POTAMOLOGY INVESTIGATIONS

REPORT NO. 10-2

TURBULENCE IN THE MISSISSIPPI RIVER

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<table>
<thead>
<tr>
<th>Report No.</th>
<th>Title</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1</td>
<td>Instructions and Outline for Potamology Investigations</td>
<td>November 1947</td>
</tr>
<tr>
<td>1-2</td>
<td>Outline of Plans for the Potamology Investigations</td>
<td>December 1947</td>
</tr>
<tr>
<td>2-1</td>
<td>Preliminary Flume Tests of Mississippi River Revetment (1st Interim Report)</td>
<td>October 1947</td>
</tr>
<tr>
<td>2-2</td>
<td>Preliminary Tests of Mississippi River Dikes, Bank Stabilization Model</td>
<td>June 1950</td>
</tr>
<tr>
<td>3-1</td>
<td>Preliminary Laboratory Tests of Sand-Asphalt Revetment</td>
<td>July 1948</td>
</tr>
<tr>
<td>4-1</td>
<td>Investigation of 110-Volt Echo Sounder</td>
<td>July 1948</td>
</tr>
<tr>
<td>5-1</td>
<td>Geological Investigation of Reid Bedford Bend Caving Banks, Mississippi River</td>
<td>July 1947</td>
</tr>
<tr>
<td>5-2</td>
<td>Field Investigation of Reid Bedford Bend Revetment, Mississippi River (3 volumes)</td>
<td>June 1948</td>
</tr>
<tr>
<td>5-3</td>
<td>Reid Bedford Bend, Mississippi River, Triaxial Tests on Sands</td>
<td>May 1950</td>
</tr>
<tr>
<td>5-4</td>
<td>Piezometer Observations at Reid Bedford Bend and Indicated Seepage Forces</td>
<td>May 1950</td>
</tr>
<tr>
<td>5-5</td>
<td>Standard Penetration Tests, Reid Bedford Bend, Mississippi River</td>
<td>May 1950</td>
</tr>
<tr>
<td>5-6</td>
<td>Undisturbed Sand Sampling and Cone Sounding Tests, Reid Bedford Bend Revetment, Mississippi River</td>
<td>May 1950</td>
</tr>
<tr>
<td>8-1</td>
<td>Hardscrabble Bend, Mississippi River, Revetted Bank Failure, Soils Investigation</td>
<td>June 1950</td>
</tr>
<tr>
<td>10-1</td>
<td>Preliminary Development of Instruments for the Measurement of Hydraulic Forces Acting in a Turbulent Stream</td>
<td>June 1948</td>
</tr>
<tr>
<td>10-2</td>
<td>Turbulence in the Mississippi River</td>
<td>May 1950</td>
</tr>
<tr>
<td>10-3</td>
<td>Evaluation of Instruments for Turbulence Measurements, 1948-1949</td>
<td>Mar 1951</td>
</tr>
<tr>
<td>11-0</td>
<td>Resume of Conference Initiating Potamology Investigations, 11 February 1947</td>
<td>Feb 1947</td>
</tr>
<tr>
<td>11-2</td>
<td>Report of First Potamology Conference With Hydraulics Consultants, 9-10 December 1948</td>
<td>December 1948</td>
</tr>
<tr>
<td>11-3</td>
<td>Minutes of Conference on Soil Studies, Potamology Investigation, 18 April 1949</td>
<td>April 1949</td>
</tr>
<tr>
<td>11-5</td>
<td>Minutes of Conference With Soils Consultants, Stability of Mississippi River Banks, 5-8 October 1949</td>
<td>October 1949</td>
</tr>
<tr>
<td>11-6</td>
<td>Report of Conference on Potamology Investigations, 6-7 October 1949 (Volume 1, Volume 2*)</td>
<td>April 1951</td>
</tr>
<tr>
<td>11-7</td>
<td>Minutes of Conference On Soil Aspects of Potamology Program, 17-18 June 1950</td>
<td>October 1950</td>
</tr>
</tbody>
</table>

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CORPS OF ENGINEERS, U. S. ARMY

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TURBULENCE IN THE MISSISSIPPI RIVER

WATERWAYS EXPERIMENT STATION

VICKSBURG, MISSISSIPPI

13 MAY 1950
(REBOUND MAY 1951)
Preface

This report contains data which were prepared for presentation, as a paper, by Mr. J. B. Tiffany, Jr., Assistant Director, Waterways Experiment Station, Vicksburg, Mississippi, at the Midwestern Conference on Fluid Dynamics, University of Illinois, 13 May 1950. These data constitute a historical compendium of the development of the turbulence phase of the potamology investigations from its inception to May 1950; therefore, the paper has been included in the series of potamology investigations reports.
Synopsis

1. This paper describes the results obtained to date of a pioneer investigation being conducted by the Mississippi River Commission and the Waterways Experiment Station, Corps of Engineers, to measure turbulence in the Mississippi River. Included in the paper are descriptions of the development of instruments used for taking the measurements and of examples of the data, principally those obtained during the 1950 flood stages on the Mississippi River. The paper does not attempt a statistical and scientific analysis of the data, since there has not yet been time for such analysis, but outlines proposed continuations of the program which will include such analyses.

Previous Related Investigations

2. An excellent paper, "Relationship of the Statistical Theory of Turbulence to Hydraulics," by A. O. Kalinske, is contained in the 1940 Transactions of the American Society of Civil Engineers. This paper also contains references to several earlier papers on the theory of turbulence and on statistical methods for its analysis. Another paper by Mr. Kalinske, "The Role of Turbulence in River Hydraulics," is
contained in the Proceedings of the Second Hydraulics Conference, University of Iowa, June 1-4, 1942. In this paper Mr. Kalinske presents and analyzes data obtained on velocity fluctuations in the upper reaches of the Mississippi River. Those data are similar in many respects to some of the data described later in this paper.

3. In a paper, "Macroturbulence in Natural Stream Flow," by Gerard H. Matthes, included in the April 1947 issue of Transactions of the American Geophysical Union, Mr. Matthes catalogs and describes several classifications of macroturbulence phenomena in rivers.

4. Considerable laboratory work on the problem in question has been conducted in the Graduate School of the University of California, and is reported upon in the following two publications: "Hydrodynamic Forces Acting on the Surface Particles of the Stream Bed," by E. A. El-Samni (Ph. D. thesis, University of California, Department of Engineering, Berkeley, 1949); and "Hydrodynamic Forces on a Rough Wall," by Hans Albert Einstein and El-Sayed Ahmed El-Samni, Reviews of Modern Physics, vol 21, July 1949.

Scope of Program of Turbulence Measurements

5. The Mississippi River Commission and the Waterways Experiment Station, Corps of Engineers, for over three years have been conducting a comprehensive and intensive investigation of certain Mississippi River characteristics and phenomena considered fundamental to the carrying out of the Commission’s program of stabilizing the banks of the Mississippi River and securing and maintaining a 12-ft navigation channel. The
complete program includes: geological studies of critical areas; thorough soils investigations, both field and laboratory, and analyses thereof; comprehensive studies and reviews of such changes in the river itself as channel migrations, bank caving, bar building, sediment transport, variations in elevation in river bottom with changes in stage and discharge, etc.; and hydraulic investigations, both full-scale and laboratory. This paper is confined to a discussion of that part of the hydraulic investigation concerned with determining the magnitude of turbulence forces in the river.

6. At the outset, responsible engineers of the Mississippi River Commission and Waterways Experiment Station perceived that a knowledge of the magnitude of turbulence forces is necessary to a solution of the problem of stabilizing the banks of the Mississippi River. It was realized that turbulence is a significant factor in the following phenomena which enter into the problem, if not in others:

a. Transportation of bed load.

b. Transportation of suspended load.

c. Bank caving.

d. Bar building.

e. Major meandering and bend migration, resulting from a combination of the above factors.

f. Variations in elevation in river bottom with changes in stage and discharge.

After careful study, it was concluded that the investigation should include:

g. The direct measurements of pressure fluctuations (if any) at and near the bottom of the river, produced by turbulence.

h. Determination of the rate of transmittal of such pressure
fluctuations to the underside of existing or proposed types of revetments, as well as the rate of transmittal within the sand stratum composing the river bottom.

1. Measurement of velocity fluctuations, particularly at or near the bottom of the river (these measurements to be correlated if possible with the pressure measurements).

2. Instantaneous determinations of the directions of currents near the bottom of the river (these observations to be correlated if possible with the velocity and pressure measurements).

3. Determination of the spatial extent of the turbulence patterns, both vertically and horizontally. The practical reason for this phase of the investigation was to determine the extent of the area, horizontally and vertically, over which a given "block" of turbulence may act simultaneously. This factor is of obvious importance in determining which frequency of turbulence might be significant in affecting the design of underwater structures. It was believed that data relative to this question might be obtained by simultaneously recording velocities from several meters spaced at varying intervals horizontally and vertically. It was also hoped that pressure fluctuations on the bottom could be recorded simultaneously at one or several points.

**Turbulence Observations During 1948 and 1949**

7. Attempts were made during the 1948 and 1949 flood seasons to measure turbulence forces at a fixed location on a revetted bank at Reid Bedford Bend, about 5 miles south of Vicksburg, Miss. The 1948 observations were not satisfactory due to failure of the installed pressure cells to function after long submergence in the river. Nevertheless, one significant velocity measurement was obtained and is described below. The 1949 program was successful in that both significant pressure and velocity fluctuations were measured. Worth-while velocity measurements were also obtained from simultaneous records from four current meters suspended at various depths from a single cable, as described later in
this paper. In general, however, it was found that the shallow sub-
mergence of the pressure cells as compared with maximum depths of 100
ft or more farther out in the stream, in combination with the mild turbu-
ulence which was experienced at the site during the observations, produced
relatively minor pressure fluctuations. Similarly the average velocities
measured were small as compared with velocities elsewhere in the river.

8. During the 1948 high-water season, as mentioned above, one 3-
hour detailed velocity measurement was made, with a standard Price current
meter, from a boat used in making routine discharge measurements. These
observations were made on the Vicksburg discharge range immediately down-
stream from the Vicksburg bridge. During the 3-hour period of this
observation, the number of revolutions of the current meter was recorded
for each 1-minute period. Figure 1 is a plot of the velocity averages
computed from these data, and includes not only the fluctuations in the 1-
minute average velocities but a plot of the traveling 5-minute average
velocity and the mean velocity for the entire period.

9. Examination of this figure reveals several interesting periodic
fluctuations. First, there is some indication of a long cycle of approxi-
mately 2-1/2 to 3 hours, based on the general shape of the curve which
trends from highest values at the beginning of the period to the lowest
values just past midway, then back to high values near the end of the
observations. Superimposed on this long cycle there appears to be a
shorter cycle of approximately 20 minutes. Further superimposed is a
fairly regular cycle having approximately a 4-minute period. Had the
meter been read at intervals less than 1 minute, it is possible that
still shorter cycles might have been revealed.
10. The considerable variation in velocity over the 3-hour period of record is of interest in that velocities varied from a minimum of about 2.3 ft per second to a maximum of about 4.5 ft per second; the mean velocity for the entire observation was 3.3 ft per second, almost midway between the minimum and maximum.

11. Figure 2 shows the results of a 2-hour velocity observation taken during the 1949 high-water season, for which four meters were suspended on the same cable at different depths from the bottom, and includes: (a) plots of the average velocities on the four meters for the entire period, (b) plots of the computed average velocities for each 5-minute interval, and (c) plots of velocities during each 30-second interval. The latter plots are, of course, much more jagged in their characteristics in that the values shown represent velocities over shorter periods of time. A significantly close correlation is evident between the velocity fluctuations at various depths. It will be seen that both maximum and minimum values occurred almost simultaneously on the four meters. It is interesting to note that the 5-minute plots show evidence of an approximate 20-minute cycle from high through low and back to high values, and that the 30-second plots indicate a superimposed cycle averaging approximately 3 minutes. These tendencies are consistent with those noted on figure 1. It may also be noted that whereas the 5-minute average velocities varied only about 0.5 ft per second plus or minus from the mean velocity, the 30-second average velocity varied as much as 1.0 ft per second plus or minus.

12. Figure 3 shows a comparable velocity plot for 45 seconds during which the velocities for each revolution of the current meters were
computed. It will be noted that the frequency as well as the magnitude of the velocity changes is considerably greater, but that the velocity fluctuations on the four meters are again in close phase, in that the peaks and troughs generally occur at the same time throughout the vertical.

Development of Apparatus for 1950 Turbulence Observations

13. Although interesting and significant measurements had been obtained from the 1949 observations, it was concluded that both the pressure and velocity measurements were taken in depths where maximum turbulence could not be expected to occur. It was also concluded that any installation attached rigidly to the bank at one certain location, even if the installation could be made in deep enough water, would have only an accidental chance of being subjected to maximum turbulence. It was therefore concluded that the procedure must be changed to make it possible to obtain the measurements in deep water. Furthermore it was concluded that the observations should not be restricted to a fixed locality but rather that it should be made possible to take measurements where maximum turbulence was evident. The above criteria resolved the problem into one of designing apparatus which could be suspended from a boat or barge anchored in the river at any desired locality. It was apparent from the 1949 observations that the pressure cell and attendant recording apparatus were sufficiently well developed, and that it was only necessary to design and fabricate some sort of device which could contain one or more pressure cells with a velocity meter attached, and which could be handled in deep, swift water.

14. After careful study of this problem it was decided that a
disk-shaped device with some type of stabilizing rudders should be
developed for this purpose. It was recognized that the disk should be
so shaped that it would not itself cause turbulence nor otherwise dis-
tort the record obtained from a contained pressure cell.

15. The shape and assembly of the apparatus were developed in the
laboratory on a 1-to-8-scale model. Figure 4 shows the model instrument
as finally developed. The apparatus consists of a circular disk with a
rudder and stabilizer assembly. A 3-cable bridle suspension was found
necessary to handle the rig, the lengths of the cables being adjusted to
provide a slight forward rake to the disk. The edge of the disk was
formed to a 2-on-1 ellipse to minimize the effects of surface discon-

16. The full-scale disk is pictured in figure 5. This instrument,
which has been named the "hydrodynamic pulsimeter", consists of 2700-lb,
cast-iron disk 5 ft in diameter and 4 in. thick. Vertical and horizontal
stabilizers, designed from the small-scale tests, are provided for proper
orientation with the flow line. The over-all length of the instrument is
10 ft. In the center of the disk is a transformer-type, pressure-variation
cell for the measurement of pressure fluctuations on the surface of the
disk. Attached to and suspended immediately above the disk is a Price
current meter for measurement of velocity fluctuations. All measurements of velocity and pressure data are recorded by means of an oscillograph.

17. The pressure cell proper (see figure 6) consists of a single bellows terminated by a bellows plate to which is fixed a shaft which actuates movement of a transformer core in a coil in such a manner that the output voltage of the coil winding is proportional to the applied pressure.

18. As the pressure cell has a maximum linear bellows range equivalent to the pressure exerted by plus or minus three ft of water, air under pressure is supplied to the inside of the cell to equalize internal and external hydrostatic pressures when the instrument is submerged to great depths. To prevent rupture of the cell due to the air pressure, a limiting stop is incorporated in the design. Since the exact air pressure required cannot be determined prior to submergence, provisions are made to adjust the air pressure after submergence (see assembly in figure 7). This is accomplished by means of a compressed-air chamber and a solenoid valve, the latter being located between the air chamber and the pressure cell. The air chamber is divided by a slack rubber diaphragm into two compartments, one of which contains compressed air while the other is subjected to the prevailing hydrostatic head by means of an open tube projecting into the free fluid. Opening of the solenoid valve adjusts the air pressure within the pressure cell to the prevailing hydrostatic head; then, after closure of the valve, pressure fluctuations about the mean hydrostatic pressure actuate movement of the bellows plate.

19. Auxiliary equipment required for field operations (see figure 8) consists of a power-propelled barge equipped with hoist mechanism
capable of handling the pulsimeter, and a stable electric power supply consisting of a 60-cycle, 110-120-volt gasoline-driven generator. In addition, anchoring equipment is required to minimize barge movement while the pulsimeter lies on the river bottom.

1950 Turbulence Observations

20. The hydrodynamic pulsimeter was completed and preliminary tests to perfect handling technique accomplished in time for observations to be made near the crest of the 1950 flood. Measurements were taken at 42 individual points in 5 general localities on a 125-mile reach of the Mississippi River extending from just below Arkansas City, Arkansas, to below Vicksburg, Mississippi. Depths of river in which the instrument was used ranged to approximately 100 ft, and the velocities encountered ranged from 2 ft per second to as high as 15 ft per second. The general areas as well as the specific points selected for observation were intended to cover a range from mild turbulence to the greatest turbulence in which it was considered safe to operate. Continuous measurements were made at each point for a period of approximately 15 minutes.

Yellow Bend observations

21. Observations were first made at 15 points along an existing revetment in Yellow Bend, which is just downstream from Arkansas City, Arkansas. The individual observation points were between 65 and 300 ft from the right bank in depths from 29 to 75 ft, and covered a longitudinal distance of about half a mile. Because of its location just upstream from several artificial cutoffs in the river, velocities in Yellow Bend
during flood stages are among the highest encountered on the Lower Mississippi River.

22. A 10-minute record of the pressure and velocity data for one of the Yellow Bend observations is shown on figure 9. On the right side of the figure is a plot showing the vertical velocity distribution. From this figure it will be noted that the pressure fluctuations plotted are the maximum and minimum values in each 10-second interval and that the velocities shown are the average velocities during the corresponding 10-second intervals. Fluctuations of considerable magnitude are indicated both from the pressure and velocity plots. The method of computing the velocities obscures several fluctuations of greater magnitude which occurred during the 10-second intervals selected for averaging.

23. Figure 10 shows a more detailed analysis of a 2-minute portion of the 10-minute record. On this figure are plotted all of the pressure fluctuations exceeding 0.02 lb per sq in, and the average velocities attained during each 5 revolutions of the current meter. Both the pressure fluctuations and the velocity changes shown are plotted in their proper time sequence. The smoother velocity curve computed from 10-second averages, as well as the mean velocity for the entire 10-minute observation, are shown for comparison. It is to be noted that whereas the maximum magnitudes of the pressure fluctuations on this figure are the same as those shown on the previous figure for the corresponding period of time, the frequencies of the fluctuations are increased many times. Concerning the velocity plot it is to be noted that both the magnitude and frequency of the velocity fluctuations greatly exceed those shown on the previous figure, which is indicative that the shorter the time interval
involved in each velocity computation the greater will be the maximum deviations from the mean. It will also be noted that whereas the 10-second average velocity deviation from the mean is about 3 ft per second, the maximum deviation from the mean of the velocities computed from each 5 revolutions of the current meter is about 5 ft per second.

24. A still more detailed analysis of a 1-minute period of the observation is shown on figure 11. Here the pressure and velocity fluctuations for the first minute shown on figure 10 are plotted to an expanded time scale. There is also added a plot of the velocities existing during each single revolution of the current meter. A comparison of the various velocity plots shown on this figure again indicates that the shorter the period over which the velocity is computed, the greater the maximum deviations from the mean and the more frequent the occurrence of the deviation. On the previous figure it was noted that the maximum 10-second average velocities deviated 3 ft per second from the mean, whereas the maximum deviation computed from each 5 revolutions of the current meter was about 5 ft per second from the mean. Here it is to be noted that for the single-revolution computations the maximum deviation is as much as 9 ft per second.

**Miller Bend observations**

25. Observations were made at 5 points along an existing revetment in Miller Bend, which is just upstream from Greenville, Miss. The individual observation points were between 150 and 350 ft from the left bank and over a longitudinal distance of about 500 ft in depths of water varying from 45 to 75 ft. Average velocities in this section of the river
during the recent flood were not so high as those existing in the previously mentioned Yellow Bend tests. Surface velocities were in the order of 10 to 12 ft per sec and bottom velocities around 6 ft per sec.

26. A 10-minute record of the pressure and velocity data for one of the Miller Bend observations is shown on figure 12. It is to be noted that the pressure and velocity fluctuations shown hereon are not so rugged as those shown on the corresponding Yellow Bend figure. However, the over-all pressure change for the 10-minute period shown amounted to about 0.5 lb per sq in. The pressure fluctuations shown are the maximum and minimum values occurring in each 10-second interval and the velocities are the average velocities during the corresponding 10-second intervals.

27. Figure 13 shows a more detailed analysis of a 2-minute portion of the 10-minute record. On this figure are plotted all pressure changes exceeding 0.02 lb per sq in. and the average velocity during each 5 revolutions of the current meter. The smoother velocity curve computed from 10-second averages and the mean velocity for the 10-minute period again are shown for comparison. Here again it is to be noted that the shorter the interval of time used for velocity computation the more rugged the resulting velocity plot becomes.

28. Figure 14 shows a still more detailed analysis of the first minute of the period shown on the previous figure. The pressure fluctuations are the same as those of the first minute previously shown but are plotted to an expanded time scale. The velocity plots for the 60-second period show the mean velocity for the 10-minute period, the 10-second average velocities, the velocities computed from each five revolutions of the current meter, and the velocities computed from each single revolution
of the current meter. A comparison of these various velocity plots again shows that the maximum velocity deviations and their frequencies vary inversely with the time element used. The 10-second average velocities deviate as much as 1.8 ft per sec from the mean, the velocities computed from each five revolutions of the current meter vary as much as 2.7 ft per sec and the velocities computed from each single revolution of the current meter as much as 5.5 ft per sec.

Reid Bedford Bend observations

29. Upon completion of field operations at Yellow Bend and Miller Bend the equipment was moved 125 miles downstream to Reid Bedford Bend, just downstream from Vicksburg, Miss., where the 1948 and 1949 turbulence investigations previously described were undertaken. A series of 10 observations were made at this site. The individual observation points were between 125 and 325 ft from the right bank in depths of water varying from 40 to 100 ft. Velocities in this reach of the river ranged from 2 to 8 ft per sec on the bottom and from 4 to 15 ft per sec on the surface.

30. A 10-minute record of pressure and velocity data for one of the Reid Bedford Bend observations is shown on figure 15. This figure is comparable to those showing the 10-minute periods at Yellow Bend and Miller Bend, the pressure fluctuations shown being the maximum and minimum pressures occurring in each 10-second period. The maximum pressure changes amounted to about 0.37 lb per sq in., which exceeds considerably any 10-second pressure changes previously shown. The velocity plot on this figure shows, in addition to the 10-minute and the 10-second average velocities, the velocities computed from each 5 revolutions of the current
meter. Here again the shorter the time interval involved in the velocity computation the more the maximum velocities deviate from the mean, and the more frequent the deviations. It is interesting to note that although the mean velocity is considerably lower than any previously shown, the velocity deviations computed from each 5 revolutions of the current meter occasionally vary as much as 4 to 6 ft per sec from the mean.

31. Figure 16 presents a more detailed analysis of a 2-minute portion of the 10-minute record. Here again are plotted in proper time sequence all pressure changes exceeding 0.02 lb per sq in. The velocity plots in the lower half of the figure are the same as those on the previous figure for 2nd to 4th minute but plotted to an expanded time scale. The pressure plot for the 2-minute period shows the pressure changes which occurred in very short intervals of time. It is to be noted that pressure changes as great as 0.3 lb per sq in. occurred within less than one second of time.

Concluding Remarks

32. The program accomplished thus far and partially reported upon in this paper has not yet been completed, nor has time yet permitted careful statistical analysis of the data. It is planned to extend the program of field observations to include other river stages from low to flood stages, at other typical locations such as in the deepest water in sharp bends and in bends of lesser curvature, in crossings, etc. The basic intent is to obtain observations of turbulence ranging between the least and the greatest existing in the river.

33. It will be noted that most of the data obtained thus far were
taken at a single point on the bottom of the river and that practically no information is yet available as to the spatial extent of turbulence. Plans are in progress for velocity measurements intended to throw light on this subject.

34. The methods used thus far for statistical analysis of the data are extremely tedious and time consuming. A contract has recently been made with the Iowa Institute of Hydraulic Research, State University of Iowa, for the development of electronic instruments which it is hoped will remove the personal element from such analyses and vastly speed up the work.

35. Whereas considerable information is now available as to turbulence-produced pressure fluctuations at the bottom of the river (which presumably would act on the top of any submerged bank revetment structures), the rate at which these pressure fluctuations are transmitted to the underside of revetments and to points within the underlying sand strata is not yet known. In this connection a contract has recently been made with the St. Anthony Falls Hydraulic Laboratory of the University of Minnesota to conduct large-scale flume tests for the purpose, among others, of determining whether and at what rate pressure fluctuations at the boundary layer are transmitted beneath revetments and within the sand. During these tests the pattern of pressure fluctuations measured in the river will be reproduced to full-scale in the water flowing through the flume, and simultaneous measurements will be taken on pressure cells placed flush with the top and bottom faces of revetment slabs placed on a sand foundation in the flume, as well as on pressure cells placed beneath the surface of sand.
NOTE: DEPTH OF RIVER AT POINT OF OBSERVATION 35.0 FEET.
DEPTH OF METER 33.2 FEET.
RIVER STAGE (VICKSBURG BRIDGE GAGE) 35.12 FEET (FALLING).
DATE OF OBSERVATION 16 MARCH 1948.

VELOCITY FLUCTUATIONS
NEAR BOTTOM OF MISSISSIPPI RIVER
VICKSBURG BRIDGE DISCHARGE RANGE
760 FEET FROM RIGHT BANK
LEGEND

- AVERAGE VELOCITY FOR EACH 30-SECOND INTERVAL
- AVERAGE VELOCITY FOR EACH 5-MINUTE INTERVAL
- MEAN VELOCITY FOR ENTIRE 120-MINUTE PERIOD

TOTAL DEPTH = 25 FT.

VELOCITY FLUCTUATIONS AT REID BEDFORD

TIME IN MINUTES

21-FOOT DEPTH
LEGEND

--- VELOCITY COMPUTED FROM EACH SINGLE REVOLUTION OF METER.
----- MEAN VELOCITY FOR ENTIRE 45-SECOND PERIOD.

6-FOOT DEPTH

11-FOOT DEPTH

16-FOOT DEPTH

21-FOOT DEPTH

TIME IN SECONDS

VELOCITY FLUCTUATIONS AT REID BEDFORD

VELOCITY IN FEET PER SECOND

FIGURE 3
1-to-3-scale model of hydrodynamic pulsimeter
PRESSURE VARIATION CELL
TRANSFORMER TYPE
Assembly for adjusting air pressure on pressure cell after submergence
Operation of the pulsimeter showing auxiliary equipment required.
PRESSURE AND VELOCITY FLUCTUATIONS AT YELLOW BEND
LOCATION 10  DEPTH  40 FEET

PRESSURE - MAXIMUM AND MINIMUM IN EACH 10-SECOND PERIOD

AVERAGE VELOCITY FOR EACH 10-SECOND PERIOD

MEAN VELOCITY FOR ENTIRE 10-MINUTE PERIOD
PRESSURE AND VELOCITY FLUCTUATIONS AT YELLOW BEND
LOCATION 10; DEPTH 40 FEET; 4 TH TO 6 TH MINUTE OF OBSERVATION
Pressure and velocity fluctuations at Yellow Bend.

Location 10  Depth 40 feet  4th to 5th minute of observation.
PRESSURE — MAXIMUM AND MINIMUM IN EACH 10-SECOND PERIOD

MEAN VELOCITY FOR ENTIRE 10-MINUTE PERIOD

AVERAGE VELOCITIES FOR EACH 10-SECOND PERIOD

PRESSURE AND VELOCITY FLUCTUATIONS AT MILLER BEND

LOCATION 21    DEPTH 47 FEET
PRESSURE AND VELOCITY FLUCTUATIONS AT MILLER BEND
LOCATION 21  DEPTH 47 FEET    7TH TO 9TH MINUTE OF OBSERVATION
PRESSURE AND VELOCITY FLUCTUATIONS AT MILLER BEND

LOCATION 21    DEPTH 47 FEET    7TH TO 8TH MINUTE OF OBSERVATION
VELOCITY COMPUTED FROM EVERY 5 REVOLUTIONS OF METER

AVERAGE VELOCITY FOR EACH 10-SECOND PERIOD

MEAN VELOCITY FOR ENTIRE 10-MINUTE PERIOD

FIGURE 15

PRESSURE AND VELOCITY FLUCTUATIONS AT REID BEDFORD
LOCATION 33  DEPTH 53 FEET
PRESSURE AND VELOCITY FLUCTUATIONS AT REID BEDFORD
LOCATION 33; DEPTH 53 FEET; 2ND TO 4TH MINUTE OF OBSERVATION