

surface, and thereby requiring a further heightening of the levees. This idea was dismissed based on further observations of the Po by Chevalier Lombardini. Following discussion of their observations, Humphreys and Abbot concluded that a fully-leveed river with no crevasses would have floods up to ten feet higher than that of 1858. Because of the increased head and the resultant velocity increase, these floods would be of shorter duration. It was therefore recommended that a levee system be built below Cape Girardeau, Mo. of sufficient height to contain the increased flood stages. A single outlet near Lake Providence connected to Bayou Tensas was also suggested as a possible way to reduce the stages in this reach of the river. Much of the Delta Survey's conclusions rest on the assumption that the bed of the Mississippi consists of hard, virtually non-erodible blue clay. Thus, Humphreys and Abbot did not claim, as later proponents did, that levees would deepen the channel, for they felt any increase must be made at the expense of the banks, producing a wider but not deeper channel. They must have felt this deterioration of the natural levees by the artificial levees was already taking place. In considering the use of bank heights in leveed sections as indicative of previous flood heights, they state that:

"...crevasses may reduce the surface of the river as low as, if not lower than, it would have been if the natural banks existed in their original, unleveed condition, for the mean level of the natural bank, where the levee system has been in operation for many years must, from constant caving, be lower than it was originally."

Before any action was taken on further flood control, the Civil War intervened and with the States' energies focused elsewhere, the existing levees were crevassed and many washed away. After the war the States were too impoverished to maintain the levees to any great extent, and the main Federal effort on the river was aimed at navigation

improvement, not flood control. Although little construction was taking place, engineers continued to discuss the issue of levees and their effects. Some rejected the Delta Survey's conclusion about the permanence of the river bed, claiming considerable deepening would or had occurred and thus there would be no increase in flood heights. Hewson, in his Principles and Practices of Leveeing, was not concerned with the bed, but suggested that a slow increase in flood heights would begin as the delta was extended by the increased amount of sediment carried into it. Others stood by the conclusion that the bed would remain at the same level, while still others continued to believe in the elevation of the bed. Obviously, the Delta Survey had not settled the question of flood control, but it did provide necessary data for subsequent discussion. While levee construction and flood control continued under the old system, the Federal government became more involved in the navigational aspects of the river. Since 1824, the Corps of Engineers had been charged with the removal of snags from the stream and other channel improvements. The first dredging occurred in 1856 and was attempted again in 1867; river gages were constructed in 1875. With this emphasis on navigation improvement, little investigation was made into flood control, but the studies which were made reached important conclusions. A commission studying the impact of the 1874 flood on the levees clearly defined the grave deficiencies in the system for levee construction and administration. Elliott reports as follows:

"In its report, submitted in 1875 and based largely on the work of Humphreys and Abbot, the Commission found the existing system defective as the result of five principal causes, to-wit: vicious levee organization; insufficient levee height; injudicious cross section and construction; inadequate inspection and guarding; and faulty location. The Commission expressed

its opinion that no practicable aid could derive from any diversion of tributaries or by artificial reservoirs; that cut-offs were pernicious in their effects; and that outlets, although correct in theory, would find no useful application on this river. A general system of levees from the head of the Alluvial Valley to the Gulf, including the valleys of the tributaries, was advocated, and it was recommended that this project be executed under the general supervision and control of a board of commissioners which would report to the supreme authority from which it would derive its legal existence. The board further stated that little could be accomplished under the existing conditions without Federal aid."

Another report in 1879 by a board of engineers considering low water navigation combined the theories of levees and navigation improvement in a manner foreshadowing the future Federal stance on levees. Elliott again reports:

"(The Board) advanced the conclusion that a complete levee system would aid commerce during periods of high water but would have little or no influence upon low-water navigation. The Board stated that the greatest obstacle to navigation improvement and levee maintenance was the instability of the river due to bank caving. The Board concluded that the levee system, if undertaken, should be developed in connection with navigation improvement."

With the establishment of the Mississippi River Commission in 1879, the entire Federal program on the river entered a new phase. The Commission consisted of four government and three civilian engineers appointed by the President and reporting directly to the Secretary of War. The jurisdiction of the MRC was confined strictly to the Mississippi from Cairo to Head of Passes, but within this area there were now two engineering bodies, the MRC and the Corps of Engineers. To insure cooperation, the president of the MRC and two commissioners were to be from the Corps. The MRC was charged with improving the river channel to aid navigation, protecting the banks, preventing destructive floods, and aiding commerce and the mails. Harrison correctly notes the debate in Congress over the true reasons for this legislation. Was it for navigation or for flood control? Opponents to the new arrangement

argued that while navigation was definitely a national concern, flood control should be handled strictly by local concerns. They feared that this step would eventually result in large expenditures by the Federal government for flood control. Proponents solved the dilemma by considering both concerns as part of the same problem. They stressed that navigation improvement was their primary aim, but if some relief from floods resulted from this work, so much the better. Illuminating, perhaps, are the opinions of one supporter, Rep. Gibson, which demonstrate this emphasis:

"In the first place, official reports show that during several months in every year immense sandbars and snags close the navigation of the river as effectually as if artificial dams were constructed across its channel. In the second place, official reports show that at other seasons the river rises over its banks throughout the alluvial region and spreads over the country for forty to sixty miles--becomes a mighty roaring torrent--destructive not only to human life and property upon its borders, but destructive to the commerce upon its waters..... In such seasons the largest boats propelled by steam are sometimes destroyed and often detained several days by the extraordinary obstacles they encounter, but that countless fleets of smaller boats, barges, and flatboats, propelled by the current of the river itself, are absolutely at its mercy and are sometimes borne into the adjacent forests and wrecked or whelmed and destroyed in the furious eddies and cross-currents..... This commission is created with the hope that they may devise some plan, economical, feasible, and complete, that shall give us deep water at all seasons of the year and prevent these destructive floods so ruinous not only to the country through which it flows, but to the mighty commerce that carried the production of the teeming millions who inhabit the great valley to the markets of the world and brings back in exchange the wealth of other countries."

The plan submitted by the MRC in 1880 followed closely the suggestions of the Delta Survey and the 1879 Board. Although levees were not absolutely necessary adjuncts to navigation improvement, they were desirable for they were thought to deepen and enlarge the channel.

Bank revetment, permeable contraction works, and the closure of chutes and alternate channels were also among the recommendations accepted and funded by Congress. In order to administer the construction of levees, the MRC simply adopted the existing system of levee districts which had been set up earlier under the States' jurisdiction. At the time, the levee districts had ample funds, while the MRC was dependent on Congressional appropriations, so the new levees were mainly built with district funds. The MRC acted as a coordinator between the districts and States. The Commissioners were not all agreed as to the true value of levees in relation to navigation, but since they were under Congressional instructions to build levees only as aids to navigation, they had to justify any construction in these terms. It was decided in 1882 that levees would be built to grade sufficient to hold the most frequent floods, but the cost of restraining abnormally high floods could not be justified. To accomplish this, gaps and crevasses were to be closed and the levee line was to be extended upstream. The history of the MRC until 1917 was a repetitious cycle of new high-water stages followed by new levee grades. These grades were set in reference to local high water with correction for water lost through crevasses and new upstream levee construction, rather than designing them for a projected flood, the present practice. This meant a new levee at one place occasioned higher levees elsewhere, and the levees were raised in see-saw fashion. For example, during every flood the low levees guarding the St. Francis basin crevassed, providing relief to the much higher levees on the east bank. The controversial closure of the front raised the 1897 flood heights at Memphis by 2.5 feet, causing great strain on the eastern levees.

The Commission recognized that levees would increase flood heights, but with each new flood the crevasses always occurred at points where the levees were still below Commission grades. The belief in the ultimate deepening of the channel and in the impracticality or injurious effects on navigation of other flood control measures encouraged the Commission to stand by its "levees only" policy, despite the continuing opposition by some engineers to it. The debate over the effectiveness of levees was quite extensive, and many other types of flood control were discussed. The Transactions of the American Society of Civil Engineers contain many debates and discussions of levees and alternatives to them. Some writers, such as Robert McMath (1884), attempted to demonstrate that the very theory behind levees was inherently faulty and the levees thus destined to failure. Others merely argued the feasibility of supplementing levees with other devices, such as outlets and reservoirs. One writer even advocates constructing a secondary stream on the western edge of the alluvium to decrease the total volume of water to be carried by the Mississippi. This may be a rather unusual suggestion, but it indicates the range of alternatives being actively considered. Any reader interested in the general feeling of these debates would be well-advised to read "The Levee Theory on the Mississippi: An Informal Discussion", Transactions of the ASCE (1903). These alternatives to levees were not accepted by the MRC and levee proponents at that time, but many points raised in the debate were ultimately utilized for flood control. For example, as early as 1882 emergency outlets to decrease dangerous flood heights were suggested. The Bonnet Carre spillway presently operates on this principle. As the years progressed the

focus of the MRC expanded from primarily navigation improvement to include flood control as a major part of its work. It was eventually conceded that the levees' influences on the navigation channel were only slight, but the passage of the first flood control act in 1917 finally permitted the MRC to build levees just for flood control. The act also made changes in the financing of the levees by stating that Federal funds would pay two-thirds while local interest would pay one-third of construction costs, as well as provide the right-of-ways and assume maintenance after completion. Levees constructed entirely by local interests were not prohibited. Although retarded a bit by World War I, the levee building progressed until almost the entire line met MRC standards and the remaining gaps were closed. The successful high-water fight of 1922 brought increased optimism to the Valley about flood control. This optimism was not totally shared by the people intimately involved in flood control. Those constructing levees recognized the great danger still posed by caving banks and pressed for more bank protection. They also realized that floods greater than 1922 could occur and that another raising of levee elevations was required. Others, such as the City Engineer of New Orleans, felt that levees alone were inadequate and should be supplemented with spillways. Throughout this period, the MRC continued its "levees only" policy, but other flood control agencies were considering alternatives. In 1924 the Chief of Engineers, Gen. Lansing Beach, stated:

"It is to be expected that in the future, as in the past, various alternative plans will be urged for achieving the results desired... All these proposals have been investigated and reported on time and again. However, with the growth of the art of engineering, plans which were not practicable in the past may become feasible in the future,

and the Engineer Corps will maintain an open mind in the investigation of any reasonable means for river control that are presented by responsible organizations or able engineers."

The MRC claimed no less a willingness to listen. In the words of its president:

"The Commission is often criticized because it does not hasten to adopt suggestions made to it. People think it so committed to archaic ideas that it will not accept suggestions from the outside--is unwilling to admit that anyone from the outside can tell it anything. On the contrary, it is glad to hear any suggestion. But when a man comes in with the same old thing that has been considered, possibly tried and discarded--nothing new about it except a name--the Commission cannot go all over the ground again. The public is loath to give credit for the amount of thought the Commission has put on river problems--thinks it obstinate when it adheres to principles that have been proven by forty-five years of careful study and observation."

The MRC showed its continuing faith in these proven principles when it considered a proposal for a spillway below New Orleans leading to Lake Borgne. With the aid of Gen. Beach, a group of New Orleans businessmen and professionals had submitted a detailed plan, but after considering it, the MRC replied that, with only the slight reduction in stage, the lengthening of levee lines, and the negative effects on the river by the spillway, "it would be wise first to make the city safe by tried methods which are wholly feasible and much cheaper. The confidence of the MRC in "levees only" and the security felt by the valley inhabitants were shattered by the extraordinary flood of 1927. For the first time, completed levees built to the existing MRC grades were overtopped and crevassed. It was called "the greatest disaster of peace times in our history," by Secretary of Commerce, Herbert Hoover. It killed at least 246 people and left 700,000 homeless while creating over \$400,000,000 in losses and damages. The magnitude of the flood and the resulting national attention forced a

total review of the existing system of flood control. Congressmen were beseeched to act with passionate appeals, such as that of Rep. Gregory of Kentucky:

"Mr. Chairman and gentlemen of the Committee, those of you who just a year ago witnessed the mad rush of the mighty Father of Waters, sweeping like a destroying angel over hundreds of proud cities, thousands of happy and contented homes, and millions of fertile fields, or who later visited the stricken area to view the scenes of the greatest peace-time disaster this country has ever experienced, know how futile would be the effort of the most gifted tongue or the most facile pen to describe the wreckage and the ruin, the horror and the agony which were left in the wake of the 1927 flood."

Long Congressional hearings were held and detailed plans for flood control were submitted by both the MRC and the Chief of Engineers, General Jadwin. What is striking about the new proposals is the universal agreement that levees alone were incapable of providing the necessary protection. The MRC was strongly criticized by the House Committee on Flood Control for its strict adherence to the "levees only" policy, and in its own new plan, levees were to be supplemented by floodways, including a spillway to Lake Borgne. A similar system was proposed by Jadwin, but while both plans urged the raising and strengthening of the levees, they included different floodways. Jadwin recommended building a levee about five miles back from the river running from Bird's Point, Missouri, opposite Cairo, Illinois, to New Madrid, Mo. The area between the levees would be flooded during great floods, dropping flood stages at Cairo. Similar floodways were proposed to conduct extra water down the Boeuf Basin and the Atchafalaya. These floodways would be activated by an untried device, a fuse-plug levee, which raised great controversy. The principle involved the construction of a section of the riverside levee, deliberately smaller in grade and section. This section would crevasse

naturally at a certain stage, allowing water into or out of the floodway. The final feature of the Jadwin plan was a spillway at Bonnet Carre to let flood waters into Lake Pontchartain. The MRC plan extended the levees up to Rock Island, Ill., and also provided for the Boeuf and Atchafalaya floodways, but none in Missouri. Instead of fuse-plug levees, entrance to these areas would be controlled by concrete spillways. Two spillways would also be built to protect New Orleans, one above at Bonnet Carre and one below at Caernarvon. The most hotly debated issue in Congress was not which engineering plan to accept, but whether local concerns should help pay for the chosen program. The economic devastation of the area raised the question of how much the people in the Valley, who already helped raise the former levees, could now pay. Some, like the President, felt that it would be wrong for the Government to pay the full expense of improvements which would make the protected lands more valuable. Others, like Congressman Reid, head of the House Committee on Flood Control, viewed the situation as follows:

"Under the present law the United States says to the threatened ones, 'No pay, no protection'....Is our civilization so little removed from barbarism that it will permit hundreds to be drowned and thousands to be made homeless and destitute while, like Shylock, it demands its pound of flesh from those who cannot pay?"

Finally, in 1928 Congress responded to the disaster of 1927 by making the control of the Mississippi a national project. The MRC was reorganized to be a consulting and advisory board under the Chief of Engineers and the Corps of Engineers took over the actual construction work. A board was appointed to examine the two proposed plans and to recommend a comprehensive project; the Jadwin plan ultimately was accepted. Perhaps the most important aspect of the new project

was the assumption of the whole cost of construction by the Federal Government. The local interests were still to provide the right-of-ways for the levees free of charge and to maintain them, but, while Congress reaffirmed the principle of those protected helping to pay, it declared that the "approximately \$292,000,000 heretofore made by the local interests" fulfilled the requirement. The direct descendant of the 1928 plan is the present system for flood control. What is interesting is that the old controversy over "Dispersion Theory" and "Concentration Theory" was superseded by the use of both principles in controlling the river. It was no longer a case of levee proponents on one side, with supporters of everything else on the other, but a situation where each suggestion was discussed on its own merits. In such an atmosphere the present system came to include outlets and reservoirs. Ironically, even the river itself suggested the adoption of what earlier writers saw as the greatest evil--artificial cutoffs. In 1929, despite all preventive efforts, the Mississippi eroded its banks until it intersected the Big Black River tributary, two miles above the latter's mouth. Over a period of years, the Mississippi's current transferred to the new channel without causing the drastic regime changes attributed to cutoffs. This prompted the making of a series of artificial cutoffs in the middle section of the river by the Corps of Engineers. These cutoffs substantially reduced the floods heights at Memphis and Natchez and permitted the elimination of the Boeuf Floodway from the flood control plan. In reaching the present situation, there has been a gradual assumption by higher authorities of the responsibility for the river, forced by the magnitude of the task of controlling the floods. Finally, the Federal

government assumed partial interest, and ultimately total responsibility, for levee construction. Each shift of responsibility came as the existing authority could no longer build levees that were sufficient to protect the lands. It was this last consideration that underlines the entire history of the levees, for, regardless of who had responsibility for them, the basic premise for their construction remained unchanged: levees are absolutely necessary if cultivated and inhabited land is to be protected. The early French believed this and each succeeding generation has continued the use of levees despite disastrous crevasses and floods and great expense. Levees do keep the river from naturally depositing its sediment on the floodplain, rejuvenating the land, but such extensive flooding and inhabitation of the floodplain are two incompatible states. A choice has been made, not only by the present generation, but by the first settlers and each succeeding generation. The increase in flood heights, although not always anticipated, has been accepted as a consequence of being able to live and utilize the Mississippi floodplain.

G. Conclusions

The inventories presented as appendices will aid in evaluation of the effectiveness of past engineering activities related to development and control of the Mississippi River. Such inventories may aid in anticipation of the effects of future engineering activities. Several problems encountered in preparing this inventory should be considered in light of the possibility that continued interest on this subject will prevail. First, the volume of data to be processed required considerable effort. Second, the variation in records or consistency

of data between Districts caused problems in tabulation. For example, revetment data in the St. Louis District had to be tabulated with a different format. Third, loss and destruction of records was a problem.