly populated centers. It was fortunate that no such disaster occurred in

1927. The new plan provides for a material strengthening of the levees but for little increase in height.

I have studied the report which seems to afford the maximum of protection with the minimum of cost, and therefore concur in the views and recommendations contained therein. I recommend your favorable indorsement of the plan.

Respectfully yours,

DWIGHT F. DAVIS,
Secretary of War.

WAR DEPARTMENT,
OFFICE OF THE CHIEF OF ENGINEERS,
Washington, December 1, 1927.

Subject: Flood control of the Mississippi River in its alluvial valley.
To: The Secretary of War.

1. I have the honor to submit the following project for the flood control of the Mississippi River in its alluvial valley.

2. The plan is a comprehensive one, providing for the maximum flood predicted as possible, and for future expansion to meet changing conditions. It includes a spillway above New Orleans, diversion floodways in the Atchafalaya and Tensas Basins, a river bank floodway from Cairo, Ill., to New Madrid, Mo., together with strengthening and a moderate raising of existing levees. It is designed to prevent any material increase in flood stages. Channel stabilization and navigation improvement are included. Exclusive of rights of way, incidental drainage works, and damages, if any, recommended to be borne by local authorities, the estimated cost of flood-control works is $185,400,000, and of channel stabilization and mapping, $111,000,000; a total of $296,400,000. The distribution of cost must be determined by law. The suggestion is made that a distribution by which the cost of flood-control works in general is borne 80 per cent by the Federal Government and 20 per cent by the valley States, and the entire cost of channel stabilization is borne by the United States, would accord with the fiscal policy of the President and the precedents established by Congress.

The reorganization of the Mississippi River Commission, Federal control over structures within natural floodways, and the comprehensive mapping of the alluvial valley are also recommended. Flood control of tributaries will be reported upon after the completion of surveys already authorized by Congress.

3. The control of Mississippi floods by reservoirs is shown to be too costly to warrant their construction. Their development for local benefits is discussed. Other suggested schemes, including levees of sufficient height to contain the maximum possible flood, are discussed but found inadvisable.

The recommended plan fundamentally differs from the present project in that it limits the amount of flood water carried in the main river to its safe capacity and sends the surplus water through lateral floodways. Its essential features and their functions are;

Floodways from Cairo to New Madrid, from the Arkansas River through the Tensas Basin to the Red River, and from the Red through the Atchafalaya Basin to the Gulf of Mexico. These will

relieve the main channel of the water it can not carry and lower the floods to stages at which the levees can carry them.

A controlled spillway to hold the levels down to safe stages at and near New Orleans.

Local setting back of the levees in the main river at bottle necks to increase its carrying capacity and reduce its flood heights.

Greater protection against crevasses by strengthening the levee by reducing flood heights through the increased widths of channel afforded by floodways, spillways, and setbacks and by moderately raising the levees where needed to meet predicted flood stages.

The progressive revetment of caving banks to protect the foundation of the levees and to stabilize the river both for flood control and navigation.

Improved navigation channels for river traffic, not less than 300 feet wide and 9 feet deep, to be obtained by dredging and training works where necessary between Cairo and New Orleans.

4. The estimated construction cost of the complete plan is $296,400,000, and it can be advantageously executed in approximately 10 years.

5. The project recommended gives the maximum of results for the minimum of cost. It recognizes the interests and protects the rights of those who will be chiefly benefited and of the taxpayers who furnish the funds. Complete flood control, embodying the cheapest practicable reservoir system, would be much more expensive.

6. The plan heretofore pursued has been the construction of levees high enough and strong enough to confine all of the flood waters within the river channels. The levees that have been constructed are not sufficiently high for such floods as are now predicted. The cost of raising and strengthening them sufficiently to carry extreme floods would greatly exceed the cost of the plan proposed. Furthermore, the extent of the disaster which follows a crevasse increases greatly as the flood is forced to higher stages by confinement wholly within the levee system. The loss of life and property in the recent great flood in the alluvial valley followed the breaking of the levees which reclaimed the land for the use of man. This reclamation had been pushed so far that insufficient room was left in the river for the passage of the unprecedented volume of flood water. The levees must be strengthened but a halt must be called on further material increase in their heights and the consequent threat to the inhabitants of the areas they are built to protect.

7. Man must not try to restrict the Mississippi River too much in extreme floods. The river will break any plan which does this. It must have the room it needs, and to accord with its nature must have the extra room laterally. In its original state the river had only one low water channel until it reached the flat land near the Gulf, but in flood it overflowed an area 50 miles wide, which is really its natural flood bed. The water which can not be carried in the main channel with the levee at reasonable height must be diverted and carried laterally. Some additional capacity can be obtained in the main river by local setbacks of the levees. As a general setback is not practicable the remainder must be supplied by floodways paralleling the general course of the river.

8. The plan recommended provides the requisite space for the passage of floods, and levees of adequate strength to withstand them,

so that should a flood recur of the magnitude of the flood just experienced, the maximum of record, it would be passed out to the Gulf without danger to life in the alluvial valley, and without damage to property except in the floodways allotted for its passage. Controlling side levees limit the area of the floodways, and protect land not in the floodways where such protection justifies its cost.

9. Should Divine Providence ever send a flood of the maximum predicted by meteorological and flood experts as a remote probability but not beyond the bounds of ultimate possibility, the floodways provided in the plan are still normally adequate for its passage without having its predicted heights exceed those of the strengthened levees. It is designed to be both simple and comprehensive, flexible and adequate to prevent a calamity such as that of 1927 from happening again as the result of any flood past or predicted. It is capable of modification or expansion, if desirable, to further accommodate an increasing population and its property.

10. *Flood control of tributaries.*—Plans for the flood control of the tributaries will be developed as funds become available in accordance with an act passed at the last session of Congress. It is impracticable to present such plans at this time, because of lack of data and time. Congress recognized the need for further data when at its last session it enacted a law in the river and harbor act, approved January 21, 1927, authorizing and directing surveys by the Corps of Engineers of a large number of rivers, including the tributaries of the Mississippi, to determine the best use of their water resources.

Flood control, power, irrigation, drainage, navigation, and water-supply must all be considered. This act was designed to promote the harmonious and coordinate development of all our water resources. Work on these surveys will require several years and will be expedited as funds are made available in future appropriation bills. Much work which has been done in arriving at the present alluvial valley project, particularly that done in the study of reservoirs, will be of value when the tributary studies are undertaken. Many reservoirs on the tributaries which would be of little help to the Mississippi will be of great value in the control of floods on the tributaries as well as for other uses.

11. For the above reasons, only the lower courses of such tributaries as are directly connected with the flood control of the Mississippi in the alluvial valley are included in the plan herein. The other parts of the tributaries will be reported on as soon as practicable as contemplated by the act of Congress referred to above.

DESCRIPTION OF PLAN FOR FLOOD CONTROL OF ALLUVIAL VALLEY

12. The details of the plan by which the surplus water will be carried with safety vary in different parts of the river. The alluvial valley of the river may be considered in three principal sections—the northern, comprising the St. Francis Basin on the west side of the river; the middle, including the Yazoo Basin on the east, and the Tensas Basin on the west, running on the east from near Memphis to Vicksburg, and on the west from the Arkansas River to the Red

River; and the southern, or Louisiana section, from the Red River to the Gulf of Mexico.

13. The main features of the plan recommended are illustrated on one of the accompanying maps. The portion of the alluvial valley from Cape Girardeau, the northern limit of the alluvial valley, to Cairo, can be protected by a slight increase in the size of the levees. The serious problem begins at Cairo at the confluence of the Ohio and the Mississippi. From here to New Madrid the main levee on the west bank chokes the river unduly and should be set back sufficiently to lower the head of water at Cairo by 6 feet in an extreme flood. The existing river-bank levee will be retained but lowered 5 feet. The floodway between the new and the old levees will be capable of cultivation at all times excepting in floods greater than that of 1922.

14. An estimate is included for removing part of the dike on the Tiptonville Ridge to reduce the backwater area at the mouth of St. Johns Bayou to the minimum practicable.

15. From New Madrid south to the mouth of the Arkansas, the levees will be raised moderately. Local setbacks will be made below Helena and at other bottle necks where necessary to restore greater cross sections in the main river. These modified works are designed to carry the highest predicted flood except that it may be found expedient not to raise the levees opposite the backwater areas of the St. Francis and White Rivers. In this event, if a possible superflood should come, it may cause a crevasse in the levees at these points, increasing somewhat the height and acreage of backwater area, but doing comparatively little harm.

16. From the mouth of the Arkansas to the Old River, at the mouth of the Red, extreme floods can not be carried between levees of the Mississippi without dangerous increase in their heights. A flood way for excess floods is provided down the Boeuf River, on the west side of the river. Excess water can not be carried through the section on the east side, since it would be forced back into the main river by the highlands on the east bank below Vicksburg and have to be carried thence for 160 miles between the main river levees to the mouth of the Red River. The entrance to the flood way is closed by a safety plug section of the levee, at present grade, which is located at Cypress Creek, near the mouth of the Arkansas. To insure their safety until this section opens, the levees of the Mississippi, from the Arkansas to the Red, will be raised about 3 feet. To prevent flood waters from entering the Tensas Basin, except into the flood way during high floods, the levees on the south side of the Arkansas will be strengthened and raised about 3 feet as far upstream as necessary.

17. The section at the head of the flood way will protect the land within the flood-way levees against any flood up to one of the magnitude of the 1922 flood. A flood of a magnitude somewhere between that of 1922 and of 1927 will break it, turning the excess water down the flood way, which will carry it safely to the backwater area at the mouth of the Red River.

18. Below the Red River, setbacks of the levees will be made at critical places in the main river, to insure the better discharge of flood waters, but the carrying capacity of the main river can not be increased materially without unwarranted hazard to life and property in the State of Louisiana. At the city of New Orleans, an

increase in levee height is considered unsafe, aside from the great cost of raising the levees and the wharves built upon them. To afford proper protection to New Orleans, with its population of nearly half a million and property value of over a billion dollars, a special floodway upstream from the city is essential. The most practicable location is on the east side of the river, discharging into Lake Pontchartrain. A controlled spillway at Bonnet Carre will limit the discharge through this floodway to that necessary for the protection of the city.

19. At high floods it is also necessary to divert down the Atchafalaya Basin the flood waters in excess of the discharge capacity between the levees of the Mississippi. This is accomplished by strengthening and raising the levees on the main river three feet for the necessary distance to assure their safety until levees at the head of the Atchafalaya Basin open. The levees on the south bank of the Red River will be strengthened and raised sufficiently to keep flood waters from entering the Atchafalaya Basin except in the floodway, through the relief or fuse plug levees at the head of the floodway. Back levees are to be constructed on both sides of the Atchafalaya Basin for the major part of its length, to enclose the Atchafalaya floodway. Funds are included in the estimate for the extension of these levees to the south, to limit the overflow in the lower part of the basin.

20. Existing levees on the Atchafalaya River will be strengthened and their grade adjusted so that the productive capacity of such parts of the floodway as are not already swamp land will be retained during any flood of record of a less magnitude than that of 1927.

21. The plan includes an extension of revetment of the banks of the river, to reduce the danger of attacks on the foundations of levees and their destruction by caving banks, thereby to further reduce the possibility of crevasses; and to stabilize the position of the river in order that contraction or regulation works may be provided, to assist in securing and holding the low-water channels needed for carrying the commerce of the valley in low water as well as in high.

22. The three maps herewith show respectively the total area of the alluvial valley subject to overflow and the area overflowed in 1927; the rainfall in March and April, 1927; and the new plan. The map of the new plan shows the main river, the floodways and the backwater areas, which serve as storage basins at the mouths of the tributaries, with figures indicating the percentage of years in which floodways will be carrying water and the percentage of swampy, timbered, and cultivated land in floodways and backwater basins.

23. The area in the alluvial valley that would be flooded by Mississippi River water if there were not protecting works is approximately 30,000 square miles. Under the plan recommended, barring accident, approximately 20,550 square miles will be protected annually. The remaining 9,450 square miles, of which approximately 3,340 square miles is cleared land, will be protected on an average of from 2 years in 3 to 14 years in 15, depending upon its location. The remaining 6,110 square miles are swamp and timber land which is not injured by flood.

24. The estimated cost of $296,400,000 for the construction of flood-control and navigation work does not include the costs of

rights of way nor possible damage to structures which have invaded the natural flood bed of the river. It is expected that these, if any of them are legal and proper, will be borne by the States or other local interests who will in general be greatly benefited by the execution of the plan.

25. *Economic necessity and local cooperation.*—As directed by the law relating to reports by the department, I submit a statement as to the general and local benefits of the plan and the local cooperation that should be required on account of local benefits. The question must be viewed from the standpoint not only of those in the valley needing flood protection, but also of the taxpayers in other parts of the country, including the regions from which the flood waters come, who suffer indirectly from flood disasters, and on whom the bulk of the burden of Federal expenditure must fall.

26. Several estimates of different well protected parts of the delta valley result in an average price per acre of $224 when towns and all property, such as houses, roads, railroads, land, etc., are included. The total area of the valley originally subject to overflow is 29,790 square miles, or 19,065,600 acres, 12,000,000 acres of which is usable. This 12,000,000 acres at $224 per acre is worth about $2,688,000,000. Adding the probable value of New Orleans would bring this sum up to about $3,500,000,000. Movable property added would make it something like $5,000,000,000.

27. The values and population behind the levees are increasing all the time. It has been estimated that damages from the 1927 flood were over $200,000,000.

28. The plan for river control contemplates spending about $300,000,000, or about one-sixteenth of the value estimated above. On the basis of 12,000,000 acres of usable land, this is an average expenditure of about $25 per acre, but it must be remembered that this includes protection to cities, towns, etc.

29. The cost of the project is unquestionably justified. It will prevent a reptition of the widespread disaster, human suffering, dislocation of the economic life of the valley, interruption of interstate commerce, and the effect on the general welfare of the Nation, that attended the recent flood. The expenditure would be justified even though such a flood occurs but once in 150 years. It will prevent the less extensive flood disasters that are likely to occur at much more frequent intervals. The protection afforded to the cities back of the levees in the valley against a flood even greatly exceeding that just past is especially justifiable from a humanitarian standpoint, since an unexpected break in the levees at these places would probably result in serious loss of life and might be an unparallelled catastrophe.

30. The estimated cost of $296,400,000 for the construction of flood control and navigation works does not include the costs of rights of way for flood control works, the cost of any drainage works required therewith nor the cost of any flowage rights that may be required, nor damages, if any, resulting from the execution of the plan. No questions of rights of way or damage arise in connection with the navigation works. Local interests should in the future as in the past provide all rights of way for flood control structures. They best can obtain the land at a fair value, and vexing questions

as to Federal ownership, administration or police of the narrow strips of land will be eliminated. Their land is enhanced in value by the works. Tax collections show that the land in the upper Yazoo Basin has ten times the value that it had before it was leveed. The United States ought not to buy a part of the land to enhance the value of the rest.

31. Such drainage works as will be required in connection with new interior levee construction are of direct benefit to the lands affected and their cost should be borne locally.

32. It is a fundamental principle that no damages lie against either Federal or State Government, or local agencies, on account of an accidental crevasse in the levees. The plan has been drawn to reduce to a minimum the damage to lands and structures resulting from the flow at high floods through the floodways. All property affected lies in the natural high-water bed of the river. Much of this land was transferred to the States by the Swamp Act approved September 28, 1850. The purpose of this act was to enable the States to construct the necessary levees and drains to reclaim the swamp and overflowed lands therein. The principle involved was not new, as the early French grants in the lower valley contained a proviso requiring the grantee to construct and maintain a levee line along the river front of his property.

In the State of Louisiana, this old servitude has been transferred by the State to the levee district in which the land is located. Whether or not the servitude or flooding was transferred to private owners when the land was sold, the servitude existed when the land was granted to the States without cost. It should not now be paid for by the Federal Government. Moreover, the lands, with some exceptions, will have the same protection as is afforded by the present levee system, a protection provided partly at the expense of the Federal Government. The exceptions are the lands in the Bonnet Carre' flood way and in the setback flood way from Birds Point to New Madrid. The acquisition of flowage rights by the State or local interests may be necessary in these cases. In any case, the lands should remain in private ownership in order that their productive capacity may be fully availed of. The United States does not in general own the bed of navigable streams; much less need it own land flooded only at long intervals. Damages, if any, which may be found legal and proper as a consequence of the plan should be met by the States, since these will be directly benefited by the works.

33. The project should be authorized subject to the condition that except when specially authorized by the Secretary of War, upon the recommendation of the Chief of Engineers, no Federal funds shall be expended upon the part of the project within any State until that State has accepted by appropriate legislation these conditions and responsibilities. The saving exception is suggested to cover the case where the procedure requisite to the enactment of the legislation would unduly delay the initiation of work of far-reaching benefit, particularly if such work is essential to the protection of another State which has fulfilled these conditions.

34. The present flood control act provides that local interests shall pay one-third the cost of levee construction. The following

table shows the proportions of the cost of levees actually borne in the past by the Federal Government and local authorities:

Amounts expended by the United States Government in the construction of levees and the amounts expended by States, levee districts, and communities interested, from 1882 to December 31, 1926, covering cost of yardage placed, rights of way, interest, engineering expenses, repair work, high-water expenses, crevasse closing, etc.

Mississippi River Commission districts	Expended by United States from Government funds	Expended by United States from contributed funds	Expended by State and local organizations	Total
Northern	$3,127,533.49	$1,083,857.69	$9,916,110.91	$14,127,502.09
First and second	19,700,161.78	4,348,420.82	42,766,497.05	66,911,079.65
Third	27,614,208.84	5,852,103.37	34,782,460.96	68,248,773.17
Fourth	20,552,089.47	3,773,898.32	64,488,106.33	88,814,094.12
Total	71,089,993.58	15,058,280.20	151,953,175.25	238,101,449.03
Per cent	30	7	63	

35. In addition to meeting the costs shown in the table, the inhabitants of the valley have been subject to recurring flood damage. The direct damages suffered from the 1927 flood are estimated by the Mississippi Flood Control Association to have been $236,334,414.06.

36. The table clearly shows that the people of the valley have borne much the greater part of the cost of flood protection, although the United States has given substantial aid. The local participation has furthered the keen interest of each locality in the proper execution of the work. It has afforded a check on pressure for the execution of works not economically justified.

37. The division of cost has led to some division of control. The enlargement of levees affecting large areas has been delayed, in some cases, by the failure of a levee district to furnish its share of the cost. It is doubtful whether these disadvantages have counterbalanced the advantage of a local proprietary interest in the works.

38. The comprehensive plan now presented does not include the protection of areas whose reclamation is not economically justified, but contemplates that such areas be left open for temporary storage and the discharge of floods. If no local contribution is required, the law and the administration of this project must be relied on to prevent the construction of works not economically justified. If a contribution, small in comparison with the cost of work already done and to be done, will assist materially in retaining the proprietary interest and watchfulness of local authorities, it would seem to be justified.

39. In view of the national aspect of the flood-control problem from the standpoint both of the cause and of the effects of the floods, and in view of the large sums spent in the past by the people of the valley for flood protection, the sacrifices they have made in meeting their allotments, the great losses suffered in the past flood, and the larger expenditures now required, it is believed that the United States should bear a larger proportion of the cost of construction than in the past, and that of the States or local interests be as small as consistent with the results desired. While the proportion must be determined in the wisdom of the President and Congress, a

division by which the United States bear 80 per cent and local interests 20 per cent of the cost of levee construction and control works in general; and by which the United States bear 50 per cent and local interests 50 per cent of the cost of the special ring levees proposed at Morgan City, Melville, Simmesport, and Arkansas City, would be in general accord with the existing policy of the President and the precedents established by Congress.

40. The expenditure for flood-control structures proper required in the comprehensive plan herein recommended, exclusive of navigation works, revetments, etc., is $185,400,000.

41. On the basis suggested, the total construction costs would be divided as follows:

By the United States:	
80 per cent of general levee and control works	$147,360,000
50 per cent of special protection works	600,000
100 per cent of works for channel stabilization and mapping navigation	111,000,000
Total	258,960,000
By local interests:	
20 per cent of general levee and control works	36,840,000
50 per cent of special protection works	600,000
Total	37,440,000

The local interests are also expected, under the project, to furnish rights of way, and protect the United States against charges for flowage easements and damages.

42. While $37,440,000 is small in comparison with the amount to be spent by the United States and with the amounts already spent by the people of the valley, it must be remembered that these people still owe considerable sums on their bonds on which the money spent was raised. Some of the levee districts are also near the limit of their bonding power under present State law and also near the limit of their credit. However, it is not equally clear that this expenditure, spread over a 10-year period among four or more States, would constitute an unreasonable burden on the States themselves, in view of the increased taxable values which will result from the improvement.

HISTORY AND CHARACTERISTICS OF THE MISSISSIPPI

43. The Mississippi River is the world's greatest river, combines size with usefulness, and is one of the grandest and most valuable assets of the United States.

44. The potential power in the Mississippi River from Cairo to the Gulf during flood is about 60,000,000 horsepower. This great amount of power, impracticable to harness, is consumed in eroding banks, transporting silt, and in driving its great volume of water down its course.

45. Through its aid to drainage, navigation, water supply, power, manufacturing, agriculture, and other incidental uses, it renders vital service to over 40 per cent of the area of the country. Its waters come from 31 States, and, were it not for the levees, would in flood cover 30,000 square miles, a territory greater than many of our States. Its flow varies from the minimum low-water measurements of 71,000 cubic feet per second below the Ohio and 103,000

cubic feet per second below the Arkansas, to a maximum measured discharge in the main river channel of 2,000,000 cubic feet per second.

46. Its alluvial valley has a growing population and contains the largest area of the richest land in the United States. New Orleans ranks second among the great ports of the country when compared on the basis of the value of their foreign commerce. It has an annual tonnage, including domestic, valued at upward of $900,000,000.

47. Its worst characteristic is that its floods inflict at times great damage upon the people and property in the alluvial valley of the lower river. They take their toll in life and in damage to property, affecting the inhabitants of the valley and investors, manufacturers, and consumers throughout the country. They interfere with the food supply and the general welfare of the country, with its postal service and transcontinental and other interstate commerce.

48. Let us pause long enough to obtain a first-hand realization and picture of the necessity for flood control as it appears to those living in the alluvial valley or Delta, as it is more frequently called locally. Paraphrasing the writings of that gifted son of the Delta, Harris Dickson, of Vicksburg, Miss., we have:

49. Newspapers report heavy rains in Olean, N. Y. How does that concern the Delta farmer? New York is so far away that it should have nothing to do with his weather, but from bitter experience he knows that he may have to wade neck deep in waters coming partly from Olean. Western Pennsylvania freshets frequently help to drown his mules. Uninvited cloudbursts from Wyoming have visited his farm and swept away his improvements, while waters from Canada chase his tenants to the hills. The Delta farmer must watch the weather in 31 States, unless he wants their drainage to catch him napping.

50. Quoting verbatin from the writings of this author:

During the past 213 years—since the Frenchman, De La Tour, in 1714—valley farmers have fought the Mississippi River.

An age-old feud, farmer against water, unending through the centuries—China, India, Mesopotamia, Egypt. The Dutch diked out an ocean. England reclaimed her fens in Lincolnshire.

Man has always warred with rivers for possession of their richer soil. Stony hillsides yield a grudging food. Fertile valleys give him their abundance.

On the lower Mississippi at first a few French planters threw up private ridges of dirt to keep the water off their indigo. Two planters would join their tiny banquettes. A neighborhood entered the partnership. Then the parish. States took up the levee question. After the terrific disaster of 1882, when we saw 284 crevasses with 50 miles of levee washed away, the National Government stepped in to assume practically half our burden. Local taxation bore the other half. With competent engineers, accurate data, and unity of purpose we began to have a genuine levee system, a consolidated system.

Behind these safer embankments which arose hundreds of towns and thriving little cities have grown up, railroads, improved highways, and other necessities of modern life made possible by protection from overflow. Beautiful schoolhouses now stand where the canebrake sheltered bear and deer, alligators and moccasins. "Varmints" are gone, the children are there instead.

Year by year, as far as meager appropriations permitted, old levees were strengthened and new ones built to "commission grade and standard." These were supposed to hold against any flood hitherto known along the river. And probably would, although few men be rash enough to make dogmatic statements concerning the lawless and treacherous Mississippi.

But this has been a year of phenomenal and simultaneous rainfall. Everything came upon us at once, and broke through our lines of defense. The marvel is, with such a water, that no more gave way.

Only one crevasse occurred in the State of Mississippi. Yet, because of increased population and property, that lone break has wrought incalculable havoc, far greater than all of them in 1882.

On April 21 the Mississippi River broke loose, tremendous, awful, more devasting than was ever recorded by man. Our people are stunned, bewildered. They know not what to do. But this they do know that if our National Government gives them a fair assurance that the present calamity will not occur again, they will set their undismayed hands to the giant task of rebuilding.

51. The flood this year took a toll of something less than 200 lives, rendered 700,000 people homeless for approximately a month, and inflicted an actual property damage estimated to be upward of $200,000,000.

52. Nearly all of the loss of life occurred in the early rush of the flood, before the rescue work could be organized by the Red Cross, and before the rescue fleet, principally of Government vessels from many branches of the service was assembled under the coordination of the Army engineers. It has been stated by an expert that the flood of 1927 below Vicksburg surpassed any previous one that had occurred in something like 200 years, and a second 200 years or even more might elapse before the appearance of a flood that will be as great or greater.

53. The people of the valley started the building of protective dikes or levees, which have been extended and enlarged to their present size. Their aggregate expenditure before receiving any assistance from the Federal Government was over $125,000,000. In 1879 the Federal Government organized the Mississippi River Commission composed of 7 men, 6 of them engineers, 1 from the Coast and man—3 of them from the Army Engineers, 1 from the Coast and Geodetic Survey, and 3 from private life. From that date until this, the Federal Government has participated in the cost. Since the commission was organized, it has supervised the expenditure of some $90,000,000 on levees. Of this some $15,000,000 were contributed by the Delta people. The cost of levee construction is by law now borne two-thirds by the Federal Government and one-third by the local people, who also furnish the rights of way. Bank revetments are paid for, with minor exceptions, by the Federal Government.

54. The levees have reached a strength that affords complete protection against the larger floods which may be said to come about once in five years and have reduced the areas inundated in really great floods.

55. The earth levee is the cheapest and most practical structure for keeping water off the land. Structures of concrete or any other known types of construction that would be effective would be far more costly. The levees are now close to their practical limit as to height. This is shown in every flood by the sand boils which develop behind the levees, and by the settlement of levees on bad foundations.

56. The integrity of the levee line is dependent upon the levees being high enough to preclude overtopping by any possible flood. Water higher than provided for will overflow a sandy earth levee and produce a crevasse with dire consequences. A sudden break or crevasse in the levee line emits a torrent at high velocity. A deep hole is quickly scoured out and a mass of sand is deposited on the adjacent land. The deep gap lets water out of the river until the river stage falls below the natural bank. This inundates an area many miles from the river for a long period of time, and replanting

of crops has to wait for the water to recede. It is not possible to close the crevasse until the next low-water season, and later secondary rises of the river, which without the crevasse would do no harm, overflow the land back of the levee again and perhaps ruin a second planting.

57. The Mississippi has flowed for ages, and will flow for ages to come. In the distant past, the Gulf of Mexico was in the vicinity of Cairo, Ill. While the river in its natural, untrammeled condition covered in flood 50 miles in width, and while its normal channel shifted in ages gone by from one location in the valley to another, it has had at any given time, except near the Delta mouth, but one low-water channel—one normal channel with the privilege of overflow when necessary to relieve floods. The river, bringing down with floods enormous quantities of earth, gradually built up the Delta valley over 600 miles long, 50 miles wide, and of unknown depth. This Delta is the natural flood bed of the river. Each overflow deposited silt on the banks and over the valley. The extension of the mouth of the river into the Gulf of Mexico, which in recent years has lengthened the river at the approximate rate of 1 mile per 21 years, lessened the slope of the river, and slowly raised the plane. This gradual raising of the flood plane will continue. Although the results of these processes are not appreciable in short periods of time, the inevitable tendencies of nature must be kept in mind, and the successful plan must be in line with them.

58. The river, in low water and in all stages up to bankful, should be carried in the main channel until we reach the flat land bordering the Gulf of Mexico. All the flood water can not be carried in this one channel. The flood stages are too great for existing levees, or for practical levee heights, both by reason of materials and foundations available for these earth dikes. Flood ways and backwater areas must be no larger than needed in order that the damages in them from the infrequent periodic overflows may be limited as much as practicable, and that the fertile land of the valley may have the maximum production. The maximum use of land will be obtained by holding protected from annual overflow much of the lands now thus protected and surrendering the use of some of this space only for infrequent, extreme high water. It would not be wise nor economic to set apart permanently and make subject to annual overflow large areas which are needed for flood waters only once in 12 or 15 years. These lands can be used during the greater part of the time. Subjecting them to annual overflow would tend to silt them up and shorten their life as flood ways by from 12 to 15 times what it would be by using them only for extreme floods.

Floods tear the earth from the banks and bed of the river and move it along until a check in velocity causes deposit; 300,000,000 cubic yards of earth are thus carried annually to the Gulf. Much of this was formerly deposited in the alluvial valley, refertilizing the latter and slowly raising it. The works along the river and at its mouth tend to concentrate the flow of silt, so that the deposits largely occur between the levees, in the backwater areas, and in the Gulf of Mexico near the mouth of the river. It would be beneficial to the land if more of this silt could continue to annually build up the swamp, but this would preclude the uninterrupted use by man of most of this fertile valley. The plan must, therefore, to be prac-

tical, keep the maximum area of land dry, consistent with allowing the flood the area really needed for its control. It must be a living plan, elastic and capable of adjustment to a slowly rising flood plane, and ready to adapt its defense to the changing points of attack of the river.

59. The aggregate reservoir capacity between low and high water of the main river, the flood ways and backwater areas, are greater than the useful reservoir capacity of Lake Erie and Ontario combined. These constitute a vast self-evacuating storage reservoir, whose capacity is the more valuable because it is located where it intercepts the water whether it comes from the tributaries or falls in the valley of the main river, and whether the flood is short or long. They are always on the job. The backwater areas absorb a material part of the flood at its peak. They are the part of the natural bed of the river in flood which remains after the reclamation of the other lands of the valley. A large percentage of these areas are swamp or timbered land, where growth continues uninterruptedly, wet or dry. Crops may be raised on the other parts during many of the years. Any other use made of these areas must be subject to the higher use for the general control of the river. No curtailment of their area should be permitted which will run contrary to the protection of life in the large cities, and to the uninterrupted cultivation of the great areas that will be permanently protected by the plan.

60. While the great floods of the Mississippi have overflowed thousands of acres of land, destroyed crops by long inundation, and driven the inhabitants temporarily from their homes, there has never as yet been such a catastrophe as would result from the breaking of a levee on the front of the densely settled areas in the cities and the larger towns of the lowlands. This fortunate result is due to the care that is given to the construction and upkeep of levees on city frontages, possible by reason of their greater resources in money and labor. Failures in the long lines of levee that have not these resources have always relieved the situation at important centers of population.

61. The catastrophe resulting from a crevasse on a city front would be so appalling that no measures should be spared to prevent it. A sure remedy would be the filling of the land to bring it above the limit of a dangerous depth if overflowed, as was done successfully in the city of Galveston to free it from dangerous inundation by storm tides. The State of Texas assisted Galveston in this work, as it has since assisted in other projects, by remitting taxes for a term of years. The cost of such a measure would probably overtax the resources of most of the low-lying communities. What would normally be considered adequate measure of safety can be provided by levees of such width, in critical places, that bank caving can not possibly cause a breach in the levees. In view of the great benefit that would result from placing the important residence areas above flood danger, it is within the range of possibilities that the United States could afford to cooperate in such a plan, by bearing a proportion of the cost of furnishing the necessary material, when this can be provided by pumping from the river bottom.

SUGGESTED ALTERNATIVES

62. It is not necessary to discuss some of the visionary schemes that have been suggested for the control of the Mississippi River. Even the richest country in the world can not afford to dig channels ten times as large as the Panama Canal half way across the continent through mountain ranges, nor pump through pipe lines over 100,000,000 tons of water per hour from Cairo, Ill., to the Gulf of Mexico.

63. Other methods advanced have been examined but discarded either because the cost is out of proportion to the benefits, too much good land would be sacrificed, or because of the length of time necessary for their accomplishment or uncertainty as to their results and effects. Included in this group are dredging the bed of the river, dredging side channels, wholesale moving back of the levees, straightening the channel, clearing the batture or flood ways, and reforestation.

64. *Dredging the river annually.*—To reduce levee heights by dredging would require not only initial excavation but annual dredging to remove the enormous deposits of silt dropped by the river each year. The annual cost for the first foot of reduction of flood stage has been estimated at $10,000,000, and the rate would increase as the dredging is carried deeper. To certainly hold the river between the present levees its stages must be reduced, in general, by 8 feet or more. To reduce the maximum stage by 8 feet would require the expenditure of more than $80,000,000 annually. This sum capitalized at 4 per cent is $2,000,000,000. It can not be hoped that even this amount would control all floods, and there is grave doubt whether the dredging could be done at a rate which would keep ahead of deposits.

65. *Side channels.*—Excavated side channels would be enormously costly and they would silt up rapidly. Vegetation would clog them rapidly and annual clearing would be very expensive. An estimate for by-passing 300,000 second-feet from Cape Girardeau to the White River by a partially dredged channel is $337,000,000. To care for the same amount of water in this reach of the main river with levees would cost about $27,000,000. Dredging side channels is not economical nor practicable.

66. Leveed side channels are much cheaper than excavated channels. If made wide enough to carry the water without clearing, which is expensive both in first cost and maintenance, they are economically practical. The land designated for the use of the river in extreme flood need be no more subject to overflow than it now is, so that the present owners do not have their protection reduced. This land, which can be cultivated with the same assurance as at present, is retained in production and not relegated entirely to the river. Leveed side channels are used in the plan recommended.

67. *Setting back levees.*—To move the levee line back on one side of the river for 1 mile would, on the average, increase the discharge capacity about 75,000 second-feet and be equivalent to something over one foot reduction in stage. The cost for the whole river would be $610,000,000. To move it back 2 miles would increase discharge 160,000 second-feet, reduce stages about 2.5 feet, and cost $720,000,000. A setback of 6 miles would increase discharge about 525,000 second-feet, decrease stages 8 feet, and cost $1,000,000,000. At least 8 feet decrease in stage is necessary in most sections to keep within the

present levee grades the floods predicted as possible. In some sections a greater decrease is necessary.

Control of floods by this method is too expensive to be practicable. A general moving back of the levee line would destroy many towns and require all settlements to locate too far from the low-water channel to be served by navigation. The moving back of the levees by 6 miles would, except in the northern part of the valley, relegate to the river the most valuable part of the valley—the high bank of the river. The new levee lines would be on lower ground and their heights would be increased rather than decreased. The cost of the levees required to contain the floods would be increased, they would be higher, and would produce a greater disaster should a failure accidentally occur.

68. Although a general setting back of levees is neither practical nor economical as a general remedy, appreciable benefits can be obtained by local setbacks at various places, and these will be made when and where practical.

69. *Straightening channel.*—Artificial or natural cut-offs shorten the reach where they occur and by increasing the slope and velocity produce a local lowering of the flood stage. However, the increased velocities immediately cause excessive bank caving either in the reach or near it, and the river eventually lengthens itself with new bends. The changes in the channel cause great damage and expense. The bank revetment now in use, expensive as it is, has not been subjected to and withstood such velocities as would be caused by cut-offs. Low-water navigation in any stretch is likely to be temporarily destroyed by bars created by the excessive bank caving caused by a cut-off. The method is too uncertain and threatening to warrant adoption.

70. In an unsettled region and on an unleveed alluvial stream a program of cut-offs and bank protection, begun at the lower end of the river and progressing upstream, might be desirable in anticipation of settlement of the region. But such a condition is not hypothetical. In the present case, the river banks are not yet revetted to the extent necessary for shortening of the stream, nor will they be for years; levees are already in place, though not to final height, conforming to the river in its present shape; valuable cultivated land would be lost, and landings and towns along the river would be cut off from navigation. Completion of the levees needed for protection can not be postponed until a cut-off and revetment project could be carried out.

71. It is advisable to adhere to the present policy of preserving the river generally in its present form and not to undertake a plan of flood control or of improvement for navigation that involves the formation of cut-offs.

72. *Clearing between levees.*—Clearing the banks and islands inside the present levee system would cost about $34,000,000, and the maintenance of this clearing would cost about $1,500,000 annually. The increased velocity would probably effect a reduction in stage of about 1 foot at certain places if spur levees now existing were removed to permit the water to flow directly across bends. However, increase in overbank velocities, even if they can be obtained, are viewed with apprehension. It is undesirable to have rapid velocities

near the levee line, because scour under or against the levees might result. Scour that might cause cut-offs should be prevented unless cut-offs are desired, and, as explained above, they certainly are not desired for the Mississippi at this time. Clearing of the banks is not a desirable procedure.

73. *Forestry.*—The relation of forestry to the prevention of floods was discussed by Col. W. B. Greeley, Chief Forester of the United States Forest Service, in an address delivered in Chicago June 3, 1927. The subject has since been studied in a report prepared by the Forest Service under the direction of the Chief Forester, and access has been had to the report. It finds that a total area of about 150,000 square miles of forest land in the Mississippi Valley is of such character that the protection of existing forests and the restoration of depleted forests would assist in preventing flashy run-off and would decrease erosion. Of this total area, about 75,000 square miles are reported to be in a condition detrimental to regularity of stream flow and stability of soil. It is stated that under adequate protection the mat of humus under the 250,000 square miles of forest land in the Mississippi watershed would absorb and retain an average of about one-half inch of rainfall more than under present conditions and that this would practically eliminate the silt such lands would otherwise contribute.

The report of the Forest Service points out that the immediate problem of flood control can be met with the required promptness only by engineering structures, and that activities designed to improve flood conditions by dealing with surface conditions and better land use must be considered as supplementary. This is in accordance with the statement made by Colonel Greeley at Chicago that "forests hold back flood discharges; but they can not prevent large floods when heavy rains occur"; that forested land like any other reservoir "overflows after it has become fully saturated with rain"; that engineering structures must be "our main reliance * * * for controlling heavy flood discharges"; that forestry "has a valuable service to offer" flood control; that forests "can supplement dams or levees, but can not take their place."

Practically all of the measures recommended in the report of the Forest Service as necessary steps in the direction of Mississippi flood control have previously been recommended by the Department of Agriculture as desirable on account of other economic benefits to be derived therefrom, such as a better timber supply, soil conservation, improved agricultural conditions, betterment of the livestock industry and protection of publicly owned grazing lands, prevention of stream pollution, increasing opportunities for outdoor recreation, and the protection of game and fish.

The report of the Forest Service recommends the acquisition of 8,500,000 acres or 12,500 square miles of land for forestation, at an estimated cost of $42,700,000 together with measures for a greater degree of cooperation by the Federal Government in forest fire prevention and forest extension.

The report states that the returns from the forests, such as the sale of forest products will pay the entire cost and carrying charges, and claims that such incidental benefits as may accrue to flood control are an added asset.

74. Our public forests assist in conserving our timber supply, and are useful in preventing hillside erosion in areas subject to this damage, besides affording important recreational and scenic advantages to the public. They may have a useful local effect in reducing the torrential floods in mountains and hilly regions. A flood of the Mississippi is, however, not the torrential rush of water from denuded hillsides, but is the slowly rising long-continued outpour of the drainage from a vast region. Studies of the reservoir board have shown that, to reduce the flood stage of the Mississippi by 1 foot it is necessary to store from 7,000,000 to 11,000,000 acre-feet of water. The absorption and retention of one-half of an inch of rainfall on the 8,000,000 acres of land covered in the recommendation of the Forestry report, would therefore reduce flood stages by but one-half an inch.

In certain regions reforestation and the maintenance and improvement of existing forests, serve a useful purpose in checking soil erosion on hillsides, and in preventing thereby the choking of local streams by the silt washed down from eroding gullies. The silt carried by the Mississippi in its alluvial valley is not determined, however, by that contributed from the various lesser tributaries of its main branches, but is the balance remaining of the load which has been picked up and deposited many times over by the river in its course down through the alluvial soil of the river valleys. A single cave in the banks of the Mississippi will contribute more silt to the stream than the yearly inflow of silt from a lesser tributary. The stabilization of the river channels, proposed in the project herein recommended, should reduce this great source of river silting, and the stabilization of the channels in the tributaries in accordance with the projects for their improvement will have a further effect in this direction.

The checking of hillside erosion by forest cover in localities particularly subject to this loss will in the long run retard the extension of the river valley into the Gulf, but the effect thereon of any reforestation or forest development within the bounds of practical accomplishment would apparently be insensible so far as present generations are concerned.

75. While therefore reforestation, like reservoir construction for local purposes is a step in the right direction, and will be beneficial in reducing erosion, it can not be considered as a measure warranting inclusion in a comprehensive flood-control project for the alluvial valley of the Mississippi.

76. *Levees only.*—The confinement of flood flows by levees has substantially raised the flood heights. There is a theory that an alluvial stream tends to make a channel to accommodate itself. Even if this theory be correct, it does not solve the problem, because the floods must be controlled before there has elapsed enough time for such a theory to work out. The water must be provided for *now* and after extreme stages are provided for, a possible future enlargement in size of the channel is of little practical value. A gradual filling of the banks of the river within the levee and the growth of the islands tends to counterbalance scour in the channel proper.

77. Several thousand cross sections of the river measured from time to time do not show any material change in the channel itself.

Although the confinement of the river between levees has caused large increases in flood heights, it has not caused as yet any cumulative changes in the elevation of the river bed itself. The bed and the natural banks of the river are continually undergoing the local changes found in any alluvial stream subject to a widely varying discharge, but the gross effect of these changes on the discharge capacity of any considerable section of the river proper, since the construction of levees, is so small as to be less than the limits of accuracy of measurement. After a review of all the evidence, it is concluded that neither the levees nor the crevasses that have occurred in them have had any measurable effect on the capacity of the channel of the river itself to carry off flood waters.

78. It is not considered necessary to discuss the effect of a spillway system on the discharge capacity of the river. Before the construction of levees, water spilled generally over the banks in every flood. There is no evidence that they have as yet permanently affected the regimen of the river.

79. The river channel is made and maintained by the water flowing the year round below the bank-full stage. If the periodic overflows, lasting only a limited time, could be confined, they would not for an extremely long time, if at all, affect appreciably the results of the channel-forming processes operating continuously. Unproved theories concerning the river channel as affected by levees or relief spillways have no practical bearing on plans for flood relief.

80. Since "*levees only*" can not be relied on to produce by scour a channel sufficiently large to care for all floods, such channel can be obtained only by setting back the levees or by raising them. Setting back is shown elsewhere to be impractical. To raise the levees on the Mississippi sufficiently to hold the maximum predicted flood with a 5-foot freeboard would require that they be raised 12 feet at Cairo, 19 feet at Arkansas City, 12 feet at Angola, and 6 feet at New Orleans. An increased section and 5-foot freeboard would be necessary for such high levees. Such a raising is most inadvisable since the levees are now about as high as they should be. Levees of such heights would increase tremendously the hazard from possible crevasses and would involve many foundation difficulties. It is doubtful if such a raising would be practicable. The cost would be $566,500,000.

81. *Reservoirs.*—The reservoir theory is an ideal one when it fits. It expects to hold the water where it falls, on comparatively cheap land, and where it can be held without harm to anyone. It aims to attack the problem at the starting point of the trouble but can not always do so because sites and cheap land are not always available where the bulk of the rain falls. Some excellent plans for small areas have been consummated successfully on this theory. The principle of reservoirs is sound within its field of application.

82. The Mississippi is so large that it constitutes a problem different from that of any other river that has been considered. To determine whether a comprehensive system of reservoir control on the Mississippi is practicable, a study was made of available reservoir sites in all of the engineer districts in the Mississippi watershed. The results were consolidated and digested by the reservoir board organized in my office.

83. It has been found that by constructing 203 headwater reservoirs at a cost about $1,300,000,000, and by operating these reservoirs primarily for Mississippi River control, it would be possible to produce a dependable reduction in stages on the river of about 6 feet at Cairo, 7 feet at the mouth of the Arkansas River, and 5.4 feet at the mouth of the Red River. The value of local benefits from these reservoirs is placed at about $150,000,000, leaving a net cost of $1,150,000,000 chargeable to the control of floods in the alluvial valley. The cost of thus reducing the stages would be over four times the cost of levees which would afford protection against the same water allowed to flow down the river. These reservoirs would afford inadequate relief at a cost four times as great as the cost of the plan for complete protection proposed herein, which includes navigation and bank protection.

84. If these reservoirs should be operated primarily for other purposes, such as power, local flood control, irrigation, etc., they would produce a reduction in gauge heights of less than 1 foot in the alluvial valley. The reservoir sites have a potential economic value to the localities in which they are situated. It is not economically sound to subordinate this asset to the protection of a distant region.

85. Reservoirs near the valley can be operated more effectively than headwater reservoirs. A system of 30 reservoirs, not more than five days' flow away from the Mississippi River, was studied. These 30 reservoirs would cost about $525,000,000 after credit for local benefits. They would produce a dependable reduction in stages on the river of about 3 feet at Cairo, 10 feet at Arkansas City, and 7 feet at Vicksburg. While these reservoirs will produce a given flood reduction for about half the cost of headwater reservoirs, they will not completely solve the flood problem and will be much more expensive than the complete project recommended.

86. The reservoirs in the above plan above Cairo are more expensive and less effective than those on the White and Arkansas Rivers. If the former be omitted, there would remain 11 reservoirs on the Arkansas and White with a capacity of about 37,000,000 acre-feet at an estimated cost of $240,000,000. In the 1927 flood these reservoirs would have reduced the stage about 8 feet at Arkansas City and 5.4 feet at the mouth of the Red River. They would have considerable value for local flood protection in the lower valleys of the Arkansas and White Rivers. They would reduce the maximum flow through the proposed Boeuf River flood channel about 50 per cent and would make unnecessary the proposed flood channel east of the Atchafalaya. They would also reclaim considerable backwater areas at the mouths of the Arkansas and Red Rivers. A calculation indicates that the value of the backwater areas reclaimed by these reservoirs would not be increased by more than $25,000,000. Under the recommended plan the area that would be reclaimed can be used four-fifths of the time. The value of all these benefits would be less than $75,000,000. The addition of these reservoirs therefore would materially increase the cost of the proposed complete project. They are therefore not advisable at present.

87. Investigation of proposed reservoirs at the mouths of several of the tributaries shows that in general controlled reservoirs at these places could be depended upon to reduce stages during floods but ltitle in excess of the reduction effected by the reservoir capacity

afforded in their present condition. The cost of securing this small additional effect would be far in excess of the cost of attaining the same protection by the plan recommended.

88. A scheme for valley storage which has been widely discussed is one for converting of the entire St. Francis Basin into a series of reservoirs by levees running east and west across the basin, with controlled openings in them to let the water in and out. It would be physically possible to construct such a system and with it enough water could be impounded to reduce stages of the river below Memphis about 6 feet. The estimated cost is $746,000,000. Since it is possible to have a stage 14 feet above the present levee top at Arkansas City, the St. Francis reservoirs would not completely solve the problem. There is to be considered, in addition to the first cost, a potential future value of land reclaimed in the St. Francis Basin as against its use for reservoir purposes and the inadvisability of increasing the potential flood hazard by accumulating large quantities of water behind earthen dams on unstable foundations. The project is not advisable.

89. As converting the uppermost basin of the Delta valley into reservoirs is inadvisable, it follows that the lower basins can not profitably be so converted since their use will not afford any protection to the land above them and the cost will be about as much.

90. The chief reasons that reservoirs do not prove feasible are that the flows of the Mississippi are so great and the flood stages last so long that a very large amount of reservoir capacity has relatively small effect. To lower the gauge height at Arkansas City 1 foot requires that about 60,000 second feet be stored over a period of from 60 to 90 days, depending upon how near the reservoir is to the valley.

91. In other words, it will take at least 7,000,000 acre-feet in valley and 11,000,000 acre-feet in headwater storage to reduce gauge heights 1 foot at Arkansas City.

92. If an attempt be made to use the reservoir capacity with rules of operation aiming at more efficient results than those adopted, greater effect may be obtained some years, but there is danger that a flood larger than expected will fill the reservoirs before the flood crest is passed, in which case the value of the reservoirs will be partially or completely nullified. In this respect reservoirs are not as safe as flood channels which operate automatically and increase in efficiency with increase in flood flows.

93. It is evident that reservoir capacity sufficient to reduce flood flows to the capacity of present leveed channels would cost several times as much as the complete project recommended. Such aid as may be hoped for from reservoirs can be secured economically only by gradual processes. As time goes on it is hoped that reservoirs constructed primarily for local purposes will withhold flood waters and thus aid Mississippi control by affording an additional factor of safety. For instance, a reservoir on the Mississippi River near Commerce, Mo., 25 miles north of Cairo, would store some flood water and develop considerable power. Its cost would be approximately $130,000,000—over twice the cost of the Muscle Shoals project. While the costs are too high at present, a market for the power may develop and a distribution of costs be arranged some time in the

future to make this reservoir feasible. There is also a reservoir site on the Osage River that may be developed later in connection with power development. Likewise there are reservoir sites on the White and Arkansas Rivers that are being considered in connection with local projects.

94. In summary, the best system of reservoirs that has been found will cost about $240,000,000. When operated primarily for the purpose of flood control on the Mississippi it would not reduce the maximum predicted flood to a discharge which could safely be passed by the present levees. The floodways and spillways provided in the recommended plan would still be necessary, but they would be subjected to less frequent use. Giving $75,000,000 credit for benefits, the addition of these reservoirs would increase the cost of a complete flood-control project by $155,000,000.

95. The studies show also that in most cases the benefits for power or local flood protection are of greater value than benefits resulting from the use of the reservoirs for flood control on the Mississippi. The people of the States where they would be constructed will probably claim a priority in their benefits over the lower States. Such reservoirs as are built would therefore probably be used primarily for benefits on the tributaries, and in that case their effect on lower Mississippi floods would be much smaller than it would be if used exclusively for the latter. They will, however, when constructed for their own purposes provide an additional factor of safety to the lower Mississippi.

DETAILS OF THE PROJECT RECOMMENDED

96. The confinement of the Mississippi River within levees and the great development of drainage systems in recent years have raised flood stages materially and this raising has exceeded estimates made in the past. Were it attempted to hold the water within the present levee lines by raising them, river stages are possible as much as 6 feet above the present levee grade at Cairo, 14 above the present levee grade at Arkansas City, and from 10 to 13 feet above levee grade below Red River. The levees now have an average height of about 18 feet. The practical means to meet this situation is to spill the water out of the main leveed channel at selected points when the stages reach the danger point. Then it must be allowed to flow to the Gulf through the most efficient natural drainage basins. The overflows into these basins must be limited by natural ridges or secondary levees whose location is determined on the economic basis of how much value they protect, after protection of live is provided for.

97. The water within the river channel does no damage whatever and it should be kept within the channel as long as possible. The excess must be spilled through safety valves when the volume exceeds the safe capacity of the river. These safety valves consist of one controlled spillway, several relief or fuse-plug levees at present levee grade and one levee of reduced height, all emptying into natural floodways wholly or partially leveed.

98. To prevent failure from causes other than topping and bank caving, the cross sections of levees must be enlarged. The section to be used will be ample to include the line of saturation and will

vary with the materials and foundations in different localities. The maximum will generally be river slope 1 on 4, crown 12 feet wide, landside slope about 1 on 6. The levees generally will be raised about 3 feet, so that the selected, weaker relief levees will be at about the elevation of the present levee top and will surely serve their purpose.

99. The plan is designed to protect against the greatest flood predicted as possible, all the land in the Delta, except the limited areas subject to backwater and within leveed floodways; the land within the floodways will be protected against any recorded flood that has occurred except that of 1927 and possibly that of 1912 and 1882. The plan is economical, adequate, and comprehensive, and provides for the disposal of all water predicted as possible.

100. The flood used in the design of this plan is that predicted by the Weather Bureau as the "maximum possible" and by the Mississippi River Commission as the "maximum probable." The stages predicted by these two bodies were practically the same. When there was a difference the higher stage was used. This resulted in a project flood with stages, if confined, of 66 feet at Cairo. The Weather Bureau obtained its "maximum possible" flood at Cairo by using the maximum Ohio flood with "the Mississippi, Cumberland, and Tennessee Rivers contributing their tides at just the proper time to insure the greatest effect at Cairo, an improbable occurrence it is admitted but nevertheless a remotely possible one." The predicted stage at Arkansas City, 74 feet, is the result of the above stage at Cairo and the Arkansas and White at their maximum predicted stage. Below the Red the same flood reduced by river channel reservoir capacity and with flow from the Yazoo and Red added gives the project flood, which is taken at 3,000,000 second-feet.

101. The project for the different sections of the river is in more detail as follows:

Below Old River.—The flood of 1927 rose to 57.5 on the Angola gauge. It has been estimated that had crevasses not occurred the gauge height would have been 61.5. The top of the present levee is 57.5. It is believed that plans should be made for a flood which is 20 per cent greater than that flood, and which if confined would be from 10 to 13 feet higher than actual stages and the present levee top. No attempt should be made to raise levees to provide for such stages. In fact, they should be raised very little.

102. Existing maximum velocities cause erosion of a serious character through New Orleans Harbor, destroying or impairing long sections of underwater bank protection and resulting ultimately in costly and dangerous bank caving. No comprehensive plan should contemplate passing water by New Orleans which can be practically diverted above that city. Much less should excess water with increased velocities be pulled past New Orleans by a spillway below. A spillway below the city operating to the limit of its capacity to hold the flood stage to 20 on the Carrollton gauge would create velocities 12 per cent in excess of those created by a spillway above the city operating to hold the same flood to the same stage. A spillway at Caernarvon was considered and discarded on this account.

103. The plan is to raise the levees on the Mississippi, varying from 3 feet near Angola and Bayou Sara to zero at Bonnet Carre and to have relief levees across the upper end of the Atchafalaya

Basin which are to be maintained at their present grade, but which will fail when the stage rises to their top. This will insure that all excess water predicted as possible, above the capacity (1,500,000 second-feet) of the leveed main river, leaves the river. In order to carry this excess water to the Gulf and limit the land overflowed, a leveed flood way will be constructed, including land on both sides of the Atchafalaya River. The following levees are proposed for this flood way.

West side.—Raise and strengthen the present Bayou Des Glaizes Levee from west of Moreauville to just east of Bordelonville, set back that part of the Bayou Des Glaizes Levee loop east of this point to a line practically direct to Hamburg, and construct therefrom a new levee to and along Bayou Jack to Bayou Rouge; to protect the Cottonport area and the thickly populated section west of Bordelonville.

From Big Cane to Port Barre when economically justified.

From Washington to Port Barre, thence to Henderson, thence extending southeastward, as economically justified; to protect the Teche Ridge.

East side.—From Bachelor approximately along Bayou White Wine and Bayou Fordoche to the present Moringouin Levee, which will be raised, strengthened and extended, to protect the Grossetete area, and as much of the Fordoche area as practical.

Raising, strengthening, and extending the present Grand River levees; to protect the Plaquemine area, the Lafourche ridge and land to the south, as economically justified.

104. The western levee line at its northern end provides for setting the levee back to a north and south line across the Bayou Des Glaizes loop from Bordelonville to the vicinity of Hamburg. The eastern part of the present loop is directly in the way of flood flow toward the Atchafalaya Basin, and local authorities are expected to make arrangement so that the existing levees around this part can be breached as soon as the set back is finished. Local authorities are also expected to arrange for drainage to be intercepted by the new levee south to Bayou Jack.

105. The levee lines are laid out so as to avoid drainage problems as much as possible. Where drainage is intercepted, gaps will be left until local authorities can arrange for the proper drainage.

106. Most of the levee lines confining the northern portion of the flood way can be constructed now. The levees confining the southern portion should be constructed as fast as justified economically and as the requisite drainage projects are developed by local authorities.

107. The territory on each side of Morgan City should not be closed with artificial obstructions. The territory to the east is now a series of swamps and bayous through which water can escape. The Southern Pacific Railroad running through Morgan City should gradually increase the openings in its embankments and also raise its tracks. As a policy for the future, this railroad should not obstruct the flow of flood water, which may not only cause damage to the people behind the embankment, but also damage the railroad itself. There should be an abundance of wide openings over a distance of from 10 to 20 miles. The same precaution should also be taken by other railroads crossing the flood way farther north.

108. Morgan City, Melville, and Simmesport, within the flood way, are to be inclosed in part or in whole with levees.

109. The control of the relief levees at the head of the Atchafalaya Basin must be under the authority of the United States. The plan is to maintain them at their present elevations and strength. Years ago, engineers said that the Atchafalaya Basin should not be leveed but should be left open for the excess floods of the Mississippi. It has, however, been partially leveed. The proposed plan gives the river room to expand when in extraordinary flood but does not take away from the existing land owners any protection which they now have. History indicates that overflows over the relief levees will not recur on the average more often than once in 15 years. Some space must be available for the Mississippi to spread into, and this territory is the most suitable hydraulically and the most undeveloped economically. It is largely swamp land now. The flood ways are necessary to make other parts of the Mississippi Valley safe, and no existing protection is to be reduced.

110. Although a flood way is provided, wide enough to take any excess water predicted as possible, it is quite improbable that more than half of the northern part of this flood way will be necessary for many floods. Therefore, the Atchafalaya River levees should be maintained high and strong enough to prevent crevasses, so that when the relief levee yields on one side of the Atchafalaya the other side will be relieved from jeopardy. In this way, one side will escape from most of the extraordinary floods that will occur. The plan is to strengthen somewhat the Atchafalaya levees, which can remain at the general height now provided. This strengthening will give better protection against floods that do not overtop the fuze plug sections of the head at the basin.

111. It is clearly desirable that the Atchafalaya River be utilized to the limit of its capacity at flood stages to carry water to the Gulf, so that the flood ways may have the minimum use. Two mattress sills were placed on the river bottom at the entrance to the river in 1888 to 1890 to prevent an undue enlargement. Estimates indicate that these mattresses have, in fact, only a minor effect on the river discharge. The project, however, permits the removal of one or both of these sills if it should later prove expedient.

112. The proposal has been advanced that the flow through the Atchafalaya flood way be diverted across the Teche ridge into Vermillion Bay. Such a plan, were it practicable would relieve Morgan City and the territory at the foot of the Atchafalaya Basin from the danger of high-flood stage in a great flood, but would unload the burden on territory heretofore substantially untouched by Mississippi floods. It would be costly and complicated and is not recommended at the present time.

113. It is obvious that no more water can pass down the main channel of the Mississippi in this reach than can flow between the levees of that river at the upper end of this reach. The remainder must go down the Atchafalaya Basin. The strengthened levees on the main river can safely discharge 1,500,000 second-feet, and with the relief levees as above outlined, will be called upon to pass no more.

114. At Bonnet Carre a controlled spillway emptying into a leveed flood way to Lake Pontchartrain is to be constructed capable of dis-

charging 250,000 second-feet. This leaves 1,250,000 second-feet to go by New Orleans and should prevent the stage at Carrollton from rising above 20 on the gauge.

115. The Bonnet Carre spillway is so designed as to afford complete control of the discharge into Lake Pontchartrain. This discharge will be begun when the flood stage at New Orleans has reached 20 on the Carrollton gauge; it will be regulated to prevent the stage rising above 20, and will be cut off as soon as the stage has fallen below that figure. Past records indicate that its operation will be required about once in five years; and for a period of from one to three months during each flood. The discharge through the spillway, in a maximum flood, will be about 10 per cent of the total flow at that latitude. Some of the silt carried by this discharge will be deposited in the flood way itself, the bulk of it in the upper end of Lake Pontchartrain. With the infrequent and limited periods of operation, the silting would not exceed an average of one-fourth of an inch of depth per annum, even if all the silt content were deposited in the lake within 10 miles of the flood way outlet. The average rate of silting for the entire lake would be one-thirty-second of an inch per annum. Discolored water from the discharge may, in a high flood, extend well into Mississippi Sound, but there will be no appreciable silt content remaining in the water at such a distance. The spillway is especially heavily designed to prevent even the remote possibility that the discharge will cut a channel from the river into Lake Pontchartrain.

116. The city of New Orleans has provided, with its own funds, levees on its river front of so wide a crown and with such flat slopes as to afford an abundant margin of safety against failure except by overtopping or by bank caving. After the Bonnet Carre spillway has been constructed, there can be no fear that the flood stages will approach dangerously close to the levee top. The danger of bank caving is minimized by the revetment which has been placed on the underwater bank. The Bonnet Carre spillway will reduce the high current velocities now occurring in great floods. Further insurance can be provided by widening the levees to introduce any desired factor of safety.

117. *Old River to the Arkansas.*—The flood of 1927 rose to 60.5 on the Arkansas City gauge. It has been estimated that had it been confined and crevasses not occurred the gauge height would have been 69. The top of the present levee is 60.5. To take care of this flood with proper freeboard would require present levees to be raised about 12 feet. Such an increase in levee height would greatly intensify the disaster resulting from an accidental failure of a levee, besides being inordinately costly. Nor would they be safe, for it has been estimated that floods might come which would produce, if confined, stages of over 74 feet. It is obvious that no attempt should be made to raise levees to such a height. The practical remedy is to raise the levee grade 3 feet on both sides of the Mississippi below the Arkansas River, to strengthen these levees so that they will not fail from causes other than accident or overtopping, and to preclude overtopping by insuring that the water in excess of the capacity of the leveed channel be spilled out near the mouth of the Arkansas.

118. To insure that excess water will leave the main river, a fuse plug section of the levee in the vicinity of Cypress Creek must be kept at its present strength and at its present grade, viz, 3 feet below the new levee grade. This relatively weak section will be long enough to discharge the greatest predicted possible excess water over and above the capacity of the leveed river below. In order to limit the land in the Tensas Basin overflowed by it, levees will be constructed on each side of the Boeuf River bottom, where natural ridges do not serve, from the Cypress Creek levee to backwater in the lower Tensas Basin. Arkansas City is to be inclosed with a levee. This floodway will be wide enough to carry the water without clearing and without maintenance except for the side levees. It is unwise to attempt to limit the volume of flow that may possibly enter the floodway to a narrower floodway that might prove of insufficient capacity. A narrower floodway cleared of timber was considered, but the clearing was found to be unwarrantably expensive in first cost and maintenance for the increased efficiency of discharge produced thereby. It will be much better to let the land be gradually cleared as it is developed for use. At some future time, the development of the region may warrant the first cost and maintenance of a cleared floodway of less width.

119. The Boeuf River bottom is selected for this diversion because it is the most suitably located to receive the water, is the most direct route, has the best width, and covers largely undeveloped swamp land. Water will not top the Cypress Creek fuse plug levee and go down the floodway until it is so high that it must find an outlet. No flood except that of 1927 has reached such a stage. However, due to an increase in flood heights by reason of levee construction and drainage, it has been estimated that a stage over the present levee top at Cypress Creek might occur in the long run about once in 12 years. The lands in the floodway will be inundated only by floods that would overtop the present levee system, and they will retain the same measure of protection that they now have.

120. The United States must have control over the Cypress Creek levee and keep it substantially at its present strength and present height. The land in question was originally an overflow channel of the Mississippi, and it must be available for the use of the river in extreme flood.

121. The remainder of the alluvial valley on each side of this stretch of the river, barring accident, will have complete protection from all possible floods. Thus the majority will gain, but not by reducing the protection of the minority. When water does top the Cypress Creek levee, the overflowed area, with safe land on each side, will be in a better situation than ever before during extreme floods.

122. *The mouth of the Arkansas to Cape Girardeau.*—In this stretch of the river, the flood of 1927 rose to 56.5 on the Cairo gauge. Had no crevasses occurred, the gauge height would have been 58.5. The actual top of the present levee is 60. It has been estimated that with the discharge confined within the limits of the present levee system, stages are possible as high as 6 feet above the present levee top.

123. From Cape Girardeau to Cairo the levees are of moderate height. They will be raised and strengthened to take care of the maximum flood predicted as possible.

124. Cairo, Ill., has a population of about 15,000. Its levee is at elevation 60 on the gauge. Parts of the city are 20 feet below this elevation. The city is situated on the point of land between the Mississippi and the Ohio, where escape from a flood which overflows its levees will be almost impossible. The 15,000 people should be protected against the highest water predicted as possible and the city should not be subjected to the jeopardy of levees higher than they now are.

125. The plan is to set back, about 5 miles, the west bank Mississippi River levee from Birds Point, opposite Cairo, to St. John Bayou, just east of New Madrid, 70 miles by river below Cairo, and to lower the present river bank levee by 5 feet, so that when the stage at Cairo reaches 55, the water will begin to flow into a wide flood way below. This enlarged channel will preclude any predicted flood from rising above the levees protecting Cairo. It will reduce the stages of a flood equal to that of 1927 so that the levees at Cairo will have at least a 3-foot freeboard. Mound City, several miles up the Ohio from Cairo, will also be benefited by the flood way. The levees along the Mississippi and the Ohio in front of these towns are to be strengthened and the former extended slightly.

126. The new west levee from Birds Point to New Madrid will be stronger and higher than the existing levees on the river bank, and will afford protection against any predicted flood. The land in the flood way between the new levee and the present river bank levee, other than the backwater area of St. Johns Bayou, will be protected against all stages or record except those of 1927. A considerable part of the total area is always subject to backwater from St. Johns Bayou. The relinquishment of the remainder to extreme floods, at long intervals, is necessary to the assured protection of the adjoining land, and to the 15,000 residents of the city of Cairo. Local authorities are expected to accept all responsibilities in connection with the reduction in height of the river side levee.

127. The cheapest diversion developed south of New Madrid was from New Madrid to and alongside Crowley Ridge and from the St. Francis to the White by a cut near Mariana. Its estimated construction cost was $220,000,000, a sum far in excess of the cost of levee raising, which is feasible in this reach. From New Madrid south to the mouth of the Arkansas levees will therefore be raised to a grade line equal to that of the maximum flood predicted as possible, except possibly between the main river and backwater areas of the St. Francis River and the White River, where a lesser raising may be expedient. A failure at these locations would do comparatively little harm, and would occur only during an improbable superflood. The St. Francis Basin generally, the city of Helena, and the upper Yazoo Basin on the east, will be protected against the greatest predicted flood and have an ample levee freeboard for a flood equal to that of 1927. These levees will be strengthened as well as raised. The draw down from the Cypress Creek relief levee into the Boeuf River diversion below makes it possible to protect the lower part of this section of the river from superfloods without excessive levee raising. The floodway between Cairo and New Madrid accomplishes the result desired above. The average amount

that levees are to be raised throughout is approximately 3½ feet above the present adopted grade.

128. For many generations at least, future developments of this plan, to care for any changes that may be caused by nature, will be along the main river channel, and expensive diversions or flood ways through the St. Francis and White Valleys will be unnecessary. On account of the unleveed land on the east, the flood channel in general is now wide, down to the upper part of the Yazoo Basin. Below, the backwater areas of the St. Francis and the White on the west can be expanded, if nature demands more room for water. It is important that the existing flood way and back water areas be not appreciably or unreasonably reduced by levees. The river needs the space it now has, and this should not be encroached upon.

129. *Auxiliary levees.*—The comprehensive project recommended is intended to control flood waters of the Mississippi River throughout its alluvial valley. In order to do this effectively, levees should be constructed where necessary to prevent the flood water of any one of the great basins of the alluvial valley from flowing into the basin below it, except through the relief or fuse plug levees intended to carry off the excess waters during high floods. The plan proposes the strengthening of the levees on the south side of the Arkansas and Red Rivers and raising them about 3 feet, as far upstream as is necessary for that purpose.

130. For the part of the Mississippi and its tributaries now under the jurisdiction of the Mississippi River Commission but not included in this project for the alluvial valley authority for flood-control work should be continued in effect under the direction of the Secretary of War and the supervision of the Chief of Engineers. It is not proposed to do any work other than emergency until definite projects are adopted for each tributary and for the Mississippi itself above Cape Girardeau as a result of the surveys which are to be made under the authority contained in the river and harbor act approved January 21, 1927.

131. *Channel stabilization.*—Since the levees within the limits of this project are to be greatly enlarged, they will be much more expensive than heretofore, so something must be done to avoid the frequent moving of them from the proximity of caving banks. In addition, the river can not be regulated for low-water navigation until the banks are made stable, this both to keep the channel in one place and to stop the enormous dumping of earth into the river by bank caving. A general bank-protection scheme must be carried out. This will consist of revetting banks by proven methods and in addition trying new and cheaper methods to accomplish the same result. At the same time regulation of the kind which has been successfully accomplished above Cairo will be undertaken below when and where the banks become stable. The plan includes a 10-year program of channel stabilization and river regulation at a total cost of $110,000,000, or $11,000,000 per year.* This program may need revision upward after some years, as the rate and total amount of work above contemplated is a minimum.

132. *Protection afforded by the plan.*—The plan recommended is designed so that the levee grades proposed are slightly above the greatest predicted flood. The improbability or infrequency of occurrence of a superflood such as is predicted as the maximum, justifies

a very slight factor of safety for it. Strengthened and widened levees will permit such a flood to be fought successfully. The grades have a normal factor of safety for a flood of the size of that of 1927.

133. With this plan, except for backwater storage areas, complete protection is given to the St. Francis Basin; to the Yazoo Basin; to the Tensas Basin, except the flood way; to New Orleans and the country east of the main river except the Bonnet Carre flood way, and to all the country west of the Mississippi except the Atchafalaya flood way. The situation is represented by the following statements:

	Square miles
Area in alluvial valley subject to overflow by Mississippi River water if there are no protecting works, approximately	30,000

Approximate conditions after recommended plan is completed

	Square miles
Protected all the time	20,550

	Cleared land	Swamp and timber land[1]
	Square miles	*Square miles*
Protected on an average of 14 years in 15	215	960
Protected on an average of 11 years in 12	950	1,300
Protected on an average of 9 years in 10	135	90
Protected on an average of 4 years in 5	1,540	3,260
Protected on an average of 2 years in 3	500	500
Total	3,340	6,110

[1] Swamp and timber land serves for the growth of trees just as well wet as if dry.

134. *Safety valves.*—In considering the plan for control of the Mississippi much study was given to providing a flexible feature such as safety-valve spillways over the levees to discharge water that might possibly come in excess of any predicted. The fuse-plug levees decided upon for the two lower sections of the river gave the flexibility desired and made unnecessary additional safety valves at this time. For the upper sections of the river the existing protective works can be modified so easily to meet the requirements for any flood predicted that it is not expedient to go to the expense of providing safety valves now. This section of the river, being above the Arkansas and therefore receiving considerably less water than the lower river, can be provided with protective works more economically than the stretches below. If the future should indicate that floods may come larger than those now predicted, safety valves can be added to the proposed project.

135. *Maps of the alluvial valley.*—The Mississippi River Commission has made good maps of the valley with many cross sections but without contours. Complete topographic contoured maps of the alluvial valley, including adequate horizontal and vertical control, have never been made by the Federal Government or by the States concerned. It has been the general policy of Congress in the past to provide for general utility topographic maps only in cases where local cooperation has been secured, although congressional authority now exists for completion of a general utility topographic map of the country as funds may be made available. Some of such maps would be of material assistance in the execution of the flood-control project, and the necessary surveys therefor may properly be included in the national plan for the control of floods in the lower Mississippi.

136. Such maps would also be useful for many other purposes but the predominant need for them in the valley at this time is in flood-control work and priorities with reference to allotment of funds, and execution of the work should be controlled by those responsible for the execution of the project. The actual execution of the surveys may well be intrusted to existing agencies of the Government now organized for mapping work in general, but the funds should be allotted by the Secretary of War on recommendation of the Chief of Engineers. One million dollars is included in the estimate for this purpose.

137. Summary of costs of structures, dredging, and mapping:

Below Red River:	
Bonnet Carré spillway	$8,200,000
Mississippi levees	18,700,000
Flood way east of Atchafalaya	12,000,000
Flood way west of Atchafalaya	17,300,000
Red to Arkansas:	
Mississippi levees	59,300,000
Boeuf Basin flood way	7,700,000
Arkansas to Cape Girardeau:	
Mississippi levees	53,000,000
Auxiliary levees	7,700,000
Channel Stabilization	110,000,000
Mapping	1,000,000
Total	296,400,000

138. *Program of work.*—The project is to be completed within 10 years. Twenty-five million dollars can be advantageously expended the first year and approximately thirty million dollars each year thereafter until the project is completed.

139. *Execution of plan.*—The plan herein recommended is general in its scope. It is recommended that the responsibility for the execution of the plan, the details of the design, and location of the engineering works and structures be placed upon the Chief of Engineers under the supervision of the Secretary of War, as is done by acts of Congress in the case of river and harbor improvements.

140. *Control of structures affecting the flood-discharge capacity of Mississippi.*—Salutary laws for the protection and preservation of the navigable waters of the United States have been enacted by Congress. Since the protection and preservation of the flood-discharge capacity of the alluvial valley of the Mississippi River is requisite to the common welfare of the Nation and to the preservation of the many lines of interstate commerce which cross the valley, it should be protected and preserved by similar legislation. The warning can not be too strongly emphasized that unless the flood-discharge capacity provided in the plan herein recommended is preserved, a future great flood will result in a disaster as great as or greater than that experienced this year.

141. *Legal procedure in acquisition of land.*—To expedite the acquisition of rights of way for structures, the procedure already authorized by the laws relating to works of improvement of rivers and harbors should be made applicable to flood-control works. The flood control act of 1917 extended to flood-control expenditures the provisions of laws then existing relating to the improvement of rivers and harbors, but beneficial legislation subsequently enacted is not now so applicable.

142. *Maintenance.*—The interest and responsibility for the levee lines which the local people carry by reason of their contributions for maintenance are too valuable and too important to lose. They must not be allowed to wane. However, depending upon local authorities to maintain levees has some inherent disadvantages. At times an expensive levee on which the United States has spent large sums is allowed to deteriorate beyond the point of safety. It is advisable that authority be granted for the funds of the United States to be spent on maintenance of any part of the levee system, provided it is demonstrated to the satisfaction of the Secretary of War that local funds can not be obtained for such purpose, and provided further that local organizations exercise the necessary police authority to protect the levees.

HYDRAULIC LABORATORY

143. The establishment of a hydraulic laboratory similar in some respects to such research organizations carried on by certain European governments has been considered. Measurements and observations on our large rivers supply the best hydraulic data on the flow of such streams, since actual experience with full-size structures is preferable to experiment with small-scale models. However, on occasion questions relative to the flow of water can be worked out by small-scale experiments. Such experiments may be useful in some of our lock and dam designs.

144. In addition, the organization in charge of a hydraulic laboratory may well be charged with the coordination of field data relative to the flow of the Mississippi and other rivers. For instance, it could advantageously take charge of discharge measurements, silt measurements, slope and velocity measurements, etc., and make studies and draw conclusions therefrom. It could be a clearing house for such engineering data and publish the same.

145. It is therefore recommended that the Chief of Engineers, under the supervision of the Secretary of War, be authorized to establish a hydraulic lavoratory, and that the Secretary of War be authorized to allot the necessary funds from annual river and harbor and flood control appropriations to pay the expenses of such a laboratory and for the necessary printing to publish the scientific data collected.

MISSISSIPPI RIVER COMMISSION

146. The Mississippi River Commission has done able work and accomplished excellent results since its formation. However, work can be done more efficiently with unit control than with divided control. At present the Chief of Engineers and Secretary of War have veto power over the Mississippi River Commission, but not initiative control. It is recommended that under the direction of the Secretary of War the Chief of Engineers be given authority to plan and direct the work on the Mississippi River, with the president of the commission reporting direct to him. The commission as at present constituted can be continued as an advisory, but not as an executive, commission. Because of the importance and magnitude of the duties under his charge, the president of the commission, while actually assigned to such duty by competent orders, should

receive the rank, pay, and allowances of a brigadier general of engineers. He should, to be eligible for such assignment, have the qualifications now prescribed by law for the Assistant Chief of Engineers.

SUMMARY OF PROJECTS

147. I recommend the adoption and authorization of a comprehensive project for the flood control of the Mississippi River in its alluvial valley and its improvement from the Head of the Passes to the Ohio River as set forth in this document, to be prosecuted under the direction of the Secretary of War and the supervision of the Chief of Engineers; the project to include the floodways, spillways, levees, channel stabilization, mapping, etc., hereinbefore recommended, with such modifications thereof as in the discretion of the Secretary of War and Chief of Engineers may be advisable, and the maintenance of a navigation channel from Cairo to New Orleans not less than 300 feet in width and 9 feet in depth, all at an estimated initial cost of $296,400,000, with $6,000,000 annually for maintenance after completion of project, with such distribution of costs as may be specified by law after considering the statements on economic necessity and local cooperation in paragraphs 25 to 42, inclusive. Its adoption should be made subject to the provision that, except when authorized by the Secretary of War upon the recommendation of the Chief of Engineers, no funds appropriated by Congress for the execution of the project shall be expended on works within a State until that State by appropriate legislation—

(*a*) Has undertaken to provide without cost to the United States and when required the rights of way for all levee structures, and such drainage works as may be made necessary by new levee construction.

(*b*) Has consented to the maintenance of the levee at the head of flood ways within the State at the grades and cross sections necessary in the opinion of the Chief of Engineers for the security of the levee system and the lands protected thereby.

(*c*) Has agreed to hold and save the United States free from all damage claims resulting from the construction of the project; and to maintain all flood-control works after their completion, except controlling and regulating spillway structures.

148. I recommend that the Secretary of War be authorized to continue in his discretion, and under the supervision of the Chief of Engineers, the prosecution of such works for the flood control of the Mississippi River as have heretofore been authorized and are not included in the project herein recommended; to expend, in an emergency, funds appropriated for the execution of the project on the maintenance of any levee, when it is demonstrated to his satisfaction that the levee can not be adequately maintained by local interests; and to secure the assistance, whenever practicable, of the United States Geological Survey, the Coast and Geodetic Survey or other mapping agencies of the Government in the preparation of maps required in furtherance of the project, and to allot funds therefor to them from funds appropriated for flood-control work.

149. I further recommend that legislation be enacted:

(*a*) Prohibiting any obstruction not affirmatively authorized by Congress to the flood discharge capacity of the alluvial valley of the Mississippi River below Cape Girardeau and providing that it

shall not be lawful to build or commence the building of any levee or other structure in said alluvial valley, or in any flood way provided therein unless the work has been recommended by the Chief of Engineers and authorized by the Secretary of War.

(*b*) Providing that the penalties and procedure applicable to violations of the laws for the protection and preservation of the navigable waters of the United States, enacted in sections 12 and 17 of the river and harbor act of March 3, 1899, shall apply to violations of the above provision of law.

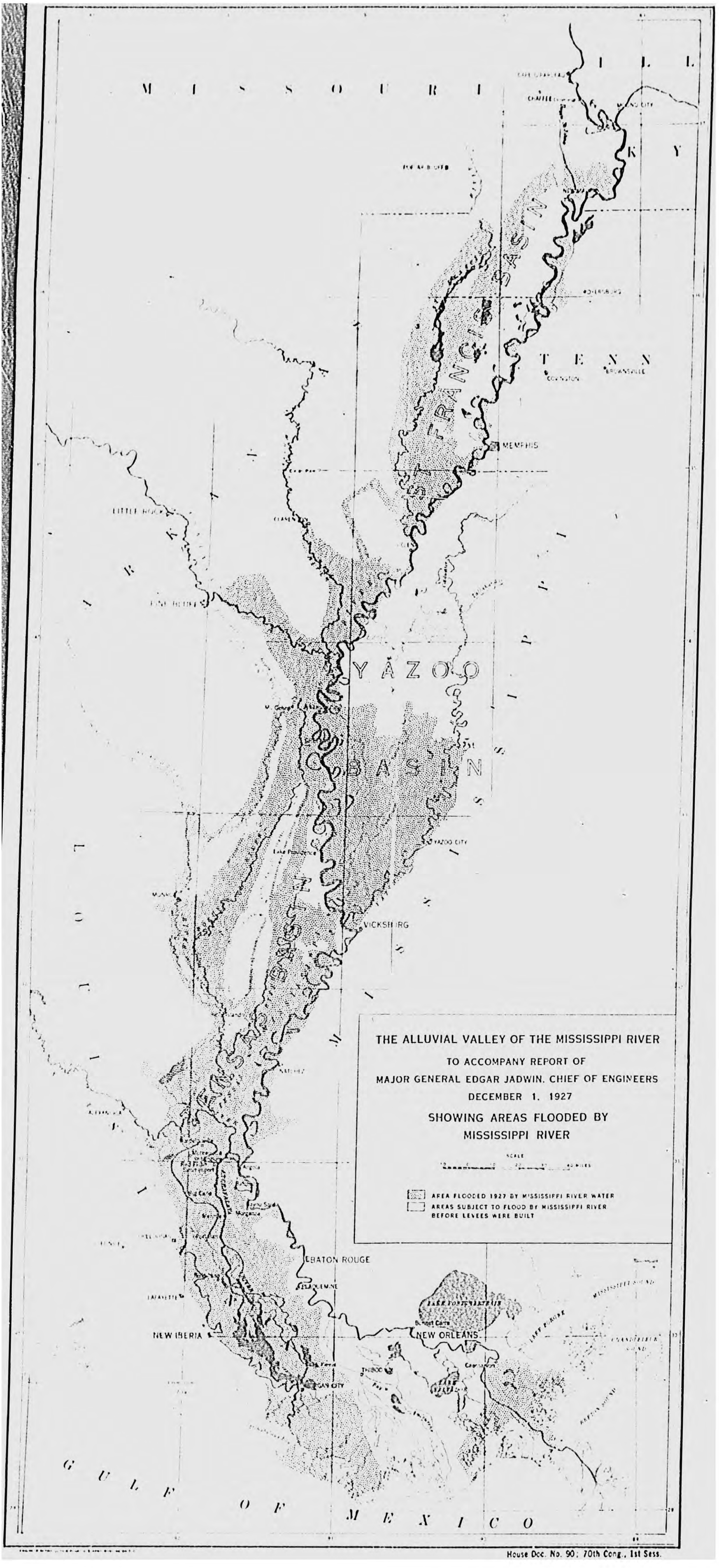
(*c*) Providing that existing laws relating to the acquisition of lands, easements on rights of way needed for a work of river and harbor improvements shall be applicable to the acquisition of lands, easements, or rights of way for flood-control works.

(*d*) Amending sections 3 and 4 of the act of June 28, 1879, constituting the Mississippi River Commission; to provide that it shall be the duty of said commission to advise on all questions relating to the improvement of navigation on the Mississippi River and the prevention of destructive floods which may be referred to the commission by the president of the commission or higher authority, and to provide that the president of the Mississippi River Commission shall have the qualifications now prescribed by law for the Assistant Chief of Engineers, and shall receive the rank, pay, and allowances of a brigadier general of Engineers while actually assigned to such duty by competent orders.

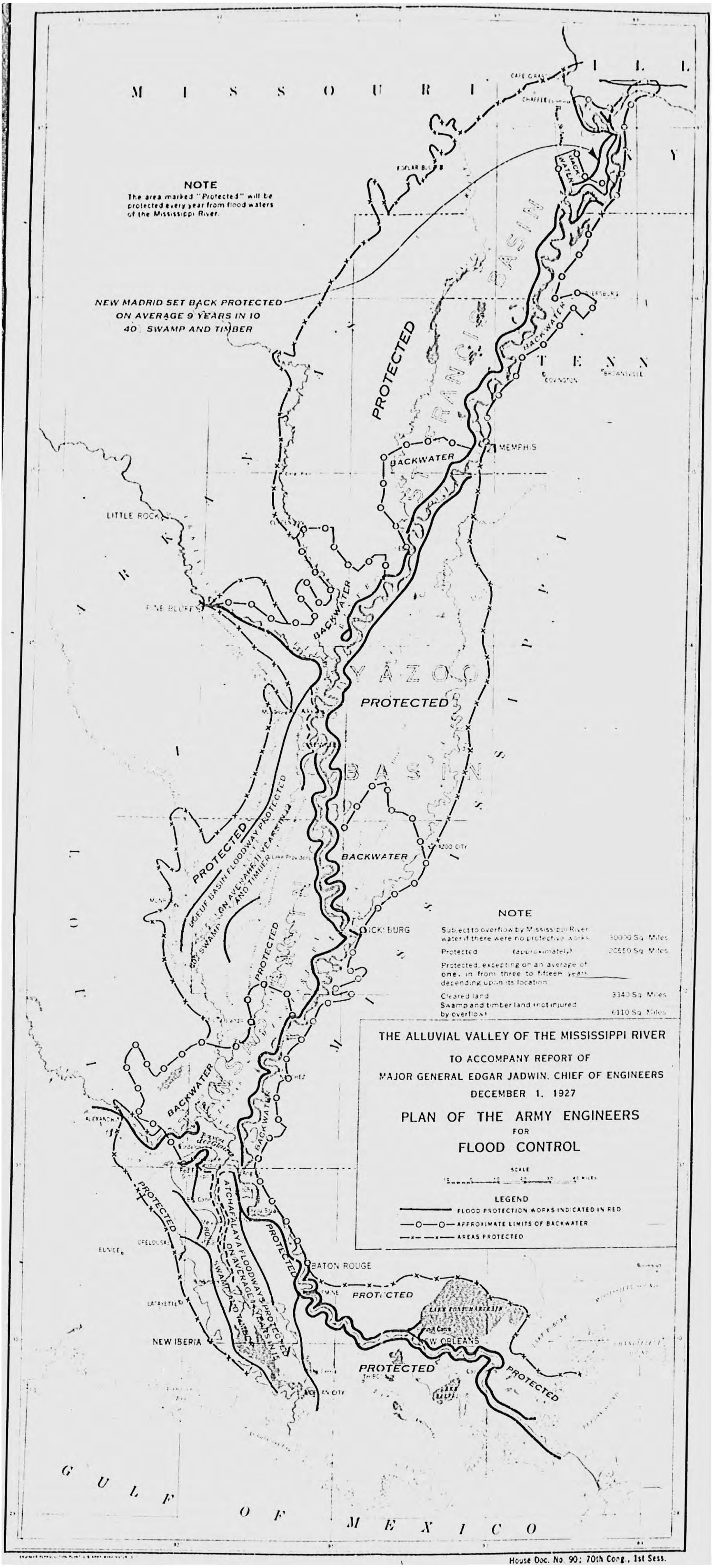
150. In forwarding this report, I wish to express my gratitude to the great number who have helped in collecting, classifying, and systematizing the data and computing and analyzing the various deductions which have been made from it. It was only by this process that it has been possible to produce a comprehensive report and develop so simple a solution for so complex a problem in so short a period. I am particularly indebted to the Mississippi River Commission, Col. Charles L. Potter, president; the spillway board, Col. William P. Wooten, chairman; the reservoir board, Col. William Kelly, chairman; subboard on navigation, Maj. Stuart C. Godfrey, chairman; subboard on diversion channels, Col. E. H. Schulz, chairman; and to the 2 division and 13 district engineers between the Rocky and Appalachian Mountains and to the other officers and civilian employees, regular and temporary, the total aggregating something like 30 or more engineer officers and 120 civilians, who have assisted most loyally and efficiently in the various phases of the work. The personnel of the various levee boards, State and local authorities, railroad officials, and various individuals have assisted whole-heartedly in the supplying of data and information. I also wish especially to acknowledge my indebtedness to Col. George B. Pillsbury, Corps of Engineers; Maj. Dan I. Sultan, Corps of Engineers; Maj. Ernest Graves (retired); Mr. William Gerig senior engineer; and the officers and force working with them and having a close personal contact with me and assisting in the coordination of the data coming in from the various boards, district engineers, and other sources, and in the preparation of this report.

EDGAR JADWIN,
Major General, Chief of Engineers.

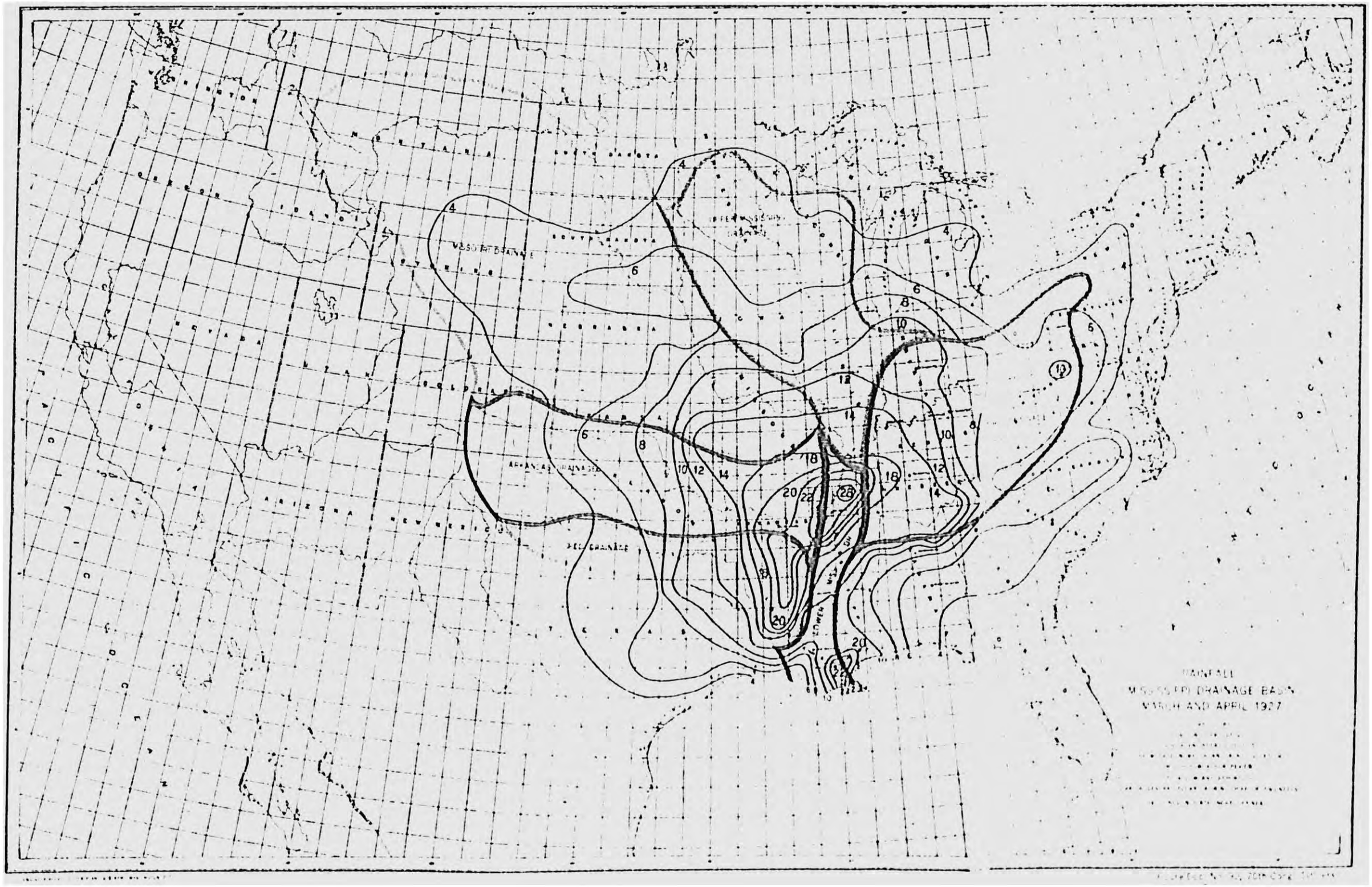
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House Doc. No. 90, 70th Cong., 1st Sess.



House Doc. No. 90; 70th Cong., 1st Sess.


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