SIMULATIONS OF FLOODING ON TCHOUTACABOUFFA RIVER AT STATE HIGHWAYS 15 AND 67 AT D'IBERVILLE, MISSISSIPPI

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INTRODUCTION

The Mississippi Department of Transportation (MDOT) proposes to relocate State Highways 15 and 67 in the Tchoutacabouffa River floodplain near DIberville, Miss. During large floods, a substantial amount of flow crosses the existing roadway near the northern edge of the floodplain. The proposed relocation on the northern side of the floodplain upstream of the existing alignment would force flows on the northern floodplain through the existing main-channel bridge at the southern edge of the floodplain. The MDOT is concerned that the proposed alignment may cause excessive backwater upstream of the site during large floods. The MDOT has proposed four alternative hydraulic arrangements for the proposed alignment. Computation of backwater for the existing conditions and the alternative proposed conditions is complicated by the State Highway 15 and old State Highway 15 embankments located about one-half mile downstream of the State Highways 15 and 67 crossing. In 1999, the U.S. Geological Survey (USGS), in cooperation with the MDOT, used a two-dimensional flow model to analyze the flood hydraulics in the Tchoutacabouffa River Basin.

Purpose and Scope

This report presents the results of a two-dimensional flow study of the Tchoutacabouffa River at State Highways 15 and 67 near DIberville, Miss. Water-surface elevations and horizontal velocities for the 100-year flood were simulated for former, existing, and alternative proposed conditions by using a two-dimensional finite-element surface-water model. Computed water-surface elevations throughout the study reach are given for each simulation. Flow distributions are given for the existing and proposed alignments, and selected velocity data are presented. This report also discusses the collection of topographic and bathymetric data used in the study, development of the model grid, and calibration and verification of the model by using discharge measurements and flood-profile data. All elevations in this report are in feet above North American Vertical Datum of 1988 (NAVD of 1988).

DESCRIPTION OF THE STUDY AREA

The study area is located in southeastern Harrison County just north of D'Iberville, Miss. The drainage area of the Tchoutacabouffa River at the State Highways 15 and 67 bridge is 217 mi^2. The study area is about 3 mi long and 1 mi wide and is located between Cedar Lake Road and Lamey Bridge Road (fig. 1). Interstate Highway 10 crosses the Tchoutacabouffa River about 0.7 mi downstream of the study area.

The Tchoutacabouffa River flows into the Biloxi River about 8.3 mi downstream of the State Highways 15 and 67 bridge. The Biloxi River flows into the Back Bay of Biloxi about 1 mi downstream of the mouth of the Tchoutacabouffa River. The study site is significantly affected by tides during low or moderate headwater flow conditions. Tidal effects are diminished during extreme headwater flooding.

The average slope of the channel in the study reach is about 1.8 Wmi. The Tchoutacabouffa River channel generally follows the southern edge of the floodplain and has numerous meanders and cutoffs. The floodplain is typically wooded with a few large open areas. Two 150-ft-wide power-line cuts run longitudinally and transversely across the study reach. Floodplain elevations at the swampy downstream half of the study reach generally range from 4 to 7 ft. The upstream half of the study reach is low and swampy near the river, but has broad knolls rising to about 16 ft along the northern edge of the floodplain.

Existing Conditions

The existing State Highways 15 and 67 alignment consists of a four-lane divided highway that crosses the Tchoutacabouffa River nearly normal to the channel and the southern

3+525 on the new alignment north of Lickskillet Road, and a triple 12 x 8 ft box culvert at station 9+550 on the proposed Lickskillet Road just upstream of the existing State Highway 15 intersection.

Proposed alternative D includes construction of a 157-ft-long relief bridge located near station 2+657 north of the main-channel bridges. Alternative D also uses the same series of box culverts specified for alternative C.

Hydrology

The USGS has operated a crest-stage gage (station no. 02480599) on Tchoutacabouffa River at the State Highways 15 and 67 crossing since 1997. The USGS operated a continuous-record gage on Tuxachanie Creek (station no. 02480500) from 1952 to 1972 and a crest-stage gage since 1972. Tuxachanie Creek flows into the Tchoutacabouffa River about 3.2 mi upstream of the State Highways 15 and 67 crossing. The gage on Tuxachanie Creek is located about 2.5 mi upstream of the mouth of Tuxachanie Creek. The drainage area upstream of station no. 02480500 is about 43 percent of the drainage area at the State Highways 15 and 67 crossing. Both of these gages are operated and maintained by the USGS in cooperation with the MDOT.

Extreme floods occurred in the Tchoutacabouffa River Basin in 1995 and 1998. Flood marks were recovered throughout the study reach after the floods of May 10, 1995, and September 29. 1998. Flood marks were recovered just east of the State Highways 15 and 67 intersection afler the September 29, 1998, flood. The average elevations of these flood marks were 16.5 ft and 14.5 ft, upstream and downstream, respectively, of State Highways 15 and 67.

Flood marks near the southern edge of the floodplain were at elevations of 16.6 ft upstream and downstream of the highway, indicating no significant difference in water-surface elevation through the main-channel bridge. Two discharge measurements were obtained at the State Highways 15 and 67 crossing on September 29, 1998, when water flowed over the road in the vicinity of the State Highway 15 intersection. Flows over the road were measured between station 14+830 on State Highways 15 and 67 and station 1+250 on State Highway 15. The peak discharges corresponding to the floods of May 1995 and September 1998 were estimated to be 34,500 and 48,000 ft^3/s, respectively.

Flood frequencies for the Tchoutacabouffa River near D'Iberville, Miss. were estimated based on a comparison of observed discharges at the State Highways 15 and 67 crossing with those recorded at station no. 02480500 on Tuxachanie Creek. Station flood-frequency discharges for the 50- to 500-year floods at station no. 02480500 were 18 to 55 percent higher than regional estimates given by Landers and Wilson (1991). Therefore, flood-frequency discharges at the State Highways 15 and 67 crossing were assumed to similarly exceed the regional estimates. The 100-year flood discharge is about 42,200 ft^3/s. This value is about 28 percent higher than the regional 100-year flood estimate. If the regional estimate based on techniques presented by Landers and Wilson had been used, then the 100-year flood would have been exceeded in both 1995 and 1998 at this site, which seems unreasonable based on gage data on Tuxachanie Creek. The flood of May 10, 1995, is estimated to have been about a 50-year flood at the site, and the flood of September 29, 1998, is estimated to have been about a 100- to 200-year flood at the site, by comparison to station flood-frequency discharges on Tuxachanie Creek.

The U.S. Army Corps of Engineers (COE), Mobile District, operates a tidal gage at the entrance to Back Bay of Biloxi. Reasonably accurate records of storm tides have been recorded there since 1882 by the COE and others. The highest recorded storm tide was 15.5 fl (during Hurricane Camille on August 18, 1969), which had a recurrence interval of about 170 years according to Wilson and Hudson (1969). A peak storm tide of 12.6 fl was also surveyed at the Tchoutacabouffa River at old State Highway 15. Analysis of tidal records collected at the gage since 1969 suggests that the storm tide caused by Hurricane Camille had a recurrence interval of about 300 years. The effect of storm tides on headwater floods in the study area was not simulated.

Cypress Creek flows into the Tchoutacabouffa River just upstream of the State Highways 15 and 67 crossing. The drainage area of Cypress Creek is about 8.4 mi^2, which is less than 4 percent of the total drainage area at the site. Because of the large difference in drainage area sizes, the response time of Cypress Creek is much **less** than that of the Tchoutacabouffa River; therefore, flows from Cypress Creek into the study reach generally do not affect Tchoutacabouffa River peaks.

DESCRIPTION OF THE MODEL

The two-dimensional Finite-Element Surface-Water Modeling System (FESWMS) (Froehlich 1989) was used to analyze flooding in the study area. A two-dimensional flow model was used because of the complex nature of flows in the vicinity of the State Highways 15 and 67 crossing. FESWMS routes flow through a model grid, which represents the topography of the study area, and **uses** the finite-element method to solve the system of equations that govern two-dimensional flow in a horizontal plane. Various hydraulic parameters are assigned to the model to reflect conditions in the study area.

Three non-linear partial differential equations (Lee and Froehlich 1989) are needed to define two-dimensional flow in a horizontal (X, Y) plane. Two equations represent motion in the **X** and **Y** directions. The third equation is the continuity equation, which ensures conservation of mass. The model grid is divided into a number of triangular and quadrilateral elements that are defined by node points at the corners and at the midpoints of the sides. The three differential equations are applied to each of the nodes. The Galerkin method (Lee and Froehlich 1989) is used to solve these equations over the entire grid. An iterative solution procedure is then applied to minimize the residuals of the solved differential equations. FESWMS computes depth-averaged velocities in the **X** and **Y** directions by integrating the three differential equations though the vertical water column.

Data Requirements

An accurate description of the topography in the study area is required to effectively model floodflows. The MDOT provided data from 16 cross-sectional and longitudinal profiles through the study reach. Additional groundelevation data were obtained from as-built plans furnished by the MDOT. Floodplain edges were determined from a 7.5-minute USGS topographic map. The channel banks were defined by using a geo-rectified aerial photograph of the study area. Channel bathymetry was determined by the USGS using an Acoustic Doppler Current Profiler, in combination with a global positioning system. Road grade and bridge data were provided by the MDOT.

Whereas a two-dimensional flow study could be performed using surveyed topographic data alone, use of hydrologic data greatly increases the reliability of the model. The aforementioned measured flows and flood profiles for the study reach were used to make the model more realistically reflect the actual flood hydraulics through the reach.

Finite-Element Grid

A finite-element grid was used to represent the topography of the study area. A grid with larger elements is **less** accurate than one with smaller elements. Mass conservation errors occur when the computed flow entering an element is not equal to the computed flow leaving the element. For greater accuracy, smaller elements are required in areas where flow direction or depth changes rapidly. The finite-element grid was created by using the Surface-Water Modeling System (SMS) (Brigham Young University 1999). Portions of the grid were refined with smaller elements to reduce mass conservation errors. The channel banks and roadways were incorporated into the grid by importing the geo-rectified aerial photograph into SMS. The grid used to model existing conditions (fig. 2) has 2,118 elements and 5,699 nodes. The grids for former and various proposed conditions required more elements and nodes.

Open- or closed-boundary conditions are applied to each node on the perimeter of the grid (fig. 2). Open-boundary conditions include a specified water-surface elevation at the downstream end of the grid and specified discharges entering the grid at selected locations. Based on flood profiles, the water-surface elevation at the downstream end of the grid was estimated to be 10.5 **fl** for the 100-year flood. The 100-year flood discharge (42,200 ft^3/s) was assigned to the upstream boundary and distributed across the section based on conveyance. For all scenarios except "natural conditions," no elements were defined for the area north of State Highway 67 and west of State Highway 15. The discharge crossing State Highway 15 north of the State Highways 15 and 67 intersection was computed by using weir-flow equations and assigned to re-enter the grid through an open boundary along State Highway

67 west of the intersection. The flow was distributed evenly across the open boundary because State Highway 67 is fairly flat west of State Highway 15. Slip conditions (velocity greater than zero at and parallel to the boundary) were applied to closed boundaries such that momentum would be conserved in a direction tangent to the boundary and no flow crosses the boundary. Weir and culvert nodes permit flow across closed boundaries.

Model Parameters

FESWMS allows the user to assign various hydraulic parameters to the model. Parameters not assigned by the user are given default values. Roughness coefficients (Manning's "n") were assigned to elements based on aerial photography. Initial roughness coefficients were selected during a site visit (Arcement and Schneider, 1989). A kinematic eddy viscosity of 10 ft^2/s was selected as a target value for each simulation; a value of about 100 ft^2/s was used to ensure convergence during the first few runs of each simulation (Froehlich 1989). A weir-flow

adjusted to accurately model measured road overflow for the discharge measurements made on September 29, 1998. Because much of the measured weir flow occurred across a superelevated roadway curve, an effective weir-crest elevation was computed for each weir segment so that the computed discharge for each segment approximately equaled the measured discharge for that segment. The 100-year flood discharge (42,200 ft^3/s) is bounded by the floods of May 1995 and September 1998.

The model was calibrated for existing conditions by simulating the flood of September 1998 (48,000 ft^3/s). Based on the surveyed flood profile, a water-surface elevation of 11.0 ft was assigned to the downstream end of the grid. Elements were classified as woods, clearing, or channel for assignment of roughness coefficients (fig. 2). By using roughness coefficients of 0.15, 0.06, and 0.034 for woods, clearing, and channel elements, respectively, computed water-surface elevations agreed closely with surveyed flood-mark elevations (fig. 3). The surveyed and computed water-surface in the roughness coefficients, because the highway embankment controls these water-surface elevations. The kinematic eddy viscosity was varied from 2 to 100 ft^2/s; a value of 10 ft^2/s was used in the calibration simulation. Again, the computed water-surface elevations at several locations were compared to corresponding water-surface elevations from the calibration simulation. For a kinematic eddy viscosity of 100 ft^2/s, computed water-surface elevations were typically 0.5 ft higher than those corresponding to a kinematic eddy viscosity of 10 ft^2/s. However, for all kinematic eddy viscosities less than 40 ft^2/s, the average change in computed water-surface elevations was less than 0.2 ft.

The model was verified by simulating the flood of May 1995 (34,500 ft^3/s). Based on the surveyed flood profile, a water-surface elevation of 9.8 ft was assigned to the downstream end of the grid. Computed water-surface elevations agreed closely with surveyed flood-mark elevations (fig. 3). Computed road overflow was 1,020 ft^3/s for the flood of May 1995.

SIMULATIONS OF THE 100-YEAR FLOOD

The model was calibrated for existing conditions, and the grids used for all other simulations are modified forms of the grid (fig. 2) used for existing conditions. Grid modifications and the results of each simulation of the 100-year flood are presented below.

Mass conservation was verified for each simulation. Flux lines were used to compute the total discharge passing various sections in the grid. The maximum computed discharge differed from the modeled inflow by only about 3 percent. The average difference was about 2 percent.

Natural Conditions

To model natural conditions in the study reach, all highway embankments, weirs, and culverts were removed from the model. Natural floodplain elevations were substituted in place of existing highway embankment elevations. One hundred and eighteen elements were added north of State Highway 67 and west of State Highway 15, where water ponds upstream of State Highway 67 under existing conditions. Several dry elements along the boundary of the grid were deleted because no backwater occurs without the highway embankments. Also, the broad knoll south of Lickskillet Road was dry, forming an island 500 ft wide and more than 1,000 ft long. About 16,000 ft^3/s flowed in the channel near the location of the existing State Highways 15 and 67 bridge. Computed water-surface elevations for the 100-year flood at the locations of the existing State Highways 15 and 67 bridge and McCully Drive were 15.4 and 16.6 ft, respectively.

Old State Highway 15 Only

To simulate conditions prior to 1976 in the study reach, the State Highways 15 and 67 embankment was removed east of its intersection with old State Highway 15. Results of the simulation indicate 36,100 ft^3/s (86 percent of the total) flowed through the old State Highway 15 bridge and 5,900 ft^3/s (14 percent), including 400 ft^3/s north of the existing State Highways 15 and 67 intersection, flowed over the road north of the bridge. About 200 ft^3/s flowed through the 9 x 3 ft box culvert near the existing State Highways 15 and 67 intersection. About 1.5 ft of water-surface differential occurred across the old State Highway 15 embankment near the northern edge of the floodplain. Computed water-surface elevations for the 100-year flood at the existing State Highways 15 and 67 bridge and McCully Drive were 15.8 and 16.9 ft, respectively.

Existina Conditions

Results of the 100-year flood simulation for existing conditions (fig. 4) indicate that about 4,430 ft^3/s (10 percent of the total) flowed over the road north and east of the State Highways 15 and 67 intersection. The 9 x 3 ft box culvert east of the intersection conveyed about 270 ft^3/s. Water depths of 1 to 4 ft were computed along Lickskillet Road. Flows crossing Lickskillet Road were modeled by using two-dimensional elements (rather than weir segments) because much of the road elevation is about equal to surrounding ground elevations. Computed water-surface elevations for the 100-year flood at the State Highways 15 and 67 bridge and McCully Drive were 15.9 and 17.3 ft. respectively. About 2.2 ft of water-surface differential occurred across the State Highways 15 and 67 embankment near the northern edge of the floodplain.

Proposed Alternative A

To model proposed alternative A, grid elements were removed along the proposed alignment and elements were inserted where portions of the existing embankment would be removed. The pair of 53-in pipes on the new alignment and the pair of 6 x 4 **fl** pipe arches on the proposed relocation of Lickskillet Road were modeled in FESWMS by using type 4 (submerged outlet) flow conditions (Bodhaine 1968). Results of the 100-year flood simulation for proposed alternative **A** indicate that about 200 **ft^3/s** flowed through the pair of 53-in pipes north of Lickskillet Road. The mean velocity computed for the pair of 53-in pipes was 6.5 **Ws.** The 2.4 x 1.5 **fl** pipe arch on the proposed relocation of Lickskillet Road was not modeled. Water flowed northward across Lickskillet Road at a depth of 2 fl. Computed water-surface elevations for the 100-year flood at the State Highways 15 and 67 bridge and McCully Drive were 16.2 and 17.8 fl, respectively.

Proposed Alternative B

In addition to grid modifications used in proposed alternative A, elements were added to model the 315-fl-long relief bridge for proposed alternative B. Results of the 100-year flood simulation for proposed alternative B indicate that about 6,830 ft^3/s (16 percent of the total) flowed through the proposed 315-fl-long relief bridge and about 170 ft^3/s flowed through the pair of 53-in pipes north of Lickskillet Road. The mean velocity computed for flow through the relief bridge was 3.1 **ft/s**. The mean velocity for flow through the pair of 53-in pipes was 5.5 **ft/s**. The 2.4 x 1.5 ft pipe arch on the proposed relocation of Lickskillet Road was not modeled. Water flowed northward across Lickskillet Road at a depth of 1.5 **ft**. Computed water-surface elevations for the 100-year flood at the State Highways 15 and 67 bridge and McCully Drive were 16.0 and 17.4 **ft**, respectively.

Proposed Alternative C

Alternative C includes elements for the proposed relief bridge, but large box culverts are specified in place of the pipes and pipe arches used in alternatives A and B. Type 3 (tranquil) flow occurred at the proposed triple 12 x 8 **fl** and triple 10 x 8 **fl** box culverts (Bodhaine 1968). Therefore, these culverts were modeled by using two-dimensional elements, because culvert computations in FESWMS do not include type 3 flow. Results of the 100-year flood simulation for proposed alternative C indicate that about 6,470 **ft^3/s** (15 percent of the total) flowed through the proposed 315-fl-long relief bridge and about 1,330 ft^3/s (3 percent) flowed through the proposed triple 10 x 8 **fl** culvert north of Lickskillet Road. About 310 **ft^3/s** flowed through the proposed triple 10 x 4 **fl** culvert on Lickskillet Road and about 1,020 **ft^3/s** crossed Lickskillet Road east of the proposed relocation with a depth of about 1 fl. The mean velocity computed for flow through the relief bridge was 2.9 **Ws.** The mean velocity for flow through the triple 10 x 8 fl culvert was 6.5 **ft/s.** Computed water-surface elevations for the 100-year flood at the State Highways 15 and 67 bridge and McCully Drive were 15.9 and 17.3 **ft**, respectively.

Proposed Alternative D

Alternative D includes a 157-fl-long relief bridge, half as long as the relief bridge specified for alternatives B and C; alternative D uses the same triple box culverts as those in alternative C. Results of the 100-year flood simulation for proposed alternative D (figs. 4 and 5) indicate that about 4,580 **ft^3/s** (11 percent of the total) flowed through the proposed 157-fl-long relief bridge and about 1,420 ft^3/s (3 percent) flowed through the proposed triple 10 x 8 **fl** culvert north of Lickskillet Road. About 280 **ft^3/s** flowed through the proposed triple 10 x **4** **fl** culvert on Lickskillet Road and about 1,140 **ft^3/s** crossed Lickskillet Road east of the proposed relocation with a depth of about 1.2 ft. The mean velocity computed for flow through the relief bridge was 4.1 **Ws.** The mean velocity for flow through the triple 10 x 8 **fl** box culvert was 6.5 **ft/s**. Computed water-surface elevations for the 100-year flood at the State Highways 15 and 67 bridge and McCully Drive were 15.9 and 17.3 **ft**, respectively.

COMPARISON OF ALTERNATIVES

Computed 100-year flood profiles along the southern and northern edges of the floodplain for the former, existing, and proposed conditions in the study reach are shown in figure 6. Significant lateral variations in computed water-surface elevations can be seen in figure 4. For the existing conditions, there was about 0.7 **fl** of backwater (above natural conditions) at a point 500 **ft** upstream of the State Highways 15 and

67 bridge (fig. 6), and there was about 1.5 ft of backwater (above natural conditions) near the northern edge of the floodplain at the upstream side of the proposed alignment (fig. 6). Water-surface elevations upstream of State Highways 15 and *67* for proposed alternative A ranged from 1/2 ft to more than 1 fl higher than those for existing conditions. For proposed alternative A there was about 2.7 ft of backwater above natural conditions (or 1.2 fl above existing conditions) near the northern edge of the floodplain at the upstream side of the proposed alignment. Upstream water-surface elevations for proposed alternative B ranged from 0.2 ft higher at the southern edge of the floodplain to 0.7 ft higher at the northern edge of the floodplain, compared to those for existing conditions. Upstream water-surface elevations for proposed alternative C were nearly equal to those for existing conditions. Upstream water-surface elevations for proposed alternative D were generally 0.1 to 0.3 ft higher than those for existing conditions. Computed water-surface differentials across the proposed alignment near the northern edge of the floodplain for the proposed alternatives A, B, C, and D were 2.6, 2.1. 1.4, and 1.5 ft, respectively (fig. 6). Much lower differentials were computed in the vicinity of the main-channel bridge.

SUMMARY AND CONCLUSIONS

The two-dimensional Finite-Element Surface-Water Modeling System. FESWMS, was used to study the effects of the proposed State Highway 67 relocation on water-surface elevations and flow distributions for the 100-year flood on the Tchoutacabouffa River near D'Iberville, Miss. Seven scenarios were modeled for the 100-year flood including: (1) natural conditions (no roadway embankments in the basin), (2) old State Highway 15 only (with the existing State Highways 15 and 67 embankment removed), (3) existing conditions, (4) proposed alternative A (new alignment with no relief bridge), (5) proposed alternative **B** (new alignment with 315-fl-long relief bridge), (6) proposed alternative C (new alignment with 315-ft-long relief bridge and large box culverts), and (7) proposed alternative D (new alignment with 157-ft-long relief bridge and large box culverts).

The model was calibrated and verified for existing conditions by using two discharge measurements obtained at the State Highways 15 and 67 crossing and two flood profiles through the study reach. Calibrated roughness coefficients corresponding to woods, clearing, and channel elements were 0.15, 0.06, and 0.034. respectively.

For natural conditions, computed water-surface elevations for the 100-year flood at the State Highways 15 and 67 bridge and McCully Drive were 15.4 and 16.6 ft, respectively. With only old Highway 15 in place, computed water-surface elevations for the 100-year flood at the State Highways 15 and 67 bridge and McCully Drive were 15.8 and 16.9 ft, respectively. For existing conditions, computed water-surface elevations for the 100-year flood at the State Highways 15 and 67 bridge and McCully Drive were 15.9 and 17.3 ft, respectively.

For proposed alternative A, computed water-surface elevations for the 100-year flood at the State Highways 15 and 67 bridge and McCully Drive were 16.2 and 17.8 ft, respectively. About 200 ft^3/s flowed through the double 53-in pipes north of Lickskillet Road.

For proposed alternative B, computed water-surface elevations for the 100-year flood at the State Highways 15 and 67 bridge and McCully Drive were 16.0 and 17.4 ft. respectively. About 6,830 ft^3/s (16 percent of the total) flowed through the proposed relief bridge, and about 170 ft^3/s flowed through the double 53-in pipes north of Lickskillet Road.

For proposed alternative C, computed water-surface elevations for the 100-year flood at the State Highways 15 and 67 bridge and McCully Drive were 15.9 and 17.3 ft, respectively. About 6,470 ft^3/s (15 percent of the total) flowed through the proposed relief bridge, and about 1,330 ft^3/s (3 percent) flowed through the proposed triple 10 x 8 fl box culvert north of Lickskillet Road. About 310 ft^3/s flowed through the proposed triple 10 x 4 ft box culvert on Lickskillet Road, and about 1,020 ft^3/s crossed Lickskillet Road east of the proposed relocation.

For proposed alternative D, computed water-surface elevations for the 100-year flood at the State Highways 15 and 67 bridge and McCully Drive were 15.9 and 17.3 ft, respectively. About 4,580 ft^3/s (11 percent of the total) flowed through the proposed relief bridge, and about 1,420 ft^3/s (3 percent) flowed through the proposed triple 10 x 8 ft culvert north of Lickskillet Road. About 280 ft^3/s flowed through the proposed triple 10 x 4 fl culvert on Lickskillet Road, and about 1,140 ft^3/s crossed Lickskillet Road east of the proposed relocation.

Significant lateral variations in computed water-surface elevations were noted upstream of State Highways 15 and 67. Computed water-surface differentials across the proposed alignment near the northern edge of the floodplain for the proposed alternatives A, B, C, and D were 2.6, 2.1, 1.4, and 1.5 ft, respectively. Much lower differentials were computed in the vicinity of the main-channel bridge.

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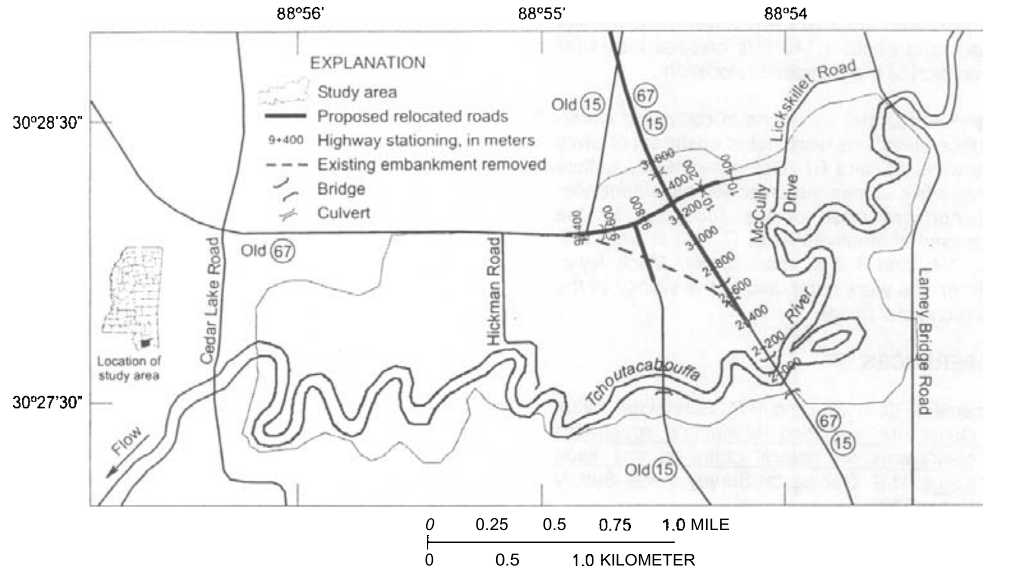

Figure **1.** Location map and proposed relocation of roads in the study area.

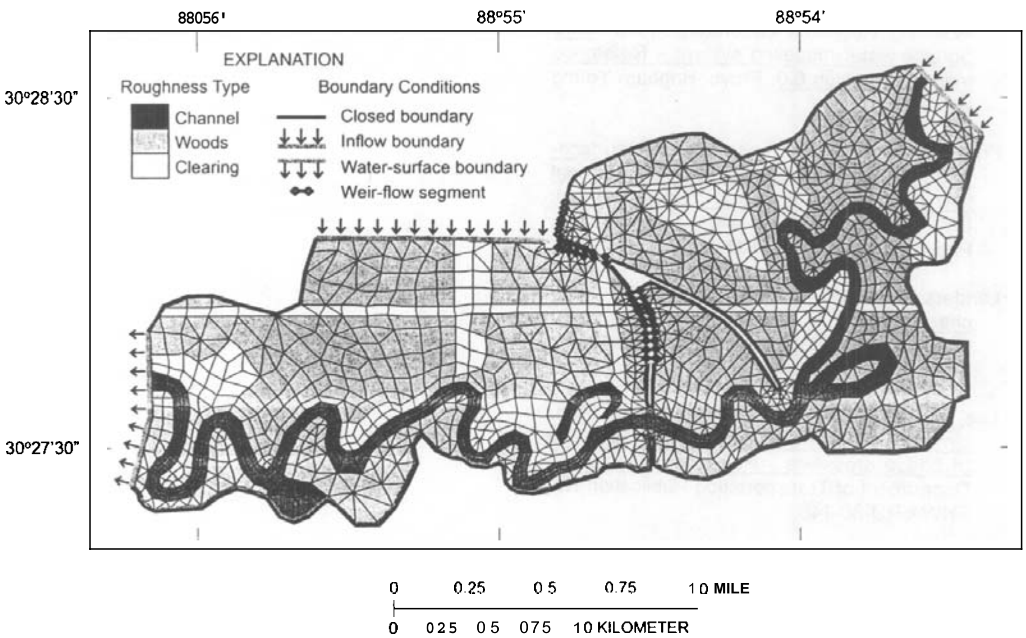

Figure **2.** Finite-element grid for existing conditions with roughness types shaded

Observed and computed flood elevations on Tchoutacabouffa River
for the flood of September 29, 1998
[ft, feet; DS, downstream; US, upstream; SR, State Highway]

Location	Observed flood mark elevation (ft)	Computed water-surface elevation (ft)	Computed minus observed (ft)
Hickman Road	14.2	14.3	0.1
DS side SR 15 and 67 intersection	14.7	14.7	0.0
US side SR 15 and 67 intersection	16.4	16.6	0.2
State Highways 15 and 67 bridge	16.6	16.5	-0.1
McCully Drive	18.0	18.0	0.0
Lamey Bridge Road	19.6	19.9	0.3

Observed and computed flood elevations on Tchoutacabouffa River
for the flood of May 10, 1995
[ft, feet]

Location	Observed flood mark elevation (ft)	Computed water-surface elevation (ft)	Computed minus observed (ft)
Hickman Road	12.1	12.3	0.2
State Highways 15 and 67 bridge	14.6	14.6	0.0
McCully Drive	16.3	16.1	-0.2
Lamey Bridge Road	18.0	17.9	-0.1

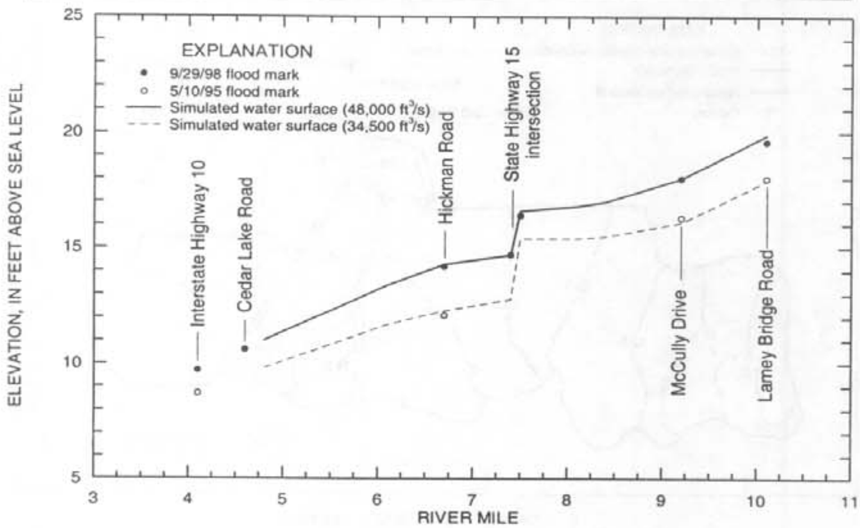

Figure 3. Surveyed and computed flood profiles.

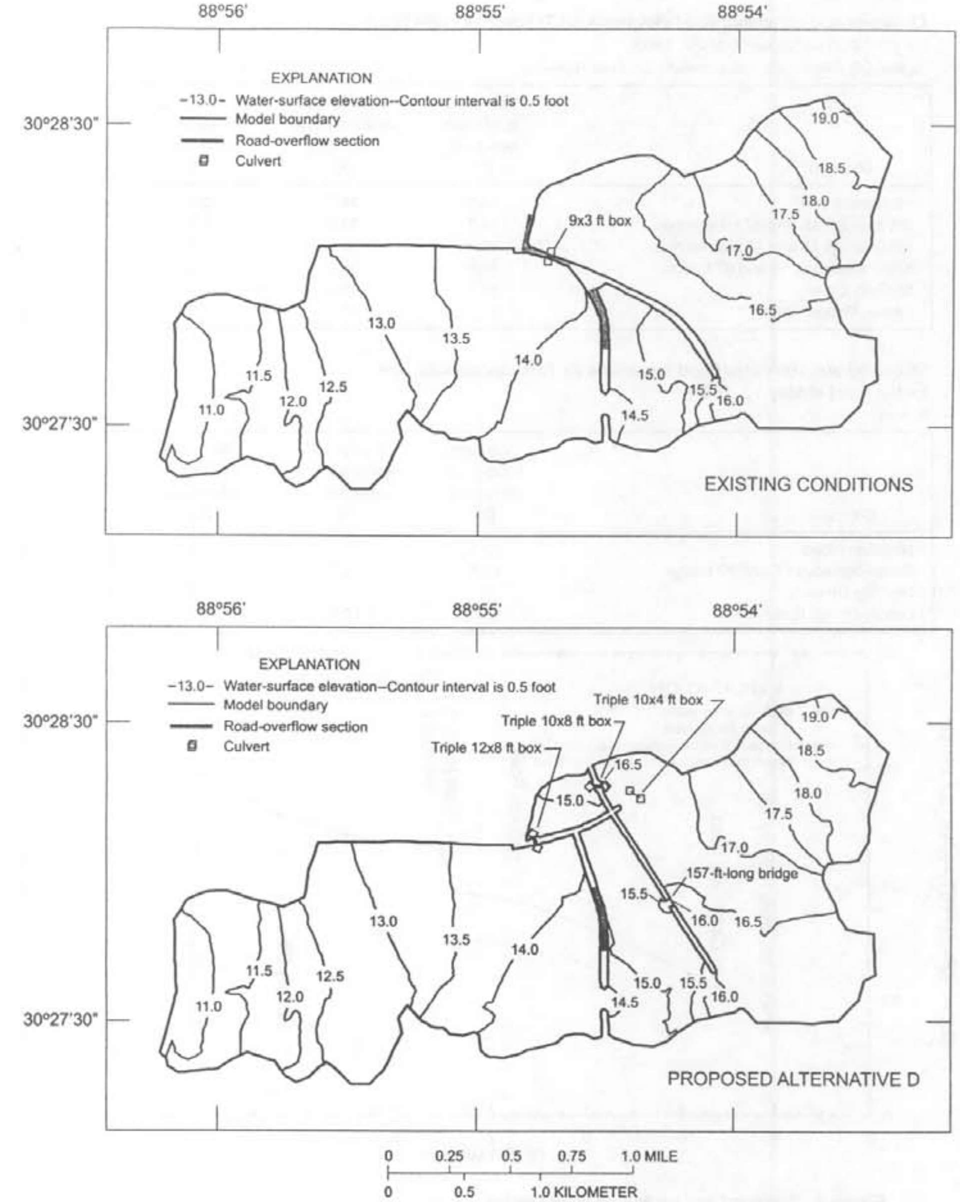

Figure 4. Computed water-surface elevations and discharges for the 100-year flood for existing conditions and proposed alternative D.

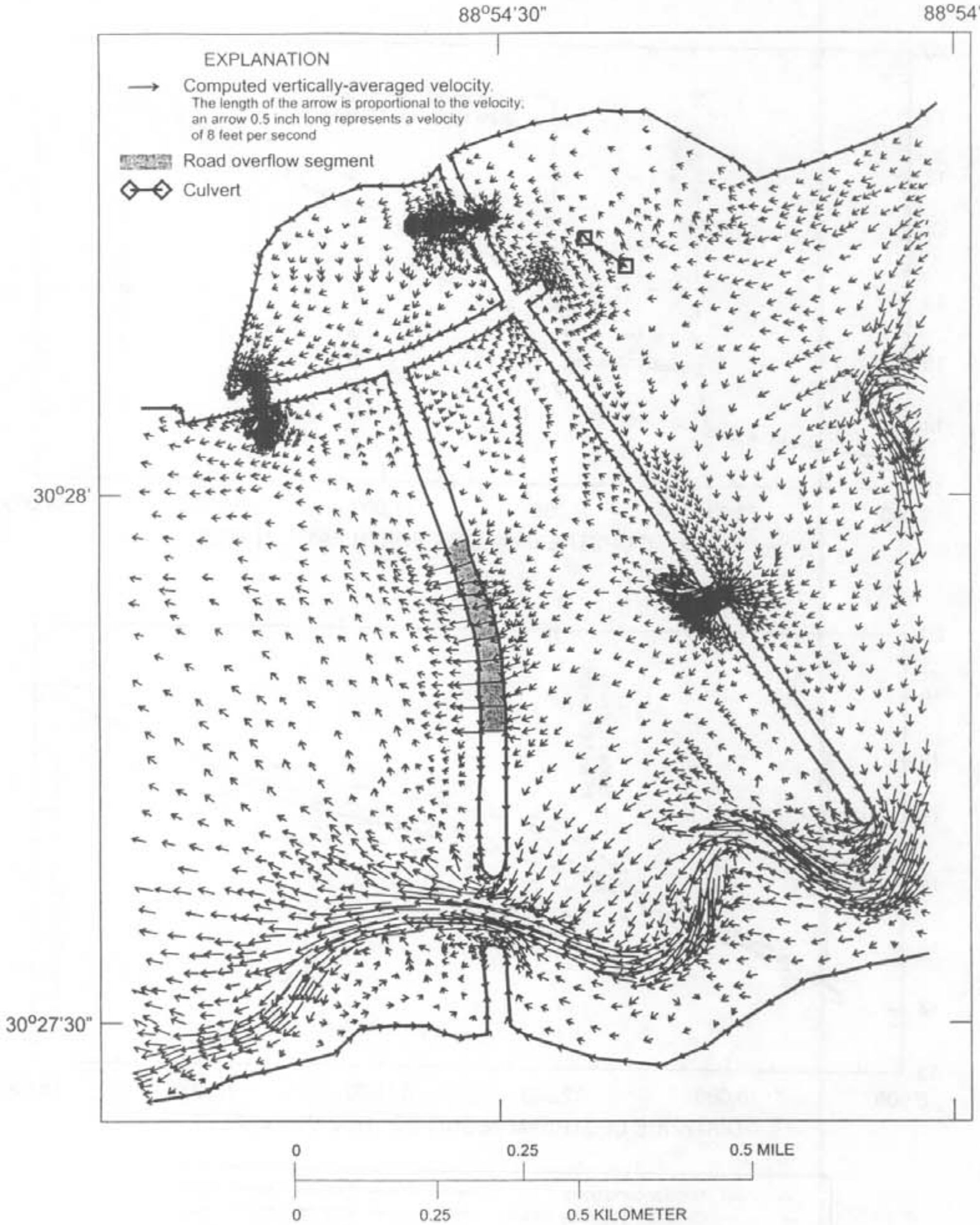

Figure 5. Computed velocity vectors for the 100-year flood for proposed alternative D.

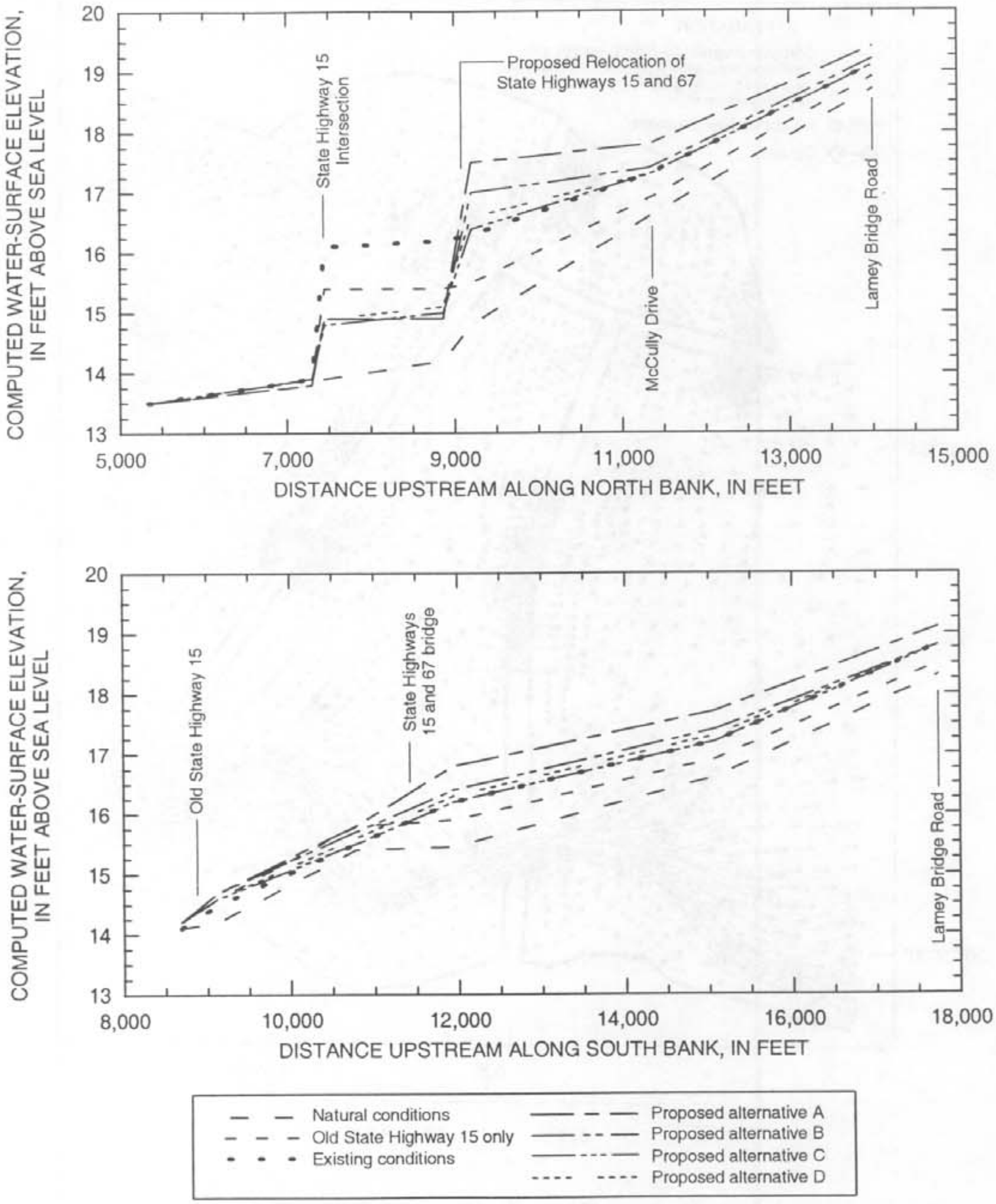

Figure 6. Computed 100-year flood profiles along the edges of the floodplain.