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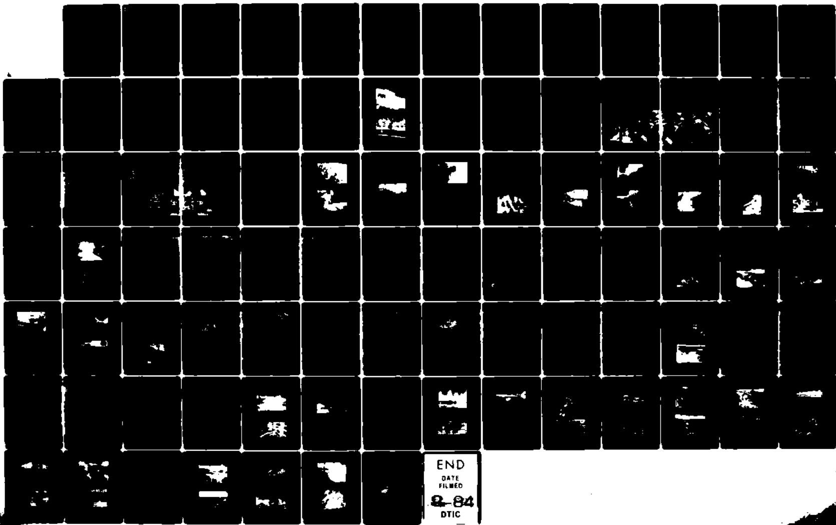

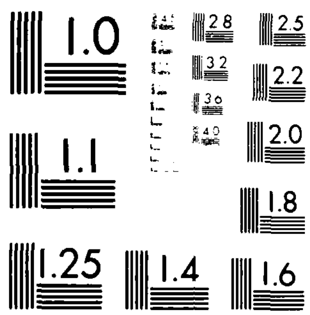

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SECTION 32 PROGRAM
STREAMBANK EROSION CONTROL
EVALUATION AND DEMONSTRATION
WORK UNIT 2-EVALUATION OF EXISTING BANK PROTECTION

FIELD INSPECTION OF SITES IN THE VICKSBURG DISTRICT IN THE UPPER YAZOO BASIN

by

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October 1978

HES Inspection-Report 5

Prepared for Office, Chief of Engineers, U. S. Army
Washington, D. C. 20314

SECTION 32 PROGRAM

STREAMBANK EROSION CONTROL EVALUATION AND DEMONSTRATION

WORK UNIT 2 - EVALUATION OF EXISTING BANK PROTECTION

FIELD INSPECTION OF SITES IN THE VICKSBURG DISTRICT IN THE UPPER YAZOO BASIN

1. Section 32 existing and demonstration sites* in the Vicksburg District (LMK) were inspected from 11-13 October 1977 by the U. S. Army Engineer Waterways Experiment Station (WES) evaluation team. These sites were located on the North and South Forks of Tillatoba Creek (Tallahatchie County, Mississippi), Hunter Creek (Tallahatchie County, Mississippi), and Batupan Bogue (Grenada County, Mississippi). WES personnel participating in the effort were Messrs. N. R. Oswalt, S. T. Maynord, D. Markle, and H. R. Smith, Hydraulics Laboratory; Dr. E. B. Perry and Mr. J. Fowler, Soils and Pavements Laboratory; and Messrs. M. P. Keown and E. A. Dardeau, Jr., Mobility and Environmental Systems Laboratory. In addition, Messrs. C. M. Elliott, B. R. Winkley, S. W. Ellis, J. V. Hines, and I. J. Hilton, all from LMK, accompanied the team.

2. On 21 November 1977, a storm event in the area that includes the Section 32 sites resulted in a maximum instantaneous discharge of 30,000 cfs through Batupan Bogue at the Mississippi State Highway 8 Bridge crossing. (The structure failed during the storm event and has been temporarily replaced by a Bailey bridge, Figure 1.) The maximum instantaneous discharge of record measured by LMK at this location is 34,000 cfs; the 30,000-cfs value (less than a 10-year flood) was estimated from the high-water mark by the U. S. Geological Survey (USGS). The USGS also estimated a maximum instantaneous discharge of 1,390 cfs at its gaging station on South Fork, Tillatoba Creek (paragraph 6). The cumulative rainfall measured at the Grenada, Mississippi, meteorological station (in the Batupan Bogue watershed) during the 24-hr period of 21 November 1977 was 5.05 in.** The measurement at the Charleston, Mississippi, station (in the Tillatoba Creek watershed) was 2.43 in. (Figure 2). Average rainfall for November at these stations is 5.22 in. and 4.85 in., respectively. On 24-25 January 1978, Messrs. Keown and Dardeau conducted a second inspection of the Section 32 sites to

* Existing sites are those locations where the bank protection works were not constructed with Section 32 funds but will be monitored under the Section 32 Program. Protection works at demonstration sites are constructed and monitored using Section 32 funds.

** Meteorological data from "Climatological Data for Mississippi," Vol 82, No. 11, November 1977, provided by the National Climatic Center, Asheville, N. C.

evaluate the storm event damage to the protection works. The resulting observations are included as part of the following text.

3. In 1971, LMK began streambank stabilization work with funds appropriated for the Yazoo Basin Project. This authority continued through 1975, and three contracts were completed under this funding (Table 1). Total expenditures were approximately $1,000,000. In 1974, Congress authorized Section 32 of the Water Resources Development Act (also known as the Streambank Erosion Control Evaluation and Demonstration Act) to evaluate different methods of bank stabilization; the Yazoo River Basin was chosen as one of the study areas. At present, seven items have been completed under this funding and another is ongoing (Table 1).

4. The projects described herein are located on four small hill streams in Tallahatchie and Grenada Counties in north-central Mississippi (Figures 3 and 4). The two basic causes of streambank erosion in this area are normal meandering of streams whose bed slopes are in equilibrium, and streambed degradation that results in bank instability from toe deepening and localized overloads of sediment. The basic design concepts under the Section 32 Program have been that each project should, insofar as practicable:

- a. Be economical, both in initial cost and in maintenance requirements.
- b. Not be identical with proven methods.
- c. Be able to withstand limited streambed degradation without significant failure.
- d. Not be environmentally degrading.
- e. Be designed in consideration of the consequences of a failure at a given location, regardless of the experimental nature of the work.
- f. Be limited as to the number of different methods tried for any one contract, in order to hold the engineering effort within the constraints of available time and money and to construct enough work of any one type to allow reliable evaluations of effectiveness.
- g. Use locally available materials.

5. Each of the 11 projects listed in Table 1 were inspected by the WES evaluation team. Each site inspection consisted of the following:

- a. Preparing a site map of the reach that included the streambank protection works.
- b. Taking pertinent photographs.

c. Identifying and taking notes on the factors affecting the integrity of the protection works.

Narratives relevant to each of the projects are provided below. The information included in the narratives was derived from the WES onsite inspections and additional material provided by Mr. Ellis. The approximate locations depicted in the pictorial views provided herein are shown on the plan maps as follows: 31-36 meaning that photographs in Figures 31 through 36 were taken in the general area indicated by the pointer.

South Fork, Tillatoba Creek

6. The South Fork of Tillatoba Creek joins the North Fork of Tillatoba Creek west of Charleston, Mississippi, to form Tillatoba Creek, a left-bank tributary of the Tallahatchie River. The South Fork drains a watershed of 118 square miles and has an approximate streambed gradient of 5 feet per mile in the area of work (Figure 3). The bed material of this stream consists of sand and some gravel, and the banks are predominantly silt. Discharges have been measured by the USGS at its gaging station on the South Fork of Tillatoba Creek from July 1975 to the present (Figure 5). The ranges of discharge values measured from July 1975 to September 1976 are: maximum instantaneous, 3,980 cfs; maximum daily, 1,760 cfs; mean daily, 59.1 cfs; minimum daily, 2.9 cfs. Daily discharges are determined using a rating curve, and stage values are obtained from a Fisher-Porter Model 1542 digital recorder with 16-channel punch-tape capability. The discharge data are published by the USGS in the annual "Water Resources Data for Mississippi."

7. Construction of streambank protection works on South Fork, Tillatoba Creek, was a four-phase effort that began in 1971 with the building of transverse and longitudinal stone dikes (Table 1) to protect agricultural areas 4 miles southeast of Charleston (Figure 6). The limits of work for this project (Phase 1) extended from mile 6.1 to mile 7.3 (mile 0.0 at the confluence with North Fork, Tillatoba Creek, Figure 3). The second phase consisted of the construction of stone dikes at Charleston (mile 0.9 to mile 1.1, Figure 7) and stone dikes, board-fence dikes, and cable-fence dikes upstream of the 1971 work area (mile 7.3 to mile 8.4, Figure 8). The work under Phase 3 (listed as Item 5A in Table 1) included the two projects noted in Figure 9 as "Bank Protection Under Construction by Government Forces." The downstream work was sand-cement sack revetment and the upstream work, used-tire revetment. The fourth phase (listed as Item 5B in Table 1) was initiated in 1977 and included the reach from mile 0.0 to mile 1.3. Banks in this reach were protected using hay-filled wire crib retards and used-tire-filled wire crib retards (Figure 9). Each of the four phases is discussed below.

Phase 1 (completed 18 November 1971)

8. Seventy-one transverse stone dikes were placed in critical bendways to create hard points at intervals on the bank line (Figure 6). The design objective was to deflect flow away from the caving bank and, to a limited extent, encourage sediment deposition. The stone dikes are typically 30 to 45 ft long (Figure 10) and contain approximately 200 tons of limestone, with each stone weighing no more than 200 lb. Stone for the project as well as other LMK projects described herein requires a specification density of more than 150 pcf, unless otherwise noted in the text. The dikes have trapezoidal cross sections, with a minimum crown width of 4 ft (Figure 11). Each dike is anchored behind the top bank with a dike head. The dike head is 10 to 15 ft long and 4 to 5 ft high and is buried below 3 ft of soil (Figure 10). Figure 12 shows a series of transverse stone dikes in place. In general, the transverse dikes have prevented bank erosion and encouraged limited deposition of materials upstream of each dike. It was noted during the 12 October 1977 inspection that overbank drainage had caused some dike heads to be leached of fines around the buried stone, and holes as large as 1 foot square (Figure 13) were observed in the ground surface. LMK has since revised the method of constructing dike heads to include the requirement that the contractor pump streambed sand around the stone. As a possible solution to the leaching of fines around dike heads, WES personnel suggested the use of filter fabric.

9. Also included as part of Phase 1 was the placement of longitudinal stone dikes of approximately 800 ft in total length. These structures were designed to prevent deepening at the toe of the bank and to discourage secondary currents from removing material from the eroding bank. The dikes were constructed with 4 tons of stone per linear foot with the existing streambed forming a base for the stone. A cross-sectional diagram of a typical dike is shown in Figure 14; a view of an in-place dike is shown in Figure 15. The dike has been effective in providing the toe protection needed to prevent bank erosion. Note that 13 of the transverse dikes shown in Figure 6 are tiebacks for the longitudinal dikes. The same problem experienced with the dike heads of the transverse stone dikes, leaching of fines (paragraph 8), was experienced with the tiebacks.

Phase 2 (completed 18 May 1973)

10. Transverse and longitudinal dikes were constructed at Charleston, Mississippi, upstream of the 1971 work (paragraph 7). At this site, a longitudinal stone dike approximately 800 ft in length was placed; in addition, eight transverse stone dikes were constructed, seven of which served as tiebacks for the longitudinal dike (Figure 7). At the upstream site, a longitudinal stone dike approximately 270 ft in length was placed; in addition, 63 transverse dikes were constructed, 26 of which were stone dikes, 22 board-fence dikes, and 15 cable-fence dikes. Three of the stone dikes served as tiebacks for the longitudinal dike (Figure 8). Four soil borings made at the upstream site locations

shown in Figure 8 indicated that the surface soil was silt and very fine sand. The design of the Phase 2 stone dikes was similar to that used for Phase 1 construction.

11. Board-fence dikes are a variation of the permeable jetty principle, i.e. reducing the water velocity such that sediment is deposited between the fences and the erosive currents of the stream are deflected by the fences away from the bank under attack (Figure 16). The board-fence dikes were constructed using 12-in.-diam (minimum) treated pilings and 3- by 8-in. treated boards 8 ft in length (Figures 17 and 18). The toe of the dikes was protected by placing a 0.5-ton/linear foot stone base, thus reducing flow concentrations and turbulence that would otherwise scour around the pilings. Flanking and runaround were prevented by placing a stone dike head at the point where each dike was tied into the top bank. The board-fence dikes have been successful in encouraging sediment deposition and in accumulating debris. During the 12 October 1977 inspection, it was noted that one of these structures had failed due to heavy drift flow during high flows (Figure 19).

12. The cable-fence dikes consist of 3/8-in., copper-coated steel cable laced between two standard 14-in. by 14-in. 20-ft precast, prestressed concrete piles (Figure 20). The dikes range in length from 15 to 20 ft, each dike having a 0.5-ton/linear foot stone base. During the 12 October 1977 inspection of the dikes, no failures due to collapse of the concrete piles, breaking of cables, or toe failure were noted. As shown in Figure 21, these structures have been successful as debris interceptors.

Item 5A (completed 30 May 1977)

13. Sand-cement bag revetment approximately 600 ft in total length was placed in this reach (Figure 9).* Reinforced paper or burlap bags were filled with a mixture of five parts sand to one part cement (Figure 22). The filled bags were then placed along the lowest level to be protected and then successively overlapped up the bank until the desired portion of the bank was covered. The revetment generally was intact at the date of both inspection visits, the only problem being the loss of bags along the toe of the revetment (Figure 23). This loss was attributed by LMK to an adjustment in the toe protection as a result of scour.

14. The upstream revetment (Figure 9) consisted of used tires held together with steel straps and cables attached to screw-type anchors (Figure 24). This toe protection extends from 5 to 10 ft riverward of the bank toe and up to one third to two thirds of the bank height. The bank slope above the tires has become vegetated with grass and

* Work completed under Item 5A is shown as "Bank Protection Under Construction by Government Forces" in Figure 9.

willow trees (Figure 25). No serious revetment failures were noted during either inspection; however, a potential problem exists in that the screw-type anchors will withstand only limited scour.

Item 5B (completed 7 July 1977)

15. The Item 5B projects are all of those shown in Figure 9 except for those items identified as "Bank Protection Under Construction by Government Forces." Four hay-filled wire crib retards approximately 1,800 ft in total length including tiebacks were placed in this reach (Figure 9). This type of bank protection consists of two parallel wire fences spaced 36 in. apart. Fencing was also placed between the parallel rows on the top and interior sides to form a crib; no fencing was used on the bottom side of the crib. Prior to placing wire fencing on the top side, each crib was filled with baled hay (Figure 26). The toe of each structure is protected by sand-cement bags. Tiebacks spaced approximately 100 ft on centers were included in the design to further stabilize the retards by preventing a secondary channel from forming behind the structure. These cribs have been very successful in trapping sediment and debris (Figure 27). After the hay was wetted by high flow, the grass seeds in the hay sprouted to form a vegetal cover on the upper surface and sides of the hay bales (Figure 28). The only significant failure noted during both inspection visits was the loss of hay bales at mile 0.8 (Figure 29).

16. Four used-tire-filled wire crib retards approximately 2,700 ft in total length including tiebacks were placed in this reach (Figure 9). These structures were identical with the hay-filled wire crib retards except that the cribs were filled with used automobile tires (Figures 30 and 31). This type of structure appears to be less effective than the hay-filled wire crib retards for trapping sediment. The fibers of the hay stems tend to swell and trap the suspended sediment when wetted, whereas the tires offer no such method for sediment interception; in addition, high flows rearrange the tires within the cribs, thus rendering them less effective (Figure 32). The absence of wire fencing beneath the tires in the cribs or inadequate toe protection of the structure often results in the launching of tires into the creek during high flows. Although no count was made, fewer tires appeared to be present in the cribs on the date of the second inspection visit compared with the first inspection. Many tires scattered along the creek bottom below the retards indicated that a significant number of launchings had taken place. The presence of these tires in the creek may reduce the aesthetic value of the surrounding landscape, and unlike the hay bales, the tires are not biodegradable. For applications where very slow sediment deposition is anticipated, tires may be preferred over hay bales (a 2- to 3-year deterioration rate is typical) provided an effective design can be developed to maintain optimum tire arrangement within the cribs.

North Fork, Tillatoba Creek

17. North Fork, Tillatoba Creek, originates in Yalobusha County, Mississippi, south of Enid Reservoir. It merges with South Fork, Tillatoba Creek, west of Charleston, Mississippi, to form Tillatoba Creek, a left-bank tributary of the Tallahatchie River (Figure 3). This stream drains a watershed of 52 square miles and has an approximate streambed gradient of 7 feet per mile in the area of work (Figure 3). The bed material of this stream consists mainly of sand and gravel, and the banks are predominantly silt. Only scattered discharge measurements have been made on this stream by the USGS at its station near Charleston (period of record: 1909, 1941-1943, 1952-1953, 1955-1956, 1959-1960, and 1973). With such a sporadic record, it is difficult to determine with any degree of reliability the daily maximum, mean, and minimum discharges; however, LMK has measured an instantaneous discharge of 12,700 cfs.

18. Construction of streambank protection works on North Fork, Tillatoba Creek, has been a four-phase effort, beginning in 1975; these phases have been designated as Items 1, 2, 3A, and 3C of the Section 32 Program (Table 1). Item 1 consisted of the placement of transverse and longitudinal stone dikes in the reach from mile 2.8 to mile 4.8 (mile 0.0 at the confluence with South Tillatoba Creek, Figures 33 and 34). Dikes were also constructed under Item 2 in the reach from mile 0.0 to mile 2.8 (Figures 35 and 36). The remainder of the work effort on this stream consisted of the construction of grade-control structures at mile 8.2 (Item 3A) and mile 11.0 (Item 3C). Work under these items is discussed below.

Item 1 (completed 29 July 1976)

19. Sixty-two transverse stone dikes and tiebacks (Figure 37) were placed through this reach to create hard points. Nineteen of the dikes were constructed using Type I specifications (Figure 38); the remaining 43 were Type II dikes (Figure 39). These dikes have successfully prevented bank erosion; no failures were noted during either inspection trip (Figure 40). The use of a sand filter in the dike head has generally prevented leaching and sinkholes; however, leaching has occurred at a few locations. Upper bank vegetation has been an important factor in reducing streambank erosion, including that caused by overbank drainage (Figure 40).*

20. Approximately 7,000 ft of longitudinal dikes were constructed under Item 1. Four types of designs are currently being used by LMK (Figure 41). Types II, III, and IV were used for the Item 1 work. The

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* A 7 March 1978 field inspection conducted by Mr. B. R. Winkley, LMK, revealed severe overbank scour at several tieback locations. Most failures noted were adjacent to cultivated fields.

approximate linear bank length protected by each type is as follows: Type II, 3,700 ft; Type III, 2,800 ft; Type IV, 500 ft. These structures were built with 1.5-4.4 tons of stone per linear foot of section, depending on the severity of the expected attack. The upper bank was graded (where necessary) to a IV-on-2H slope, planted with various grasses according to the season, and overseeded with Bermuda grass (Figure 42). The dikes were designed to stabilize the toe until the vegetation became established; the lower ends of the dikes were tied into the bank to protect against flanking. The newly vegetated areas were protected with one of the following treatments: (a) hydraulic mulch combined with a chemical soil stabilizer that binds the surface particles together; (b) woven nylon-paper net laid over the planted area and pegged down; a d (c) nylon net pegged over standard straw-asphalt mulch. The dik have performed well, perhaps due in large part to the experience gain on South Fork, Tillatoba Creek, that led to reinfinements in design o failures were noted during either inspection visit. Establishment of upper bank vegetation has been effective in halting erosion in most cases.*

Item 2 (completed 17 September 1976)

21. Structural design for the transverse and longitudinal dikes placed under Item 2 work was identical to that of Item 1. One hundred transverse stone dikes and tiebacks were placed under this work (Figures 35 and 36); 32 of these were Type I and 68 were Type II dikes. Approximately 6,400 ft of longitudinal dikes were constructed. The approximate linear bank length by each type is as follows: Type I, 600 ft; Type II, 3,200 ft; Type III, 1,600 ft; Type IV, 1,000 ft. The performance of both the transverse and longitudinal dikes has been similar to those dikes placed upstream under Item 1 (paragraphs 19 and 20).*

Items 3A and 3C
(completed 1 November 1977 and
26 September 1977, respectively)

22. The bed gradient in the upper reaches of North Fork, Tillatoba Creek, exceeds the average gradient in the lower reaches (7 feet per mile), and headcutting is the natural mechanism to reduce this gradient. This degradation originated at the Mississippi River and has worked its way into the headwaters of the Yazoo River. Cultural activities have possibly aggravated the migration of headcutting and disturbed geologic controls by (a) construction of cutoffs, (b) construction of dams, (c) land clearing, (d) poor farming practices, (e) practices of drainage districts on the smaller streams in the watersheds, and (f) sand and gravel removal for ready-mix operations. During the 12 October 1977 inspection, the WES Section 32 team observed an operator scooping sand from North Fork, Tillatoba Creek, with a front-end loader and stockpiling this material on the bank (Figure 43).

* See footnote pertaining to paragraph 19.

Removal of streambed material from a creek is a privilege regulated by the issuance of permits; however, this practice could seriously affect the stability of the streambed.

23. The construction effort under Items 3A and 3C will provide two grade-control structures on North Fork, Tillatoba Creek. The design objective of these structures is to control the problem of headcutting (such as that shown in Figure 44), which leads to bank erosion and loss of bank vegetation, including large trees (Figure 45). The structure at the Item 3A site consists of a sheet-pile sill and a grouted riprap baffle designed to serve as an energy dissipator (Figure 46). Limestone riprap placed over filter cloth covers the banks and bottom of the structure. Figure 47 shows employees of the contractor placing filter cloth prior to riprapping the banks and bottom at the construction site. Figure 48 shows the structure under construction at the time of the 12 October 1977 inspection visit.

24. The second grade-control structure (Item 3C) consists of a sheet-pile sill and a hanging baffle as the downstream energy dissipator (Figure 49). The upper and lower banks and the bottom of the creek have been protected with filter cloth and are covered with limestone riprap (Figure 50). Both structures have experienced bank-full flows since completion of construction and have performed as designed.

Hunter Creek

25. Hunter Creek is a right-bank tributary of the South Fork of Tillatoba Creek. The stream drains a watershed of 9.5 square miles, and has an approximate streambed gradient of 13 feet per mile in the area of work (Figure 3). There have been no long-term gaging or water quality stations on Hunter Creek; however, LMK has estimated that the maximum instantaneous discharge is approximately 2,000 cfs. The bank stabilization efforts by LMK on Hunter Creek were accomplished in two phases: Item 1 (which also included work on North Fork, Tillatoba Creek) and Item 1A (Table 1). The limits of work for Item 1 (Figures 51 and 52) extend from mile 0.0 to mile 0.5 (as measured from the confluence with South Tillatoba Creek). The banks in this reach were protected with transverse and longitudinal stone dikes. The reach from mile 0.6 to 1.4 was included in the Item 1A effort (Figures 53 and 54). Transverse and longitudinal dikes also were placed for bank protection in this reach. The 12 October 1977 on site inspection indicated that the streambed material is sand with some gravel and the banks are predominantly silt.

Item 1 (completed 29 July 1976)

26. The work to be accomplished under Item 1 included 59 transverse stone dikes and tiebacks (Figure 55) and approximately 3,600 linear feet of longitudinal stone dike (Figure 56); however, under the Item 1 effort only 20 transverse dikes and approximately 1,850 ft of

longitudinal dikes were completed. The remainder of the work was completed under the Item 1A work (compare Figures 51 and 52 with Figures 53 and 54). The structural design used for both the Item 1 and Item 1A work on Hunter Creek followed the same design used for the Item 1 work on North Fork, Tillatoba Creek (Figures 37, 38, and 41).

Item 1-A (completed 23 March 1977)

27. The work accomplished under Item 1A includes that work not accomplished in Item 1 within the reaches noted in paragraph 25. No damage was noted to any of the protection works on Hunter Creek during the 24 January 1978 visit. All appeared to be essentially in the same condition as that observed during the 12 October 1977 visit.

Batupan Bogue

28. Batupan Bogue is a left-bank tributary of the Yalobusha River, the confluence being northeast of Grenada, Mississippi, approximately 0.2 mile east of the Illinois Central Gulf Railroad bridge (Figure 4). Batupan Bogue drains a watershed area of 243 square miles and has an approximate streambed gradient of 3 feet per mile in the area of work (Figure 4). No long-term gaging or water-quality stations have been operated on Batupan Bogue; however, LMK has measured an instantaneous maximum discharge of 34,000 cfs. During the 21 November 1977 storm event, the USGS estimated from the high-water mark that the maximum instantaneous discharge passing the Mississippi State Highway 8 Bridge was 30,000 cfs.

29. The LMK bank stabilization work on Batupan Bogue is a two-phase effort that was initiated in 1973 (Table 1). The limits of work for the first phase extend from mile 0.2 to mile 1.5 (as measured from the confluence with the Yalobusha River, Figure 57). The bank protection works consist of board-fence revetment and dikes as well as longitudinal and transverse stone dikes. The second phase (listed as Item 4A in Table 1) included the reach from mile 1.9 to mile 3.9 (Figure 58). Longitudinal stone dikes, used-tire revetment, and sand-cement bag revetment were placed in this reach under the Item 4A work. Both phases of the streambank protection effort on Batupan Bogue are discussed below.

Phase 1 (completed 14 February 1975)

30. Four soil borings were made in this reach; the locations of the borings are shown in Figure 57. Results of the borings indicate that the bank material consists mainly of lean and fat clays and poorly graded sands. During both inspection visits, the bed material was observed to be sand. The bank protection though this reach consists of approximately 2,600 ft of longitudinal board-fence revetment (with board-fence tiebacks at 125-ft spacings) and 20 transverse board-fence

dikes spaced at 100-ft intervals. In addition, 600 ft of longitudinal stone dike (with stone tiebacks at 125-ft intervals) and 24 transverse stone dikes were placed in this reach.

31. The board-fence revetment was constructed using 12-in.-diam treated pilings (varying in length from 16 to 25 ft) and 3-in. by 8-in. by 12-ft treated boards (Figure 59, longitudinal view). Each piling was braced as shown in Figure 59, lateral view. The boards were bolted to the pilings as shown in Figure 60. The toe of the revetment was protected by a course of stone (Figures 59 and 60). To provide additional mechanical stability for the structure and to prevent formation of a secondary channel, tiebacks were constructed at approximately 75-ft intervals using the same materials as those used for the fence (Figure 61). The resulting structures (Figures 62 and 63) serve as permeable fences. When the bank is attacked by the stream the water velocity is significantly reduced by the fence, thus encouraging sediment deposition which then serves as a substrate for vegetation growth. At the time of both inspection visits, the fences appeared to be structurally sound, and measurable sediment deposition had occurred. The only problem appeared to be failure of the stone foundation at a few points (Figure 64); this failure could conceivably lead to scour around the pilings and failure of the fence.

32. The board-fence dikes were constructed of 12-in.-diam treated piles (varying from 16 to 25 ft in length) and 3-in. by 8-in. by 8-ft treated boards (Figure 65, longitudinal view). The dikes were braced laterally by boards nailed to the piling but bolted to a treated brace pile (Figure 65, lateral view). Scour was prevented around pilings by placement of a course of stone riprap (Figure 65). The resulting dikes function as permeable jetties. The velocity of the water flowing through the dikes is reduced, thus encouraging sediment deposition and eventual establishment of vegetation along the bank (Figure 66). In addition to encouraging sediment deposition, the dikes tend to deflect the erosive currents away from the banks toward midchannel. At the date of both inspection visits, very little damage to the dikes was apparent; measurable sediment deposition had occurred. The minor damage noted consisted generally of broken boards, possibly as the result of impact by debris.

33. Structural design for the transverse dikes placed in this reach was identical with that used for the Phase 1, South Fork, Tillatoba Creek work (Figures 10 and 11). The longitudinal stone dike was constructed over sand fill (Figure 62, right-hand portion of photograph). The crown width of the structure was 3 ft, with 1V-on-3H-side slopes; the total height of the dike was 8 ft.

<u>Item 4A (ongoing project)</u>

34. The bank protection works through this reach were broken down into 13 work areas. Information pertinent to these areas is given in Table 2. During the inspection visit of 11 October 1977, Work Areas 9-13 were visited; during the 25 January 1978 inspection visit, Work Areas 6-13 were visited.

[illegible]. The bank protection in Work Area 6 consists of a Type III longitudinal stone dike (Figures 41 and 67); the upper bank will be protected by Type III mulch and willow sprouts. The vegetative treatment had not been placed at the time of the 21 November 1977 storm event; however, the bank had been graded according to project specifications (Table 2). Serious scour occurred on the bank above the stone dike as a result of the storm; the bank has since been paved with riprap at the critical point in the bendway shown in Figure 68.

[illegible]. In Work Area 7, burlap bags (filled with a 5-to-1 sand-cement mixture) were used to protect the lower bank (Figure 69); Type I mulch (Table 2) and willow sprouts were used on the upper bank. The revetment extends [illegible] ft riverward and up to one half of the bank height. The [illegible] January 1978 inspection indicated that some shifting of the sand-cement bags had occurred as the revetment adjusted to toe scour (Figure 70); in addition, a major upper bank failure (Figure 71) had occurred.

27. The bank protection in Work Area 8 consists of used tires held together with steel straps and cables attached to screw-type anchors (Figures 24, 72, 73). This toe protection extends from [illegible] to [illegible] ft riverward from the bank toe and up to one third to one half of the bank height. The bank slope above the tires will be vegetated with Type II mulch (Table 2) and willow sprouts. In addition, willow sprouts were planted in each tire. The upper bank vegetative treatment had not been placed at the time of the 21 November 1977 storm event; however, the bank had been graded to specifications. Damage to the tire revetment in this work area was minimal (Figure 74); some upper bank failure occurred as shown in Figure 75.

[illegible]. The sand-cement bag revetment at Work Area 9 was being placed at the time of the 11 October 1977 inspection visit (Figures 76 and 77), using the same design as that work completed at Work Area 7 (Figure 69). The bank slope above the revetment will be vegetated with Type III mulch (Table 2) and willow sprouts. The vegetative treatment had not been placed at the time of the 21 November 1977 storm event; however, the bank had been graded to project specifications. The 25 January 1978 inspection indicated several failures of the revetment and the upper bank (Figures 78 and 79, respectively).

[illegible]. Construction of a longitudinal stone dike (Figure 41) was in progress at Work Area 10 at the time of the 11 October 1977 inspection visit. Prior to placement of the stone revetment, fill material was removed from the upper bank or streambed as part of the bank penetration procedure (Figure 80). After placement of the rock, the upper bank will be vegetated with Type I mulch (Table 2) and willow sprouts. The vegetative treatment had not been placed at the time of the 21 November 1977 storm event; however, the bank had been graded to project specifications. The [illegible] January 1978 inspection visit indicated that severe upper bank failure had occurred (Figure 81).

40. The longitudinal stone dike in Work Area 11 was constructed using the same design as that used for the dikes in Work Areas 6 and 10. The upper bank will be vegetated with Type II mulch and willow sprouts. The vegetative treatment had not been placed at the time of the 21 November 1977 storm event; however, the bank had been graded to project specifications. During the 25 January 1978 inspection visit, it was noted that severe scour had occurred behind the dike due to the 21 November 1977 storm event (Figure 82); in addition, one section of the dike failed (Figure 83).

41. The longitudinal peaked stone dike (Figure 84) in Work Area 12 and a portion of Work Area 11 were inspected. The objective of this type of protection is to stabilize the toe of the bank and allow the planted vegetation to stabilize the upper bank (Figure 85). The stone placed for the dike had a density of 1.5 tons per linear foot of streambank, was generally oblong, and was 6 to 18 in. in diameter. Inspection of the dike during the 25 January 1978 visit indicated that apparent failures have occurred (Figure 86); however, LMK surveys indicate no large-scale failures. According to LMK, stone launching has occurred to heal scour holes which meets the project design objectives.

42. The used-tire revetment placed in Work Area 13 was constructed using the same design as that employed in Work Area 8 (Figures 24 and 87). During the 11 October 1977 inspection, two types of failures were noted at this site: toe failure (Figure 88), and lateral cutting of the vegetated top bank (Figure 89). Although the toe of the bank failed, the flexibility of the used-tire revetment allowed some adjustment to accommodate the new bank geometry. The top bank failure probably resulted from excessive flow in the lateral and outlet drainage ditches such that the lateral ditch overflowed and subsequently eroded or the bank became saturated and failed. The problem possibly could be avoided by increasing the cross-sectional area of the lateral drainage ditch to provide a greater discharge capacity, creating a flatter slope, placing protection higher on the bank or by a combination of these methods.

43. During the 21 November 1977 storm event, the revetment in Work Area 13 failed completely. Pictures taken during the 25 January 1978 inspection visit are shown in Figures 90 and 91. Several mattresses of tires were scattered along the toe of the bank (Figure 90); in addition, tires were found in the woods above the top bank in Work Area 13 and a mile downstream along the toe of the bank. This revetment was placed in late summer; had it been placed in late spring or early summer, the vegetation might have had a chance to become established and thereby prevented the complete failure of the protection works. There is also the possibility that the used-tire revetment floated away from the bank due to entrapped air; holes drilled in the sidewalls of the tires would prevent this problem.

44. Examination of the previous comments regarding the failures that occurred on Batupan Bogue during the 21 November 1977 storm event

indicate that bank preparation (all work areas) and vegetative treatment (Work Areas 7 and 13) had occurred late in the summer after the project initiation date (2 August 1977). The loose soil, in combination with poorly established root systems, undoubtedly contributed to the bank failures. If the project had been initiated earlier in the growing season, possibly the magnitude of the failures could have been mitigated. In cases where the design of a bank protection project depends in part on the vegetal root system for added bank stability, starting the project late in the growing season is undesirable in regions where heavy precipitation may follow.

45. LMK has initiated action (Item 4A-1) to repair damage in Work Areas 7-13 which resulted from the 21 November 1977 storm event. This work effort will consist of the following:

- a. Work Area 7: Type II tiebacks will be constructed through scour holes at the end of the revetment. Longitudinal protection will be extended downstream from the existing revetment using a 3-ton-per-linear-foot, peaked stone dike.
- b. Work Area 8: A Type II longitudinal stone dike (with a Type I tieback in the scour area) will be constructed at the lower end of the protection works.
- c. Work Area 9: The same procedure as that used in Work Area 7 will be employed in this reach; in addition, stone paving will be placed upstream of the scour area between the top bank and the top of the sand-cement bag revetment.
- d. Work Area 10: Type II tiebacks will be added in the scour area. A Type III longitudinal stone dike will be placed between two tiebacks in a portion of the work area containing an outlet ditch.
- e. Work Area 11: Type II tiebacks will be added in the scour area at the lower end of the revetment.
- f. Work Area 12: A Type II longitudinal peaked stone dike will be added in the scour area plus an additional 1.5 tons per linear foot of stone on the existing longitudinal peaked stone dike.
- g. Work Area 13: Used-tire paving will be placed above a Type II longitudinal stone dike to be constructed at the toe of the bank at the lower end of the work area. Type I longitudinal stone dikes will be used across the scour area.

LMK anticipates awarding the contract for Item 4A-1 by 15 May 1978 (at an estimated cost of $300,000 to $400,000).

Table 1

Section 32 Existing and Demonstration Sites in Vicksburg District (LMK)

LMK Project Name	Type of Bank Protection	Construction Notice to Proceed	Date Work Completed	Cost at Time of Construction
South Fork, Tillatoba Creek Bank Bank Stabilization (Phase 1)	Transverse and longitudinal stone dike	9 Sep 71	18 Nov 71	$257,664.[illegible]
South Fork, Tillatoba Creek Bank Stabilization (Phase 2)	Transverse and longitudinal stone dikes, board-fence dikes, and cable-fence dikes	19 Sep 72	16 May 73	$[illegible]
Batupan Bogue, Bank Stabilization (Phase 1)	Board-fence revetment and dikes, and longitudinal and transverse stone dikes	19 Oct 73	14 Feb 75	$565,010.00
Item 1: North Fork, Tillatoba Creek; and Hunter Creek	Transverse and longitudinal stone dikes	24 Nov 75	[illegible] Jul 76	$625,521.25
Item 2: North Fork, Tillatoba Creek	Transverse and longitudinal stone dikes	6 Jul 76	17 Sep 76	$529,879.50
Item 1A: Hunter Creek	Transverse and longitudinal stone dikes	14 Jan 77	1 Apr 77	$111,587.50
Item 3A: North Fork, Tillatoba Creek	Grade-control structure	[illegible]	1 Nov 77	$[illegible],000.00
Item 3C: North Fork, Tillatoba Creek	Grade-control structure	[illegible]	[illegible] Sep 77	$[illegible],420.20
Item 4A: Batupan Bogue	Longitudinal stone dikes, used-tire revetment, and sand-cement bag revetment	[illegible] Aug 77	In-going	[illegible]
Item 5A: South Fork, Tillatoba Creek	Sand-cement bag revetment and used-tire revetment	[illegible] Feb 77	[illegible] May 77	[illegible]
Item 5B: South Fork, Tillatoba Creek	Hay-filled wire crib retards and used-tire-filled wire crib retards	[illegible] May 77	[illegible]	[illegible]

Table 2

Information Pertinent to Work Areas on Batupan Bogue (Item 4A)

Work Area	Method of Bank Protection	Approximate Length of Bank Protected	Bank Grading Required	Vegetative* Treatment
1	Used-tire revetment 1/3 of total bank height	600	Yes	I
2	Longitudinal peaked stone dike	1500	No	None
3	Longitudinal peaked stone dike	200	No	None
4	Longitudinal peaked stone dike	800	No	None
5	Longitudinal stone dike, Type II**	150	Yes	II
	Longitudinal stone dike, Type III	800	Yes	II
6	Longitudinal stone dike, Type III	2350	Yes	III

(Continued)

* Type I mulch is erosion-control fabric equal to "Hold/Gro" as manufactured by Gulf States Paper Corporation, P. O. Box 3199, Tuscaloosa, Alabama 35401. Type II mulch is threshed straw of cereal grain such as oats, wheat, barley, rye, rice, etc. Materials that contain objectionable weed seeds or other species that might be detrimental to the planting being established or to adjacent farmland are not acceptable. Netting for Type II mulch shall be equal to Conwed Erosion Control Netting as manufactured by Conwed Corporation, 332 Minnesota Street, St. Paul, Minnesota 55101. Type III mulch is wood cellulose fiber, air-dried and dyed a green color or hue to make the material plainly visible when applied, and shall contain no growth or germination-inhibiting factors. The material must be manufactured and packaged in such manner that when added to water with fertilizer, grass seed, or other necessary additives, agitation will readily cause separation of fibers and uniform suspension to form a homogeneous slurry. When sprayed on soil, this will form a blotter-like cover that will permit rainfall or mechanical watering to percolate to the underlying soil.

** The height and width of Type I and Type II longitudinal stone dikes are shown in Figure 41.

Table 2 (Concluded)

Work Area	Method of Bank Protection	Approximate Length of Bank Protected	Bank Grading Required	Vegetative Treatment
7	Sand-cement bags revetment, 1/2 of total bank height	500	Yes	I
	Sand-cement bags revetment, 1/3 of total bank height	450	Yes	I
8	Used-tire revetment 1/2 of total bank height	1050	Yes	II
9	Sand-cement bags revetment, 1/3 of total bank height	2200	Yes	III
10	Longitudinal stone dike, Type II**	850	Yes	I
	Longitudinal stone dike, Type III	600	Yes	I
11	Longitudinal stone dike, Type II	600	Yes	II
	Longitudinal stone dike, Type III	1000	Yes	II
	Longitudinal peaked stone dike	600	No	None
12	Longitudinal peaked stone dike	800	No	None
13	Used-tire revetment 1/2 of total bank height	650	Yes	III
	Used-tire revetment 1/3 of total bank height	350	Yes	III

** The height and width of Type I and Type II longitudinal stone dikes are shown in Figure 41.

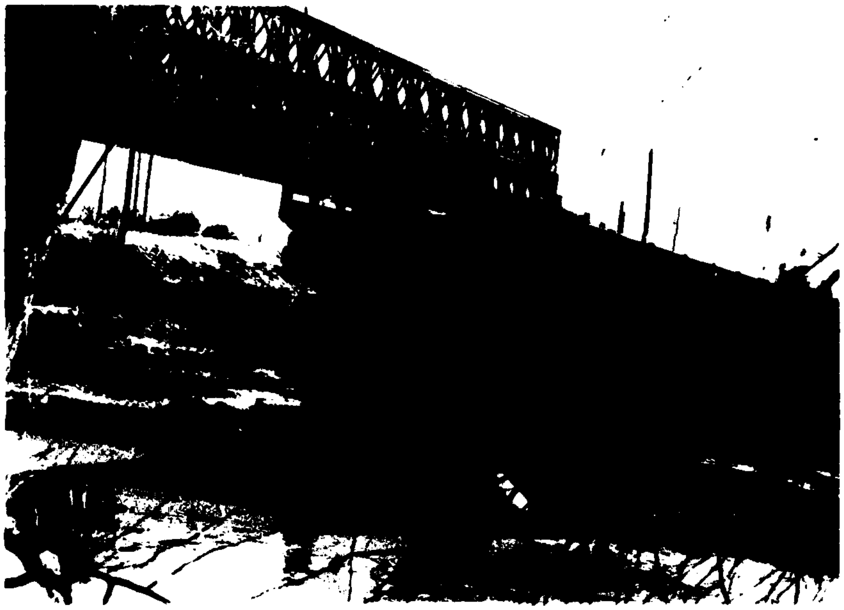


Figure 1. Bailey bridge assembled at the Mississippi State Highway 8 crossing of Batupan Bogue after failure of the permanent structure during the 21 November 1977 storm event (25 January 1978)

Figure 2. Meteorological station at Charleston, Mississippi (24 January 1978)

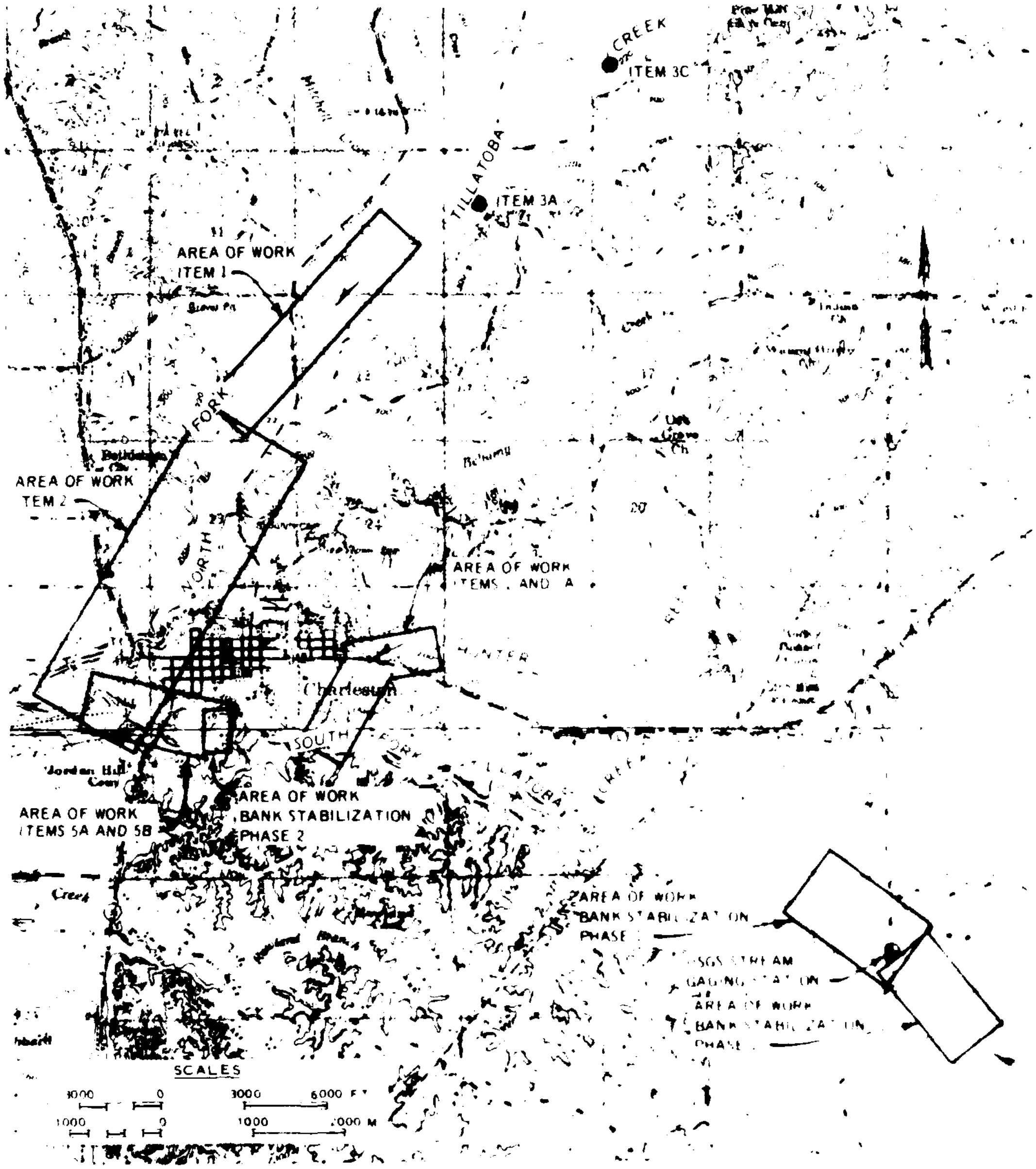


Figure 3. Location of areas of work ... stration sites on South Fork, Tillatoba Creek, ... Creek; and Hunter Creek (Source: ... maps for Crowder, Mississippi, ...; ... Mississippi, 1967; and Grenada, Mississippi, ...

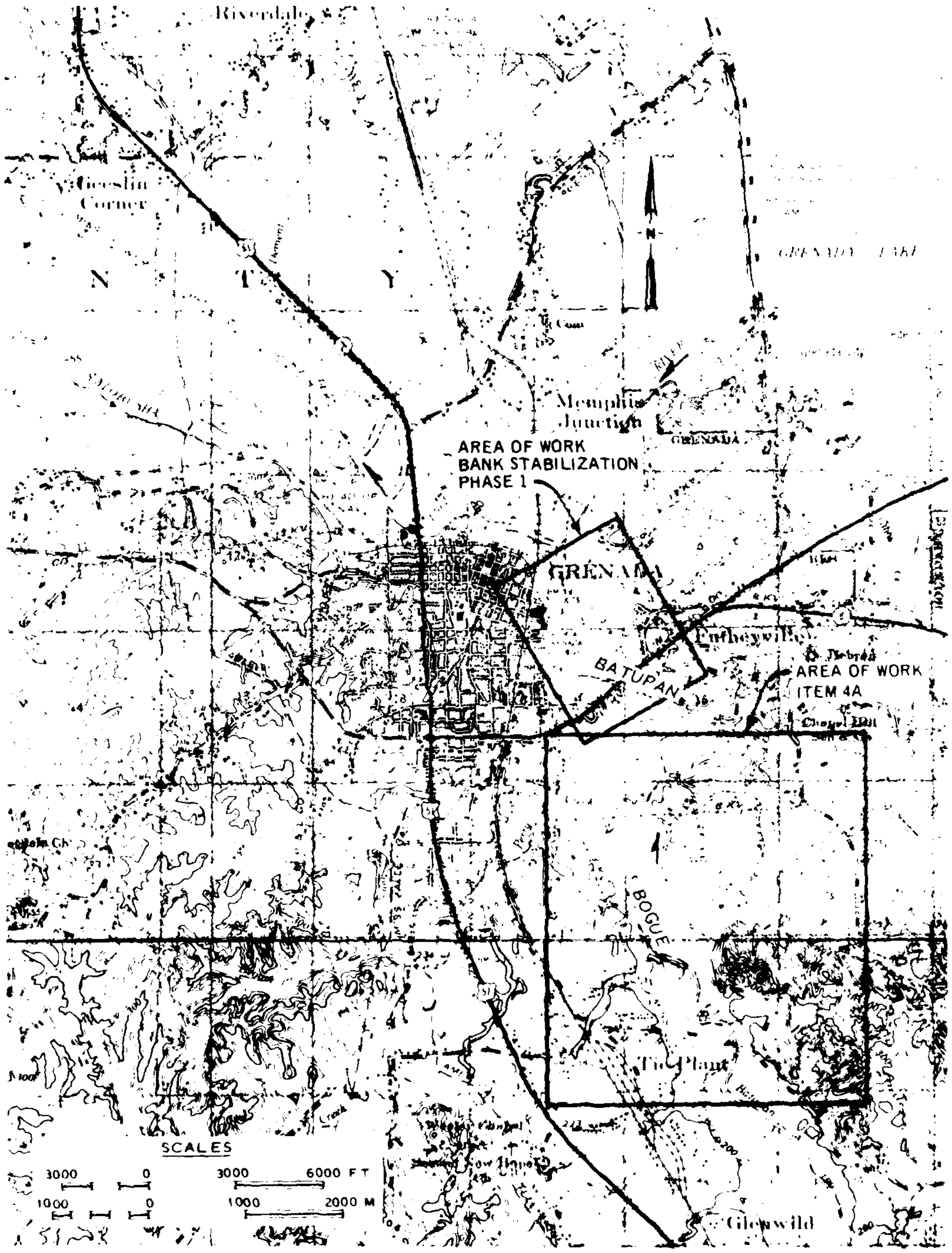
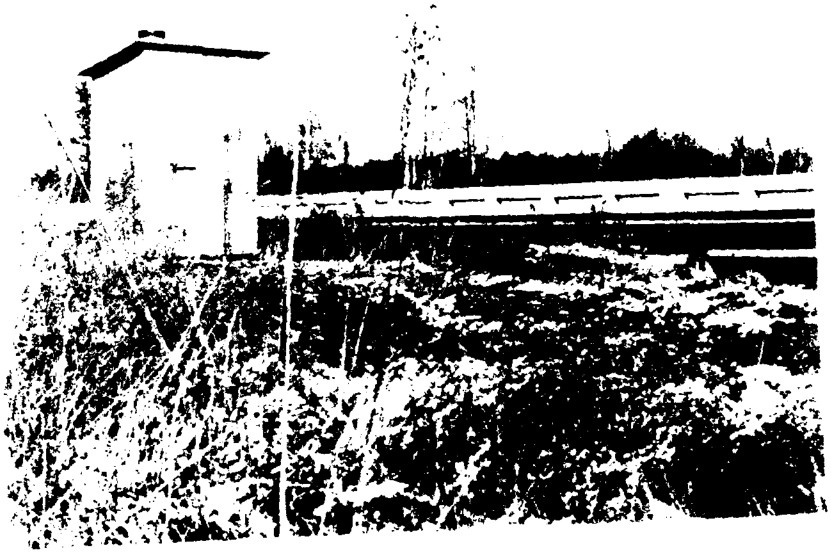
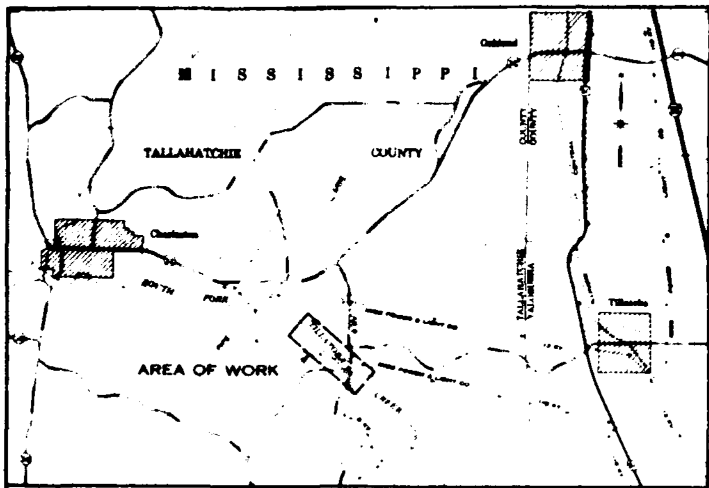


Figure 4. Location of areas of work for Section 32 existing and demonstration sites on Batupan Bogue (Source: USGS 1:62,500 topographic quadrangle maps for Grenada, Mississippi, 1954; and McCarley, Mississippi, 1954)



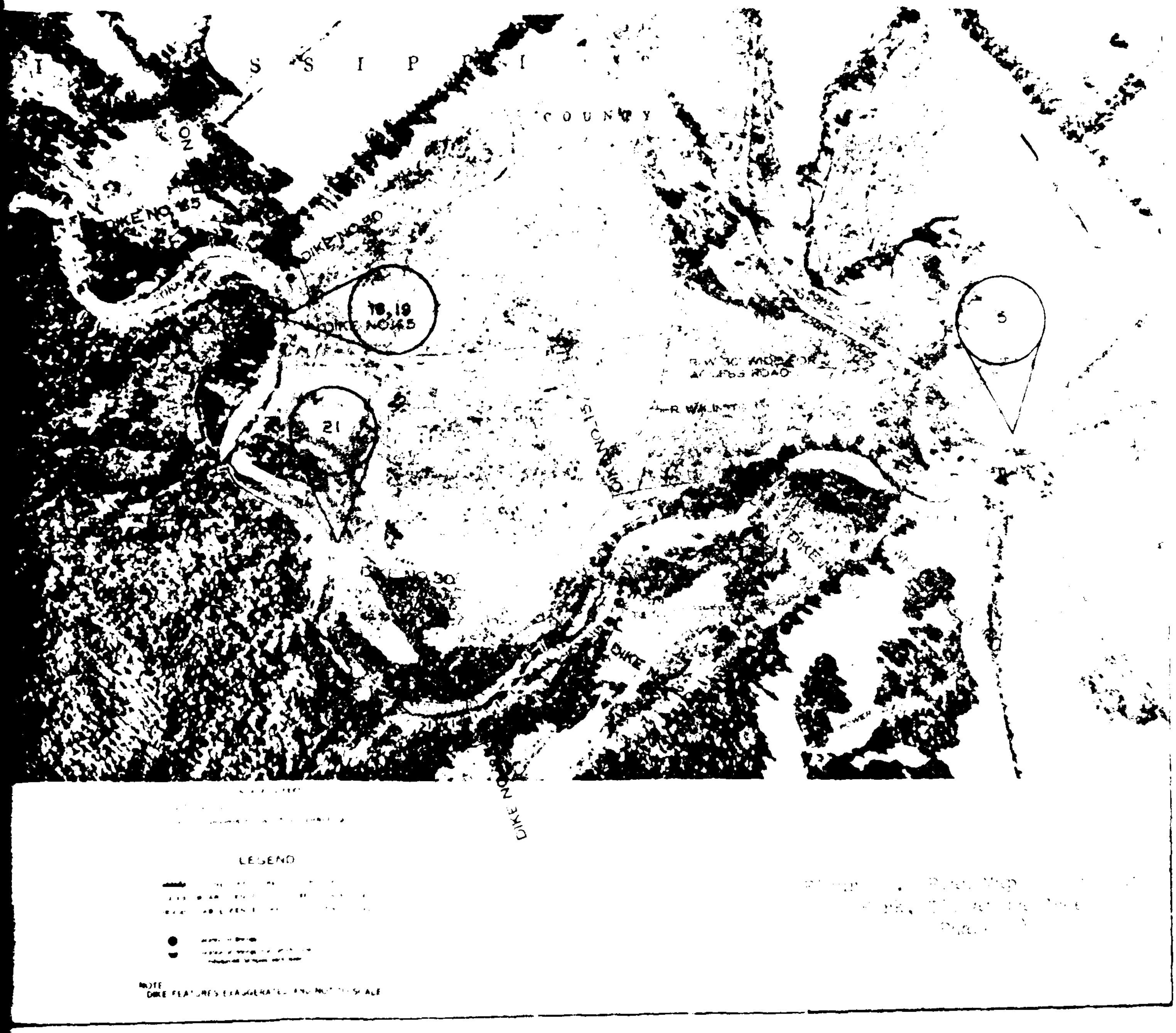


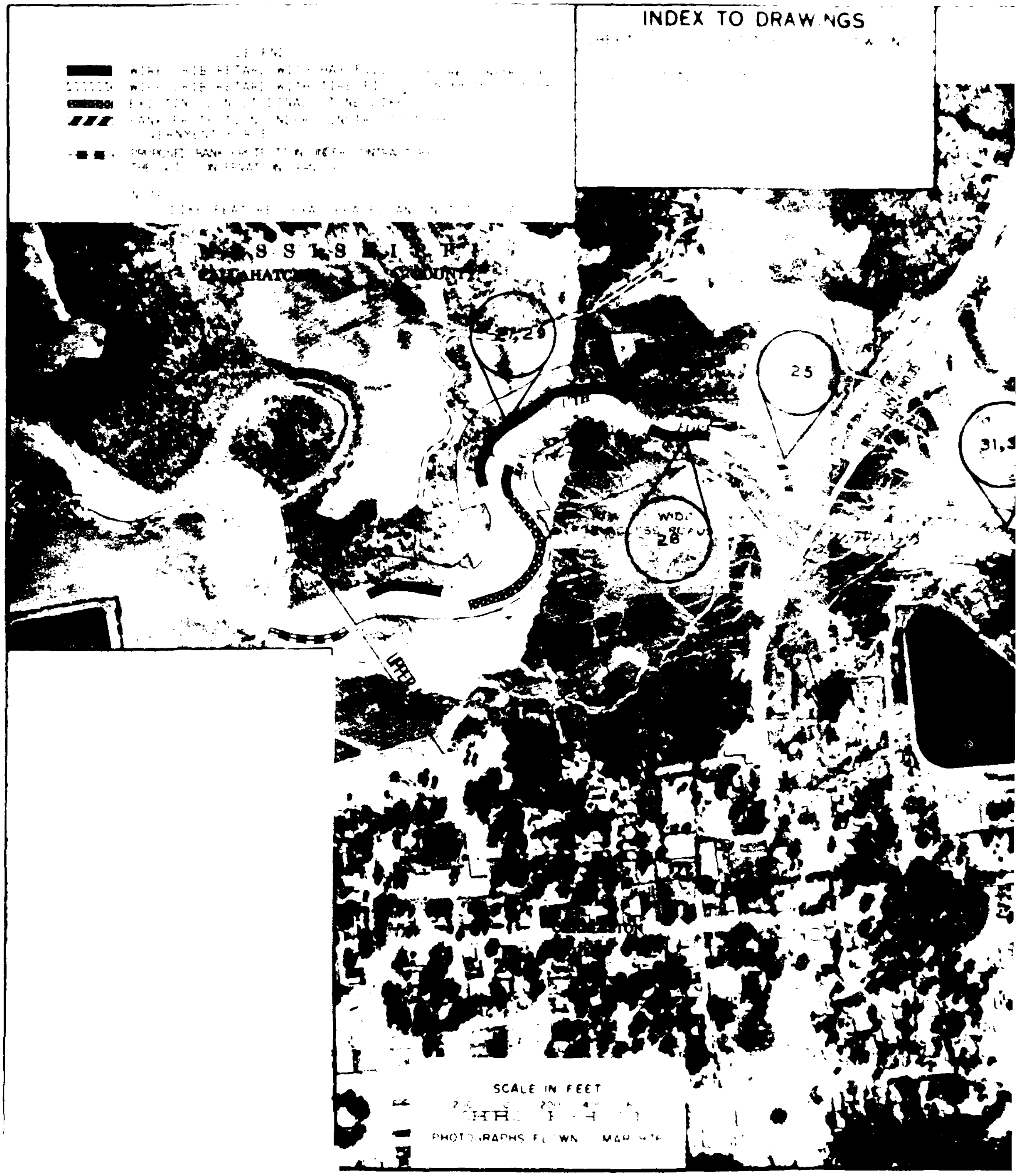
LOCALITY MAP

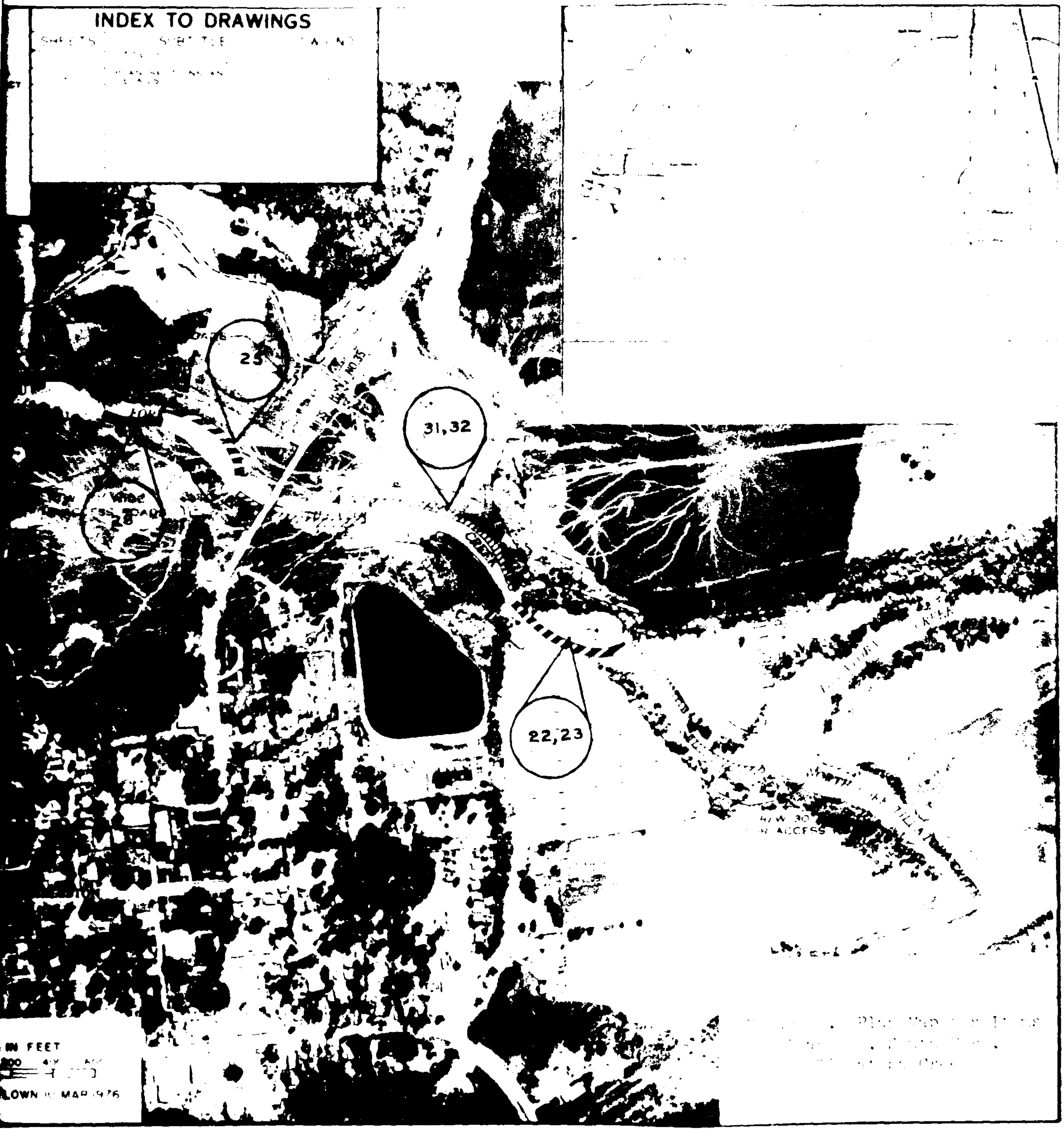
Figure [illegible]. Plan Map [illegible] Fork, Tillatoba Creek (Phase [illegible])

Figure [illegible]. Plan Map [illegible]

R. M I S S I P P I
DIKE NO. 65
16,19
21


COUNTY
21
5
R/W 30' WIDE FOR ACCESS ROAD
LEGEND


INDEX TO DRAWINGS
25
28
UPPER
SCALE IN FEET


INDEX TO DRAWINGS
25
31,32
22,23
28
IN FEET

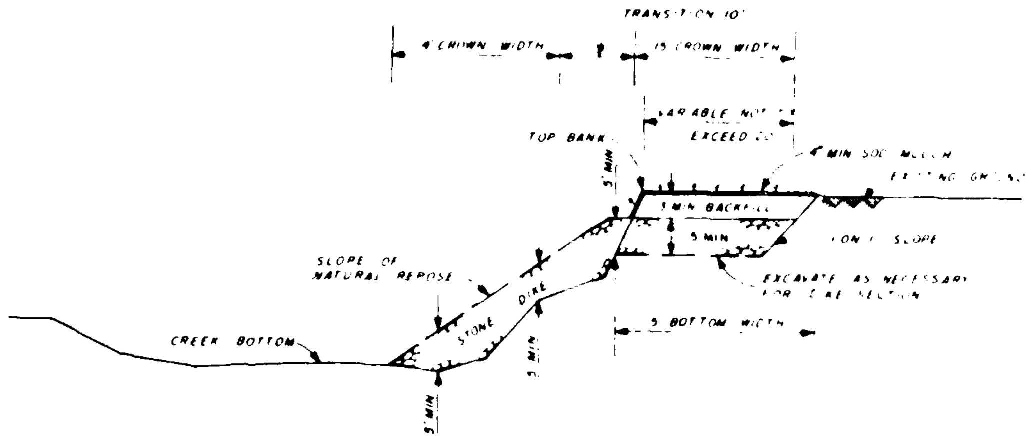


Figure 10. Profile view of typical transverse dike (Source: Bank Stabilization, South Fork, Tillatoba Creek, Drawing No. [illegible], LMK, [illegible])

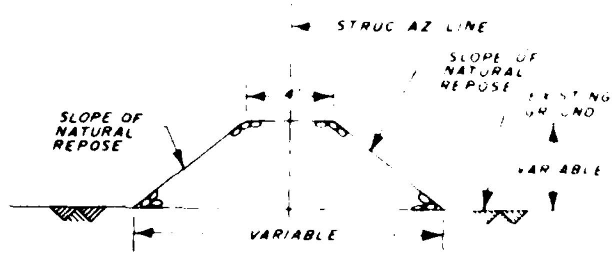


Figure 11. Lateral view of typical transverse dike (Source: Bank Stabilization, South Fork, Tillatoba Creek, Drawing No. 2, LMK, 19[illegible])

Figure 12. Series of transverse stone dikes, South Fork, Tillatoba Creek (12 October 1977)

Figure 13. Hole in soil of upper bank above dike head caused by leaching of fines around stone, South Fork, Tillatoba Creek (12 October 1977)

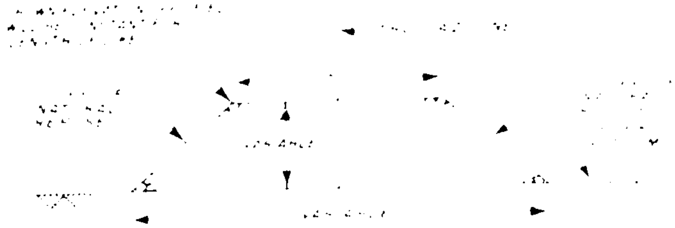


Figure 16. Board-fence dikes, South Fork, Tillatoba Creek (12 October 1977)

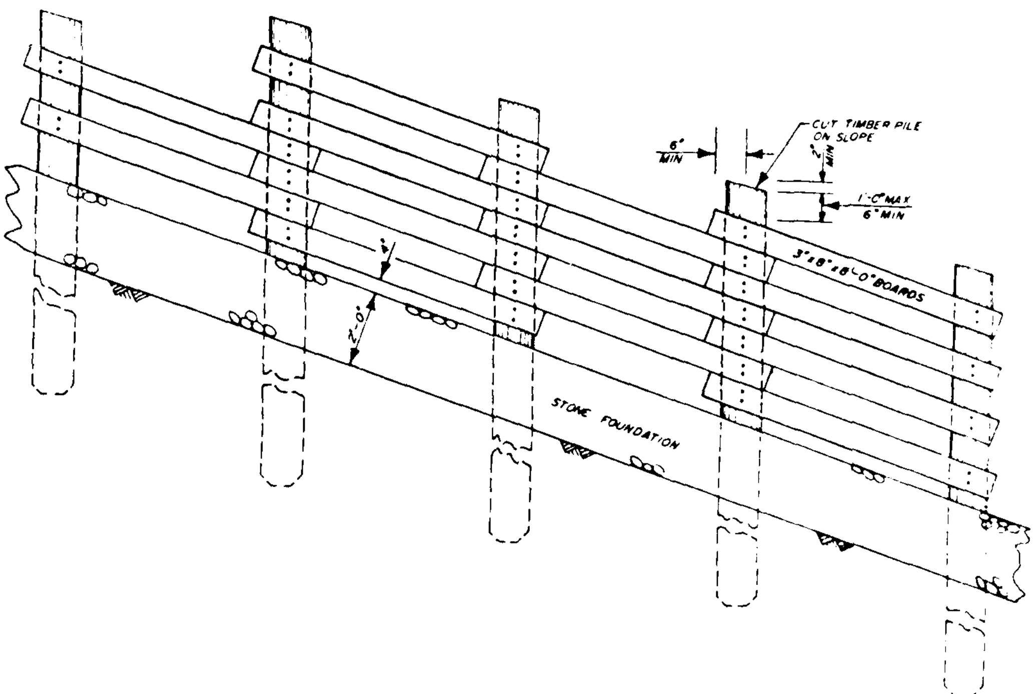


Figure 17. Longitudinal view of a board-fence dike (Source: Bank Stabilization, South Fork, Tillatoba Creek, Drawing No. 4, LMK, 1972)

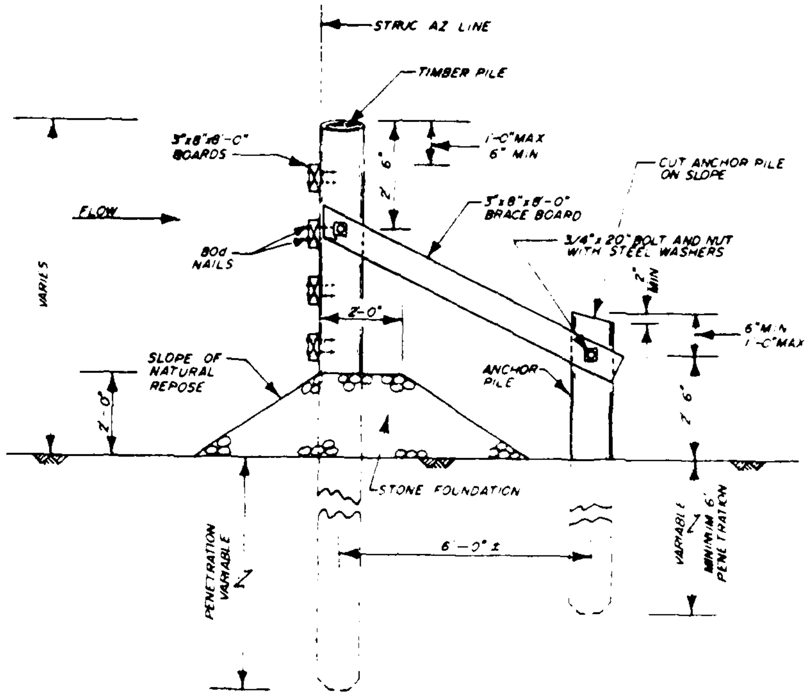


Figure 18. Lateral view of board-fence dike; one to three braces were required per dike (Source: Bank Stabilization, South Fork, Tillatoba Creek, Drawing No. 4, LMK, 1972)

Figure 19. Failure of board-fence dike due to heavy drift load, South Fork, Tillatoba Creek (1[illegible] October 1977)

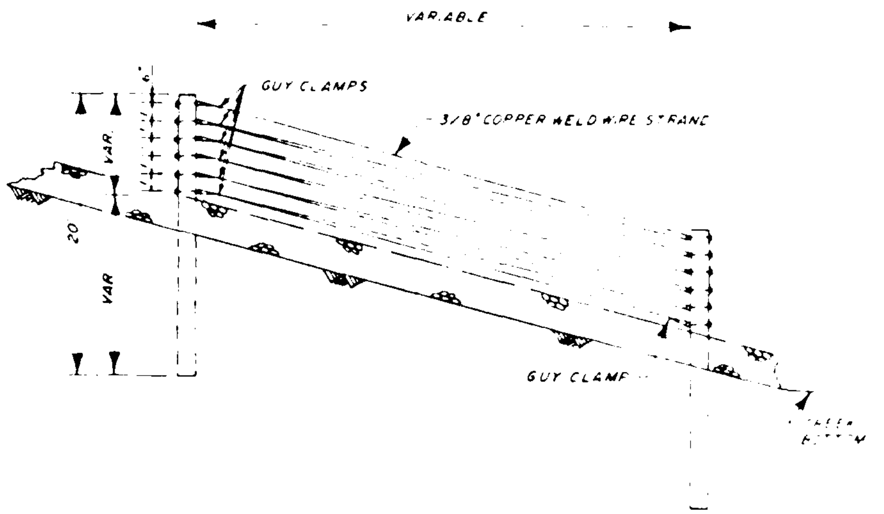


Figure [illegible]. Longitudinal view of cable-fence dike [illegible] bank stabilization, South Fork, Tillatoba Creek, (Drawing [illegible], LMK, 197[illegible])

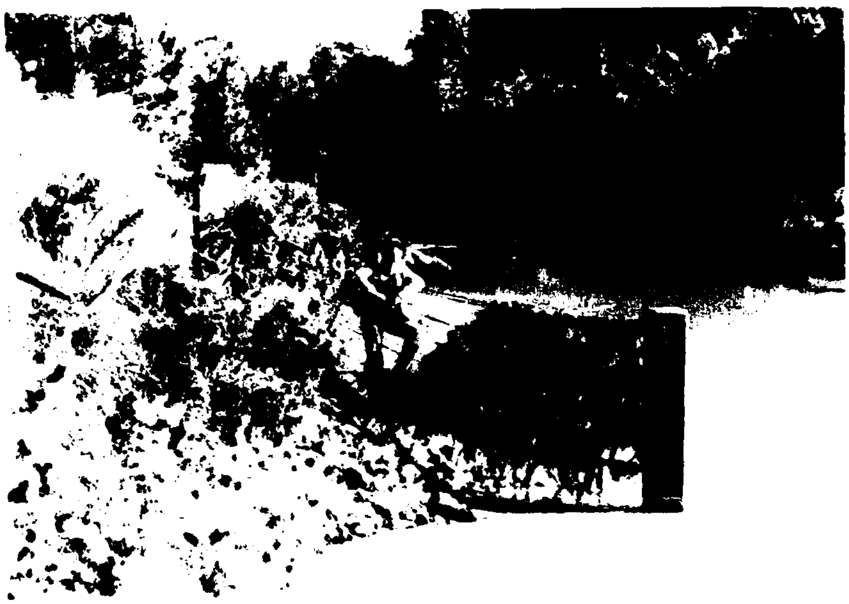


Figure 21. Cable-fence dike showing accumulated debris, South Fork, Tillatoba Creek (1[illegible] October [illegible])

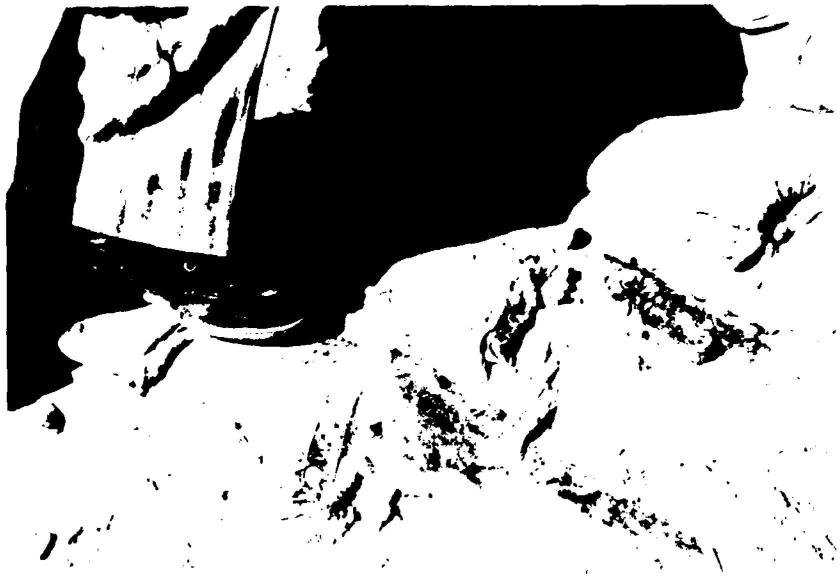


Figure 22. Sand-cement bag revetment, South Fork, Tillatoba Creek (12 October 1977)

Figure 23. Completed sand-cement bag revetment, South Fork, Tillatoba Creek (12 October 1977)

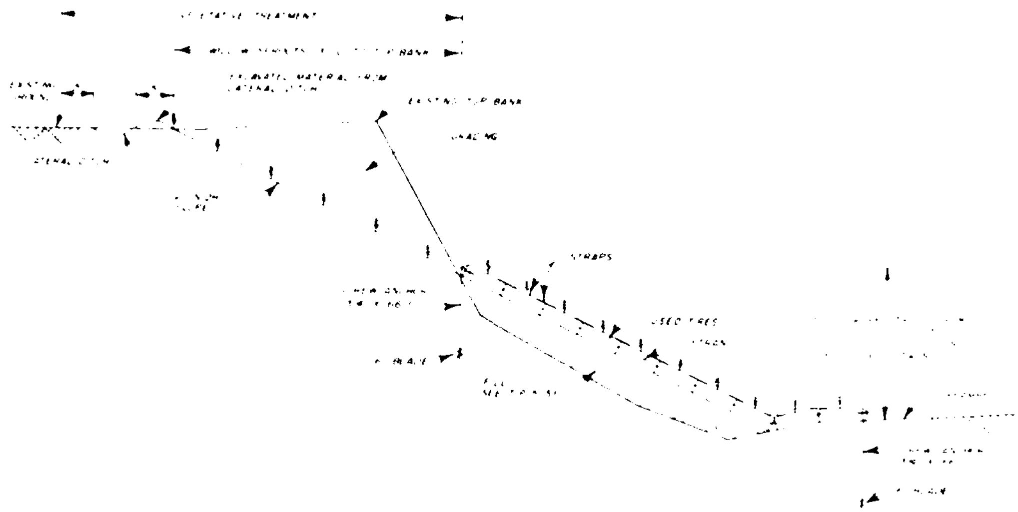


Figure 24. Lateral view of used-tire revetment, South Fork, Tillatoba Creek (Source: Bank Stabilization, [illegible], Drawing No. 2, LMK, 197[illegible]

Figure 25. Used-tire revetment, South Fork, Tillatoba Creek (1[illegible] October 197[illegible])

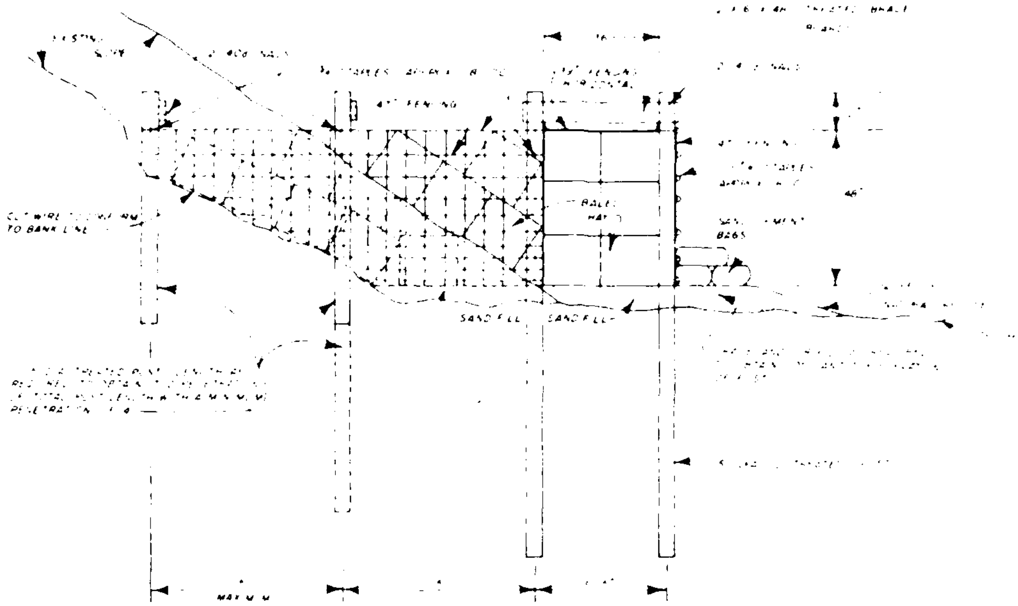
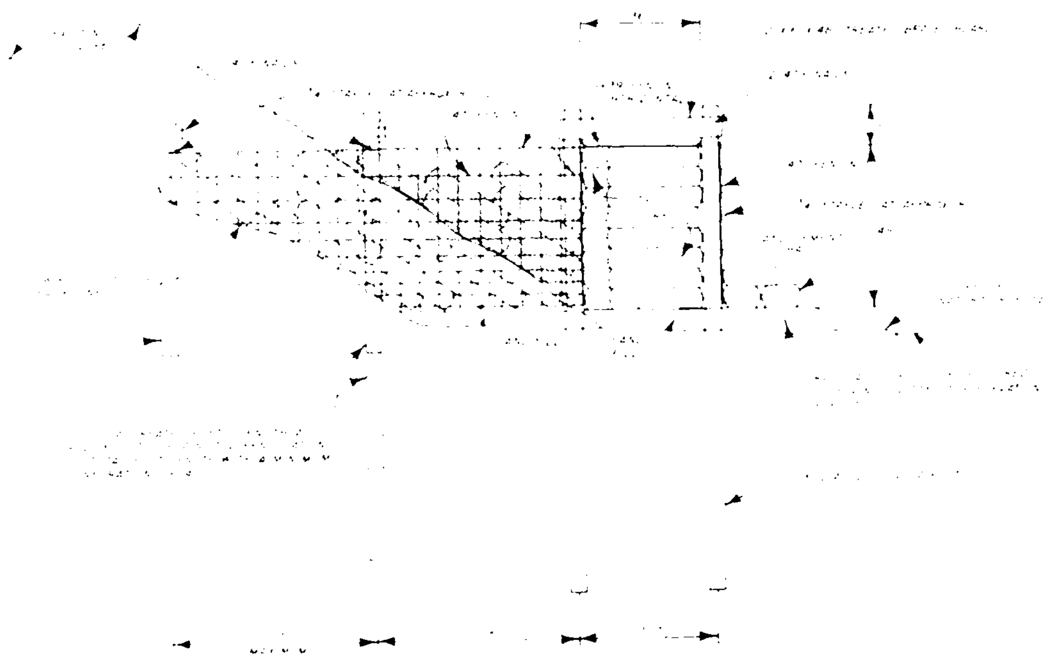


Figure 26. Profile of hay-filled wire crib retard showing tieback and toe protection (Source: Item 55, South Fork, Tillatoba Creek, Drawing No. 2, LMK, 1977)

Figure 27. Hay-filled wire crib retards have been successful in trapping sediment and debris (South Fork, Tillatoba Creek, 24 January 1978)

Figure [illegible]. Hay-filled wire crib retard showing [illegible] ... [illegible] Tillamook Creek ([illegible] 197[illegible])

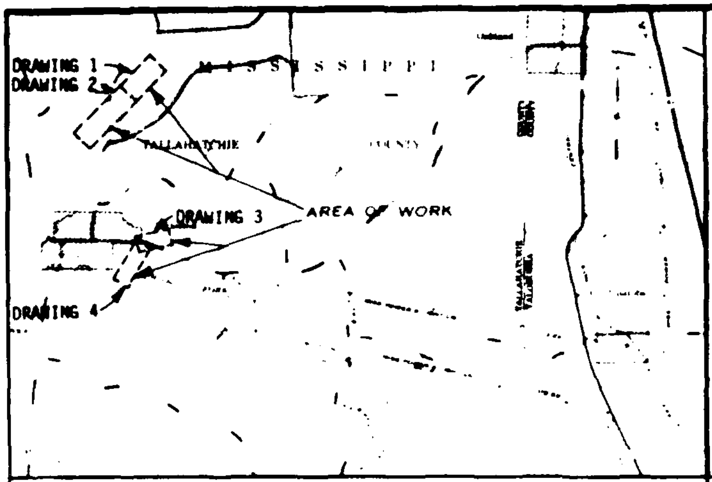
Figure 29. Failure of hay-filled wire crib retard, South Fork, Tillamook Creek ([illegible] 197[illegible])



[illegible] Profile of [illegible]-fire-filled crib return, South Fork, [illegible] Dam [illegible], South Fork, Tillatoba Creek, [illegible] Drawing No. [illegible], [illegible], 1977)

Figure 31. In-place used-tire-filled wire crib retard, South Fork, Tillatoba Creek (12 October 1977)

Figure 32. Rearrangement of tires in crib due to undercutting, South Fork, Tillatoba Creek (12 October 1977)



LOCALITY MAP

NOTE:
DIKE FEATURES EXAGGERATED AND NOT TO SCALE.

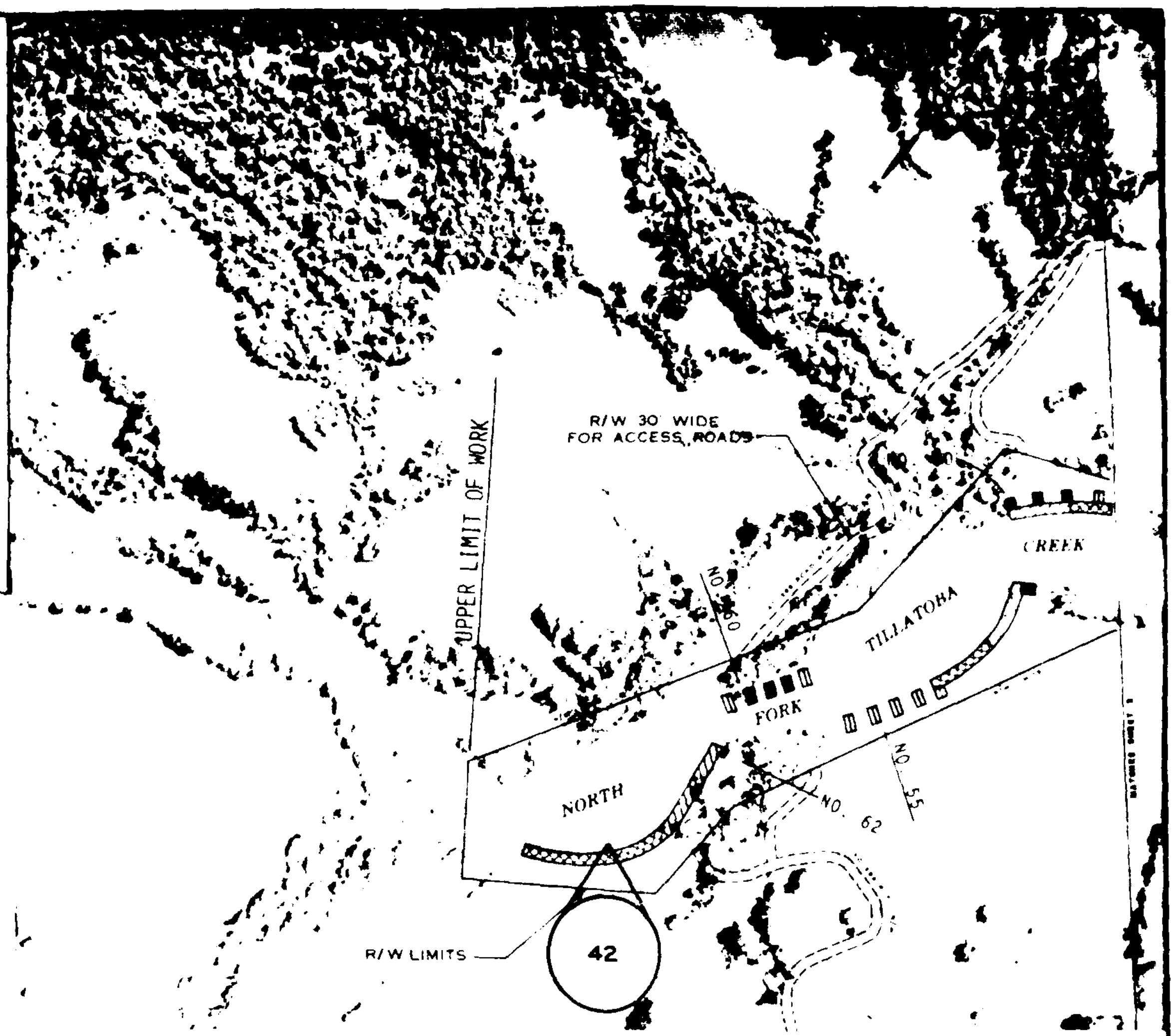
SCALE IN FEET

PHOTOGRAPHS FLOWN ... 1974

LEGEND

- LONGITUDINAL STONE DIKE - TYPE I - TO BE CONSTRUC
- LONGITUDINAL STONE DIKE - TYPE II - TO BE CONSTR
- LONGITUDINAL STONE DIKE - TYPE III - TO BE CONST
- LONGITUDINAL STONE DIKE - TYPE IV - TO BE CONSTR

- TRANSVERSE STONE DIKE OR TIEBACK -
- TRANSVERSE STONE DIKE OR TIEBACK -



FEATURES EXAGGERATED AND NOT

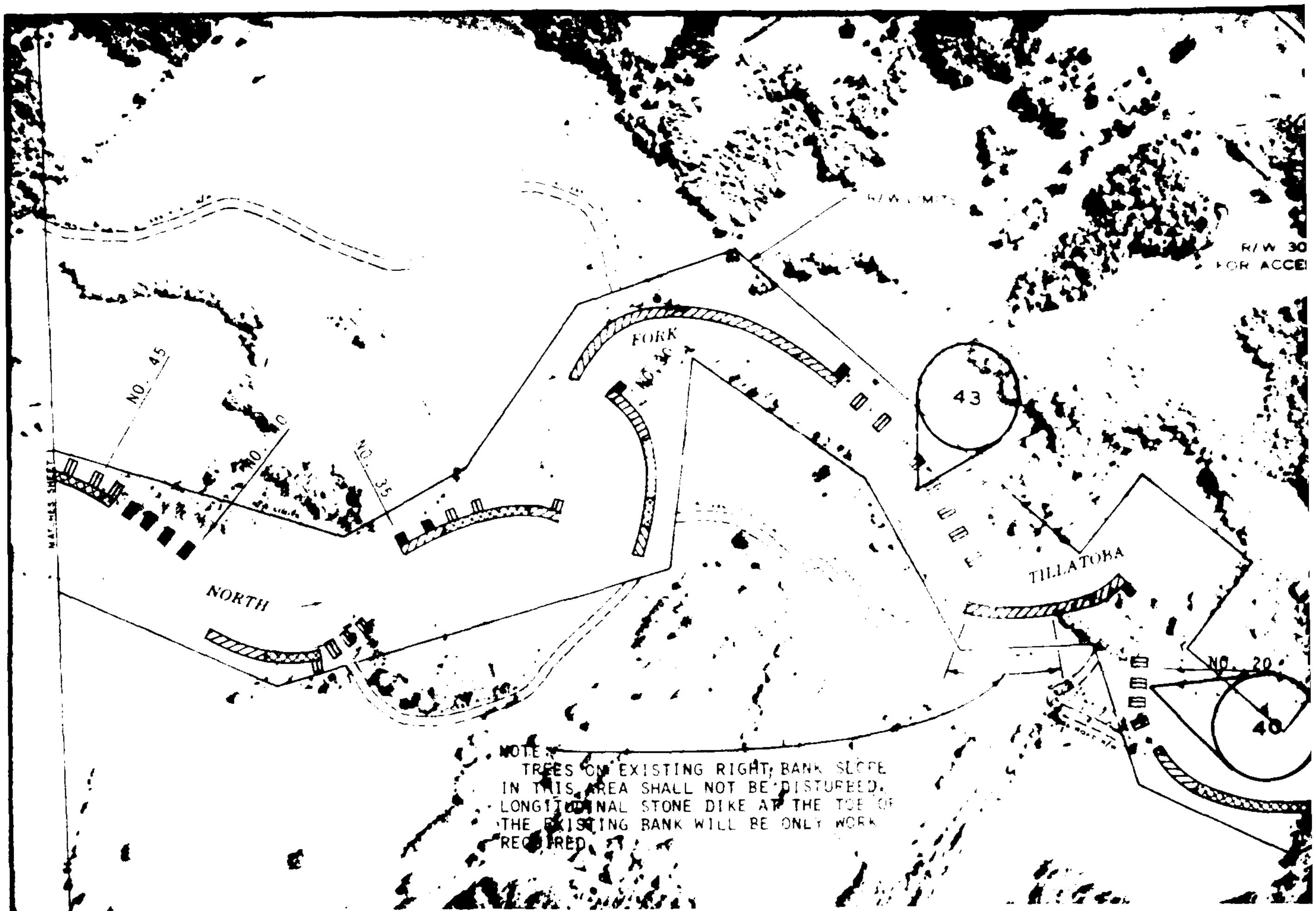
SCALE IN FEET

PHOTOGRAPHS FLOWN [illegible]

LEGEND

- LONGITUDINAL STONE DIKE - TYPE I - TO BE CONSTRUCTED
- LONGITUDINAL STONE DIKE - TYPE II - TO BE CONSTRUCTED
- LONGITUDINAL STONE DIKE - TYPE III - TO BE CONSTRUCTED
- LONGITUDINAL STONE DIKE - TYPE IV - TO BE CONSTRUCTED
- TRANSVERSE STONE DIKE OR TIEBACK -
- TRANSVERSE STONE DIKE OR TIEBACK -

Figure [illegible]. Plan Map [illegible]
North Fork, Tilla[illegible]



SCALE

PHOTOGRAPHS F

SCALE IN FEET

PHOTOGRAPHS FLOWN 30 SEPT 1974

Figure 34. Plan Map [illegible] for Item 1,
North Fork, Tillatoba Creek
(Legend on Figure [illegible])

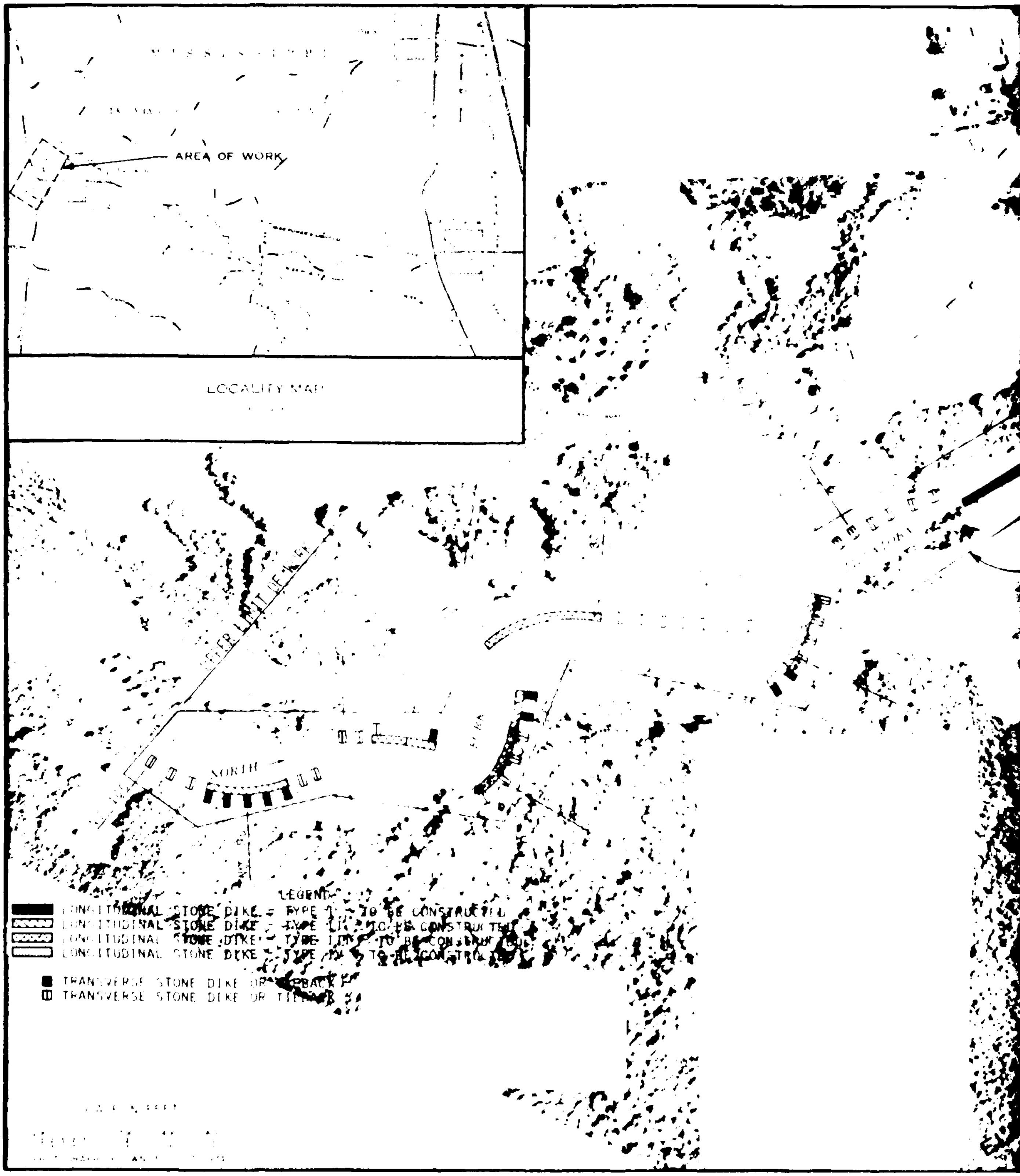
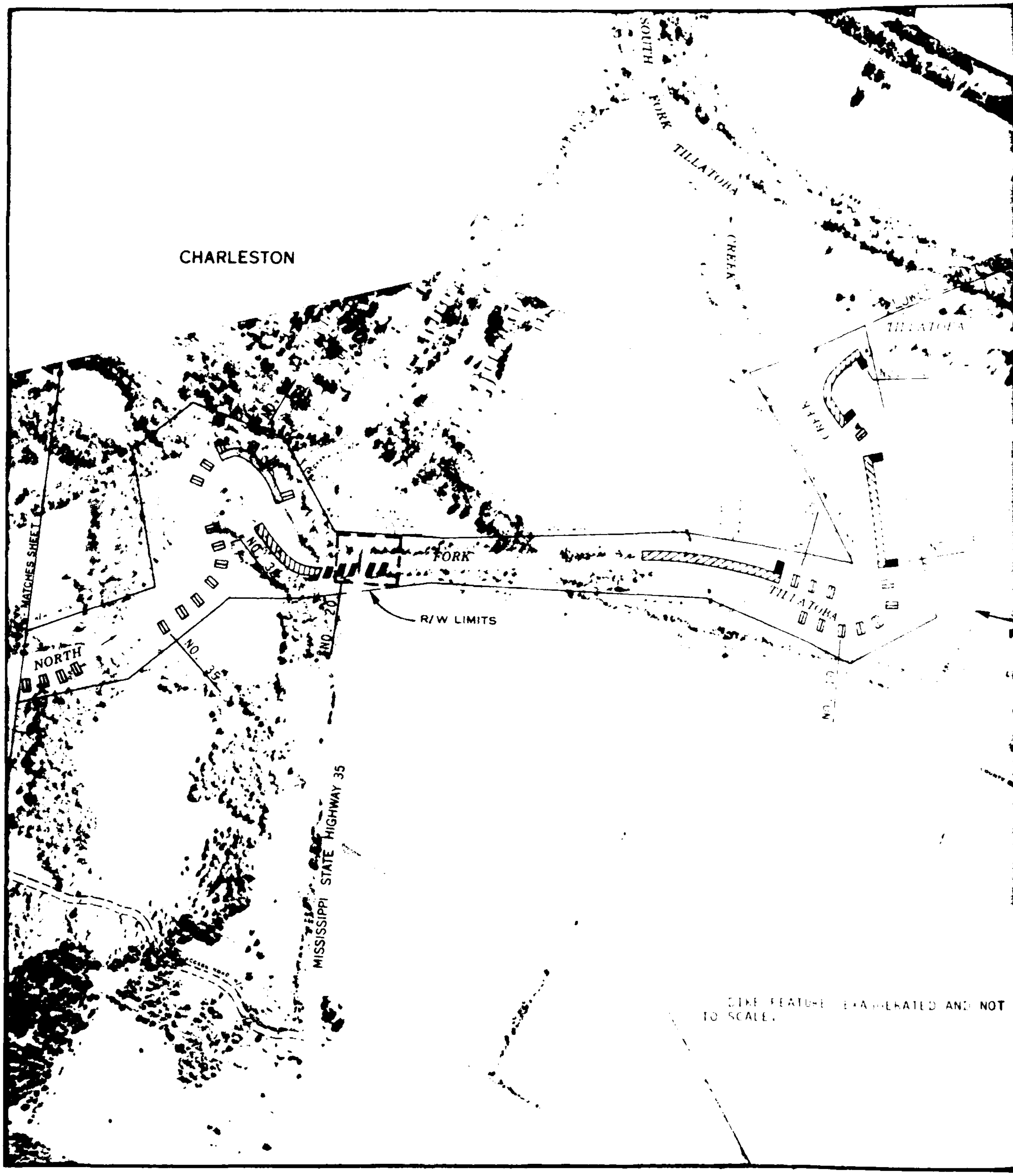

AREA OF WORK
LOCALITY MAP
NORTH
LEGEND
LONGITUDINAL STONE DIKE
LONGITUDINAL STONE DIKE
LONGITUDINAL STONE DIKE
LONGITUDINAL STONE DIKE
TRANSVERSE STONE DIKE OR
TRANSVERSE STONE DIKE OR

Figure 2[illegible]. Plan Map 1 for Item [illegible].
North Fork, Tillatoba Creek



CHARLESTON
SOUTH
FORK
TILLATOBA
CREEK
NORTH
FORK
TILLATOBA
NO. 34
NO. 35
NO. 20
R/W LIMITS
MATCHES SHEET
MISSISSIPPI STATE HIGHWAY 35

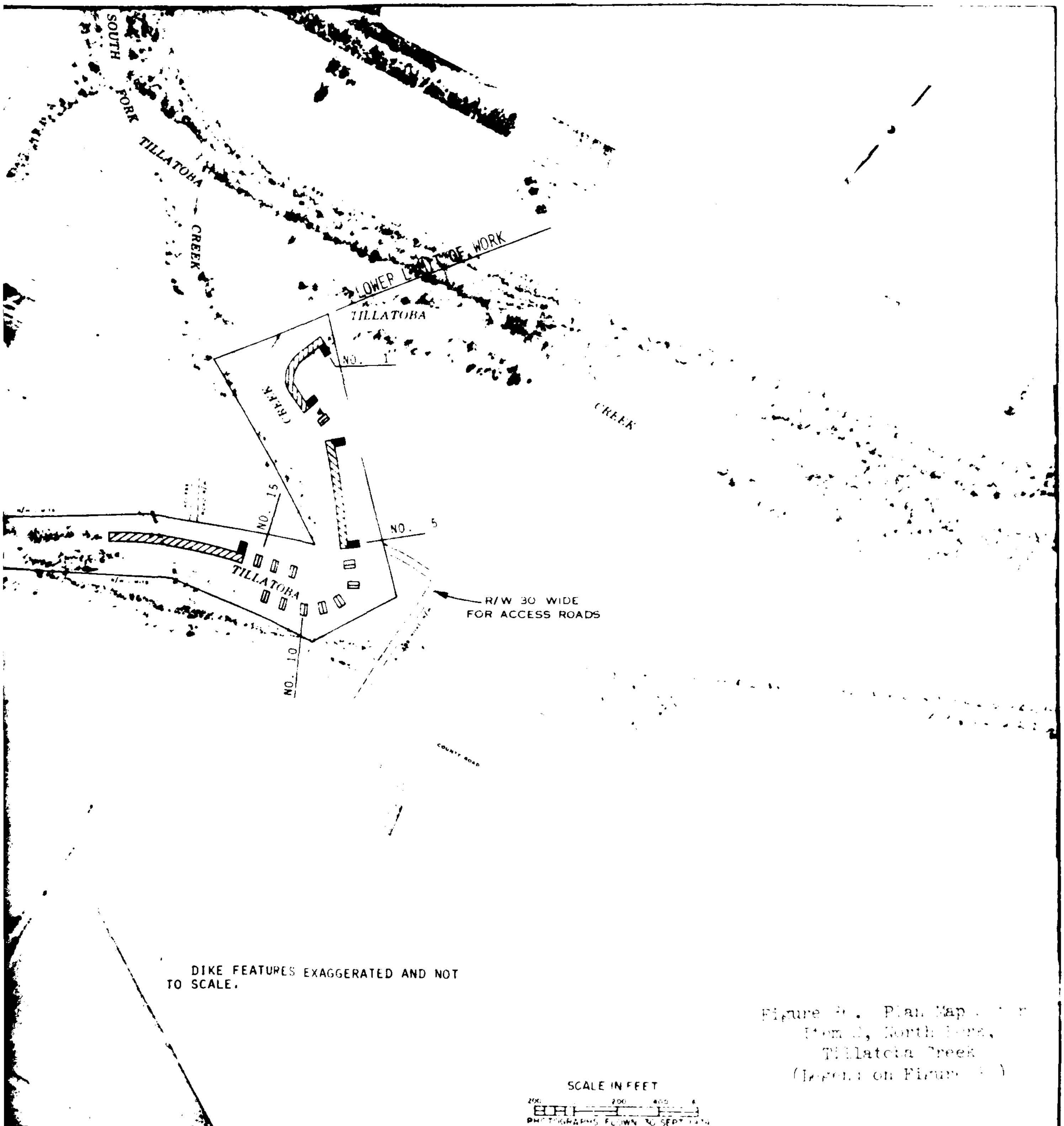


Figure [illegible]. Plan Map [illegible]
Item [illegible], North Fork,
Tillatoba Creek
(Legend on Figure [illegible])

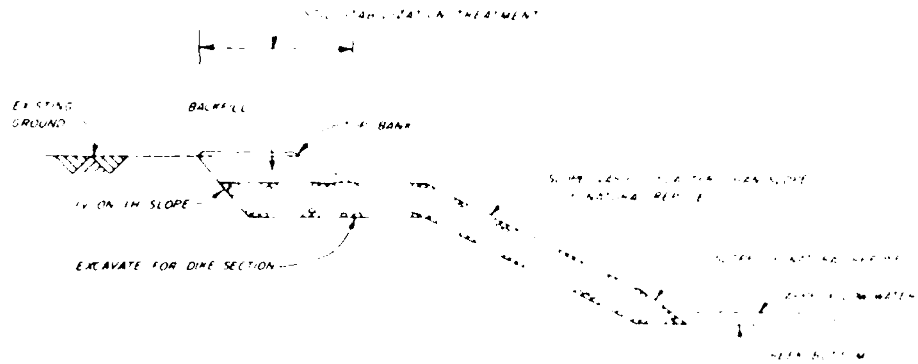


Figure 37. Longitudinal view of typical transverse stone dike (Source: Streambank Erosion Control, Item 1, North Fork, Tillatoba Creek, and Hunter Creek, Drawing No. [illegible], LMK, 1979)

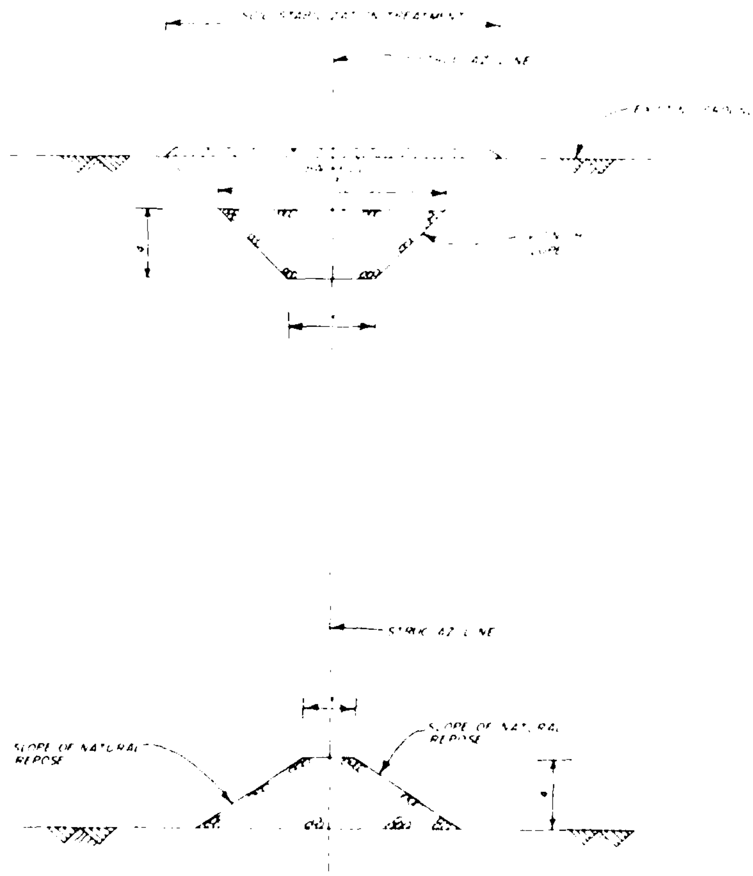


Figure 38. Typical lateral sections for Type I tieback and transverse dike (Source: Streambank Erosion Control, Item 1, North Fork, Tillatoba Creek, Drawing No. [illegible], LMK, 1979)

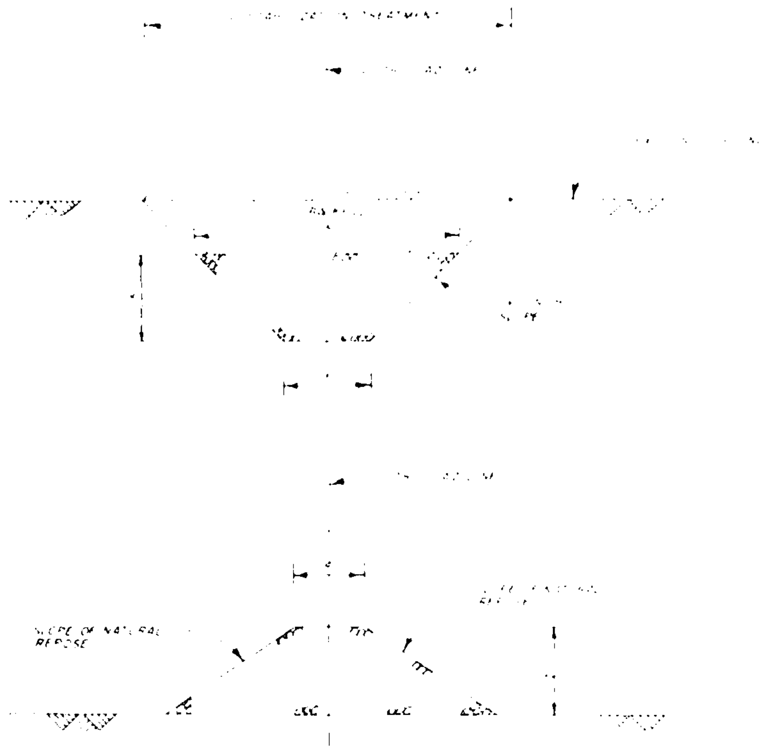


Figure 39. Typical lateral sections for Type II tieback and transverse dike (Source: Streambank Erosion Control, Item 1, North Fork, Tillatoba Creek, Drawing No. 5, LMK, 1979)

Figure 40. Transverse stone dike, North Fork, Tillatoba Creek (12 October 1977)

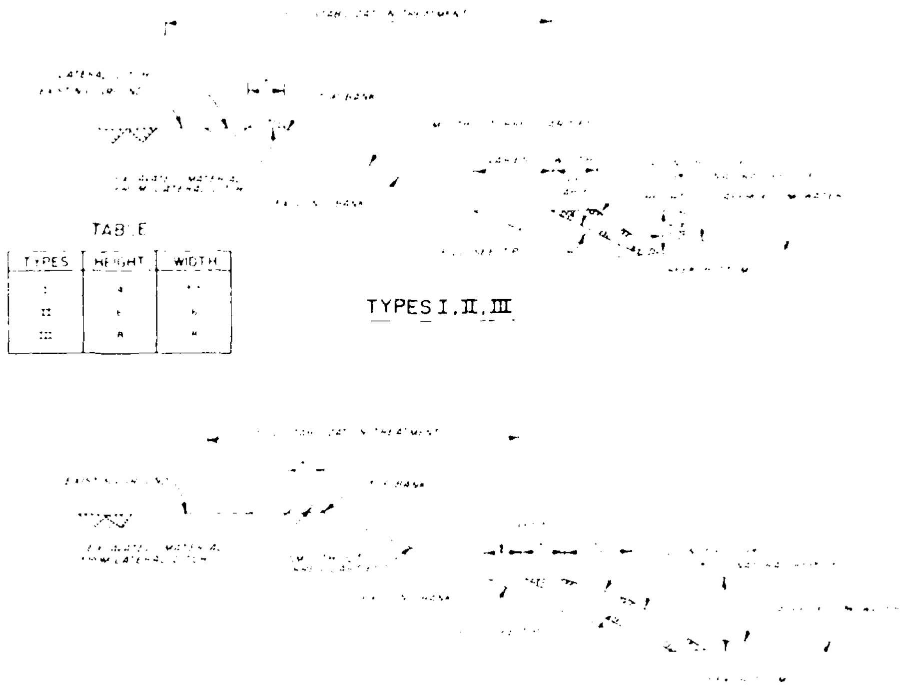


Figure 41. Four types of longitudinal dike design[illegible] [illegible] LMK [illegible] Streambank Erosion Control, Item 1, North Fork, [illegible] Creek, [illegible] No. 6, LMK, 1975)

Figure 42. Longitudinal stone dike with [illegible] established on upper bank, North Fork, [illegible] (1[illegible] October [illegible])

Figure 43. Sand being removed from North [illegible] [illegible] for use in a ready-mix [illegible] [illegible] October 197[illegible]

Figure 44. Headcutting on North Fork, [illegible]
([illegible] October 197[illegible])

Figure 45. Dead and dying trees that have resulted from bank caving, North Fork, Tillatoba Creek (12 October 1977)

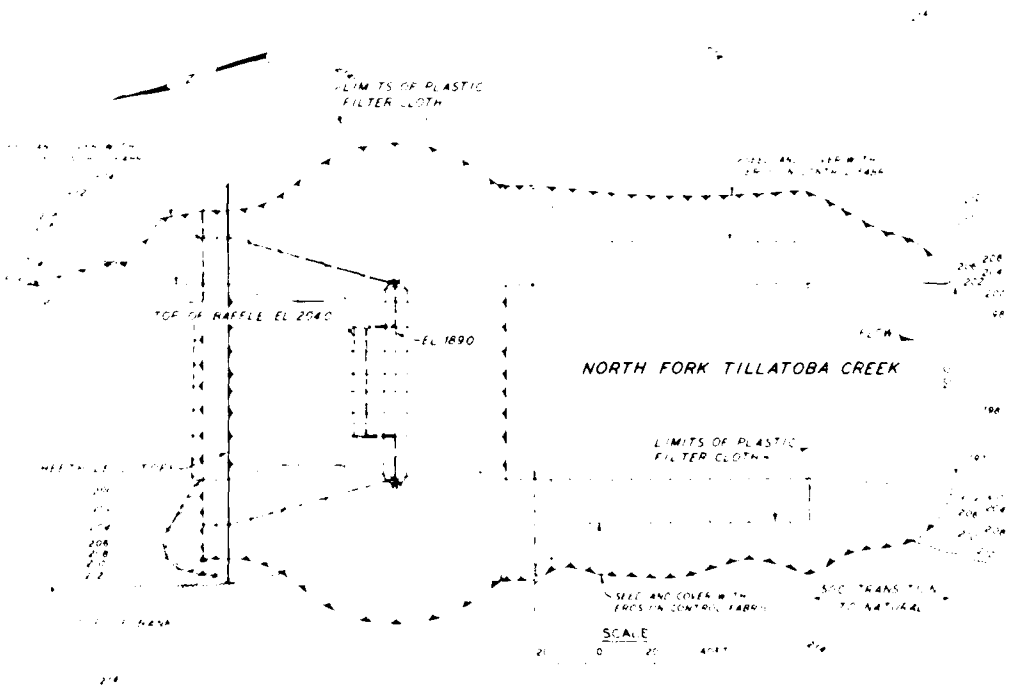


Figure 46. Plan view of grade-control structure (Source: Streambank Erosion Control, Item 3A, North Fork, Tillatoba Creek, Drawing No. 2, LMK, 1977)

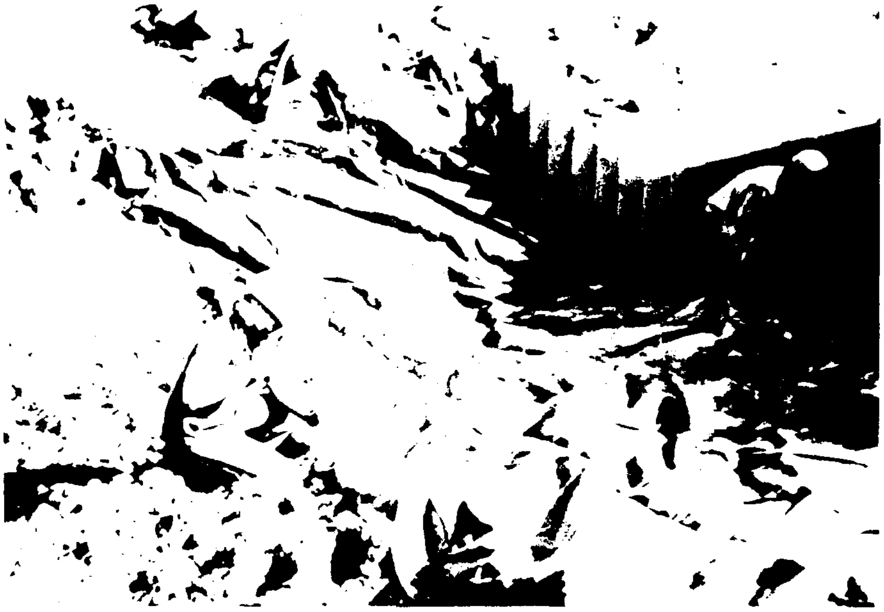


Figure 47. Filter cloth being laid prior to placement of limestone riprap on upper bank of grade-control structure (Item 5A), North Fork, Tillatoba Creek ([illegible] October 1977)

Figure 48. Grade-control structure (Item [illegible]) under construction on North Fork, Tillatoba Creek (17 October 1977)

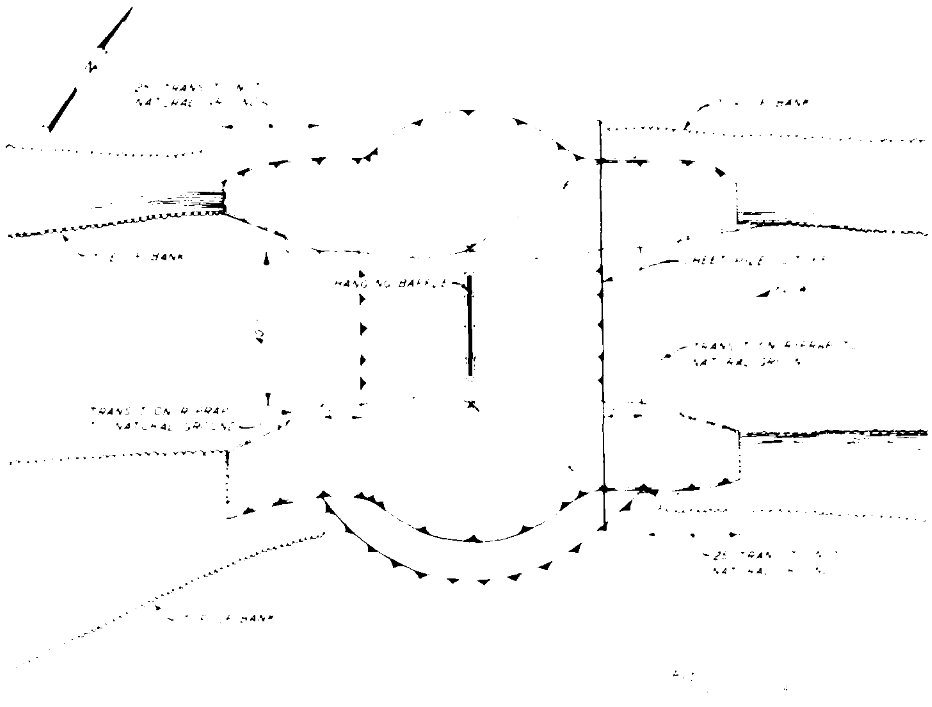


Figure 49. Plan view of grade-control structure [illegible] Erosion Control, Item [illegible], North Fork, Tillatoba Creek, Drawing [illegible], [illegible], 19[illegible]

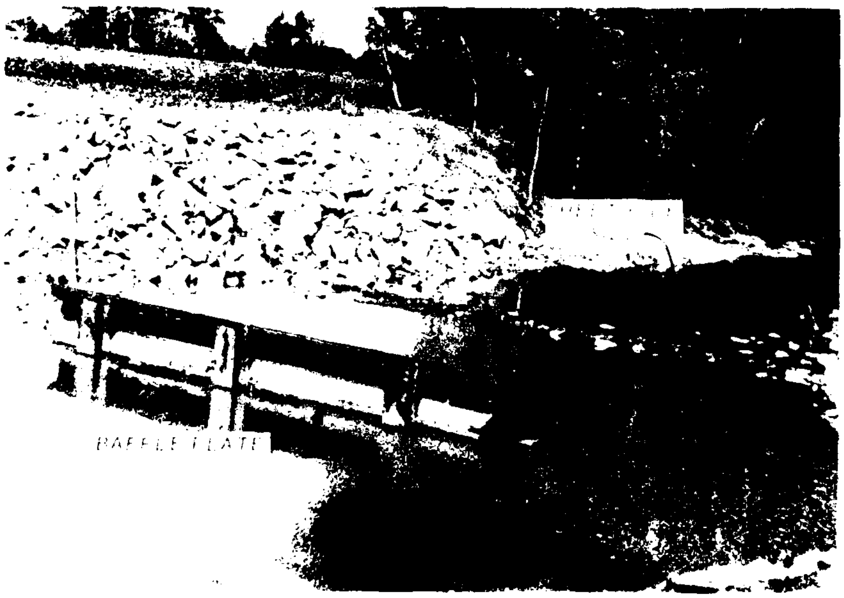
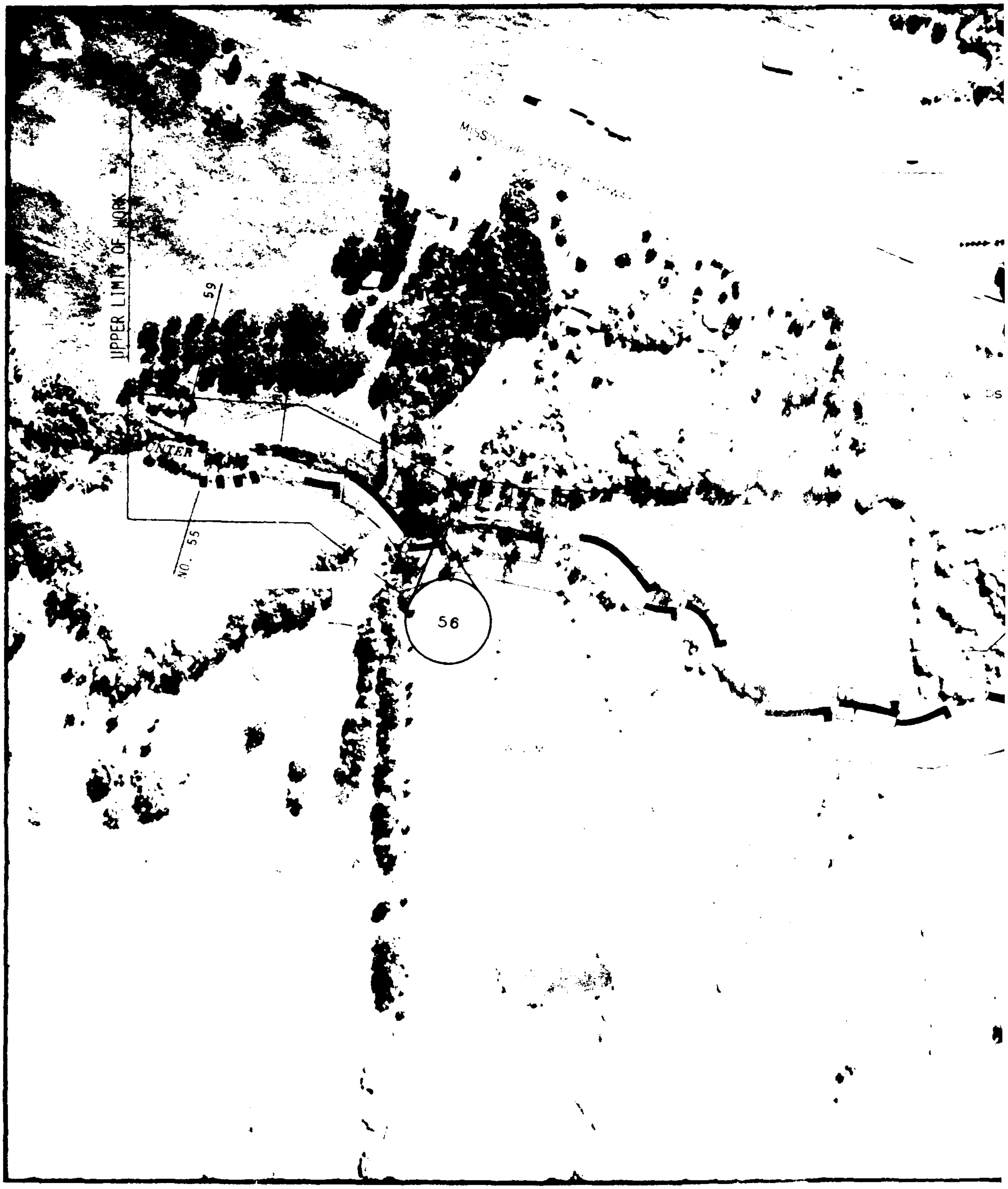
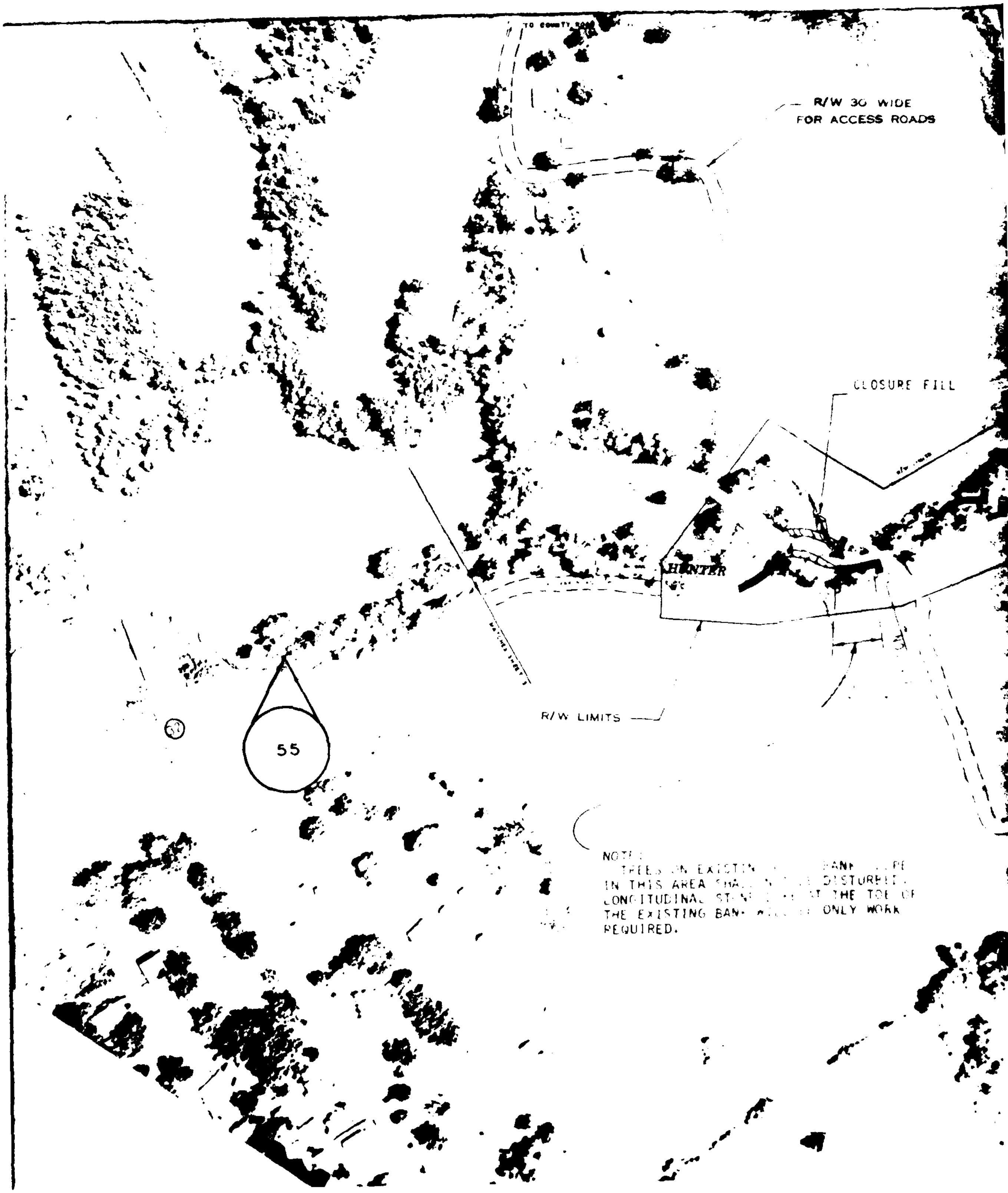


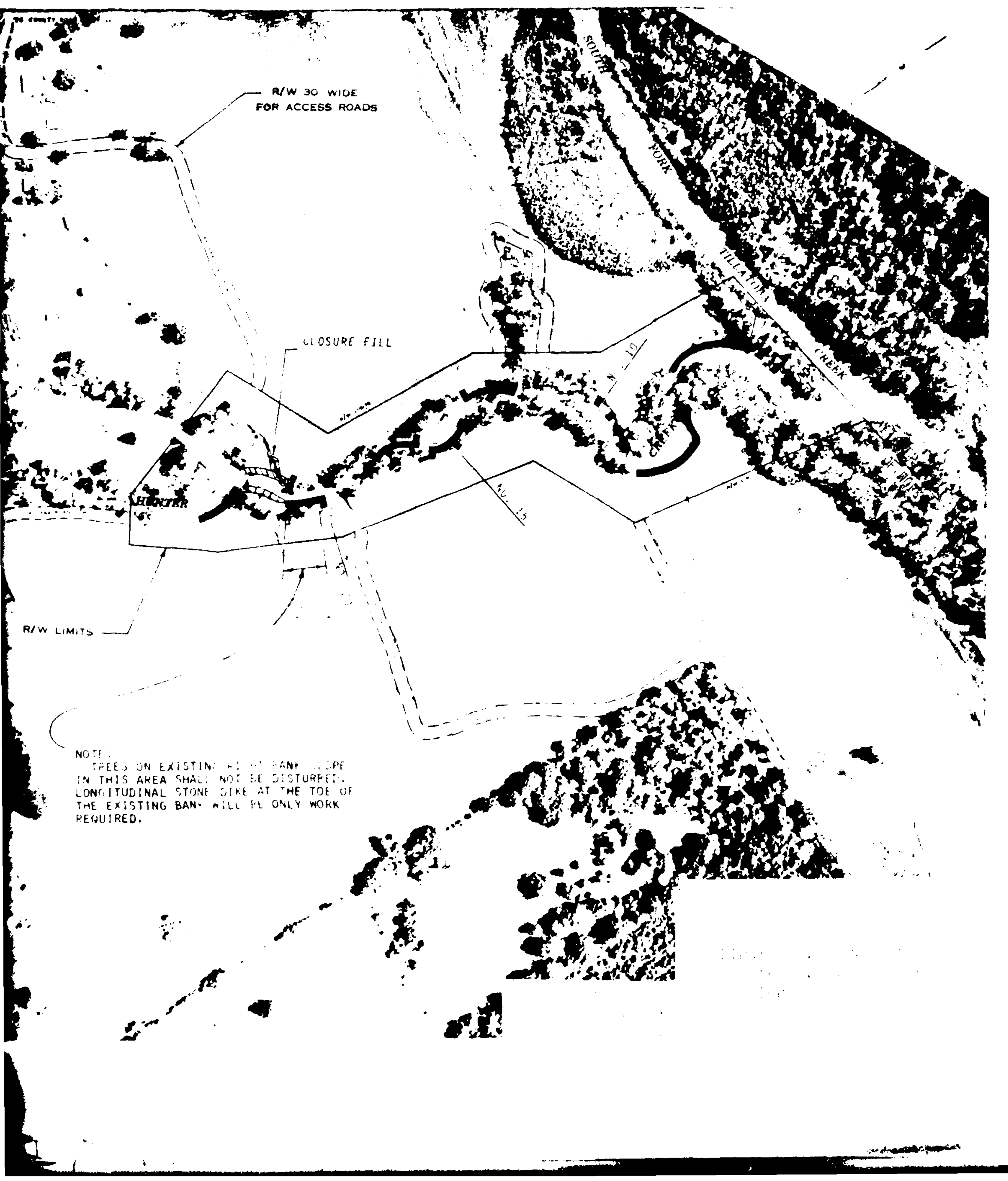
Figure 50. Completed grade-control structure (Item [illegible], North Fork, Tillatoba Creek ([illegible] 1977)


UPPER LIMIT OF WORK
59
NO. 55
56


STATE HIGHWAY 32
CREEK



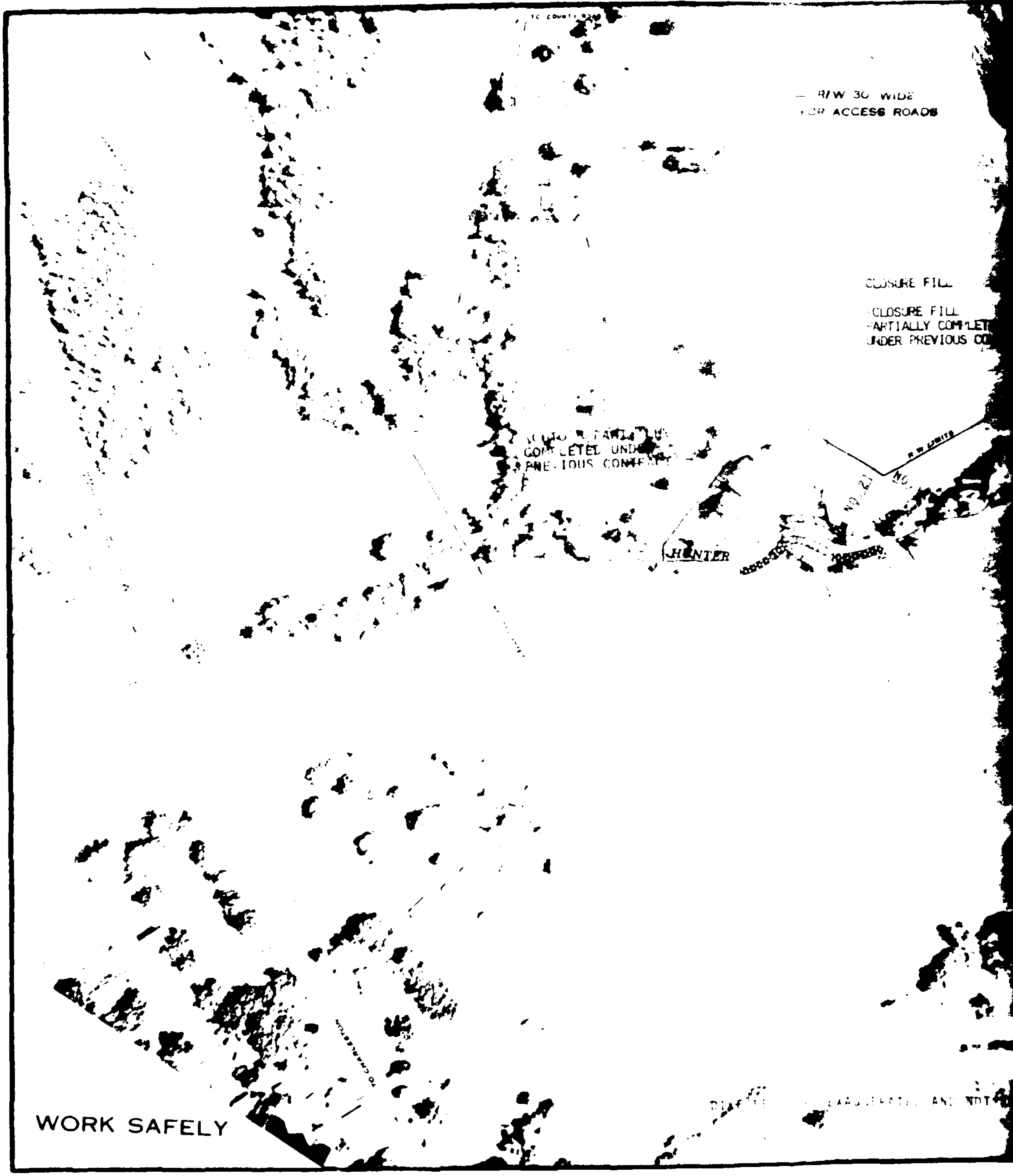
R/W 30 WIDE
FOR ACCESS ROADS
CLOSURE FILL
HUNTER
R/W LIMITS
55
NOTE:
IN THIS AREA
ONLY WORK
REQUIRED.



R/W 30 WIDE
FOR ACCESS ROADS
SOUTH
FORK
TILLATOBA
CREEK
CLOSURE FILL
CREEK
HUNTER
R/W LIMITS
NOTE:
TREES ON EXISTING HIGH BANK SLOPE
IN THIS AREA SHALL NOT BE DISTURBED.
LONGITUDINAL STONE DIKE AT THE TOE OF
THE EXISTING BANK WILL BE ONLY WORK
REQUIRED.


NOTE
BANK
DIKE
MISSISSIPPI STATE HIGHWAY

NOTE:
BANK
OTHER AREAS
SHOWN.
STATE HIGHWAY 32
ROADS
CREEK
NO. 3
LEGEND
LONGITUDINAL STONE DIKE
LONGITUDINAL STONE DIKE
TRANSVERSE STONE DIKE
EXISTING TRANSVERSE



R/W 30 WIDE
FOR ACCESS ROADS
CLOSURE FILL
CLOSURE FILL
PARTIALLY COMPLET
UNDER PREVIOUS CO
COMPLETED UNDE
PREVIOUS CONTR
R.W. LIMITS
HUNTER
WORK SAFELY

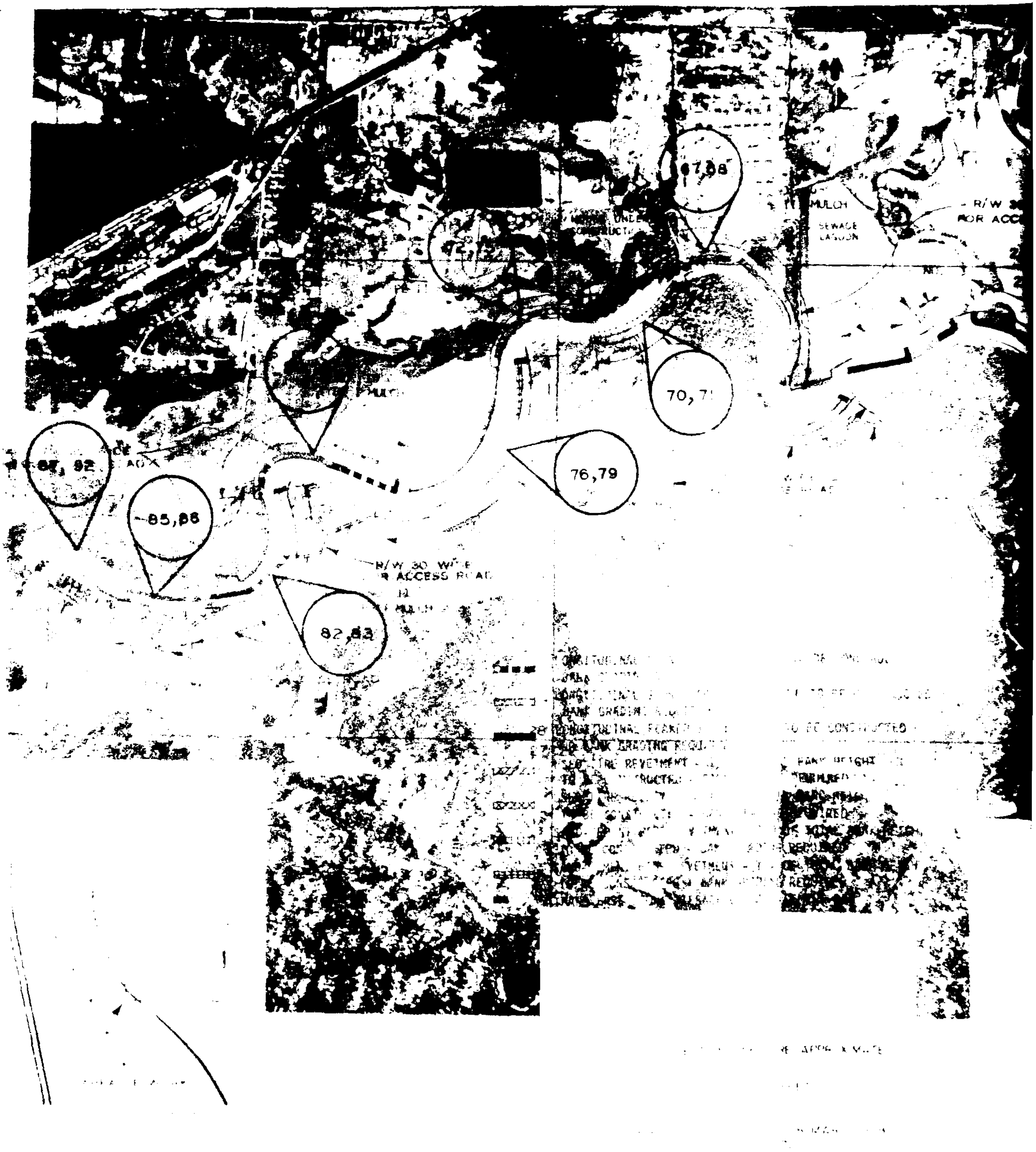

R/W 30' WIDE
FOR ACCESS ROADS
CLOSURE FILL
(CLOSURE FILL
PARTIALLY COMPLETED
UNDER PREVIOUS CONTRACT)
SOUTH FORK TILLATOBA CREEK
HUNTER
DIKE FEATURES EXAGGERATED AND NOT TO SCALE

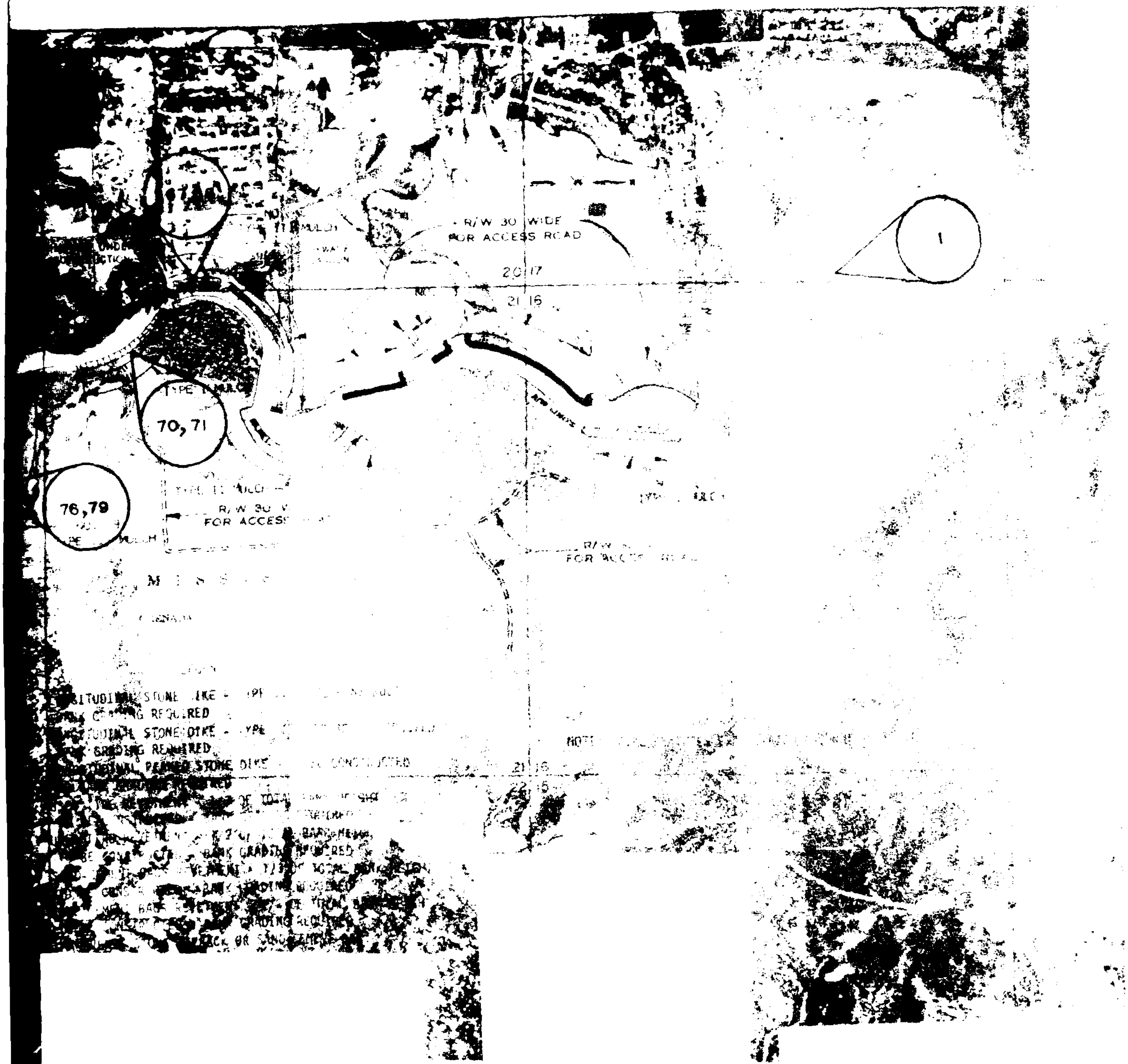
Figure 55. Transverse stone dike, Hunter Creek
(24 January 1978)

Figure 56. Longitudinal stone dike, Hunter Creek
(24 January 1978)


GRENADA LAKE
RIVER
Grenada
AREA OF WORK
GRENADA
LOWER LIMIT OF
R/W
GULF
RAILROAD


PHOTOGRAPHS FLOWN
TELEPHONE
POWER
62,63
64
66
LEGEND


87,88
MULCH
SEWAGE
LAGOON
70,71
76,79
85,86
82,83
R/W 30 WIDE
ACCESS ROAD
CONSTRUCTED
BANK HEIGHT



SECTION LINES ARE APPROXIMATE

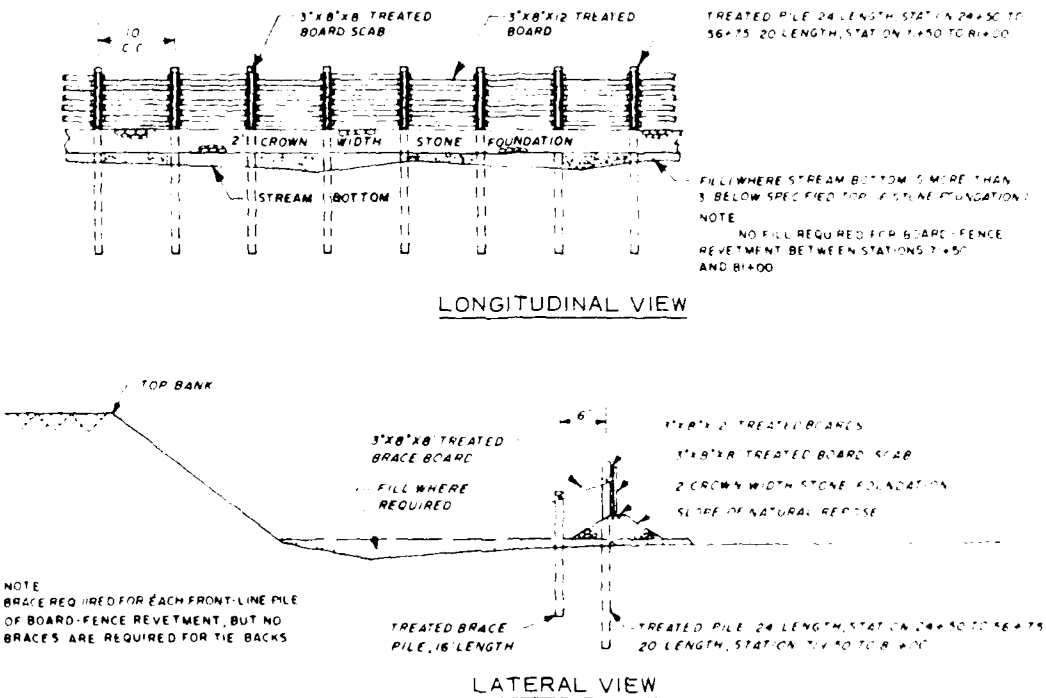


Figure 59. Board-fence revetment construction details (Source: Bank Stabilization, Batupan Bogue, Drawing No. 4, LMK, 197_)

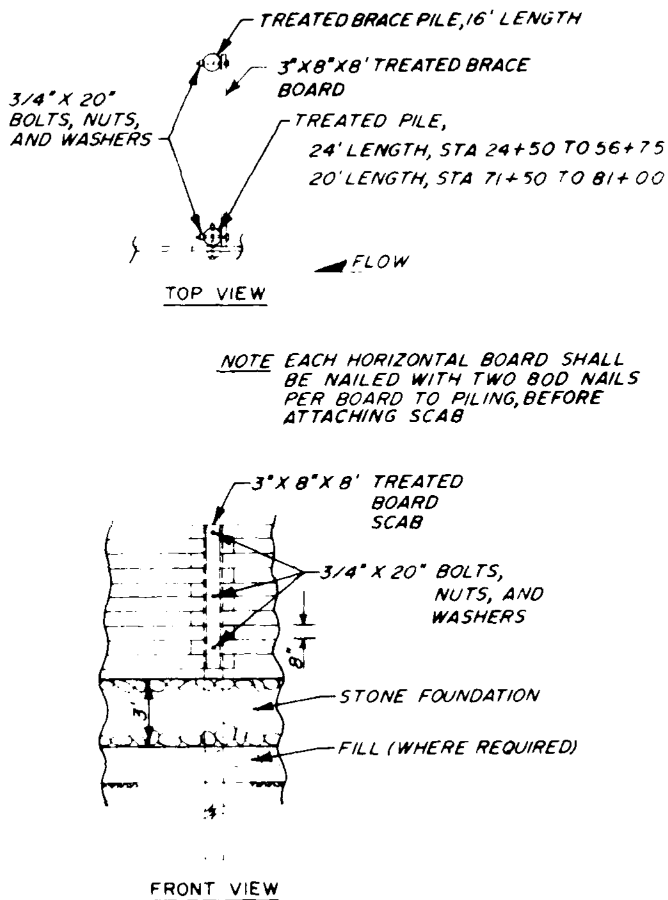


Figure 60. Boards attached to pilings with bolts (Source: Bank Stabilization, Batupan Bogue, Drawing No. 4, LMK, 197[illegible])

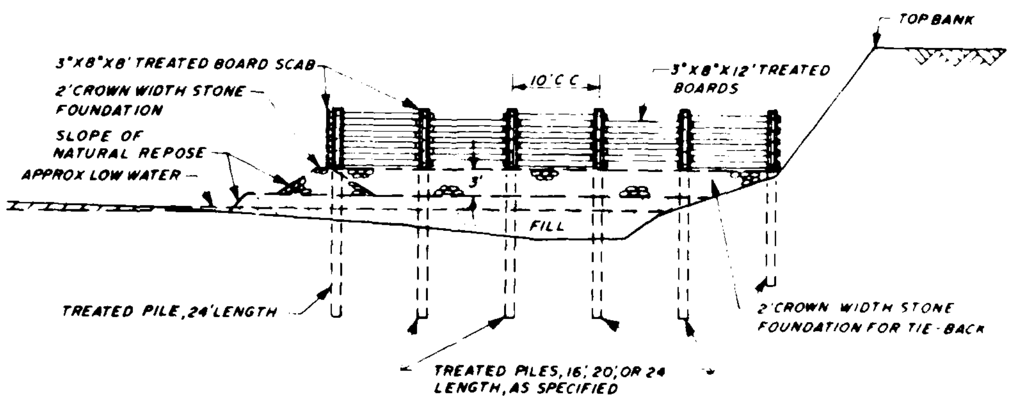


Figure 61. Tiebacks were constructed at regular intervals to provide additional mechanical stability for the structure and to prevent formation of a secondary channel (Source: Bank Stabilization, Batupan Bogue, Drawing No. 4, LMK, 197[illegible])

Figure 62. Board-fence revetment and longitudinal stone dike, Batupan Bogue (25 January 1978)

Figure 63. Braces used to support board-fence revetment, Batupan Bogue ([illegible] January [illegible])

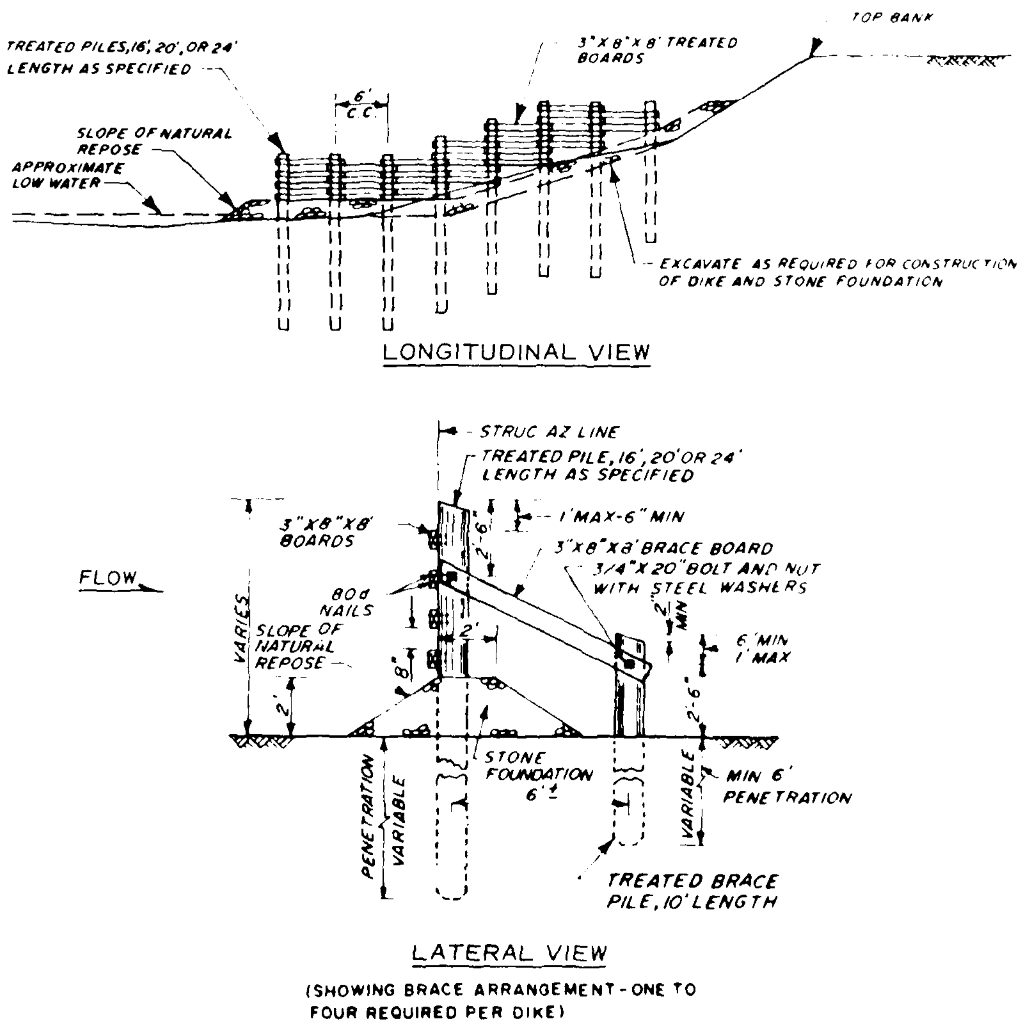


Figure 65. Board-fence dike construction details (Source: Bank Stabilization, Batupan Bogue, Drawing No. 4, LMK, 1972)

Figure 66. Board-fence dikes placed on the bank of Batupan Bogue (11 October 1977)

Figure 67. Type III longitudinal stone dike, Work Area [illegible], Batupan Bogue ([illegible] January [illegible])

Figure 68. Serious scour occurred on the upper bank in Work Area 6 during the 21 November 1977 storm event, Batupan Bogue (25 January 1978)

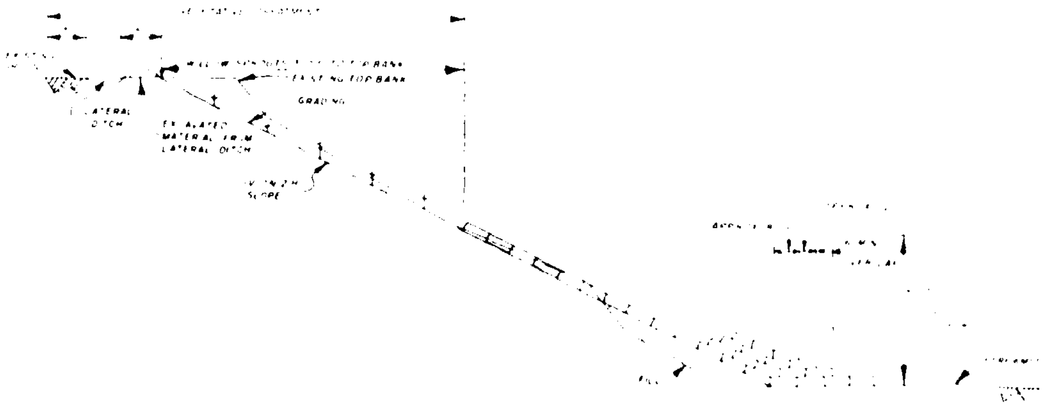


Figure 69. Lateral view, sand-cement bag revetment [illegible] Batupan Bogue, Drawing No. [illegible], LMK, [illegible]

Figure [illegible]. Upper bank failure, Work Area [illegible]
[illegible] January [illegible]

Figure 72. Used tires held together with steel straps and cables, Work Area 8, Batupan Bogue ([illegible] January 197[illegible])

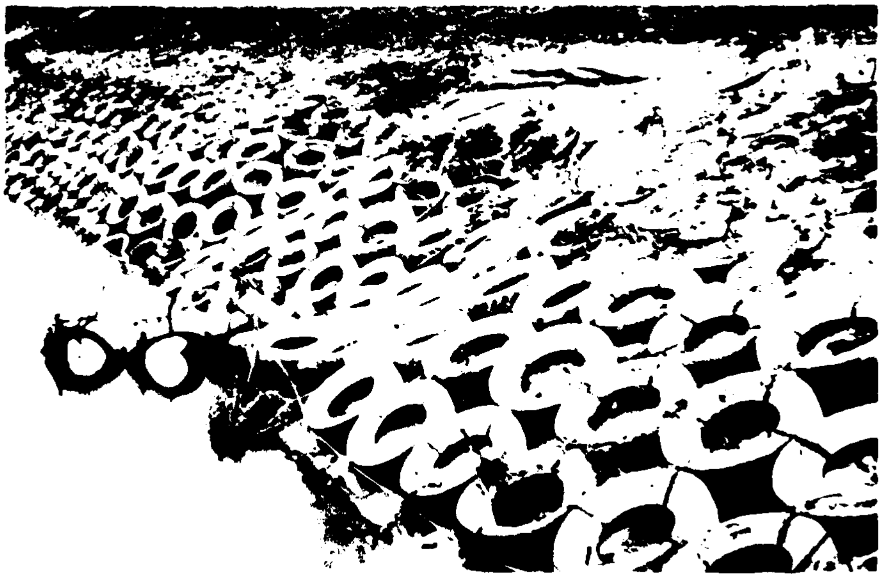
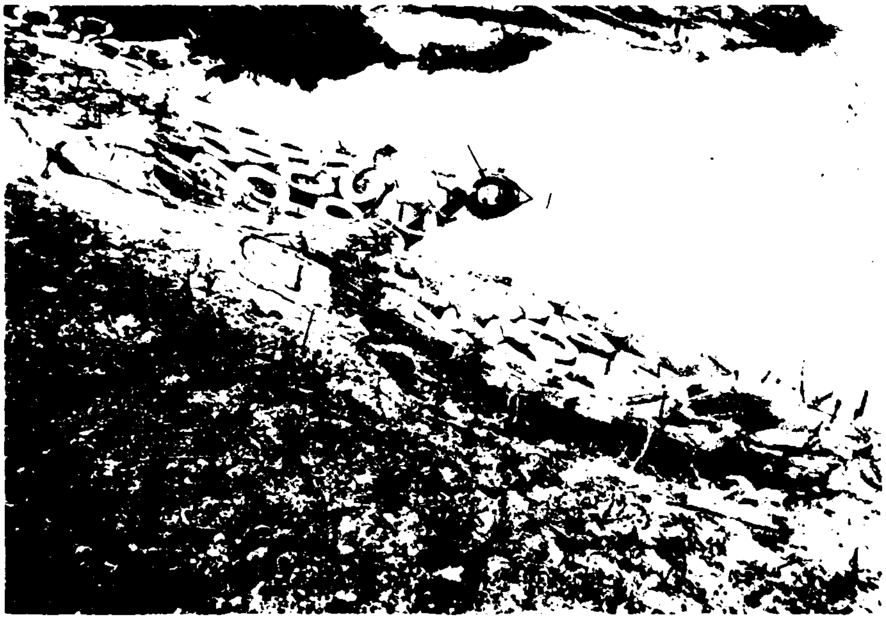


Figure 73. Used-tire revetment, Work Area 8, Batupan Bogue (25 January 1978)



[illegible]

Figure 75. Upper bank failure, [illegible]
([illegible] January [illegible])

Figure 76. Ongoing placement of [illegible] revetment, Work Area 9, Batupan [illegible] 1977)

Figure 77. Completed section of [illegible], Work Area 9, Batupan B[illegible] [illegible] 1977)

Figure 7[illegible]. Revetment failure in Work Area 9, Batupan Bend
([illegible] January 19[illegible])

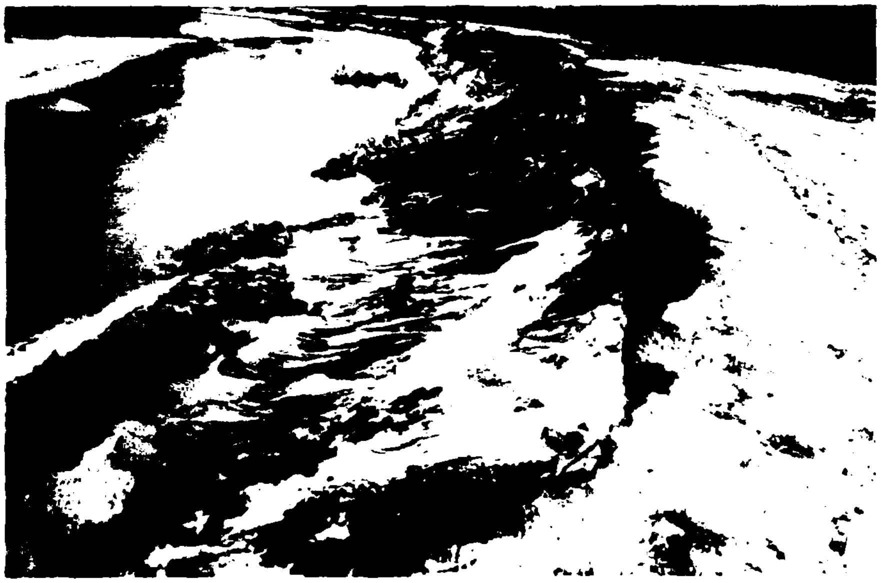
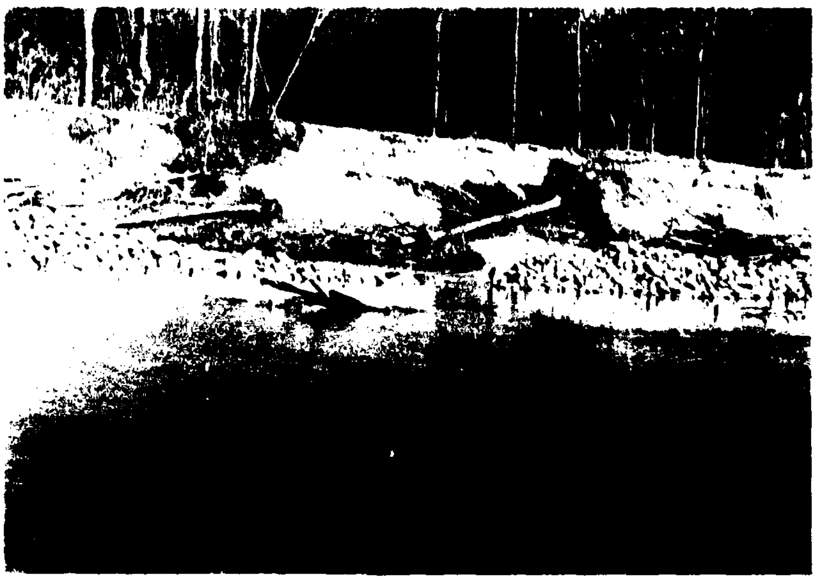


Figure 79. Upper bank failure, Work Area 9, Batupan Bend
([illegible] January 1978)

[illegible]

[illegible]

[illegible]



[illegible]

[illegible] Apparent failure of longitudinal peaked stone [illegible]
[illegible]
[illegible]
[illegible]

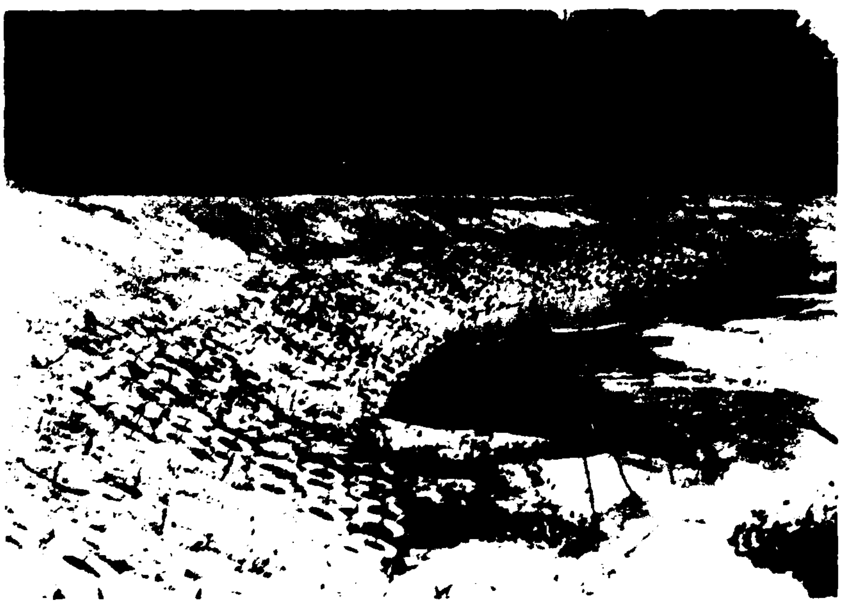


Figure [illegible]
[illegible]

Figure 88. Toe failure at Work Area 13, Batupan [illegible]
(11 October 1977)

Figure 89. Top bank failure at Work Area 13, [illegible] [illegible]
(11 October 1977)

Figure 90. Failure at Work Area [illegible], [illegible]
([illegible]9 January 1978). Compare with [illegible]

Figure 91. Bank failure, Work Area [illegible], [illegible]
([illegible] January [illegible])

DATE
ILME