MEASUREMENTS OF TIDAL EFFECTS ON STAGE AND DISCHARGE ON THE JOURDAN AND PASCAGOULA RIVERS NEAR THE MISSISSIPPI GULF COAST

Paul C. Floyd
U. S. Geological Survey
Pearl, Mississippi

INTRODUCTION

During September 19-22, 1996, the U. S. Geological Survey (USGS) measured stages and discharges on the Jourdan and Pascagoula Rivers near U. S. Interstate Highway 10 (I-10) near the Mississippi Gulf Coast (Figures 1, 2). These measurements were made in cooperation with the Mississippi Department of Transportation and are being used to better understand how tides affect river flows and bridge hydraulics in the gulf coast region.

Discharge measurements were made continuously at both sites during low-flow conditions throughout a complete tidal cycle when river stages and discharges were controlled primarily by the tides. Temporary staff gages were installed at each site and datums were established. River stages were determined from the staff gage readings during each measurement. The data collected during these two studies are summarized in this report.

DESCRIPTIONS OF MEASUREMENT LOCATIONS

I-10 at the Jourdan and Pascagoula Rivers is located in an estuarine environment where the conditions are swampy and marsh-like. At both sites, the rivers have interconnecting channels through marsh grass and lowlands making representative discharge measurements difficult to obtain. The water table is at or near the ground surface, and during low-flow conditions (usually the fall of the year), the surface-water flows at the sites are primarily from ground-water discharge through aquifer outcrops in the basin.

Jourdan River

The measuring site on the Jourdan River is about 3,800 ft (feet) downstream of I-10 in Hancock County (Figure 1). The Jourdan River flows into Bay St. Louis about 4.0 mi (miles) downstream of the measuring section. The drainage area at the site is about 288 mi^2 (square miles). A small slough (Cutoff Lake) about 1,200 ft north of the measuring section diverges from the main channel of the Jourdan River and flows into Bay St. Louis. The discharge through Cutoff Lake was assumed to be negligible because of the shallow depths and constricted interconnecting channels and, therefore, was not measured.

Pascagoula River

The Pascagoula River near I-10 in Jackson County (Figure 2) has three main channels which convey surface-water flows: 1) the West Pascagoula River, 2) the Pascagoula River, and 3) Third Bayou. There are interconnecting channels and bayous between each of the three main channels. Third Bayou converges with the West Pascagoula River about 3,500 ft downstream of the I-10 bridge; the West Pascagoula River and the Pascagoula River do not converge, but continue to flow separately into the Gulf of Mexico. The I-10 bridge over the Pascagoula River system is 4.0 mi long and has an access canal between the two 2-lane bridges for most of the 4.0 mi. The total drainage area at the site is about 8,420 mi^2. The measuring site on the West Pascagoula River is about 3,700 ft downstream of I-10 near river mile 4.3 (about 4.3 mi upstream of the confluence of the river with the Gulf of Mexico). The Pascagoula River measuring site is about 700 ft downstream of I-10 near river mile 7.9 and the measuring site on Third Bayou is about 800 ft upstream of the I-10 bridges.

DESCRIPTION OF TIDAL EFFECTS ON DISCHARGE

Measuring river discharge in an estuarine environment is difficult because of constantly changing water-surface elevations and discharges. This dynamic environment is caused by the tidal fluctuations in the Gulf of Mexico which influence river hydraulics in an estuarine environment. It has been documented that during the flood tide, river discharges in an estuarine environment are reduced by the incoming tide and that a full flow reversal may occur. In simpler terms, the river may flow upstream because of the incoming tide. When flow reversals occur in an estuarine environment, the water near the bottom of the river is the first to slow, stop, and then begin flowing upstream due to a rising tide. During this process, the water near the surface begins to slow, but is still flowing in the downstream direction. This phenomenon is called bi-directional flow. Furthermore, as the tide elevation continues to increase, the volume of water flowing upstream increases until its influence causes the water near the surface of the river to begin flowing upstream. All of the water in the river channel is then flowing upstream in a fully reversed flow situation.

During bi-directional flows, the downstream flow at the surface can be visually observed, but the upstream flow near the river bottom cannot be. Therefore, it is difficult to positively determine if bi-directional flows are occurring when making a conventional discharge measurement with a mechanical flow meter.

A recent breakthrough in electronic technology has led to the development of a boat-mounted device which can measure water speed and direction in three dimensions at various depths in a river by sending acoustic pulses through the water and monitoring the return signals. The device has four transducers which listen for a change in frequency of the return signal (called the doppler shift) to determine the magnitude and direction of flows. The device, called an Acoustic Doppler Current Profiler (ADCP), has an internal compass and in addition to measuring flow velocities and directions, can track the river bottom to calculate boat speed and direction of travel. As the boat travels across the river during a measurement, an onboard program in a laptop computer drives the ADCP and calculates the discharge in the river using: 1) velocity and direction of boat travel, and 2) depth, velocity, and direction of water flows. The U.S. Geological Survey used an ADCP to measure discharges at the Jourdan and Pascagoula Rivers.

Jourdan River

The study on the Jourdan River began on September 19, 1996, at about 1500 hours (3:00 p.m.) and continued 25 hours through a complete tidal cycle. During the study period, 118 consecutive discharge measurements (about one measurement every 12 minutes) were made with the ADCP at the measuring section (Figure 1). The temporary staff gage which was installed at this site on the right (west) bank near the measuring section was read at the conclusion of alternate discharge measurements as the boat returned to the right bank.

Pascagoula River

It was not possible to make continuous measurements on the Pascagoula River as was done on the Jourdan River because discharges had to be measured in each of the three main channels and then added together to calculate a total discharge for the site. The study began at 0900 hours on September 21, 1996, with four discharge measurements on the Pascagoula River. The measuring crew then traveled 1.1 mi down the canal between the I-10 bridges to the measuring section on Third Bayou where two measurements were made. After measuring Third Bayou, the measuring crew traveled another 2.6 mi down the canal to the measuring section on the West Pascagoula River where four measurements were made. When the measurements were complete on the West Pascagoula River, the sequence was repeated by returning to measure the Pascagoula River. The temporary staff gage established at this site was located on the left (east) bank of the Pascagoula River about 700 ft downstream of the I-10 bridges. A total of 117 measurements were made during a 24-hour period (about one measurement every 12 minutes) at the three main channels of the Pascagoula River system near I-10.

RESULTS

The data collected during the two studies were used to produce hydrographs showing discharge and water-surface elevation through time for each site (Figures 3, 4). A hydrograph is a plot of a hydraulic variable such as stage or discharge through time.

Jourdan River

The average water-surface elevation of the Jourdan River during the study was 1.7 ft. The minimum and maximum water-surface elevations were 0.7 and 2.8 ft. The average discharge during the study was 80 ft^3/s (cubic feet per second), with minimum and maximum measured discharges of -3,980 ft^3/s and 5,580 ft^3/s (Figure 3). The negative discharge indicates a net upstream flow during the flood tide.

Although continuous measurements were made at the Jourdan River, the timing between measurements was irregular. Therefore, the average discharge could not be computed by simply averaging the measured discharges. The average discharge had to be computed by interpolating between the measured discharges to estimate the discharge at one-half hour intervals and then averaging those regularly time-spaced estimated discharges through the time of the tidal cycle (25 hours). This same method was used to estimate the average water-surface elevation during the study. The Jourdan River near I-10 is a classic estuarine river system with three identifiable flow regimes: 1) fully downstream flow, 2) bi-directional flow, and 3) fully upstream flow. Each flow type was observed and documented while measuring with the ADCP on the Jourdan River. Selected data from a measurement made during a bi-directional flows are plotted in Figure 5.

Pascagoula River

The average water-surface elevation of the Pascagoula River during the study was 1.0 ft and the minimum and maximum water-surface elevations were 0.1 and 1.8 ft (Figure 4). The average total discharge during the study was 2,580 ft^3/s with minimum and maximum total discharges of -14,400 and 27,800 ft^3/s.

As with the Jourdan River, the average discharges for the three channels of the Pascagoula River system were obtained by interpolating the data into regular time intervals. The regularly time-spaced data for each of the three channels representing the Pascagoula River system were then added together to produce the data for a total discharge hydrograph (Figure 4). The discharge measured in Third Bayou was deemed insignificant for plotting in Figure 4 because Third Bayou usually conveyed less than 1 percent of the total flows at the site. The three flow regimes discussed earlier (fully downstream, bi-directional, and fully reversed) were also observed and measured in the three channels of the Pascagoula River system near the Gulf of Mexico.

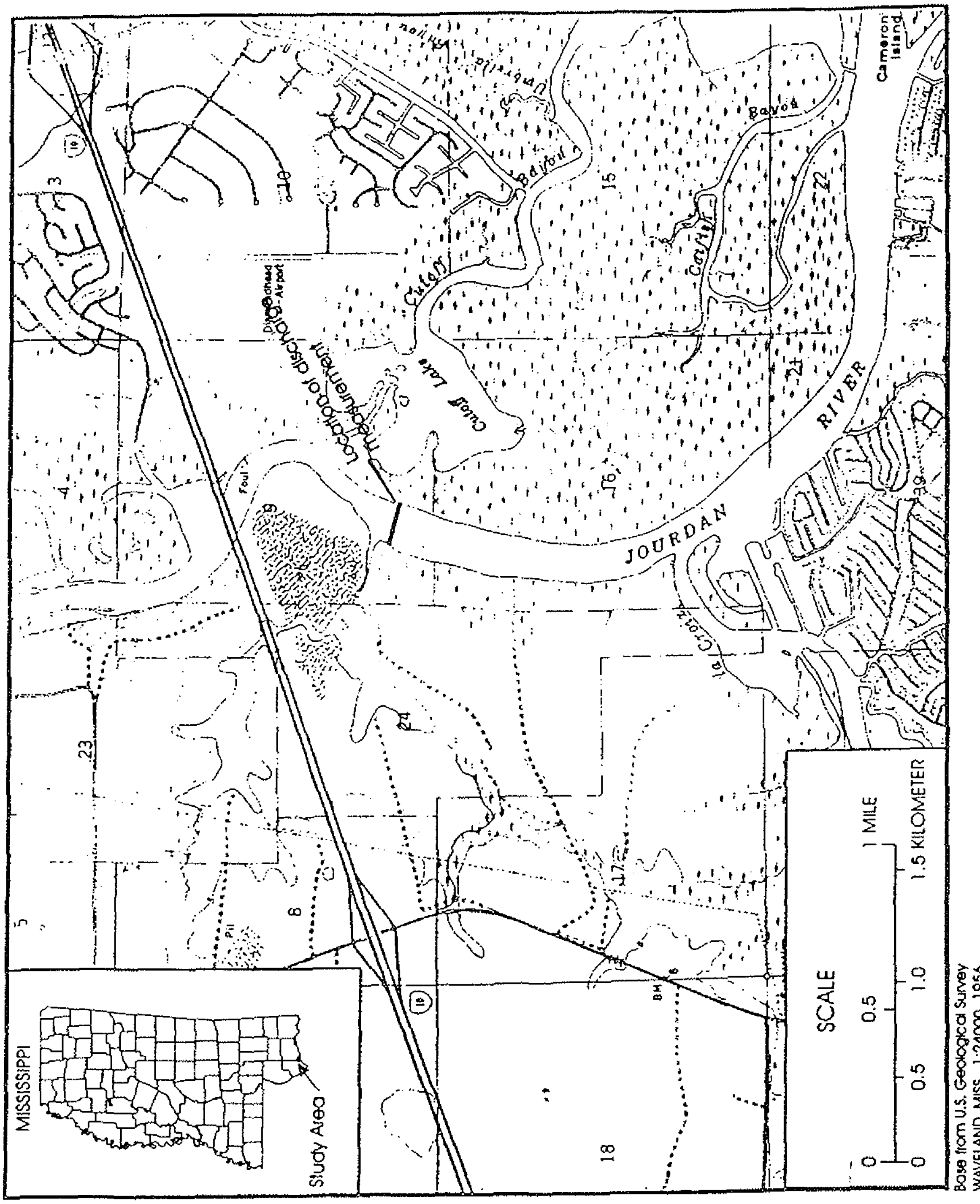
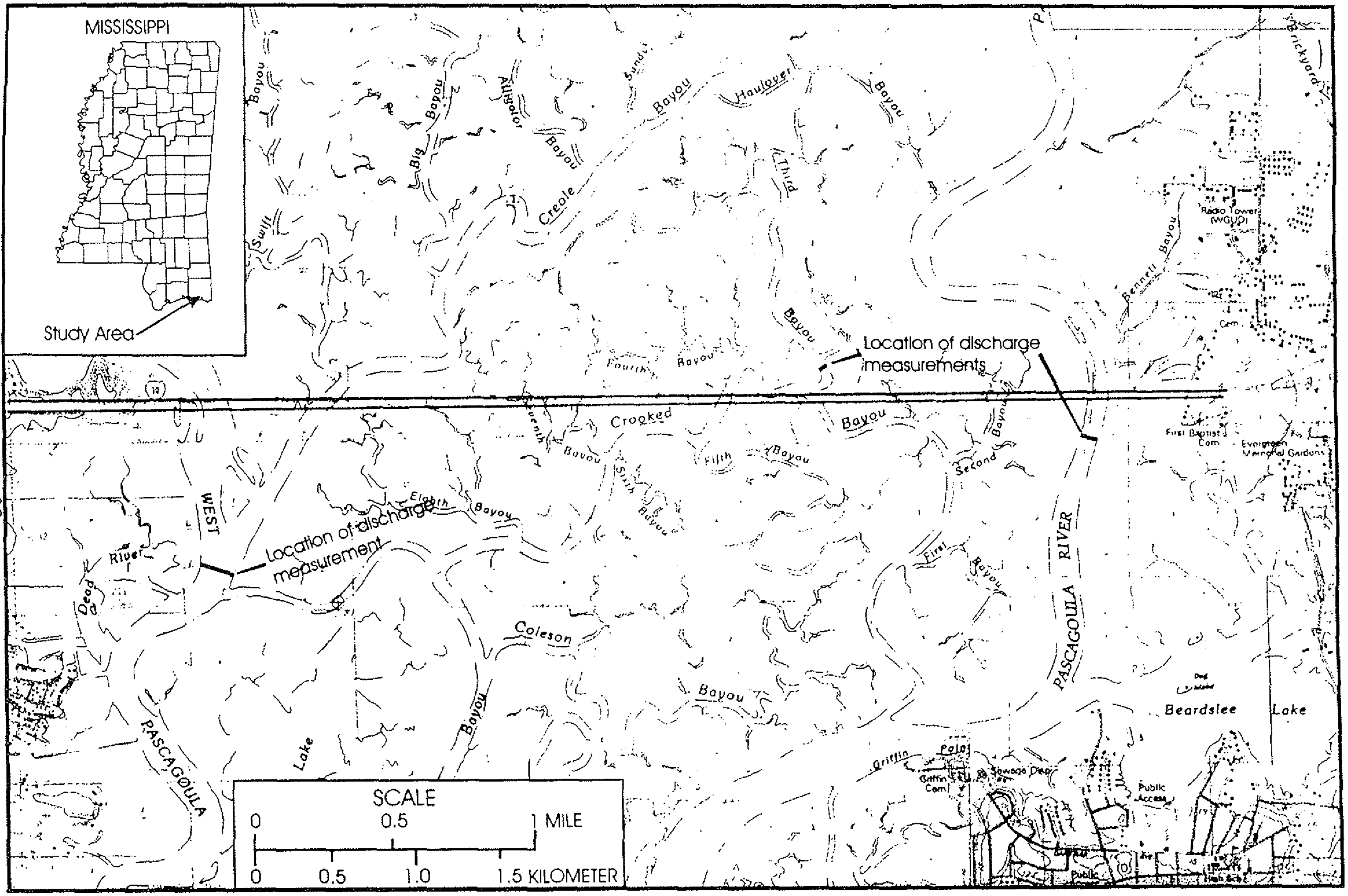


Figure 1.-- Location of discharge measurement section on the Jourdan River near U.S. Interstate Highway 10 near the Mississippi Gulf Coast.



Base from U.S. Geological Survey
PASCAGOULA NORTH, MISS., 1:24000, 1982

Figure 2.-- Location of discharge measurement sections on the Pascagoula River system near U.S. Interstate Highway 10 near the Mississippi Gulf Coast.

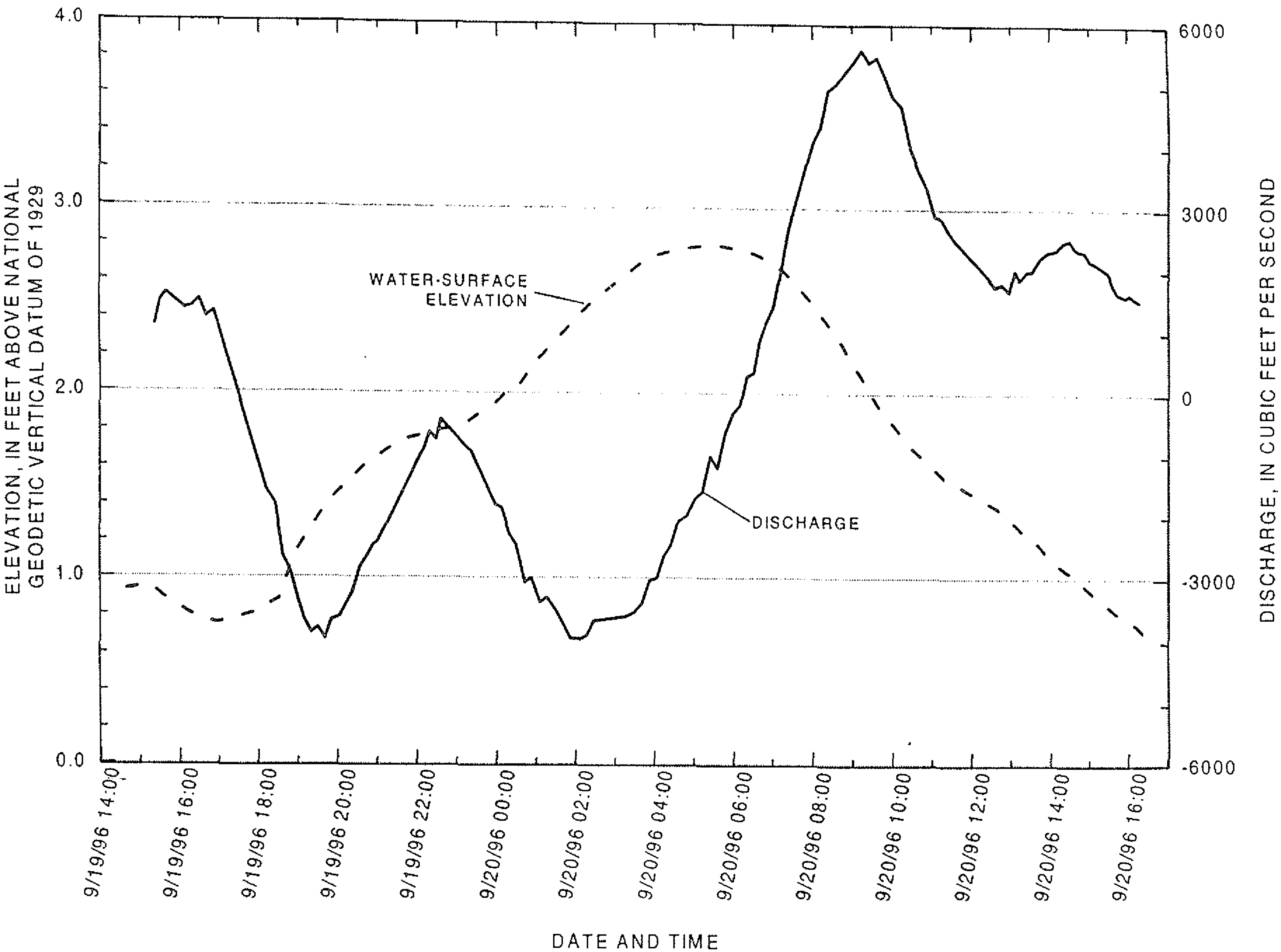


Figure 3.-- Stage-discharge hydrograph for the Jourdan River near U.S. Interstate Highway 10 near the Mississippi Gulf Coast (September 19 - 20, 1996).

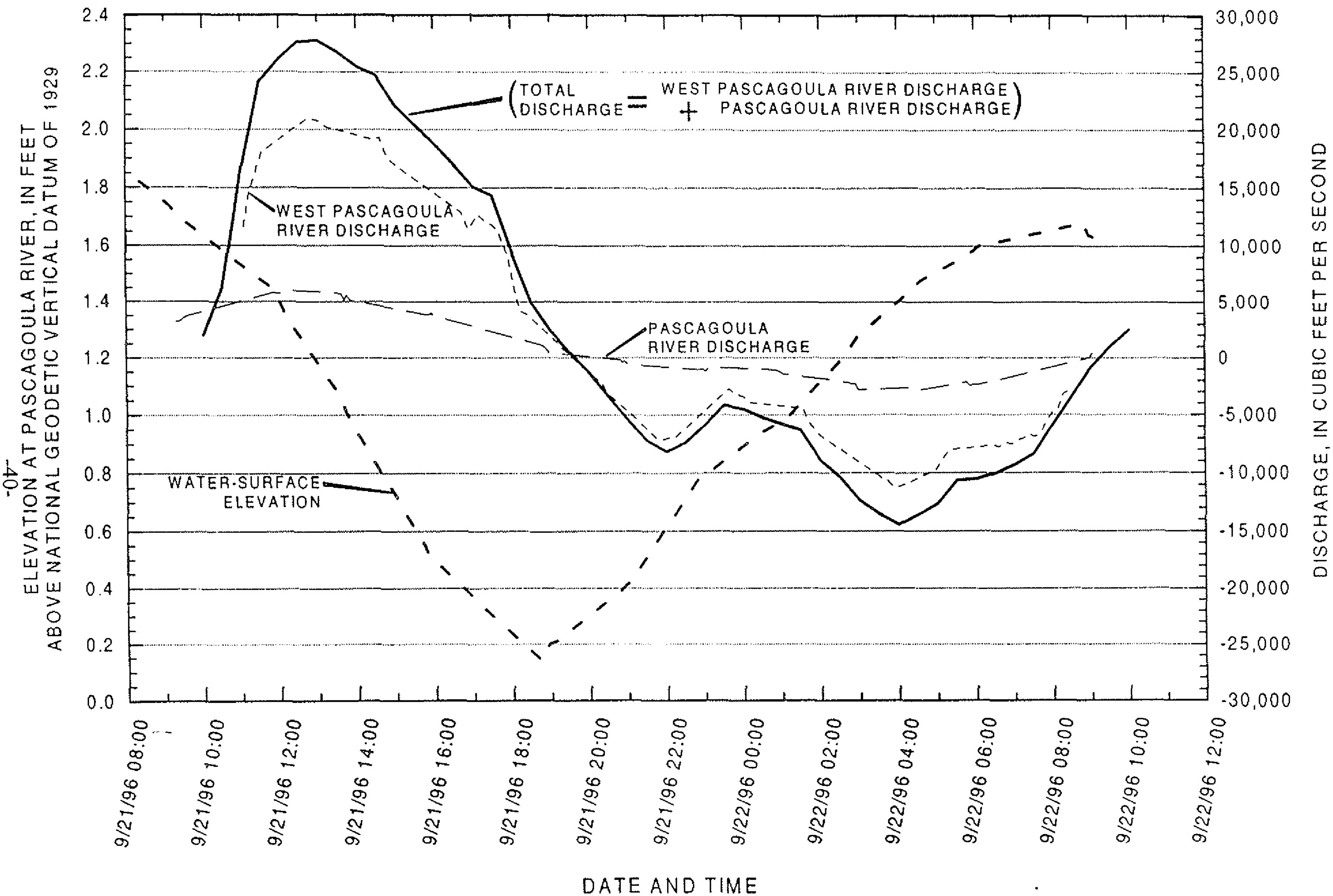


Figure 4.-- Stage-discharge hydrograph for the Pascagoula River near U.S. Interstate Highway 10 near the Mississippi Gulf Coast (September 21-22, 1996).

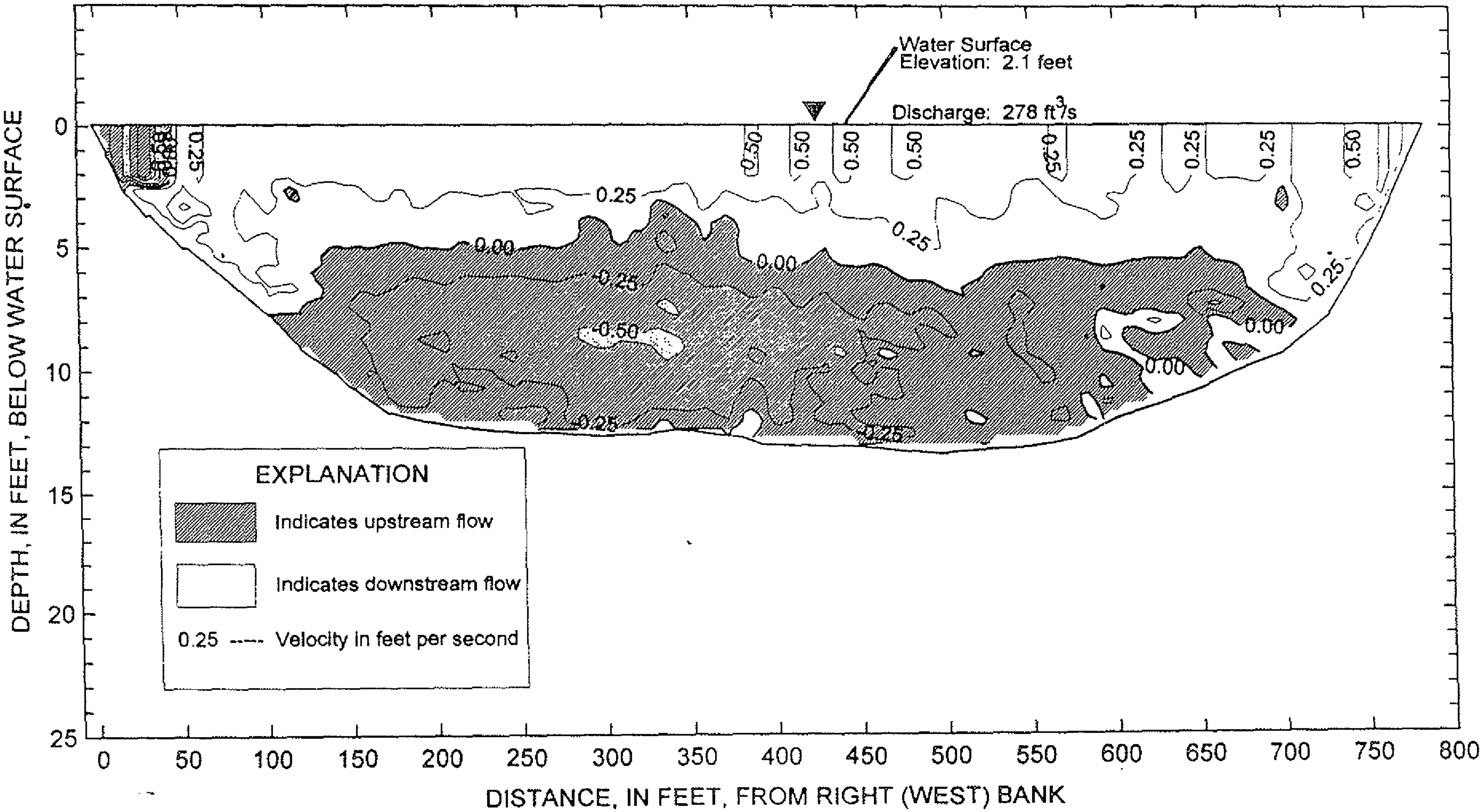


Figure 5.-- Plot of data from Acoustic Doppler Current Profiler measurement showing bi-directional flows at Jourdan River near U.S. Interstate Highway 10.