Geologic and Geomorphic Aspects of Streambank Erosion in the Yazoo Hill Streams

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INTRODUCTION

The Streambank Erosion Control, Evaluation, and Demonstration Project was enacted by the 93rd Congress as part of the Water Resources Development Act of 1974, Public Law 93-251. Section 32 of the law reads as follows:

Sec. 32. (a) This section may be cited as the "Streambank Erosion Control Evaluation and Demonstration Act of 1974."

(b) The Secretary of the Army, acting through the Chief of Engineers, is authorized and directed to establish and conduct for a period of five fiscal years a national streambank erosion prevention and control demonstration program. The program shall consist of (1) an evaluation of the extent of streambank erosion on navigable rivers and their tributaries; (2) development of new methods and techniques for bank protection, research on soil stability, and identification of the causes of erosion; (3) a report to the Congress on the results of such studies and the recommendations of the Secretary of the Army on means for the prevention and correction of streambank erosion; and (4) demonstration projects, including bank protection works.

(c) Demonstration projects authorized by this section shall be undertaken on streams selected to reflect a variety of geographical and environmental conditions including streams with naturally occurring erosion problems and streams with erosion caused or increased by man-made structures or activities. At a minimum, demonstration projects shall be conducted at multiple sites on-

(1) the Ohio River

(2) that reach of the Missouri River between Fort Randall Dam, South Dakota, and Sioux City, Iowa;

(3) that reach of the Missouri River in North Dakota at or below the Garrison Dam; and

(4) the delta and hill areas of the Yazoo River basin generally in accordance with the recommendations of the Chief of Engineers in his report dated September 23, 1972.

(d) Prior to construction of any projects under this section, non-Federal interests shall agree that they will provide without cost to the United States lands, easements, and right-of-way necessary for construction and subsequent operation of the projects; hold and save the United States free from damages to construction, operation, and maintenance of the projects; and operate and maintain the projects upon completion.

(e) There is authorized to be appropriate for the five-fiscal-year period ending June 30, 1978, not to exceed $25,000,000 to carry out subsections (b), (c), and (d) of this section.

Erosion is a natural geological process that has been occurring without hesitation since the creation of the earth some 4½ billion years ago. Without erosion and the subsequent depositional process, the Yazoo Basin and earth as a whole would have characteristics of an entirely different nature. Within the Mississippi Embayment, virtually all the landforms on the surface and subsurface strata to a considerable depth are of sedimentary origin. Without erosion actively taking place in the uplands, thus producing sediments which were deposited in the lowlands, the landscape of the lowlands would only be igneous metamorphic formations much lower in elevation than the present surface.

The problem with which this report deals is that the erosion rate in the hill areas of the Yazoo Basin has increased to the extent that economic losses are occurring at an ever increasing rate within the Basin. These losses come not only from the loss of agricultural land, but from the destruction of roads, buildings, bridges, and various other natural and man-made features. (Fig 1 & 2).

HISTORICAL BACKGROUND

Prior to the arrival of European man into the Yazoo Delta, the streams in this area of Northern Mississippi were sinuous, tree lined, and according to Schumm, would be classified as graded streams. The inhabitants of the area were peaceful, tribal Indians who lived by farming and co-existed with nature. During

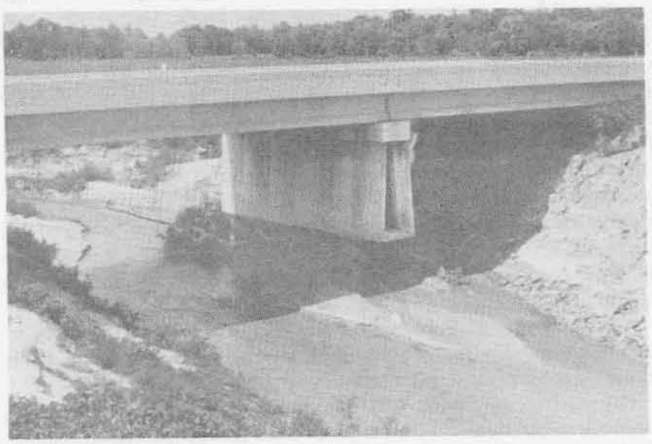

Fig. 1. Degradation at Bridge Site - 1 Year After Completion

Fig. 2. Headcut Moving Through Pasture

the Indian occupation of the area, erosion was probably at a moderate rate.

With the arrival of the Europeans in this area in the early 1800's the Indians were driven off and the land divided up into parcels. The main cash crop of this period was cotton. As time passed, to facilitate more income, more land was cleared and put into the production of cotton. A large portion of the Loess Bluffs immediately to the east of the alluvial valley of the Mississippi River was also cleared during this period. This exposed vast amount of loessal soil to the erosive forces of wind and water.

The accelerated rate of erosion, which was the result of early agricultural process, opened up a "Pandora's Box" which has remained opened for nearly 150 years. The domino effect began to occur within the Yazoo Basin. Due to the removal of vegetation, an increased runoff rate was experienced. With increased runoff, an increase in erosion in the hills and deposition in the delta occurred. With the increase in deposition came higher flood heights, more levees had to be built or raised, and streams were channelized and straightened to reduce the magnitude and duration of the flood peaks and to facilitate easier levee construction. With the increase in erosion, valuable land was washed away or gullied so badly that it couldn't be utilized for agricultural purposes. Additional lands were then cleared to replace the damaged fields which were abandoned. With this, the cycle was complete and free to start again.

STREAM MORPHOLOGY

Before any stream can be effectively stabilized, a thorough knowledge of the forces causing the bank instability are necessary. The factors affecting the magnitude and rates of erosion can not be analyzed without studying the geology, hydrology, geomorphology, stream geology, land use, changes in the stream imposed by man, and the transportation and deposition of sediments within the stream channel. These variables change from stream to stream and in most instances from reach to reach along a particular stream. Very often, stream stabilization measures have been undertaken without a thorough knowledge of the geologic controls. The lack or loss of geologic controls of the streams is the main problem within the Yazoo Basin.

It is our belief in Potamology Section that a large majority of the bank instability problems of the hill streams have been instigated by man's activities.

The controlling factor of stream bank erosion in the Yazoo Hill streams is bed degradation. One is hard pressed to find a stream in the Yazoo Basin that has not been straightened, channelized, or altered to some extent. Channel straightening and cutoffs have the same effects upon a stream channel in that they increase water surface and thalweg slopes, decrease stream sinuosity, and encourage degradation upstream and aggradation downstream of the work. Figure 3 is a schematic of the before and after conditions of a cutoff. Channel straightening can be considered as an elongated cutoff, and therefore, its effect upon a stream may have a more pronounced effect than a single cut-off. Figures 4-9 are examples of what one short cut-off has done to the upper reaches of South Fork Tillatoba Creek.

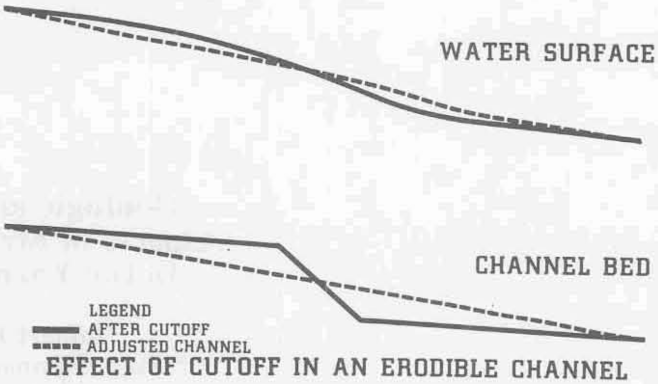

Fig. 3. Profile of a Cutoff

From this series of aerial photos, it is apparent that the instability of the reach above the cut-off was instigated by the "channel improvement" works downstream. Before the cut-off, the entire reach was stable and tree lined. The construction of the cut-off upset the stream's natural slope, alternate bar sequence, sediment movement, and channel geometry. The combination of those factors destroyed any natural grade or bed control which was present and a headcut or lowering of the stream's base level was started.

Eventually the stream will regain its natural slope, but in the process, many acres of farmland will be rendered useless or completely destroyed by caving banks. This process will involve the upstream migration of the head-cut until the thalweg slope between the sources of the stream and the cut-off are approximately the same as before the cut-off or until the headcut encounters some geologic or man-made control which will stop the bed degradation. Figure 10 is a schematic of how the bed of Tillatoba Creek has degraded.

From this diagram it is evident that the base level of Tillatoba Creek, namely the Tallahatchie River, was lowered by approximately 4 feet. This instigated a series of headcuts which proceeded up Tillatoba Creek and lowered this creek by the same amount. It should also be kept in mind that this is only one example and that each tributary has undergone similar degradation.

Fig. 4. Cutoff on South Fork Tillatoba 4 Feb 69

Fig. 5. Cutoff on South Fork Tillatoba 9 Feb 71

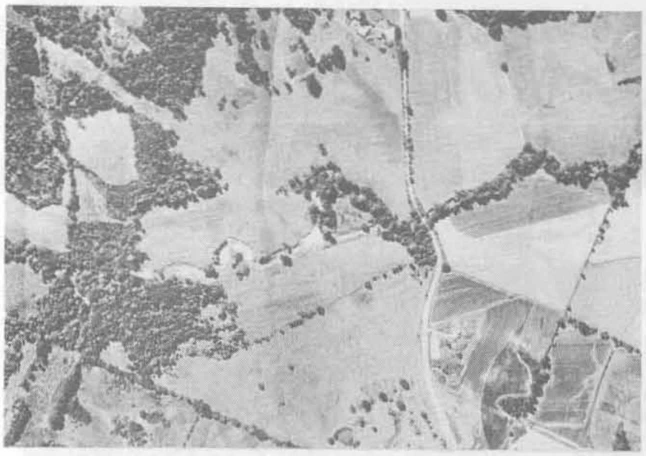

Fig. 6. Cutoff on South Fork Tillatoba 30 Sep 74

Fig. 7. Cutoff on South Fork Tillatoba 18 Mar 76

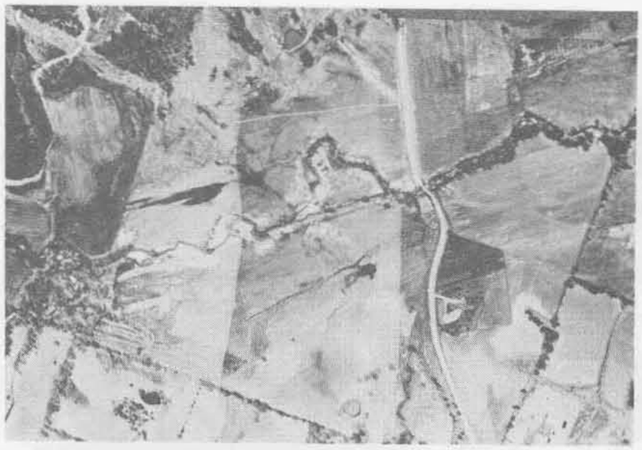

Fig. 8. Cutoff on South Fork Tillatoba 23 Mar 77

Fig. 9. Cutoff on South Fork Tillatoba 12 Mar 79

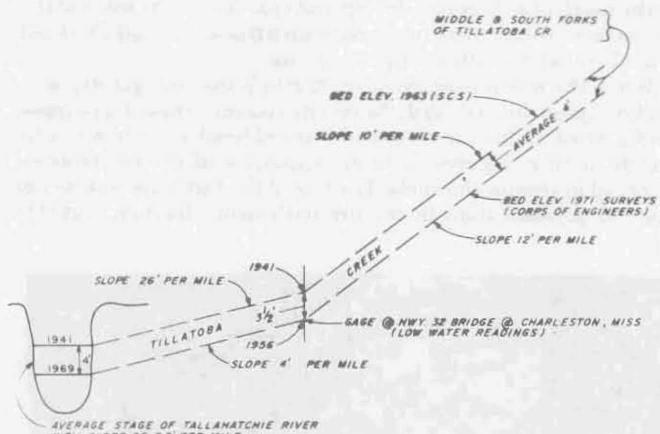

Fig. 10. Comparative Thalweg Surveys, Tillatoba Creek

GENERALIZED GEOLOGY OF YAZOO HILL STREAMS

As previously mentioned, the streams with which we are dealing, primarily the hill streams north of Yazoo City, have definite lack of stabilizing geologic formations within the channels themselves. Any bed rock that is exposed within the channels is predominately a poorly cemented iron sandstone generally referred to as "ironstone." (Figure 11) The ironstone is actually the uppermost layers of the Zilpha Formation of Eocene Age which were cemented after deposition by solution activity. Even though these layers do afford a more resistant geologic bed control, the cementation breaks down eventually, and the headcut will proceed further upstream. These ironstone ledges can only be considered a temporary natural grade control. Any work that is contemplated on a stream which has these formations must consider these as such and take precautions to preserve the natural slope of the stream and not accelerate the

Fig. 11 "Ironstone" Exposed in Channel

erosion of these ledges. One should also remember that once this layer is destroyed the underlying Zilpha layers consist of 40-50 ft. of unconsolidated sands, silts, and clays.

Overlying the ironstone of the Zilpha formation is a sequence of gravels, sands, and some silts which are a pre-settlement alluvium which was derived from upland erosion and river deposited by streams over 10,000 years ago. These streams are now non-existent. The thickness of this layer varies from a few feet to approximately 40 feet. The pre-settlement alluvium is unconsolidated and offered very little resistance to bed degradation. The gravels, at times, form an amoring layer which locally protects the bed from scour but has no effect upon headcuts. Streams which are flowing in this layer can be classified as unstable or potentially unstable.

On top of the pre-settlement alluvium are two layers of paleosols or buried soils. These two paleosols have been radiocarbon dated at approximately 10,000 and 5,000 years old. The old paleosol is characteristically a brown to buff colored silt with a very pronounced polygonal structure. (Figure 12) This structure is the result of a thorough drying and cracking of the soil and the subsequent filling in of the cracks with a fine sand or silt. The soil was then buried with younger deposits.

When the streams erode down through the younger deposits and reexpose this paleosol, the cracks become zones of weakness and a block failure or a type of vertical headcuts 2 to 6 feet in height occurs. Figures 13-15 are examples of the old paleosol exposed in stream channels. The rate of the headcuts is slower in the old paleosol than in the pre-settlement alluvium, but this formation does not afford any positive prevention to bed degradation.

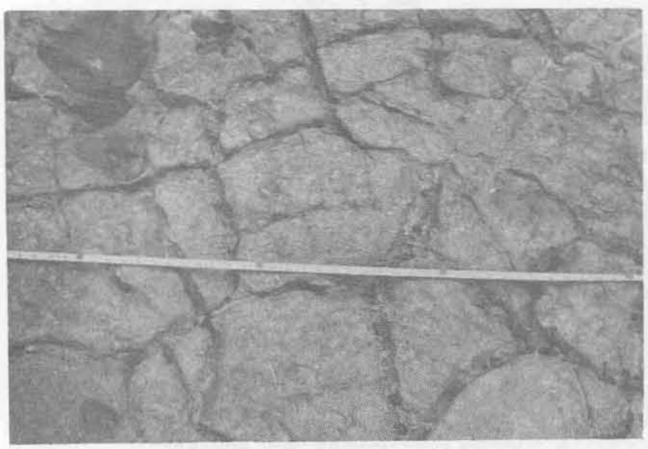

Fig. 12. Polygonal Cracks on "Old" Paleosol

The younger paleosol (Figure 16) is essentially a channel fill deposit in the old paleosol. It is a poorly layered light gray silt with fine sand inter-layered. This structure offers very little erosion resistance. Due to the nature of the deposition of this unit, the aerial extent of young paleosol's influence upon present day stream morphology is limited to the intersection of present

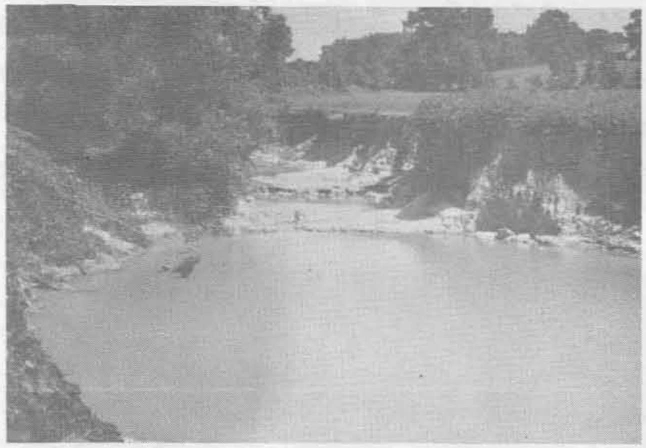

Fig. 13. "Old" Paleosol Exposed in Channel

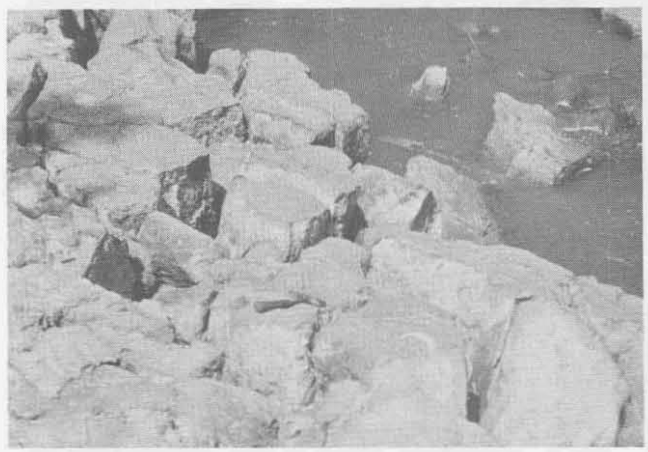

Fig. 14. Close-up of Old Paleosol Block Failure

Fig. 15. Hotophia Creek Headcut

Fig. 16. Young Paleosol in Bank

channels with the paleo-channels which contain this buried soil sequence. Therefore, the significance of the young paleosol is not as great as the old paleosol. The young paleosol is less erosion resistant than the old paleosol. When a stream does encounter this deposit, it is able to more freely meander than when in the old paleosol. This is the factor which is responsible for the streams' changing their channel geometry dramatically from reach to reach.

Capping the entire sequence of materials is a layer of sand and silt which has been deposited in the valleys since the arrival of European man in the area. (Figure 17) This unit has been named the Post-Settlement Alluvium and varies from 1 to 12 feet in thickness. As mentioned previously, when this area was settled, vast amounts of forest land were cleared for agriculture. This layer is the depositional equivalent of the erosion in the head lands.

This layer is unconsolidated and has very little strength of its own. When underlying layers are eroded from under this material, it will spall off and form vertical banks. When high river stages encounter this layer, large scour pockets and gullies develop.

Also included in this Post-Settlement Alluvium is the material which filled the channels which were eliminated by the cut-offs and channel straightening. In some instances, when the improved stream channels are at bank full stage, some of the flow will jump channels and re-establish flow in the old channel. Precautions should be taken to prevent this when any stream modifications are considered.

Fig. 17. Post-Settlement Alluvium in Bank

EROSION PROCESSES

The bank erosion process is instigated by a headcut moving upstream. During this process, the banks, which were previously stable, are undercut. Tension cracks (Figure 18) soon develop in the soil on the top bank along zones of weakness in the soil structure. These cracks usually form from 1 to 6 feet away from the top bank line. When the soil on the streamward side of the tension crack becomes saturated or when the cracks enlarge and deepen to a significant extent, the blocks of soil topple into the stream. (Figure 19) These blocks are then eroded away and the stream again attacks the toe of the bank. As more degradation moves through a stream, the banks become more susceptible to this process due to the increased vertical height of the banks.

The rate at which the banks erode is directly related to the resistance of the materials in the bed and the banks. Too often, the bed material of a stream has not been analyzed carefully enough before any work has been instigated on a stream. Even though a stream may have stable banks composed of a relatively erosion-resistant bank material before construction, the banks start to erode after the construction. This will happen when the natural grade control is as fragile as the ones which are in the Yazoo Hill streams. When analyzing streams for channel stabilization, channel improvement, or flood control, more attention should be given to the composition of the bed of the stream for this is the key to future conditions of the stream.

PREVENTION OF BED DEGRADATION

We in Potamology Section have taken the Streambank Erosion Project as an opportunity to plan, develop, and evaluate methods

Fig. 18. Tension Crack in Top Bank

Fig. 19. Blocks About to Topple

of bank stabilization which work with the aid of nature, not against it. It is obvious that the first objective must be the re-establishment of stable stream bed controls.

One of the main objectives in the Vicksburg District's Section 32 program is the construction of grade control structures on several Yazoo Hill Streams. (Figures 20-21) These structures consist of a sheet pile water cut-off weir, a pre-formed scour hole which is lined with rip-rap, and a hydraulic energy dissipating baffle. These structures are successfully creating a man-made bed control of these streams and stopping headcuts from moving further upstream. Presently we are in the process of determining the minimum requirements needed for successful operation of these structures. Hopefully, we will be able to develop methods to bring the cost of these structures down to a point where private individuals can install them. When this task is accomplished, serious erosion in the Yazoo Hill Streams may be brought down to acceptable limits.

The opinions, findings, and conclusions in this paper are those of the author and not necessarily those of the Corps of Engineers.

Fig. 20. Grade Control Structure - Perry Creek

Fig. 21. Grade Control Structure - North Fork Tillatoba