

Reprint. "Taming the Mississippi" June, 1927

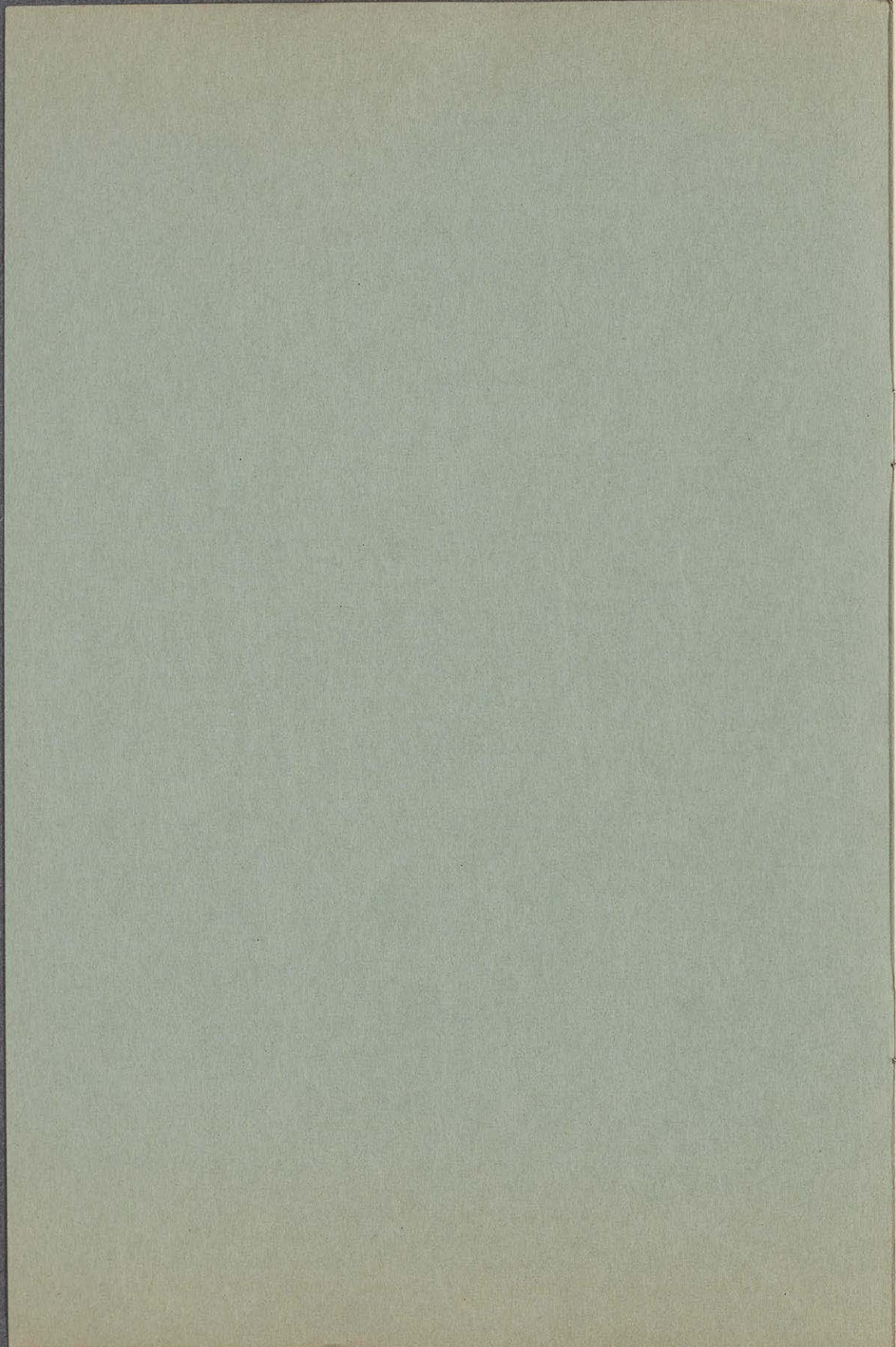
J.R. FREEMAN - MC 51

# Taming the Mississippi

By

JOHN R. FREEMAN C.E.

*(Reprinted from The Outlook of June 8 and 15)*



# Taming the Mississippi

By JOHN R. FREEMAN, C.E.

TO one who appreciates the magnitude of the forces at work there is no more thrilling sight in the world than the mighty Mississippi at the full height of a great flood, almost anywhere between Memphis and New Orleans—a mile in width, a hundred feet in depth, boiling and swirling along with a current of five miles per hour, and with water surface only a foot or two below the top of the levees, threatening at a hundred places in its 1,500 miles of levee line a crevasse which may drive thousands from their homes for one or two months, and cause damages amounting to many millions of dollars.

After all that can be done by completing levees to full height all along, the danger of a great inundation once or twice in every forty years will always remain and this danger should be made plain and prepared for by all who live behind these levees.

While the flood of 1922, which brought the highest water ever known at many points until the present flood, was nearly at full height the writer inspected many miles of levees near Memphis, Greenville, Vicksburg, Baton Rouge, and New Orleans and studied the two great crevasses of that year in full flow. He had long been interested in the flood problems of American rivers and had studied those of "China's Sorrow"—the Hwangho—on the ground, and has taken great interest in following the story of the recent disasters and their lessons.

## *The Bright Side of the Picture*

WHILE the newspapers are daily carrying new stories of the widespread disaster along the lower Mississippi, telling of fourteen thousand square miles of land flooded, of three hundred thousand people driven from their homes, of the break at Stopps Landing which has inundated much of the east side district around Greenville,

I will not dwell on this picture of disaster, but turn to the examples of successful resistance of the flood by levees.

Almost nothing is being said about the bright side of the picture and the wonderfully good record of steadfastness that is being made for about six hundred miles of east side levees between Cairo and the Gulf, and several hundred miles of west side levees, opposite and below Baton Rouge, which are protecting many thousands of homes and many hundred thousand acres of fertile land. There was imminent danger of failure upstream from Greenville in the flood of 1922, near where the recent great breaks have occurred. The writer then inspected many miles of dikes upstream to Stopps Landing and found examples of dangerous percolation, of sand boils, of scant thickness and scant height, and wonders if these had been raised or thickened within the past five years.

Notwithstanding the disastrous failures it is well worth while to study the facts of successful resistance. True, the breadth and total area of low bottomlands is much smaller on the east side of the Mississippi than on the west side, but the lessons of the success of the east bank levees in the present flood and of the greater success of levees on both sides in the great flood of 1922 are more important than the lessons drawn from failures, because they prove the benefits of a levee system and clearly point the way toward a future success of, say, ninety-five per cent, when all levees are completed to the prescribed height.

In this flooding of vast areas there is nothing new. No longer than forty years ago nearly all of the vast areas of bottomlands on both sides of the river, more than 25,000 square miles in extent, were covered by every great flood, whereas in 1922, with floods higher at Vicksburg than ever before known, there was only a single break in the 1,500

miles of levee on both sides of the river. True, other crevasses were imminent at Old Tom, Tunica, Stopps Landing, and elsewhere, but these were restrained by prompt and mighty efforts.

There were 712 crevasses in 1882-83-84, when most of the great river basins had only fragmentary levees, and practically all lands behind the levees were flooded. In the old days, most of the residents kept boats in readiness for retreat if surrounded by the slowly rising flood or the more rapid rise from a crevasse. In 1912 there were about 15 crevasses in the main river levees, flooding only about thirty per cent of the territory dependent on them. In the greater flood of 1913 only about half as many breaks occurred as in the previous year, and in 1916, only one break of major consequence. In the great flood of 1922, the progress in perfecting the levee system had been such that from Cairo to New Orleans, a distance of 969 miles by river, comprising more than 1,500 miles in length of levees, with flood heights higher than ever before recorded, only one break occurred, flooding less than one per cent of the entire area. The Poydras break of 1922 was below New Orleans and its inundation was upon land mostly of small value and relatively small in area.

The long and bitter controversy of twenty to forty years ago must now be considered as settled in favor of the levee system so completely that if a vote could be taken among those best informed living up and down the Valley, probably it would be ten to one in favor of the levee system. The old argument that, with floods and sediment confined between levees, the river-bed would continually be raised and that because of the rising river-bed levees would continuously have to be built higher, has no proof to support it, and the few soundings available for comparisons of difference in bed elevations of forty years ago with those of recent times show no important change.

That the sediment of a widespread flood brings fertility to the land, cannot

be doubted, but these bottom-lands contain such a store of fertility from the floods and sediments of countless ages, that restoration by this means is far less to be desired than the protection of levees. Whenever enrichment by this means is desired, flood water can be admitted under control and its spread controlled by small dikes, as has been done at some places in China; unless many years hence the flood plain of the river becomes ultimately lowered by scour of the swift, deep flow concentrated between the levees.

There can no longer be doubt that the levees all along the Mississippi and its tributaries below Cairo, should be completed with all practicable speed, up to the latest revised height and thickness specified by the Mississippi River Commission. This work was said to be five-sixths done by the former standards, but perhaps now the standard section will be raised.

### *A Complete Levee System Not a Complete Protection*

WITH the levees completed to the full height great flood dangers will still remain. The problem of holding this meandering river to its course, so as to prevent its attack from undermining levees, is a far more difficult, far more slow, and far more expensive matter than all of the levee construction involved from beginning to end.

The accepted methods of restraining the river from undermining levees and threatening farms or populous cities with inundation, by holding it back by revetment of these banks with mattresses composed of interwoven willow trees, wires, and slabs of concrete, cost at a rate of nearly one-third of a million dollars per mile of shore line. At the rate of construction of the past twenty years, two hundred years would be required to protect all of the shore line, and beyond this cost of original construction would be added many millions of dollars per year for its maintenance. Work of this kind cannot be largely hurried without

extravagant cost, because of lack of willow mattress material and other reasons.

*It is not yet certain that this method of mattress revetment is the best and most economical method that can be worked out for holding this restless river to a permanent pathway; nor is it certain that the river should everywhere be held to its present crooked path.*

Levees costing fifty million dollars plus revetments costing four hundred million dollars more, would not be a perfect or permanent remedy, and yearly maintenance costs will be enormous. The facts should be collected and looked squarely in the face.

The threatened crevasse at Old Town, Arkansas, in 1922, began apparently with the tearing out of a section of mattress revetment by the high flood.

### *Progress, Past and Future*

THE studies, experiments, and constructions of the past seventy years have produced many admirable results, have safeguarded the waterfronts of important cities, have provided a safe channel in which great ocean freighters can enter the river at all times and proceed rapidly up to New Orleans or as far as the great oil refineries at Baton Rouge. Levee sections have been developed that have afforded protection to ninety per cent of all of the cultivated bottom-lands, which a few years ago were covered by each flood. A more or less stable channel across the bars, nine feet in depth by two hundred and fifty feet in width, has been provided up river as far as St. Louis, and a successful beginning has been made upon barge transportation over this distance.

After all of this, there now opens up to view a chain of important problems of greater service by the river and of more complete control and a higher degree of safety, which require *a far more intensive and far more scientific study of many factors than has been given to the problems presented by this great river in the past.*

The best permanent success for a long future requires a new departure and a broader outlook and more profound study of many separate factors. All of this may require ten years of investigation, but during this time, levee building need not wait.

Observations and many experiments are needed along the river, and in the field, upon methods of erosion and sediment action, upon the facts of change in depth by scour, on the conditions controlling scour and deposit in flood and in drought, on the composition and origin of gravel bars, on the method of transportation of material thrown into the current by caving banks; *all of which field work should be supplemented by experimental work in a hydraulic laboratory*, similar to those which have been developed abroad, particularly in Germany (the "Wasserbau Laboratorien" or river-building laboratories) during the past twenty years.

### *The Hydraulic Laboratory*

THE hydraulic laboratory is but one of the many means that should be used in these studies, but it is one of very great and fundamental importance. The laboratory would be used first to separate the various elements in the problem out for study, rather than to attempt the duplication of river conditions in a model of a broad reach of the whole river upon a small scale. The logical procedure would be that of trying parallel methods in field and laboratory and to begin with small river sections of the tributaries (for example, those of the Missouri or the Arkansas), and proceed by slow, safe steps from smaller to larger problems, until finally problems of the greatest magnitude could be taken from out-of-doors into the laboratory, and the line of successful attack in the riverbed could be reliably indicated by results upon small scale models in the laboratory. These European river laboratories have been doing wonderfully good work and effecting marvelous econ-

omies in time and cost of river improvement.

### *Need of a Long View Ahead*

THE problems of the future, which a broader outlook now present, include those of far greater use for navigation than at present, of safe, deep permanent channels such that large ships may proceed much further upstream, of far greater reclamation of swamp lands for agriculture, of far better protection for the farmers, their homes, and their domestic animals. Also, there are difficult problems of outstanding importance relating to temporary or permanent spillways below New Orleans and an adjustable spillway at the old confluence of the Mississippi and the Atchafalaya. There are vast difficulties and costly problems presented of retaining this wonderfully crooked river from changing its course through the broad delta, so that it will neither eat its way through the heart of a prosperous city, nor leave the city far removed from its present waterfront.

In the remote, dim distance there are speculative possibilities of training the river, while causing it to dig its own channel deeper, or lessening the caving of banks and of causing the river to transport its burden of sediment to the sea, so as to establish its future flood height at a much lower level; *possibly below that of the general surface of the bottom-land*, for all that portion of the river between Vicksburg, Mississippi, and Keokuk, Iowa, so that levees would no longer be a necessity; and it is not beyond the proper limit of dreams to consider the feasibility of restraining-dams, locks, and power-drops, along the straightened course, from which thousands of horse power could be developed.

### *Impracticable Proposals for Flood Relief*

AT this point it may be of interest to say a few words about some of the many projects of flood prevention which are put forward after each great flood:

1. *Reforestation*—This plainly is im-

practicable—the greater part of this drainage area within regions of large rainfall, not now forest-covered and upon which forests would grow, are far more valuable in farms than in forests.

2. *Reservoirs on Head Waters*—The great floods do not originate on drainage tributary to the headwaters. The possible reservoir sites are manifestly insufficient, and moreover, the experiment was tried on a large scale many years ago by building a few vast shallow reservoirs in Minnesota, and all thought of further construction abandoned after the futility of such reservoirs had been demonstrated. These were expected to both retain flood-water and aid in navigation in the Upper Mississippi by release of water in the dry season, but their effect was found practically unnoticeable below Lake Pepin. Uses for flood prevention and for dry season water supply conflict. A reservoir for flood detention should normally be kept empty. One for dry season water supply should be kept always as full as practicable.

3. *Detention Reservoirs in the St. Francis and other basins below Cairo*—These were given much discussion many years ago. Surveys prove the storage space available would be insufficient. Moreover, the land is more valuable for reclamation, and meanwhile levees have been proved mostly successful, so that such vast, costly reservoirs are found to be both unnecessary and impracticable.

4. *Spillways*—The spillway idea received a great impetus in the flood of 1922, when the natural crevasse at Poydras apparently lowered the flood height at New Orleans, ten miles up-stream from Poydras, by two feet; and it has received new support by the recent (May, 1927) dynamiting of the levee at Caernarvon, a little down-stream from Poydras, which appears to be now holding the New Orleans flood level below the danger point. Had one known that they were coming the recent breaks on the west side would have made this costly breach at Caernarvon unnecessary.

The chief objections to permanent controlled spillway sluices at this point are possible injury to navigation channels that may be caused by diminished power for the scour and transportation of sediment in the main channel, and the uncertainty of maintaining with safety the outflow channel from the spillway.

There are better possibilities for a spillway here at Caernarvon or at Poydras than farther up-stream, due to small value of land flooded by the breach, but it is open to question if it is not better to rely on the possibility of an artificial temporary breach, like the present, in rare emergencies—perhaps, once in twenty-five years—rather than incur the vast expense of permanent sills, sluices, and safe discharge channels.

Also there are possibilities for an emergency spillway opening into the Atchafalaya that are well worthy of thorough investigation, because of the much shorter, straighter channel thence to the Gulf, and its position up-stream from New Orleans and Baton Rouge. Extensive research would be needed all along the Atchafalaya, and with this, or any other spillway, the possible effect in shoaling the navigation channel under the lessened velocity must be more carefully studied in the light of far more data than now available.

After all that is practicable has been done (unless the remote hope of lowering the river-bed by flood scour materializes), whoever settles on these fertile lands *should recognize that he is taking chances*, and should, like the earlier settlers, always be ready for an emergency.

#### 5. *Safety Mounds.*<sup>1</sup>—The building of

<sup>1</sup>Such mounds should be built all through the lower Mississippi bottom-lands which are behind levees that may be ruptured, at intervals of a mile along all main highways, each rising to a height of perhaps four feet above the flood profile and having an area perhaps fifty feet by one hundred feet, intended to serve as a refuge for the residents of the neighborhood and their live stock. It would be wise to place each farmhouse, and a shelter for cattle, upon such a small mound. Naturally these mounds would be placed some distance back from the main levee and their banks below the permanent water level could be protected by a crude, wooden sheet-piling surmounted by a thin concrete paving upon the slopes, sufficient to resist the moderate currents that may be expected over the flooded lands.

small islands of safety at frequent intervals along all main highways over the bottom-lands and within the broad delta gives such promise that these are worthy of most careful investigation. The writer has seen many of these islands of safety in China, each rising a few feet above flood level; some only large enough to hold the farm buildings and give narrow yardage for domestic animals, and others large enough to contain a small village. It is said that along the coasts of Holland, Friesland, and Northwestern Germany many mounds of this character were built centuries ago by the farmers, who placed their homes upon them to give safety during storm-tides from the sea, and that later on some of the present great dyke systems were formed by joining these ancient mounds.

These mounds seem to be well worth their cost because of the risks of crevasses occurring in future as described in next week's article.

### *Quick Recovery*

THE floods drain off and their effects disappear in surprisingly short order after the river recedes to the so-called "bank-full stage." The planting is delayed, the year's product lessened and in rare cases it is almost wholly lost. A few months after the flood of 1922, the writer traveled more than twenty miles over the ground, near Ferriday, which he had seen covered with apparent ruin, and was astonished at the small evidence of disaster left. Crops were growing finely, and the rate and amount of recuperation almost beyond belief.

The houses and farm buildings throughout most of these flooded areas, so far as the writer has had opportunity to observe, are seldom of an expensive character, save in the sugar plantation districts; in fact, a frequent impression in many places between Memphis and Vicksburg is of occupancy by tenant farmers who remain pitifully poor, while owners and lessors live safe on high ground in the neighboring cities. Perhaps other localities, as in the Acadian



settlements, may be different. To make certain of such mounds or islands of safety, as described above, they would have to be built by and at the cost of the levee district, best perhaps, as appurtenances to the highways.

### *Dangers to Completed Levees*

COMPLETING the levees does not finish the job of safeguarding the farmers. There is far more in these Mississippi problems than the building of levees to the full height and thickness prescribed by the Mississippi River Commission. Such levees, projecting three feet above the highest flood, may be breached over night from either one of several causes:

1. By "sand-boil" enlargement, caused by water percolating beneath the levee with increased rapidity as the flood rises, through hidden porous strata of sand or gravel left by an ancient river channel across which the levee has to be built.

2. By an unexpected sudden caving in of the fore-shore, where a chance deflection of current caused, perhaps, by a water-logged tree, or by a deep collection of snags, or perhaps by one of those mysterious eddies, whirlpools, or "boils" that result from the contact and momentum of opposing currents. This caving often begins without warning, sometimes in seemingly sheltered covers or along back channels, by undercutting near the bottom, followed by a toppling over or slumping near the top, section after section, each five or ten feet thick, rapidly eating its way back towards the levee.

3. By rapidly increasing percolation through the levee itself under the flood-head. This is found at many localities where levees have been constructed of porous material (perhaps the best available), or constructed without sufficient tamping, or solidification by time. After a few days of flood-height, the percolating water softens the in-shore slope of the levee, while myriads of little streams trickle down its surface and threaten its immediate collapse.

4. The dangerous burrowing of the crawfish beneath the levee has to be reckoned with.

The writer saw frightful examples of all of these causes of failure in the course of an inspection tour along many miles of representative levees while the flood of 1922 was near its full height, and so much emphasis has recently been put upon the immediate completion of levees to their full height, as if it were the sole and sufficient means of salvation, that it is well to emphasize some of these dangers that will remain after the levees are completed.

(a) At Stanton Plantation, on the west shore, eight miles below New Orleans. No one expected danger in this locality, sheltered behind a promontory and by a dense grove of trees along the fore-shore, until a little girl, looking from a second-story window in her home back of the levee, saw a large tree slump out of sight, and then another; whereupon the alarm was spread. The deep river current apparently had taken a new freaky turn toward the shore and undercut the bottom of the slope, so that the bank above was gradually sloughing off in slices, five or ten feet in thickness, and threatening the destruction of the levee, although this was abundantly high. Men and teams were hurriedly brought to the danger-point and started at building a second line of defense in form of a new loop of levee, perhaps a thousand feet long, and a few hundred feet back of the original line.

(b) At the Weecama Crevasse, upstream from Ferriday, about twelve miles up from Natchez on the opposite side, the writer inspected a crevasse in full flow, more than one-fourth mile in width of breach, with the back country four to six feet under water as far as the eye could see in every direction. A few natives and their live stock were still huddled at the end of the levee, which was plenty high above flood-level.

The story told by several was that the break came unexpectedly in the night, probably from percolation through porous strata beneath the levee. Some said

a woman had noted a big "sand-boil" just prior to the general wide-spreading crevasse. This location also was on an old abandoned channel sheltered from the direct impact of the main river current.

(c) Near Tunica, below Memphis, Mr. W. H. Dabney, the experienced levee engineer who led the successful fight against the breach of the levee by caving banks, told a thrilling story, pointing out on the ground how they combated the unexpected attack of the river at the "Devil's Hole," located on a back channel shielded from the main current by dense groves of willows, but where a new inflow from up-stream started an eddy that undercut the bank. An alarm was spread, plantation bells were rung, laborers were hurried in from ten miles around, who filled the grain sacks with sand, tied them to ropes forming so-called "snakes" which they rolled over the top of the caving banks while building a deflecting pier to ward off the current.

(d) At Poydras Crevasse, about ten miles below New Orleans, the breach grew to nearly half a mile in width. The levees here were abundantly high, and nothing was apparent in the location to suggest special danger. Nevertheless, undercutting and sloughing banks made a breach which widened rapidly and soon discharged a flow larger than that of the St. Lawrence River, which lessened the flood-height at New Orleans by about two feet.

(e) Near Milliken's Bend, and elsewhere, the writer inspected danger spots where percolation through levees that presumably had been constructed from pervious or poorly packed material had so softened the in-shore slopes that they were almost alive with trickling streams. These slopes had been covered with a loose mat of freshly cut brushwood to prevent gulying, with sand-bags on top of much of the brushwood. Also along this reach many threatening sand-boils were seen which had been successfully "hooped" by sand-bag cofferdams, whereby the head causing the flow

through them was lessened and the impending crevasse prevented.

The above instances have been cited to prove that *compliance with the present loud call for extending levees everywhere to the full height and thickness of the Mississippi River Commission specifications will not remove all danger of a sudden break at the height of a flood as great as that of 1913, 1922, or 1927.*

Had the Tunica Crevasse, far back from the main river, not been stopped by prompt and mighty effort, the vast Yazoo Valley would have been flooded in 1922.

### *Peculiar to Itself*

THE Mississippi presents problems on a scale found nowhere else in the world, unless it be along the Hwangho in China, or on some of the great rivers of India. Experience gained in flood protection works along the great rivers of Europe is applicable only in small degree to conditions found along the Mississippi. These European rivers present far smaller volumes of flood-flow, far smaller flood-heights, and their beds are mostly through relatively narrow valleys, over beds composed of glacial drift, which is far less subject to erosion than the deep, soft, alluvial deposits through which the Mississippi and its main tributaries wind their devious, uncertain way.

The sediments of the European rivers comprise coarse gravels and sand-grains of far greater size than the almost impalpable mass of which the Mississippi River sediment is mostly composed. Therefore, while much can be learned from the successes and failures of European practice, and from the laws of sedimentation, transportation, and scour developed in European laboratories, much original scientific investigation must be carried on here to reasonably cover these different American conditions.

The Mississippi, for the lower 500 miles of its course, flows through a broad delta more than 100 miles wide at Greenville and over 40 miles wide

at Vicksburg, over sedimentary deposits of depths largely unknown. Probably there is nowhere less than 200 feet of soft silt, mud, or clay beneath the channel bed, with here and there irregular deposits of gravel. Conditions of transportation and deposit of silt, sand, and gravel in any one particular locality has varied in the course of many thousands of years while the river has shifted its channel back and forth across the delta. In general, the sand grains in the bed of the river below Cairo are seldom so large as the one-hundredth part of an inch in diameter. More often they are only one one-thousandth of an inch, and are interspersed with a variable amount of colloidal matter of still finer grain which, to some extent, binds the whole mass together so as to resist erosion. Gravels, mostly of small sizes, have been rolled in, along beds of tributaries chiefly at flood time, and sorted out by the current from caving banks, so that they form a small but extremely important percentage of the whole mass; because it is these gravels, along with the coarser sand-grains that, rolling along in the course of ages, have become concentrated and gathered together so as to form the bars at the cross-overs between the bends, which gravel-bars resist deep-cutting by the flood currents, and form submerged, slowly shifting dams between the deep pools in the river bends. The strange fact is well proved that one of the first acts of a Mississippi flood is to gather up or roll along the scattered pebbles from the pools by the quickened flood velocity and drop them on the cross-over bars, where in flood time the velocity of water is less because of their greater width at the flood level, thereby increasing the height of the flood by a foot or more. The height of surface corresponding to a stated flow in cubic feet per second is higher after a flood than before. Subsequently the gravel on the crest of the bar is slowly moved down-river into the next pool, and the bars very slowly travel downstream.

The soil physics of the river-bed, and

its constitution, are yet largely unknown, but *these unknown factors may hold the key to possibilities of most profound changes in future methods of controlling the shape and course of the main river channel.* This subject of the sediments, their physics, geologic or physiographic origin, their cementation, erosion, and behavior against currents of various velocities, alone might keep a large hydraulic laboratory and its attendant field party busy for five or ten years, and finally produce results of incalculable value. This study of sediments should apply also to the lower reaches of the great tributaries, the Missouri, Arkansas, St. Francis, the Yazoo, the Tensas, the White, the Black, and the Red River, and to the Atchafalaya.

### *A Far Greater Ancient River*

FOR hundreds of miles along the upper reaches of the Mississippi above St. Louis, the high bluffs on both sides of the river, varying from two miles to five miles apart, give evidence of an ancient river in pre-glacial times that was far more magnificent in width, depth, and volume, than the present river; which as it shrunk in volume during the disappearance of the northern continental ice cap, and subsequent to the diversion to the eastward of the waters that now form the St. Lawrence, refilled its ancient bed with sediments to the depth of about 200 feet and shrunk in width so as to occupy only a fraction of its ancient channel. Perhaps the gravels which are now found in caving banks and in cross-over bars were transported to their present locality, in part, by the more powerful current of this ancient river. Study of the origin of the particles that form these gravel bars by competent geologists would be of much interest, and might be one of the many aids in establishing better future methods of regulation.

At Keokuk, Iowa, fortunately for power development, ancient glaciers from the northwest pushed the location of the modern river to the eastward,

over ledges at a higher level which in due course produced the present rapids and provided the excellent foundation for lock and power development; but for all of the remaining distance downstream to the Gulf of Mexico, so far as known, there lies beneath the river-bed 200 feet or more in depth of sediment, mostly fine and soft, interspersed here and there with lenses of gravel, except for a space near Commerce, Missouri.

The main river and its lower tributaries all flow mainly over unstable material, and have meandered through countless ages back and forth across the delta, leaving old bayous and old concentrations of sand and gravel into pervious beds, so that foundations for levees vary greatly in stability and imperviousness. Nevertheless *it is on these uncertain foundations that levees must be built*, and in many places they must of necessity be built out of material that the engineer would reject as unsuitable for an earth dam. Thought is thus forced to the possibility (probably beyond reach but nevertheless worthy of consideration) of *training the river to dig itself deeper* into its soft, deep bed, so that future flood-levels would come below the level of the broad bottom-lands, over which the floods do their damage.

The Mississippi is the crookedest great river in the world. It travels 868 miles from St. Louis to Natchez in covering a distance of 515 miles in a straight line. In many reaches of a hundred miles the length could be cut nearly in half. The lessened friction on a straight course would save nearly half of the actual drop of 379 feet between St. Louis and New Orleans. *If one could straighten the river and hold it to a straight course*, over only portions of its length, it is thus plain there would be plenty of vertical space available within which to lower both the river-bed and its flood-plain safely below the adjacent bottom-land, all the way from Vicksburg to Keokuk.

On the other hand, all engineers experienced in river control have been taught to fear a cut-off across a river

bend or "ox-bow" as second in danger only to a great flood crevasse, because of the under-cutting and caving at river bends which follows and may extend twenty miles more up the river by reason of the quickened current.

In a state of nature erosion is continually going on near the foot of the steep slope at the concave shore of each great river bend. The loop thus tends to become longer, and as length increases the resistance to flow increases, and finally natural forces attempt to shorten the distance by a short-cut across the narrowing neck of land left between one loop and the next down-stream in time of flood.

It has long been the settled policy of the engineers-in-charge to prevent these cut-offs and to hold the river always to its present curved channel, by building protective coverings of willow mattresses **over the places** where erosion is most active. The swift current, the great depth, the steepness of the submerged bank all make this a highly difficult and expensive operation, but one in which great technical skill has been developed. The weaving of a durable mattress is not only slow and costly but requires such quantities of willow trees that the supply becomes exhausted if more than a limited length is built in one year.

We have not space here to explain the foundations for a belief that by long-continued, patient investigation in field and laboratory, methods could be devised within reasonable limits of cost, by which after a time the river could be straightened and subsequently held to a straightened course, this under-cutting and caving of banks prevented, *and the flood-plain lowered so that future floods would hold no terrors* for the farmers who have been enticed to settle down on these ten million acres by the fertility of the land and the supposed safety of the levees.

### *The Function of the Hydraulic Laboratory*

**E**UROPEAN river and harbor engineers now are taking many of their prob-

lems of river and harbor improvement into the laboratory and being guided by experiments on small-scale models under mathematical theory pointed out by Sir Isaac Newton, but only developed and applied extensively during the past twenty or forty years.

Our American problems are largely different, but even those of the Mississippi and Missouri Rivers can be studied in the laboratory with great advantage.

Some of our American engineers who have scoffed at using this method with such a giant river apparently fail to grasp that the fundamental idea is not to make a little-scale model of the river in a long box and watch it perform while prodded or tickled in spots until perhaps one of the later stages of the proceedings. The idea is to take separate elements or factors of the great problem each by itself into the laboratory, discover the laws of sedimentation, of scour, of producing vortex motion by opposing currents, and thereby doubling the scouring velocity, etc. The writer believes that such a laboratory *in competent hands* could save the people of the United States more than a million dollars per year.

### *Levee Heights and the Rising or Falling River-Bed*

THE recent increase in flood-heights does not prove that the river-bed is rising, as was predicted by opponents of the levee plan. The best data available from soundings shows no important change in elevation of the river-bed.

The Commission's profile for levee height has wisely been an increasing one, in the interests of economy. Obviously confining the flood to a width of about one mile of main channel instead of permitting it to spread out over the old flood-plain of the bottom-land, ten to fifty miles or more in width, must gradually increase the flood-height, except as the concentration may scour the channel to greater depths. Obviously the recent flood would have risen to

greater heights except for release of large volumes through the broken levees.

We have as yet insufficient scientific data upon the increasing amount of scouring and deepening of the river-bed which goes on until the height of the flood is reached and the amount of refill that occurs as the flood goes down. The excuse given for this non-investigation is that the engineers are terribly busy in time of flood protecting the levees. The gravel-bars at the contra-flexures between the bends control the permanent height. The writer is inclined to agree with the views so strongly expressed by Captain Eads and which led to his retirement from the Mississippi River Commission, that one large part of the Mississippi problem is to determine the means by which the river can be made to cut its channel deeper through the gravel-bars at "cross-overs," and that a concentration and quickening of the current over the bars, to be obtained by contracting the width and by dredging, may prove a valuable aid, and dissipate much of the gravel composing these bars within the deeper water of the pools between the bars.

One of the greatest factors in deepening the channel over the bars would be the stopping the feeding-in of the fresh supplies of gravel that come from the caving banks—probably the finer-grained material is largely carried onward to the sea, while the gravel and coarser sands are in part carried along near the bottom until they join other deposits of like nature at the cross-over bar.

It is not generally known that for perhaps ninety-five per cent of its course the Mississippi is deep enough to take large ocean steamers up to St. Louis, and that the obstacles to navigation and to flow are largely on the narrow cross-over bars, five, ten, or twenty miles apart, with deep pools between.

The average depth from Natchez to St. Louis has been said to be over thirty feet, while the natural depth over the bars at low water is only five or six

feet save where channels nine feet deep are cut through by the Government dredges.

### *Questions of Policy*

IT is true that the present wide-spread destruction and suffering is the result largely of planters having been induced by prospective valuable crops from the rich and wonderfully fertile soil to purchase, clear off thickets of trees and canebrake, and cultivate lands in the river bottom which, until relatively a few years ago, were submerged in every great flood and correspondingly cheap.

Until within a few years past these lands were farmed in the full expectation of occasional flooding, while precautions were taken for the retreat of families and domestic animals to the higher ground during the flood season. It would be of interest to trace the development of the present idea that all of these vast areas should look so largely to the Federal Treasury for their safety; particularly since these bottom-lands are understood to have been ceded by the Federal Government to the several States in consideration of the State (or its legal subdivision) undertaking to bear the cost of reclaiming them. There have been great speculations and appreciations in value of land, increases from less than five dollars per acre to as much as fifty dollars per acre having followed the near-completion of the levee system, the cost of which has been in part assessed back on the lands, but not wholly so. The early levees were built solely at the expense of the planters; later levee districts were formed under authority of the States, with power to assess lands benefited, and later the Federal Government was called in, apparently on the theory that building levees would be an aid to navigation. The present Federal aid to reclamation of flooded land became established as a settled policy of the Government only eleven years ago. The Mississippi River Commission was not organized until 1879, and first of all, surveys had to be made of nearly 2,000

miles of river banks. Then followed many costly experiments on methods of channel control. There were long debates in Congress as to whether it was within Constitutional power of the Federal Government to assist in building levees. This was not settled until the Flood Control Act of 1916, which authorized the Commission to build levees upon the receipt of not less than one-third the cost involved from the levee districts concerned. It was not until the Act of 1923 that this authority was extended to the tributaries of the main stream which were affected by its flood-waters.

Also it would be interesting to trace the history of the change in interest of the Federal Government from control and improvement of the river for purposes of navigation, formerly its sole interest, to that of taking so costly a share in this vast project of safeguarding about 18,000,000 acres of farm lands; and to recent proposals that it expend vastly larger sums, chiefly for agricultural betterment, since the present interests of navigation within the river above Baton Rouge or New Orleans have so greatly declined that the total freight bill from Vicksburg and St. Louis would be an insignificant percentage of what the Federal Government expends per year along this section of the river in mattresses and levees.

Regardless of the causes by which this change has been brought about, it is now an assured fact that the problem of flood protection for the reclaimed farm lands along the Mississippi and its lower tributaries is now largely in the hands of the Federal Government. It has become the biggest and most costly reclamation project in the world.

Apparently no one has dared make a thorough estimate of total cost from start to finish, or to undertake an *intensive scientific study of the problems with a long view to the future*, or attempt to disentangle the proportion of costs strictly pertaining to navigation from those pertaining to reclaiming swamp lands and overflowed lands for agriculture.

