SEDIMENTATION STUDY OF THE YAZOO RIVER BASIN

PHASE II GENERAL REPORT

VOLUME I

CONTRACT NO. DACW 38-76-C-0193

Prepared for

U. S. ARMY CORPS OF ENGINEERS
VICKSBURG DISTRICT
Vicksburg, Mississippi

Prepared by

Civil Engineering Department
Engineering Research Center
Colorado State University
Fort Collins, Colorado

D. B. Simons
R. M. Li
G. O. Brown

November, 1983

CER83-84DBS-RML-GOB22

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AUTHORIZATION

This investigation is the second phase of a study conducted for the U.S. Army Corps of Engineers, Vicksburg District, Lower Mississippi Division, under Contract No. DACW38-76-C-0193. Larry Banks was the authorized Project Manager for the Vicksburg District and Daryl B. Simons and Ruh-Ming Li were the Principal Investigators for Colorado State University. The purpose of this investigation was to determine the extent of sediment problems in the main stem Yazoo-Tallahatchie-Coldwater River System and principal tributaries excluding the Sunflower River Basin. In addition, this study recommends ways to control these sedimentation problems and others that may be encountered with the proposed Upper Yazoo Project (formerly the Upper Auxiliary Channel Alternative) in operation.

In accordance with the contract, the general report which describes the findings of the investigation is submitted.

ABSTRACT

The purpose of the Sedimentation Study of the Yazoo River Basin conducted by Colorado State University and the Vicksburg District was to determine the effectiveness of the Vicksburg District Corps of Engineers proposed flood control project (Upper Yazoo Projects) in the Yazoo River Basin with respect to anticipated sedimentation problems and their influence on the maintenance of flood control and navigation in the basin. The study analyzed the engineering feasibility of various modifications which could reduce potential sedimentation problems. Study results showed that these modifications could make the main stem river system more efficient in maintaining the increased channel capacity provided by the UYP and maintaining long-term reductions in flood damages with a minimum amount of maintenance dredging.

The study involved use of a water-sediment routing model of the entire Yazoo River and its major tributary streams to determine system reactions to changes such as the enlargement of the main-stem channel, channel cross section modifications, tributary stabilization and grade control, and land use changes. The results are summarized through compilation of the degradation (scour) or aggradation (filling) of principal reaches of the streams as indicated by the model for the 50 year period analyzed.

The Vicksburg District has recognized for many years the nature of the sediment problems in the Yazoo River Basin and the potential for additional severe problems associated with channel enlargement. No detailed sediment analyses were conducted as part of the Design Memo No. 41 (Upper Yazoo Projects); however, potential for sediment problems were discussed extensively in the Hydraulics Appendix of the report. A

commitment was made that a detailed sediment analysis be completed prior to the time that channel construction reaches the major problem areas in the vicinity of Greenwood.

Preliminary projections by the District which were included in DM No. 41 indicated that the Upper Yazoo Project would require over $2 million per year for operation and maintenance with a major part of this amount required for maintenance dredging activities. A major objective of the Sedimentation Study of the Yazoo River Basin was to provide a more refined estimate of the anticipated sediment deposition rates and maintenance dredging requirements and to determine the impact of anticipated aggradation on the channel capacity for the Yazoo System.

Results of the study indicated that the main stem Yazoo System between Belzoni and Arkabutla Dam was aggrading at the rate of about 180,000 cubic yards per year under existing or pre-project conditions. The study indicated that if the Upper Yazoo Projects were completed with no stabilization or tributary grade control, the river system would aggrade during a 50 year period about 29 million cubic yards or at a rate of nearly 600,000 cubic yards per year. This is due to major degradation of the hill tributaries resulting from the lowering of the flowlines on the Yazoo and increase in gradients in the tributaries and the associated increase in tributary sediment transport. The study results indicated that if the UYP channel construction was completed and no maintenance dredging was provided, the Yazoo River channel would aggrade such that the flowlines could eventually be higher than the existing flood flowlines. This indicates the importance of continued periodic maintenance dredging of the channels and the need for investigating modification of the project to lessen possible project induced sediment problems on the tributaries.

The study analyzed various alternatives to reduce both existing and potential project-induced sediment deposition problems in the Yazoo Basin. The following is a summary of various alternatives analyzed:

1. Sediment Storage Areas. It was determined that natural detention or sediment storage areas such as Matthews Brake on Abaica Creek worked effectively to trap heavy sediments from the hill tributaries to minimize main stem aggradation. The study recommended that, where possible, these areas should continue to serve as natural sediment traps. The relative value of maintaining sediment flows into these areas was determined along with the rate of filling of these natural sediment detention areas. Construction of borrow areas within leveed floodways as proposed on the Pelucia Creek Project was also found to be effective in reducing sediment contributions to the main stem Yazoo.

2. Grade Control. Construction of grade control structures on the major hill tributaries was analyzed and the study found that these could serve to maintain the channel gradients on the tributaries to near that under existing conditions and thereby significantly reduce headcutting on the tributaries, the major new source of sediment contribution to the main stem which could result due to lowering of the main stem flowlines with UYP construction.

3. UYP Cross Section (Step Cut). The study determined that a Yazoo-Tallahatchie River channel cross section consisting of a smaller low water conveyance area with a step cut to provide for flood flows could allow the main stem to more effectively convey sediments through the 179 mile project reach.

4. Panola-Quitman Detention Area. The study indicated that significant degradation of the Panola Quitman Floodway and its tributaries would occur with the UYP in place and that maintenance of the

Greenwood to Panola Quitman reach would be a significant problem. Control of the sediment flow from the Little Tallahatchie and Yocona Rivers through Panola Quitman Floodway could significantly minimize maintenance of the Greenwood to Panola Quitman reach of the Tallahatchie. It was determined that a system of grade control structures constructed to make the Panola Quitman Floodway a designated sediment detention area could be utilized to achieve the desired flood control capability on the Tallahatchie with a major reduction in maintenance dredging.

The combination of the above mentioned elements could reduce the total sediment deposition on the main stem to about 12.5 million cubic yards or to about 250,000 cubic yards per year. This amounts to near a 60 percent reduction in the annual sediment deposition in the main stem as compared to the condition assuming UYP complete as specified in DM No. 41 (without grade control or sediment detention). This reduction could be achieved through modification of the UYP channel cross section, construction of grade control on major tributaries, continued utilization of natural sediment detention areas, and construction of structures to make the Panola Quitman Floodway a designated sediment detention area.

The Sedimentation Study of the Yazoo River Basin was intended to provide necessary technical information and an effective tool which can be utilized by the Vicksburg District in further evaluations leading toward a Supplement to GDM No. 41 which addresses the feasibility of additional modifications to the UYP project required to alleviate the anticipated sediment maintenance problems. The study does provide an exceptionally good basis and additional justification for modification of the Upper Yazoo Project to provide a flood control plan which can be expected to achieve the project benefits as specified in DM No. 41 with a significant reduction in annual maintenance dredging required to maintain channel capacity.

The study also offered guidance on the regulation of the Greenwood Cutoff Structure. It demonstrated that the structure can be effectively regulated to keep the Greenwood Bendway open and to maintain the flood control capability required to protect the City of Greenwood during major floods.

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I. EXECUTIVE SUMMARY AND CONCLUSIONS

1.1 General

The Yazoo River Basin covers approximately 13,400 square miles in the northwest portion of Mississippi. About 6,600 square miles are in the alluvial valley of the Mississippi River, while the remaining 6,800 square miles are hill watersheds. According to overflow characteristics, the Yazoo Basin is divided into backwater and headwater areas. The Yazoo headwater area is the portion above Yazoo City comprising about 2,300 square miles of alluvial lands and 6,600 square miles of rolling and rugged hill watersheds (Figure 1.1). The Upper Yazoo Project is a complex flood control system located upstream from the Will M. Whittington Auxiliary Channel. The project provides for approximately 178 miles of channel enlargement of the main rivers, about 203 miles of levees, and 109 floodgate structures.

The Yazoo Basin Sedimentation Study involved a system analysis of the main channel and its tributaries from which water and sediment are routed through the main channel. The purpose of this analysis was to determine the effectiveness of the proposed system considering flood control, navigation, and the location of aggradation and degradation problems in the main channel and its tributaries. Methods of minimizing operation and maintenance problems were also evaluated. This analysis provided a method for evaluating the Upper Yazoo Project system and the various design alternatives outlined by the U.S. Army Corps of Engineers (Design Memorandum No. 41).

In the Phase I study the emphasis was to evaluate the river response to the various design alternatives on the main stem Yazoo-Tallahatchie-Coldwater River system and principal tributaries such as the Little

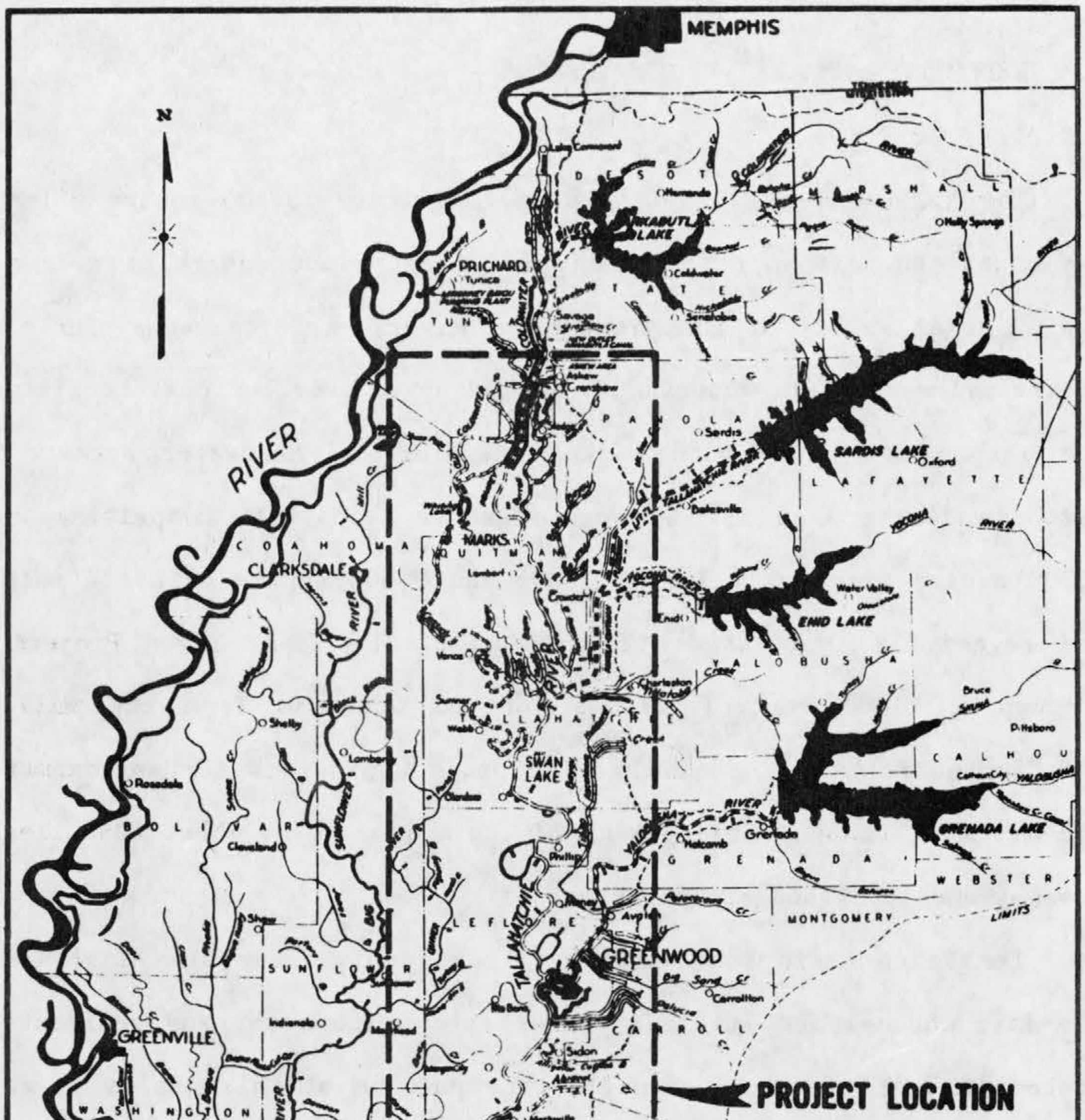


Figure 1.1. Project location map.

Tallahatchie, Yocona, and Yalobusha Rivers. The Sunflower River Basin was excluded from the analysis. In this phase of the study a more detailed analysis of the important tributaries and watersheds was conducted to allow a more accurate assessment of their effects on the mainstem and to indicate possible measures to help mitigate the more serious sedimentation problems in the area. The known discharge sediment routing mathematical model, KUWASER (Brown, 1982) developed in Phase I of the study was used exclusively in this study. Utilizing the model, the effects of channel enlargement on flowline, sediment depositional rates, and other aspects of river response were evaluated.

1.2 Previous Work

Considerable work has been performed in Phases I and II of this study. Under the original contract DACW 38-76-C-0193 and by letters dated March 9 and June 19, 1978 the following reports were prepared:

1. "User's Manual for Known Discharge Sedimentation Model," by D. B. Simons, R. M. Li, and G. O. Brown, 1979.
2. "Cross Sectional Data," by D. B. Simons, R. M. Li, and G. O. Brown, 1978.
3. "User's Manual for Program CHANSEC," by D. B. Simons, R. M. Li, G. O. Brown, and L. A. Barkau, 1978.
4. "Temporal Design," by D. B. Simons, R. M. Li, T. J. Ward, and N. Duong, 1978.
5. "Sedimentation Study of the Yazoo River Basin, Phase I General Report," by D. B. Simons, R. M. Li, G. O. Brown, Y. H. Chen, T. J. Ward, N. Duong and V. M. Ponce, 1978.

By letter dated June 30, 1978 nine additional runs were directed to perform a detailed analysis of the Greenwood Bendway and the following report prepared.

6. "Greenwood Bendway Study," by D. B. Simons, R. M. Li, and G. O. Brown, 1979.

Under Modification P00001 dated August 15, 1978 of the contract the Yazoo Basin Data Storage and Retreival System which was used in Phase I was converted to the Cyber 175 of Boeing Computing in Seattle, Washington and the following report prepared.

7. "User's Manual for the Yazoo Data Storage and Retrieval System, Volumes I and II," by D. B. Simons, R. M. Li, and N. Duong, 1978.

Under Modification P00002 dated July 13, 1979 Phase II of the Study was undertaken. In addition to this report the following report was prepared.

8. "Yazoo Basin Tributaries Data Collection," prepared for Colorado State University by Water and Environment Consultants, Inc., 1980.

Several progress reports have been submitted under Phase II. All progress reports are superceeded and replaced by this General Report. The following progress reports are presented as Appendices D, E and F because of their general importance.

"Evaluation of Riparian Greenbelt," by D. B. Simons and R. M. Li, 1980.

"Analysis of Two Navigation Plans," by D. B. Simons, R. M. Li and L. Y. Li, 1980.

"Sedimentation Study of Abiaca and Pelucia Creeks," by D. B. Simons, R. M. Li, R. A. Mussetter and D. K. Tuan, 1982.

Appendix G presents the separate short report "Analysis of Channel Modification of Panola-Quitman Floodway and Yalobusha River," by D. B. Simons, R. M. Li and G. O. Brown, 1983.

1.3 Alternative Study Runs

1.3.1 General

Under Phase II eight system alternative runs were authorized. By letter dated August 1, 1983 three additional runs were authorized for a total of eleven. Four runs have been completed and reported previously. The first was Run H of the Greenwood Bendway Study (Simons, Li and Brown, 1979). The equivalent of one run was performed for the evaluation of a riparian Greenbelt (Appendix D). Two runs were performed for the analysis of navigation plans (Appendix E). One additional run was performed to evaluate flood control channel enlargement on the Yalobusha River and P-Q Floodway (Appendix G). The remaining six system runs are presented here.

The six alternative runs were designed by the Corps and CSU to identify the extent of sedimentation problems in the mainstem and major tributaries, and to evaluate possible remedies. The alternative runs represent a wide range of conditions from an approximation of the existing, to a high degree of management. The six runs not only quantify the river response to their specific conditions but also indicate the value of pursuing the study of additional management work in the basin. Overall the six runs represent a relatively in-depth analysis of the existing conditions, conditions with the Upper Yazoo Project as specified in GDM-41 (Plan E) in place and conditions with Plan E and other river works designed to mitigate the sedimentation problems, minimize maintenance, improve flood control, and aid reservoir emptying.

All six simulation runs had the following five items in common.

1. The runs simulated 50 years of water and sediment movement in the basin. The discharge hydrograph was constructed from 14

years of recorded data and 36 years of folded (or repeated) data.

2. The runs evaluated the river system from Belzoni upstream to Arkabutla, Sardis, Enid and Grenada Reservoirs. In addition Pelucia, Big Sand and Tillitoba Creeks were analyzed in detail.
3. Ten tributaries, Teoc Creek, Potococowa Creek, Ascalmore Creek, Cane Creek, Batupan Bogue, Peters Creeks, McIvor Drainage, Arkabutla Creek, Strayhorn Creek and Lake Cormorant Bayou were considered point sources of water and sediment. The water and sediment input to the mainstem from Abiaca Creek was obtained from output of a previous study (Appendix F). It is assumed Abiaca Creek is flowing through Matthews Brake. All other tributaries were not directly considered.
4. The Fort Pemberton cut-off of Greenwood Bend is regulated by a structure or earthen plug and is only open at discharges greater than 25,000 cfs (15,000 cfs in Run 6). The structure or plug only operates as closed and wide open in sediment investigations conducted as part of this study.
5. All management activities such as weirs, channel dredging or tributary sediment control are in place at the start of the runs. No additional man related activities take place during the 50 years of simulation.

The following lists the specific conditions of each run. Table 1.1 summarizes this information.

Table 1.1. Alternative Run Conditions

Number	Mainstem[1] Channel	Craigside Cut-off	Pelucia Creek	Grade Control[2] Sructures	Point Sources Trib. Sediment	Ft. Pemberton Cut-off Regulated
1	Existing	Not in place	Existing Channel	0	Normal	25000
2	Plan E	Open	Borrow Excavation	0	Normal	25000
3	Plan E	Open	Borrow Excavation	8	Normal	25000
4	Plan E	Open	Borrow Excavation	8	Reduced 25%	25000
5	Step Channel	Open	Borrow Excavation	9	Normal	25000
6	Step Channel	Open	Borrow Excavation	19	Normal	15000

[1] See Table 1.2 for specifications.

[2] See Table 1.3 for specifications.

1.3.2 Run 1 (Existing Conditions)

This run approximated existing conditions, with the exception that the earthen plug in the Fort Pemberton cut-off was in place and assumed open for flows greater than 25,000 cfs. Also, the Craigside cut-off was not completed.

1.3.3 Run 2 (Plan E)

This run simulated Plan E conditions with few sediment control features assumed in operation. The following were used: (1) the original Plan E design channel was in place from Belzoni to Darling (Table 1.2); (2) the Craigside cut-off was open and its bendway closed; (3) construction of a borrow excavation in the Pelucia Creek Floodway was assumed to be completed.

Because of the differences in the Abiaca and Pelucia sediment load this run is not comparable to Run 2 of Phase I. In Phase I these two streams were assumed to be channelized and delivered their total bluff line sediment load to the mainstem, while in this study Abiaca Creek continues to flow through Mathews brake and Pelucia flows through a borrow excavation (Appendix F).

1.3.4 Run 3 (Grade Control)

The third run simulated the placement of grade control structures on the major tributaries. Those structures were designed to stop head-cutting of the tributaries due to the stage lowering of Plan E. The run was similar to Run 2 except the grade control structures in Table 1.3 were in place.

1.3.5 Run 4 (Tributary Control)

The fourth run simulated the effects of upland sediment control practices on the mainstem and major tributaries. The run is similar to

Run 3. The sediment input from the eleven point source tributaries is reduced by 25%. The reductions could be the effect of land use change, S.C.S. type flood water retarding structures, grade control or stream bank protection. The type or amount of work required to reduce the sediment input to the mainstem by 25% was not evaluated, but it is felt that a very large effort would be required to reach that level.

Table 1.2. Channel Specifications

Reach		Plan E	Step Channel			
From (mile)	To (mile)	Bottom Width (ft)	Bottom Width (ft)	Bottom Slope (ft/mi)	Step Height (ft)	Step Width
116.2 (Belzoni)	162.5 (Greenwood)	150	110	0.32	15	75
173.0 (Greenwood)	234.65 (P-Q)	130	90	0.40	15	75
234.65 (P-Q)	253.19 (Lambert)	100	65	0.57	15	50
253.19 (Lambert)	272.50 (Darling)	75	65	0.57	15	50

1.3.6 Run 5 (Step Channel)

This run simulated a modified Plan E channel (Table 1.2). The channel had a bottom width which varied from 110 to 65 feet and a step at 15 feet above the channel thalweg. One additional grade control structure was added and several structures were raised (Table 1.3).

1.3.7 Run 6 (Maximum Mitigation)

This run simulated a modified Plan E channel and a high level of sedimentation mitigation work. The run is similar to Run No. 5 with the exception of the redesign of the grade control structures on the P-Q Floodway, Little Tallahatchie River and Yalobusha River (Table 1.3).

Table 1.3. Grade Control Structures*

		Runs 3 & 4		Run 5		Run 6	
Stream	Location	Elevation	Height	Elevation	Height	Elevation	Height
P-Q	0.00	133.0	2.1	135.0	4.1		
	1.00					140.0	9.0
	8.00					145.0	8.0
	14.00					147.0	0.0
Little Tallahatchie	19.00					155.0	1.0
	24.00					161.5	0.0
	29.00					169.0	3.0
	33.84	180.0	5.9	180.0	5.9		
	34.00					176.5	2.0
	39.00					184.0	1.5
	39.34	185.0	1.7	185.0	1.7		
Yocona	0.00	151.0	0.0	156.0	5.0	156.0	5.0
Tillitoba	0.00	133.0	4.6	135.0	6.6	135.0	6.6
Yalobasha	0.00			106.0	5.0	106.0	5.0
	5.00					107.8	0.0
	15.00					117.3	1.0
	20.00					121.0	1.5
	25.00					128.0	2.0
	30.00					135.0	0.0
	34.31	138.0	2.1	138.0	2.1		
	35.00					142.0	1.0
	40.00					149.0	1.0
	40.26	150.0	1.4	150.0	1.4		
Pelucia	0.0	102.0	2.3	112.0	12.3	109.0	9.3

*Single structures listed here may be replaced by multiple structures, closely spaced with same total height.

The P-Q Floodway was acting as a designated sedimentation area, and the Ft. Pemberton Cut-off was open at 15,000 cfs.

1.4 Outline of Study Results

1.4.1 General

A balanced three step approach has been used to upgrade and improve the analysis performed in Phase I. The steps taken were: 1) a qualitative geomorphic analysis of the basin, 2) a quantitative hydrologic and hydraulic analysis of the streams of interest, and 3) a detailed numerical modeling of the river system using a known discharge, uncoupled, sediment routing model. This approach has resulted in a successful analysis which is not only the largest erosion and deposition study ever completed, but also has provided design and analysis to the Corps of Engineers on a continuing basis. With this balanced approach the Corps has been able to proceed with detailed design and construction of some features of the Upper Yazoo Project while this project continued to improve and complete the system design and impact analysis. The following outlines the results of the numerical modeling.

The calibration of the model KUWASER was updated and improved from Phase I with the addition of tributary water and sediment data taken in Phase II. The model has been shown to be reliable and accurate in its application in the Yazoo River Basin. This section summarizes the results for both the six study runs and the sedimentation study of Abiaca and Pelucia Creek (Appendix F).

1.4.2 Abiaca and Pelucia Creeks

The simulation for Abiaca Creek considered the aggradation and degradation potential for the approximate six mile reach above Matthews Brake, as well as the sediment trapping potential for Matthews Brake and its effect on the sediment delivery to the main stem. The results of the 50-year simulation for the six-mile reach of Abiaca Creek indicate total cumulative aggradation of 0.169 million cubic yards (MCY). This aggradation occurred fairly continuously throughout the simulation period at the rate of approximately 3380 cubic yds per year. Cumulative sediment yield from Abiaca Creek into Matthews Brake was 5.9 MCY or an average of approximately 0.12 MCY per year. In order to evaluate the percentage of this material trapped in the Brake, a model was developed which performed level pool routing to determine the hydraulic conditions within the swamp. The results indicate that the average reduction in sediment yield to the main stem by allowing Abiaca Creek to continue to flow through Matthews Brake is approximately 80 percent.

Sediment routing was performed for Pelucia Creek with existing conditions and a proposed borrow excavation plan. The results for the existing condition indicate degradation of 0.13 MCY for the 50-year period. The total sediment yield to the mainstem for the same period was 7 MCY. With the proposed borrow excavation aggradation in the creek increased to 0.6 MCY while the sediment yield to the mainstem was reduced to 5.7 MCY yards.

1.4.3 <u>Study Runs</u>

For existing conditions the mainstem river will be relatively stable for the next 50 years with the exception of aggradation at the confluence of the P-Q Floodway. The P-Q Floodway will experience slight aggradation while the Little Tallahatchie will have considerable bank and bed erosion. The Yocona River, Tillatoba Creek and Pelucia Creek will have modest aggradation. The lower Yalobusha will be stable but the upper reach will have erosion. Mainstem river stages will remain constant or increase slightly.

With Plan E the mainstem and major tributaries will have significant aggradation and loss of channel capacity at the end of 50 years. The overall aggradation is produced by a complex response system. Initially, with Plan E, mainstem stages are reduced by channel enlargement. The stage reductions increase tributary sediment input due to head cutting. The increased sediment input is coupled with a decreased mainstem sediment transport capacity caused by the channel widening to produce mainstem aggradation. Finally, as the mainstem aggrades, the tributaries experience a steady and increasing backwater effect causing higher tributary stages and aggradation. The Plan E channel cannot continue to provide necessary flood control benefits without some combination of channel modification, tributary sediment mitigation or maintenance.

With low grade control structures at the mouths of the P-Q Floodway, Yocona River, Tillatoba Creek and Pelucia Creek mainstem aggradation is reduced slightly. The Pelucia structure reduces mainstem aggradation by about 0.5 MCY while the P-Q and Tillatoba structures cause a combined reduction of approximately 0.8 MCY over the 50 years of simulation. Isolated structures on the upper ends of the Little Tallahatchie and Yalobusha River are somewhat effective in stopping upstream erosion but induce downstream degradation.

Reducing sediment input by 25% from the ten point source tributaries reduced mainstem deposition approximately 0.7 MCY for 50 years. The reduction reduced aggradation on the P-Q, Little Tallahatchie by 0.7 MCY and on the Lower Yalobusha by 0.3 MCY. The reduction increased erosion on the Upper Yalobusha by 0.4 MCY.

Modifying Plan E with a step channel and raising the grade control structures on the tributaries produced a reduction in mainstem deposition by 2.1 MCY, but more significantly the flood stage reductions of Plan E were significantly maintained with no simulated maintenance. (Maintenance of the channel would improve its flood stage reductions.) Maximum mainstem water surfaces were two to four feet lower than the original Plan E. With the mainstem stage reduction maintained the tributaries experienced neither reduced aggradation or increased erosion.

By adding numerous grade control structures to the P-Q, Little Tallahatchie and Yalobusha mainstem aggradation was reduced by 14.6 MCY. Almost all reduction occurred in the reach above Greenwood Bend to Arkbutla Dam. The P-Q Floodway will aggrade significantly and the Little Tallahatchie will be relatively stable. The Yalobusha River will undergo a moderate uniform degradation.

1.5 Conclusions

The 50-year simulation for the six-mile reach of Abiaca Creek above Matthews Brake indicates that significant aggradation will occur within the channel. Continued diversion of the flow from Abiaca Creek through Matthews Brake will significantly reduce the sediment yield to the main stem. The rate of filling of Matthews Brake was such that approximately 50 percent of the volume will be lost in the 50-year period. The average reduction in sediment yield was estimated to be approximately 80 percent over the entire simulation period.

Pelucia Creek in its existing conditions has a tendency to degrade, with the amount controlled principally by the water-surface elevations in the main stem. The proposed borrow excavation will reduce the transporting capacity of the stream, inducing aggradation within the channel. The final thalweg profile at the end of the simulation for the excavated channel was approximately the same as the 1977 profile. Sediment yield from Pelucia Creek was reduced by approximately 20 percent for the proposed channel. The final grade of the stream, particularly in the downstream portion of the reach, is controlled significantly by the water-surface elevations in the main stem. Lowering of these elevations will lower the base level for Pelucia Creek, allowing futher degradation and increasing the sediment yield to the main stem.

The step channel design for the mainstem is far superior to the trapezoidal cross section. While the step channel will require more right of way it will provide long term flood stage reduction with reduced maintenance requirements. The mainstem aggradation is insensitive to the operation of the Ft. Pemberton cut-off of Greenwood Bend at the discharge levels studied here. If a structure replaces the existing earthen plug experience should indicate the best operation. Until that time the initial operation of the structure with a 15,000 cfs rule should be adequate to maintain channel capacity around Greenwood Bendway.

The results indicate grade control structures at the mouths of Pelucia Creek, Tillatoba Creek, the Yalobusha River, the Yocona River, Little Tallahatchie River and the P-Q Floodway will be benificial. These structures should be constructed to the highest elevation possible without causing significant upstream flooding. In particular a very high structure one mile upstream of the confluence of the P-Q and Tallahatchie (above Black Bayou) will significantly reduce mainstem aggradation and flood stages. Such a structure will turn the Floodway into a sediment detention basin but will not significantly increase flood stages on the Little Tallahatchie or Yocona Rivers.

Bank stabilization is needed on the Little Tallahatchie River between Batesville and Sardis Dam. The exact nature and manner of work is best determined by site specific studies. These cannot be specified here since design of bank stabilization is beyond the scope of this study.

II. BASIN OVERVIEW

2.1 General

The drainage basin of the Yazoo River covers 13,355 square miles of northwestern Mississippi. It is bordered on the north by the Wolf and Hatchie Rivers basin in Tennessee, on the east and south by the Tombighee and Big Black River basins, and on the west by the artificial levees of the Mississippi River. About 6,600 square miles are in the alluvial valley of the Mississippi River while the remaining 6,800 square miles are hill lands. Major tributaries of the Yazoo are the Tallahatchie, Coldwater, and Yalobusha Rivers and the Big Sunflower-Steele Bayou system. Two major man-made channels exist in the basin, the Panola-Quitman Floodway and the Lower Auxiliary channel.

Based on overflow characteristics the basin can generally be divided at Yazoo City into backwater and headwater areas. Below Yazoo City the basin is subject to backwater flooding from the Mississippi River. The terrain is relatively flat with very small slopes. Above Yazoo City the headwater area is normally only subjected to flows of local origin. The mainstem Yazoo lies in the alluvial valley of the Mississippi River but all of the major tributaries rise in the hill lands to the east. Four large flood control reservoirs control a large portion of the hill tributaries.

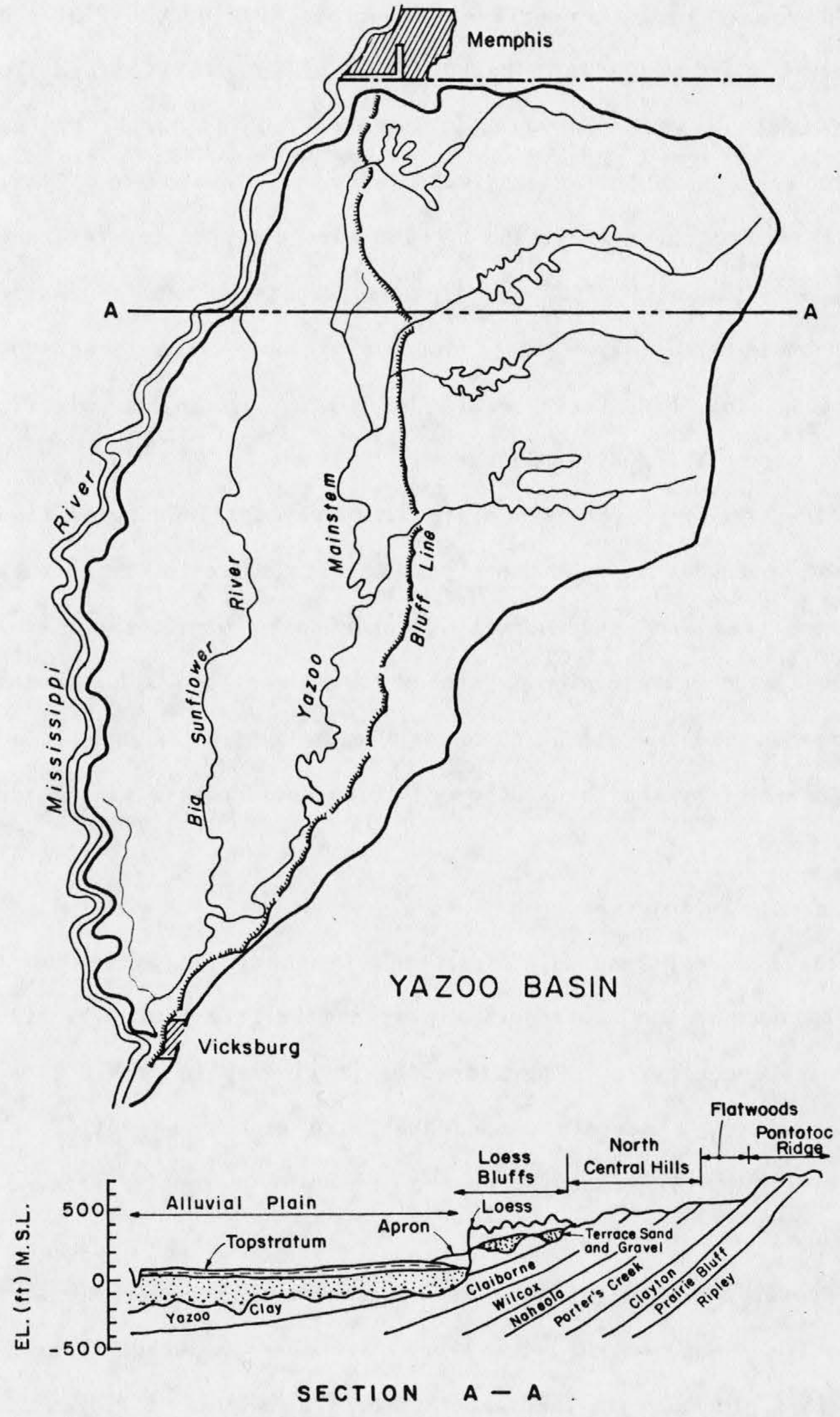
Before settlement the basin was covered by backswamp and hardwood forests. Early explorers characterized most of the Delta as impenetrable, but the early travelers also recognized its greater agricultural potential if properly drained and protected from flooding. The first settlers cleared the high lands adjacent to the rivers. Later arrivers cleared the hill areas and later constructed levees to protect the lower areas of the alluvial valley. By the late 1800's the entire basin had been settled. With increased development, flooding erosion and sedimentation became major problems and local drainage districts were formed from 1888 to 1935. These local districts were unable to alleviate the situation. The U.S. Army Corps of Engineers since the 1928 Flood Control Act have had increasing involvement regarding flood control and drainage improvements which have reduced flooding significantly. They have been limited in authority regarding bank erosion and sedimentation control and problems still persist which are impacting operation of flood control and drainage works. Erosion from hill slopes deposits in the mainstem reducing channel flood capacity and hinders capability for evacuation of flood control storage on all four of the Yazoo Basin Reservoirs. Channel dredging to remove deposition requires disposal of material on farmland to prevent adverse impacts on areas required for wildlife habitat.

2.2 Geology

2.2.1 General

There are five distinct physiographic provinces which make up the Yazoo Basin (Walters, 1977). Beginning with the higher elevations in the northeastern portion of the basin these provinces are: (1) Pontotoc Ridge, (2) the Flatwoods, (3) the North Central Hills, (4) the Loess Bluffs, and (5) the Mississippi Alluvial Plain, commonly called the Yazoo Delta (Figure 2.1).

The youngest materials forming the surface are located within the Mississippi Alluvial Plain and in the Loess Bluffs. Ages range from 25,000 years to the present. In contrast, geologic formations ranging in age from Late Cretaceous (100,000,000 years) to middle Eocene



SECTION A — A

Figure 2.1. Yazoo River Basin

(50,000,000 years) form the surface of Pontotoc Ridge, the Flatwoods, and the North Central Hills. Most of the older geologic formations consist of soil in that the material can be crumbled easily by hand. They may be very dense but offer little resistance to erosion. Erosion by area streams, by sheet flow, and by wind have stripped the less dense and easily erodible soils from one area and deposited them on another. Smaller channels with narrow flat floodplains merge with larger downstream floodplains and these with floodplains along the principal tributaries to the Yazoo River System.

The older geologic formations dip at fairly shallow angles toward the west and southwest so that the oldest materials lie in the northeast corner of the basin and successively younger soils form the surface as it nears the Yazoo Delta region. Farther to the west the older geologic horizons are buried beneath a cover of Pleistocene loess underlain by sand and gravel or by the thick Holocene or Recent deposits of the Yazoo Delta.

2.2.2 Pontotoc Ridge

The three oldest geologic formations in the basin are, from the oldest to youngest, the Cretaceous Ripley and Prairie Bluff formations and the Paleocene Clayton. They form the physiographic province known as Pontotoc Ridge, a densely wooded area with pronounced relief. The highest elevations in the basin, on the order of 700 feet, are found in this province.

The Pontotoc Ridge reflects the presence of the various strata which underlie it and which, as a group, are more resistant to erosion than materials elsewhere in the Yazoo Basin. The series of ridges rises to conspicuous heights above the Flatwoods province to the west. Dips of the strata are on the order of 30 feet per mile.

2.2.3 Flatwoods

West of the Pontotoc Ridge is a flat area which has been called the Flatwoods since 1860 or earlier. Elevations range from 300 to 400 feet. It is underlain by the Porter's Creek clay which offers little resistance to erosion and yields a heavy soil which is difficult to cultivate. Unpaved roads in the area are practically impassable in wet weather. There are relatively few hills, and most of those that are present are erosional remnants of the overlying red Wilcox sand.

The Porter's Creek clay is a dark-gray montmorillonitic marine clay, which weathers to a sticky clay soil at the surface. It is about 300 feet thick in the northeast Yazoo Basin. Much of the unweathered material shows no stratification, but possesses an ability to break out into lumps from one to four inches in diameter. When cut with a knife, its texture is much like soap.

2.2.4 North Central Hills

This physiographic province is characterized by thorough stream dissection, moderate to gentle slopes, flats developed along streams from their mouths well up toward their heads, and terraces or second bottoms bordering the floodplains of larger streams. The region is well drained by a complex of streams forming a dendritic pattern. Hills and ridge tops are well rounded and lineations of hills and ridges follow the strikes of the underlying geologic formations. The contact between the Claiborne and Wilcox groups, for example, stands out as a series of disconnected ridges.

The clays of the Wilcox formations form red silty loam at the surface; the sands form fine silty micaceous soils which are some of the poorest in the Yazoo Basin for agricultural purposes. The clays form low rolling hills and ridges, whereas the sands form hills and ridges more rugged and of greater relief. Landslides are common in the Wilcox clays after long periods of rainfall along the hillsides, road cuts, and gullies.

2.2.5 Loess Bluffs

The Loess Bluffs are formed of the most distinctive and homogeneous of the soils in the Yazoo Basin. They consist of tan to buff-colored silt that characteristically forms pronounced vertical bluffs. Under appropriate conditions these bluffs will retain there near vertical faces for decades. A closer examination and laboratory tests of loess reveal it to consist of more than 95 percent angular silt-size particles. The particles are stacked in random fashion resulting in a high-porosity material of low density. Calcareous clay binds the silt particles together. As long as the cement is effective, the material will stand vertically. Wetting quickly breaks down this bond between the particles; and when this occurs, the soil loses strength and quickly fails. As a result, dissection by running water has carved the loess into some of the most intricate relief found within the Yazoo Basin.

The deposit is about 90 feet thick, on the average, at the bluffs and gradually, but irregularly, thins eastward. Beyond this eastern boundary of the Loess Bluffs, and extending for another 30 to 40 miles farther east, is a sporadic deposit generally called "brown loam." It varies from a few feet to about 10 feet in thickness and is considered to be windblown silt and clay similar in origin to the loess but reworked by physical, chemical, and alluvial processes to the point where it no longer has the properties or the general appearance of the undisturbed loess of the Loess Bluffs. It also will not stand vertically. Much of the North Central Hills of the Yazoo Basin are covered with "brown loam" and distinctions are possible between it and residual soils developed on the ancient Tertiary formations.

More pertinent perhaps has been the history of agriculture in the Loess Bluffs. There is evidence that early settlers found large flat areas within the Loess Bluffs which they promptly cleared of their forests and planted or used for pasture. Today such flat uplands are extremely rare. There is good evidence that the headward growth of gullies became pronounced in a few decades, so much so that farming the Loess Bluff became impracticable and even grazing became marginal economically. The amount of loessial silt that moved down the many small creeks in the Mississippi Alluvial Plain was great and the effect of gullying and siltation has continued, at a lesser rate, through to the present.

At the present time agricultural practices are less responsible for continued sedimentation problems than is the extensive grading and other earth-moving necessary for construction of highways, housing developments, industries, channelization of creeks and rivers, etc. Equally troublesome from the standpoint of adverse sedimentation is the mining of the sand and gravel which often lies beneath the loess.

The origin of the Pleistocene sand-and-gravel units is thought to be the same as that of the sand-and-gravel substratum which underlies the present Mississippi Alluvial Plain. The sand-and-gravel units beneath the loess are considered to be terrace remnants of older alluvial plains of the ancient Mississippi formed during previous ice advances and retreats and now standing at higher elevations.

2.2.6 Mississippi Alluvial Plain

The Mississippi Alluvial Plain covers approximately two-thirds of the Yazoo Basin, an immense flatland oval shaped with Memphis at its northern end and Vicksburg at its southern end. The area is referred to as the Yazoo Delta although the Yazoo River has no true delta of its own.

The Yazoo Delta is one of the most fertile and productive regions in the State of Mississippi. Its lack of relief and its high concentration of sluggish streams and lakes contrasts markedly with the upland areas of the Yazoo Basin. The eastern border of the delta is well defined by the steep escarpment of the Loess Bluffs. Its western border, also the western border of the Yazoo Basin, is along the top of the artificial levee which borders the Mississippi River.

Natural drainage follows arcs, loops and the generally curved patterns characteristic of meandering streams rather than the dendritic patterns characteristic of the upland areas of the Yazoo Basin. It is obvious from an aerial view that small streams quite often follow broad arcuate patterns and in many instances these smaller streams have formed small tightly looped meanders within the broad arcs left by relict Mississippi River courses. Plowed fields reveal the remnants of huge meanders now marked only by light and dark-colored arcs that extend for miles in either direction. Ox-bow lakes that were once obviously bendways of the Mississippi River are now miles in distance from the Mississippi. In some instances the Yazoo River, the Big Sunflower, and other streams follow along the huge arcs left by earlier courses of the Mississippi. In other instances they disregard these abandoned courses and have formed their own channels in the lowland areas away from the larger, formerly occupied channels.

In summary, the Mississippi Alluvial Plain is the result of a complex history of occupation and deposition by ancient meandering courses of the Mississippi River and its tributaries. Contrasting with the widespread areas of meander scars and meandering drainage are isolated remnants of two distinctively different landforms. One consists of low-lying areas of interior drainage, the backswamp, where floodwaters ponded before artificial levees restricted overflow from the Mississippi and where clays have been deposited to depths of 50 feet or more. The other landform consists of silts and sands deposited by a connecting network of shallow drainage channels left behind when the Mississippi was a braided rather than a meandering stream. These are the remnants of the oldest soils which form the surface of the Yazoo Delta.

The Mississippi River began its meandering perhaps as long as 8000 years ago in the Yazoo Delta. Detailed geological and engineering soils mapping (Kolb et al., 1968) delineates deposits left by four or possibly five distinct meander belts that have crossed the area. Sancier (1974) has assigned dates to these meander belts based on recent archeological and carbon-14 determinations and has fit them into a consistent chronological sequence. Sancier differs from Fisk, who attempted a similar chronologic assessment in 1944, principally in that he considers Fisk's age assignment too recent. Current data suggest that the various meander belts are older, sometimes as much as two or three times older, than Fisk had proposed.

The oldest meander belts are along the eastern valley wall. Because of their age and the few segments exposed at the surface, the history of these belts is far from certain. It is possible to distinguish two separate meander belts which occupied essentially the same area as that currently occupied by most of the Coldwater-Tallahatchie-Yazoo river system. The two meander belts were active from about 9000 to 6000 years ago. The remnants of these two meander belts are probably buried beneath the present deltaic plain.

The Big Sunflower River now follows a previous meander belt of the Mississippi that is broad, well defined, and well preserved. It probably began by diversion from the two combined meander belts along the eastern valley wall about 6000 years ago and was occupied by a full-flow Mississippi River for about 1500 years.

About 4500 years ago it is believed that the meander belt now occupied by the Big Sunflower River was gradually abandoned and a divided flow condition developed. This consisted of two separate channels; the western arm followed essentially the present Mississippi River meander belt along the Yazoo front and the eastern arm followed basically the same trace as the two earlier combined meander belts along the eastern valley wall. Due to the split flow conditon the meanders were smaller. The smaller meanders are particularly well preserved along the valley wall where many are now followed by the Yazoo and the Tallahatchie Rivers.

It is estimated that flow was divided as described until about 2500 years ago when eventually the western arm enlarged enough to accept the full flow of Mississippi and the present meander belt was formed.

Alluvial environments of deposition within the Yazoo Delta are divided into: 1) braided stream remnants, 2) backswamp, 3) point bar, 4) abandoned channels, 5) abandoned courses, 6) natural levees, and 7) alluvial fans. Each classification represents a specific depositional process and has its own individual set of soil properties. The different types of topstratum present can provide a key to patterns of stream behavior. For example, in the more cohesive soils, stream meanders migrate very slowly and banklines demonstrate a degree of stability not found in predominantly sandy soils. Channels in sandy alluvium tend to be wider with more rapid migration rates and form islands much easier.

Braided Stream. Braided stream deposits are the oldest deposits exposed in the Alluvial Plain. They were laid down by a network of shallow shifting streams and the greater mass of the sediment was coarse grained. However, a thin, fine-grained portion is present as topstratum which also includes alluvial fan and apron deposits near the valley wall.

Braided stream deposits are exposed in the northeastern and west-central portion of the Yazoo Delta. These areas are remnants of once larger masses now situated between meander belts or a meander belt and the valley wall and are essentially at the same level or only slightly higher than the bordering alluvial environments. Because of this slight elevation difference the braided surfaces were chosen early for farming.

Backswamp. Backswamp deposits consist of fine-grained sediments laid down in broad, shallow basins within the floodplain during periods of flooding. The sediment-laden floodwater may be ponded between the natural levee ridges on separate meander belts, or between natural levee ridges and the uplands. Backswamp areas typically have very low relief and a distinctive, dendritic drainage pattern in which channels alternately serve as tributaries and distributaries at different times of the flood cycle.

Backswamp deposits are present in various portions of the Yazoo Delta, but are widespread only in the southern portion where they occur between meander belts. Soils consist of heavy plastic and organic clays which settle out in sheets that vary from paper thin to inches thick. Some of these clayey deposits are 50 or more feet thick. These low-lying areas were not necessarily used for farming until comparatively recent times. As cultivation increases, however, many of these areas are cleared of timber and drained artificially.

Point Bar. Point bar deposits consist of sediments laid down on the insides of river bends as the river meander. Point bar deposits are by far the most common sediments in the Yazoo Delta. These deposits are attributed to the Mississippi, Ohio, Yazoo and smaller rivers.

Abandoned Channel. Abandoned channels are partially or wholly filled segments of meandering stream formed by bendway or neck cut-offs. Soon after formation they are characterized by oxbow lakes. In time they fill with a wedge of fine grain sand in the upper portion and with a clay plug in the downstream end.

Abandoned Courses. Abandoned courses, as distinguished from abandoned channels are long segments of the river abandoned when the river shifted into an entirely new meander belt. They mark the final position of the river before it was abandoned. The abandoned courses are often occupied by smaller streams and bayous. On being abandoned by the Mississippi, these naturally available drainage-ways became the ancestral courses for minor drainage within the Yazoo Delta. The Yazoo, the Tallahatchie, the Coldwater, and the Big Sunflower Rivers use segments of the abandoned courses.

Natural Levees. Natural levees are broad, low ridges which flank both sides of streams that periodically overflow their banks. Since the coarsest and greatest quantities of sediment are deposited closest to the stream channels, the natural levees are highest and thickest in these areas and gradually thin away from the channels.

The largest and most widespread natural levees in the Yazoo Basin occur along the present course and abandoned courses of the Mississippi River. They attain crest heights of 10 to 15 feet above the adjacent backswamp elevation and may be as much as two miles in width. Typical natural levee deposits consist of stiff to hard, light tan to grayish-brown silts and silty clays. They are usually well drained and because of their height were the first areas that were inhabited and cultivated within the Delta.

Alluvial Aprons. Alluvial aprons or fans are broad, gently sloping features composed of both alluvial and colluvial deposits that concentrate at the base of the valley walls. Typically, symmetrical alluvial fans are present at the mouths of streams that drain the uplands. When the streams are closely spaced, the fans coalesce to form the alluvial aprons. When the streams are widely spaced, the fans are separated and the intervening portions of the aprons are less well developed and composed mainly of sediment introduced from the uplands.

These aprons occur at the base of the valley wall from Memphis to Vicksburg. They are well developed at the points where streams, such as the Tallahatchie River, discharge from the uplands and have constructed large alluvial fans. Because of the extent and proximity of the Loess Bluffs, the aprons are mostly composed of silt with lesser amounts of clay and fine sand. Occasional gravel and large rock masses are present where Pleistocene and Tertiary formations are exposed nearby in the uplands. The apron deposits are generally fairly high with respect to the remainder of the Delta and are well drained.

2.2.7 Conclusions Reached from Geology

From the previous information several significant conclusions about the sediment mechanics of the basin can be reached. First since there are numerous lithologic units present facies can change rapidly. The streams in the area can be expected to have irregular patterns and shapes particularly on the delta since they may have to come to equilibrium with several different materials. Second, no significant formation or unit would be able to stop stream erosion or create a control point for any long period of time. Third, almost all material near the basin surface is comprised of sand sizes or smaller with the exception of a few sand-and-gravel units. And finally in its natural condition the basin above the bluff lime was an erosional area while the delta was depositional area.

2.3 Hydrology

2.3.1 Climate

The climate of the Yazoo Basin is mild and humid. Summers are long and hot and provide a long growing season. Some double cropping is done in the basin since the winters are moderate. The average daily temperature at Greenwood ranges from 44°F in January to 80°F in July with an annual mean of 65°F.

The Yazoo Basin has moderate to heavy rainfall. During the period 1900 to 1973 the annual rainfall at Greenwood ranged from a minimum of 30.16 inches in 1965 to a maximum of 83.33 inches in 1973. Based on the 20 year period from 1954 to 1973 the mean precipitation is 50.87 inches.

The average annual precipitation over the basin is approximately 52 inches. Sixty-seven percent of the rainfall occurs during the months of December through May. The driest period occurs during August through October, but locally intense runoff can occur any time during the year. Table 2.1 presents the average rainfall at Greenwood. Major floods are caused by storms of several days in duration commonly with wet anacedent conditions. Major flooding has occurred in 14 of the 45 years from 1931 to 1975 (Corps of Engineers, 1975).

Table 2.1. Average Rainfall at Greenwood 1954-1973 (after Corps of Engineers, 1975)

Month	Rainfall (inches)
January	5.62
February	5.04
March	5.70
April	4.81
May	4.06
June	3.75
July	4.45
August	3.06
September	3.12
October	2.39
November	4.70
December	5.41
Total	50.87

2.3.2 Runoff

The Corps of Engineers (1975) reported runoff in the basin to range from 50% to 90% of precipitation depending on antecedent conditions. They also report annual runoff of 18 inches in the upper end of the basin to 16 inches at Vicksburg. Watson (1982) presents runoff data for various land uses in northern Mississippi that range from 1.49 inches for pine plantations to 20.00 inches for bare fallow fields. His data are presented in Table 2.2. This data may be low for large watersheds since the study plots were small and would not have measured groundwater return flows.

Table 2.2. Annual Runoff for Single Cover Watersheds in Upland North Mississippi (after Watson, 1982)

Land Use	Annual Runoff Average (inches)	Range (inches)
Open Land		
Cutivated	15.39	6.2-24.0
Pasture	16.52	12.9-23.4
Bare Fallow	20.00	10.0-30.0
Forest Land		
Abandoned Fields	6.65	1.2-20.7
Depleted Hardwoods	5.94	1.2-13.1
Pine and Hardwoods	8.74	0.4-19.8
Pine Plantations	1.49	0.1-9.7

The Corps of Engineers (1981) has estimated the change in forested land in the basin. Their data are presented in Table 2.3

Table 2.3. Percent of Land in Forest

	1800	1860	1880	1900	1930	1940	1950	1980
Delta	100	88	78	72	44	39	35	10
Hills	100	88	78	72	30	36	41	50

Additional hydrologic data are presented in the temporal design.

III. GEOMORPHOLOGY

3.1 General

The previous section has described the geologic and hydrologic setting of the Yazoo River Basin. This section describes the general geomorphic conditions which prevail in the basin and qualitatively describes the expected response of the system to Plan E and other design alternatives. The purpose of this material is to provide a foundation for the detailed engineering mathematical model. As such the geomorphic analysis was maintained at a qualitative level to insure efficiency and clarity. Recently, more detailed geomorphic analyses have been completed on selected streams in the basin (Watson, 1982; Schumm et al., 1981; Biedenharn, 1983; Corps of Engineers, 1979).

3.2 Existing Geomorphic Conditions

3.2.1 Mainstem

The mainstem channel as defined for this study consists of the Yazoo River from Vicksburg to the confluence of the Yalobusha and Tallahatchie Rivers, the Tallahatchie River to the confluence of the Coldwater and Old Little Tallahatchie Rivers and the Coldwater River to Arkabutla Dam. Except for a short portion of the upper Coldwater River the entire mainstem lies on the Mississippi Alluvial Plain or the "Yazoo Delta." Thus the mainstem has inherited a valley floor with a slope and composition that it did not create. As a consequence the river has always had a remarkable variability in slope, sinuosity and shape as it adjusted to conditions in the Alluvial Plain. An example of this is the Greenwood Bendway. The Bendway is not a true bendway of the Yazoo but is instead the remains of a Mississippi meander which the Yazoo has occupied. Examinations of aerial photographs show that the Tallahatchie

River which comprises the upper half of the Bendway meanders slightly within the limits of the old channel. Before the start of man's activities in the basin it is believed that the mainstem was relatively stable. The reasons behind this assumption are: 1) the mainstem has had a long time to adjust to the current alignment and 2) there are no geologic materials present in the Delta which could create a long term control. On the first point, Sancier (1974) states the last Mississippi occupation of the eastern delta ended 2500 years ago.

The earliest activities of man on the mainstem were clearing and snagging for navigation purposes (Walters, 1977) which started in the early 1800's as cotton production in the basin started. No detrimental affects are recorded as a result of this early navigation. As farming expanded in the second half of the 19th century numerous accounts of upland erosion were recorded which undoubtedly delivered large amounts of sediment to the mainstem, but again no detrimental mainstem affects are known. The suspected reasons for the mainstem's insensitivity are: 1) the basin received large overflows from the Mississippi which would have a flushing action even if the overflows brought significant sediment with them, and 2) the Delta had few levees to restrict flows and large backswamp areas were present to absorb local increases in runoff and sediment. Starting in the 1900's channel deterioration became a problem along the mainstem. This then led to flooding problems due to inadequate channel capacity. The reasons for this channel instability induced flooding are: 1) elimination of Mississippi overflows with the final closure of the Yazoo Pass after the 1927 flood, which served to scour the mainstem, 2) clearing of low lying lands which was possible due to the elimination of Mississippi overflows, and 3) the channelizing of many bluff line tributaries directly into the mainstem past backswamp areas. These events combined to reduce the channel flows and increase the sediment input. The mainstem experienced a gradual decline in channel capacity. The channel capacity reduction is not well documented, but an indication of its magnitude is shown in Figure 3.1. The figure shows that at this location (mile 9.6) the Yazoo lost over 4000 sq. ft. of channel capacity in the period 1940 to 1972. Since the 1940 measurement was taken 13 years after the last Mississippi overflow it is possible and probable that the channel initially was much larger than the 1940 section.

Starting in the 1930's with projects approved by Congress in the 1928, and subsequent flood control acts, significant flood control features were constructed on the mainstem. With cutoffs, the mainstem was shortened from 366.9 miles in 1939 to 301.4 miles in 1970. This increased the river slope by 22%. Levees were constructed over long reaches such that the river lost much overbank storage, and in 1962 the Will M. Whittington Auxiliary channel was completed which added significant flood capacity to the lower Yazoo. Starting in 1942 with the completion of Sardis dam the major tributaries have been controlled and regulated. Arkabutla Dam was completed in 1945, Enid Dam in 1955 and Grenada Dam in 1955. This has reduced mainstem peak flows. At Greenwood the pre-reservoir (and post Yazoo Pass) maximum discharge occurred in 1932 and had a value of 72,900 cfs. The 1973 flood which occurred in the wettest year on record had a peak discharge of 43,800 cfs. Discharges on the mainstem before closure at Yazoo Pass have not been reported, but the basin as a whole (Mainstem, Big Sunflower and overbank) is believed to have carried up to 500,000 cfs from the Mississippi.

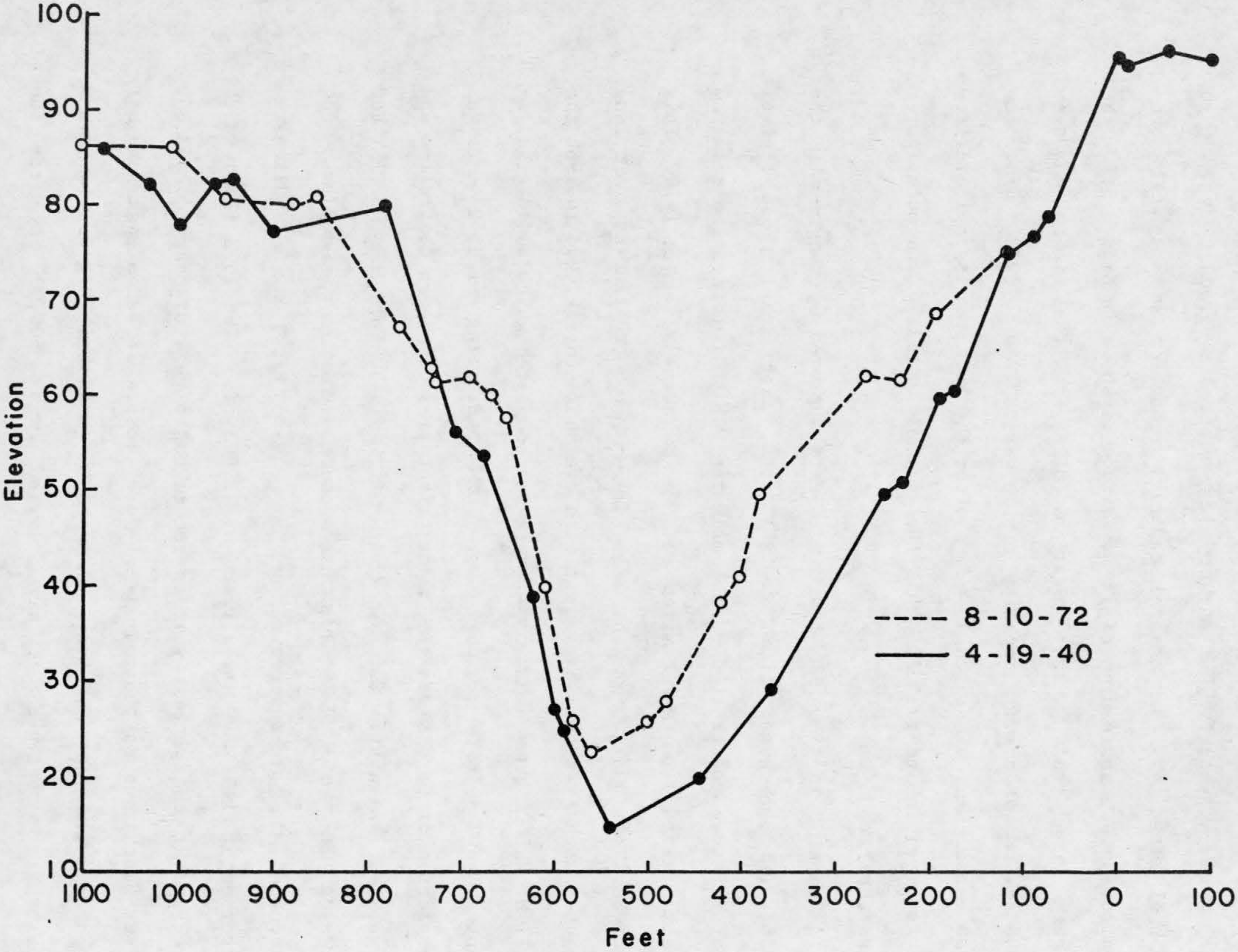


Figure 3.1. Yazoo River cross section P.R. 9.6.

In summary, when compared to conditions at the start of this century the Yazoo mainstem has

1) higher tributary sediment input
2) less flow volume and lower peak flows
3) greater bed slope
4) smaller cross sectional area
5) less channel and overbank storage

Lane's (1955) relationship can be used to analyze channel response

$$Q_s \, D_{50} \sim QS \tag{2.1}$$

where Q_s is the sediment discharge, D_{50} the bed material size, Q the water discharge and S the stream slope. Lane did not differentiate between bed and energy slope but for mild slope streams such as the Yazoo the energy slope is best used. If it is assumed that the sediment size is constant or increases slightly due to tributary erosion it can be seen that an increase in sediment load (item 1) and a decrease in water discharge (item 2) can only be balanced by an increase in slope. On the mainstem the energy slope has been increased by two factors, the shortening of river by cut-offs (item 3) and the reduction in flow area (item 4). A surprising conclusion can then be reached. That is, that the construction of cut-offs on the mainstem in the 1940's may have improved channel stability by helping to offset the increased tributary sediment load. Without the cut-offs the mainstem may have experienced even greater aggradation.

The affect of loss of channel and overbank storage (item 5) was to increase peak discharges, but it was not enough to counter the effects of the reservoirs. Again from a stream stability view point, levees may have improved channel stability.

3.2.2 Regulated Tributaries

There are three regulated tributaries to the mainstem, the Little Tallahatchie, Yocona and Yalobusha Rivers. The Little Tallahatchie was realigned by the Panola-Quitman Floodway (P-Q) in the 1920's and the Little Tallahatchie and P-Q are considered here as one river. These rivers share several common traits. These traits are: 1) they are regulated by large reservoirs, 2) they flow through valleys which are recent in age and of their own making, and 3) they have been significantly straightened and shortened in the last 40 years. All of these streams have been altered significantly from their natural state.

Yalobusha River. Before regulation the Yalobusha River at high stages would discharge its overflow onto the flat alluvial lands and a large storage area adjacent to the hills provided a natural regulation of this flow which greatly reduced the peak flow of the Yalobusha into the Yazoo River.

The original condition of the river was such that navigation was possible at high stages to Grenada, and before the construction of a railroad bridge across the river at Grenada, navigation was possible up to Graysport about 12 miles upstream from that point. At medium and low stages passage was difficult and dangerous due to snags, stumps, sunken logs and leaning timber. The least available depth during high water was about 25 feet. Since about 1886 or 1887 steamboat traffic declined due not so much to stream conditions as to lack of cargoes favorable to steamboats.

The initial work by the Federal Government on the Yalobusha was sponsored by the River and Harbor Act of March 3, 1881. Previously, during the summer of 1878 the county of Grenada had completed clearing along the bankline. The approved project provided for the removal of leaning timber, log racks and drift, and the most dangerous snags between Grenada and the mouth. The original project was completed in 1884 and maintenance was continued until 1886. From this point in time until 1932 there was no maintenance work on the channel.

By 1932, work by drainage districts on its tributaries caused severe sedimentation problems, especially on two particular tributaries; 1) Topashaw Creek which enters the Yalobusha above the present location of Grenada Dam, and 2) Potacocowa Creek which was not originally a tributary but was artificially connected to the Yalobusha by a diversion canal in the Yazoo Delta. Potococowa had deposited enough material into the Yalobusha that at one point, before dredging, the Yalobusha abandoned its channel, reversed the flow through McIntyre Lake and then flowed down Little Tippo Bayou into an open channel just above Whaley.

After the construction of Grenada Dam and Reservoir in 1955, degradation below the dam caused considerable bank caving. The input of large quantities of sediment into the channel resulted in an increase in meandering and further bank caving which lasted several years.

The Yalobusha River has had considerable straightening. The river to Grenada Dam has been shortened from 63.5 miles in 1939 to 45.7 miles in 1982. The reservoir has also dramatically reduced peak flows. The maximum observed discharge at Grenada of 78,900 cfs occurred in 1948. Since closure the maximum of about 45,000 cfs occurred in 1983 all of which was from Batupan Boque.

Yocona River. The Yocona River is only 13.5 miles long between Enid Dam and its confluence with P-Q Floodway. The Yocona is the most altered of any of the basin streams. Before 1900 the Yocona was a sinuous river which had its confluence with the Little Tallahatchie six miles west of the present confluence with the P-Q. The river was straightened and canalized in the 1940's. These changes undoubtedly resulted in lowering the Yocona's base level several feet. This lowering coupled with the reduction of upstream sediment due to Enid Dam resulted in significant degradation. Due to the degradation the Yocona River must have been a prime contributor to the channel filling that occurred in the P-Q Floodway.

Enid Dam has reduced peak flows considerably. The pre-reservoir maximum of 36,300 cfs occurred in 1948. The post-reservoir maximum of 5,000 occurred in 1983. The channel is considered relatively stable at the present time.

Little Tallahatchie River. A detailed geomorphic analysis of the Little Tallahatchie River has been carried out by Biedenharn (1983). Biedenharn stated that comparison of plan maps dating to 1833 indicate that the Little Tallahatchie was actively meandering. The channel sinuosity ranged from 1.85 in 1833 to 1.73 in 1928. The Little Tallahatchie River Basin historically experienced frequent flooding. A 1882 flood was estimated at 100,000 cfs. Biedenharn found that water surface profiles from floods in 1882, 1902 and 1932 show a convex break in slope near Belmont Bridge. This convexity still exists today. The only current explanation of the convexity is the outcrop of ironstone 0.5 miles upstream from the bridge.

Two major man-induced changes have occurred on the Little Tallahatchie. They are the construction of the P-Q Floodway and the closure of Sardis Dam in 1940.

The P-Q Floodway was built by the Panola-Quitman Drainage District during the 1920's. The Floodway is paralleled by a levee on the west side to a point just above the confluence of Black Bayou with the

Floodway. The Floodway intercepts both the Little Tallahatchie and Yocona Rivers. The Floodway effectively shortened the Little Tallahatchie by approximately 23.5 miles but when the length of the P-Q is added the total distance to the confluence of the Tallahatchie was increased by about one mile. The Floodway, of course, caused a base level reduction by moving the confluence downstream approximately 18 miles. Assuming a slope of only 0.5 ft/mi the base level reduction would be 9 ft.

Sardis Dam was the first of the basin reservoirs to be completed. It, along with all of the other reservoirs, has been successful in reducing peak flows. At the Belmont Bridge gaging station above Batesville, the maximum pre-dam discharge of 64,850 cfs occurred in 1932. The maximum flow released from Sardis Dam was 11,900 cfs in 1973.

The effects of the dam and the Floodway have combined to create a very unstable system. Biedenharn determined the Little Tallahatchie underwent a complex response with the dam closure, first degrading and rejuvenating the tributaries. As the sediment load from the tributaries increased the channel aggraded. After 1950 the rate of change decreased. The flood of 1973 disturbed the equilibrium. Large amounts of sand were deposited in the channel and bank erosion was induced which continues today.

The P-Q Floodway has undergone cylic erosion and deposition. After construction, degradation in the Yocona River caused severe aggradation in the Floodway. The initial channel was filled in places and a new channel formed along the west levee. With the flow at the base of the levee, caving and scour occurred at numerous locations and the levee crevassed near Crowder. A primary levee has been added to the initial secondary levee in this reach. As the increased sediment load has moved through the P-Q, the Tallahatchie River has experienced severe aggradation at the mouth of the Floodway. This has required emergency dredging. Banks (1976) reported that after dredging the Tallahatchie, the Floodway degraded one to three feet and more degradation was likely. Thus it can be seen that the Floodway reacts quite quickly to any upstream change in supply or downstream change in base level.

3.3 Gage Record Analysis

Watson (1977) performed specific gage analysis of several basin stations. Specific gage records were plotted from available stage and discharge data at various gaging stations on the Yazoo Mainstem and its tributaries. The measurements were intermittant at some gages while at others readings had been discontinued. Enough data were available to partially fill-in the picture of the effects of channel works on the regime of various streams and the system.

3.3.1 Little Tallahatchie River

Two gage records are available on the Little Tallahatchie. The first is located at the Belmont Bridge several miles downstream of Sardis Dam. The record is good from 1929 to 1943, but after that, only the year 1962 had sufficient measurements for comparison (Figure 3.2).

The change of regime occurring in the vicinity of this gage was minimal. Only a slight amount of degradation was indicated after storage began in Sardis Reservoir in 1939. The overall effect on the rating curve was a downward shift of about 1 to 1.5 feet. But by the 1960's the rating curve was back up to its 1930 position or maybe a little higher as shown in Figure 3.3. The upward shift of the rating curve indicates that aggradation was occurring in the channel in the vicinity and downstream of the Belmont Bridge gage location. This followed a

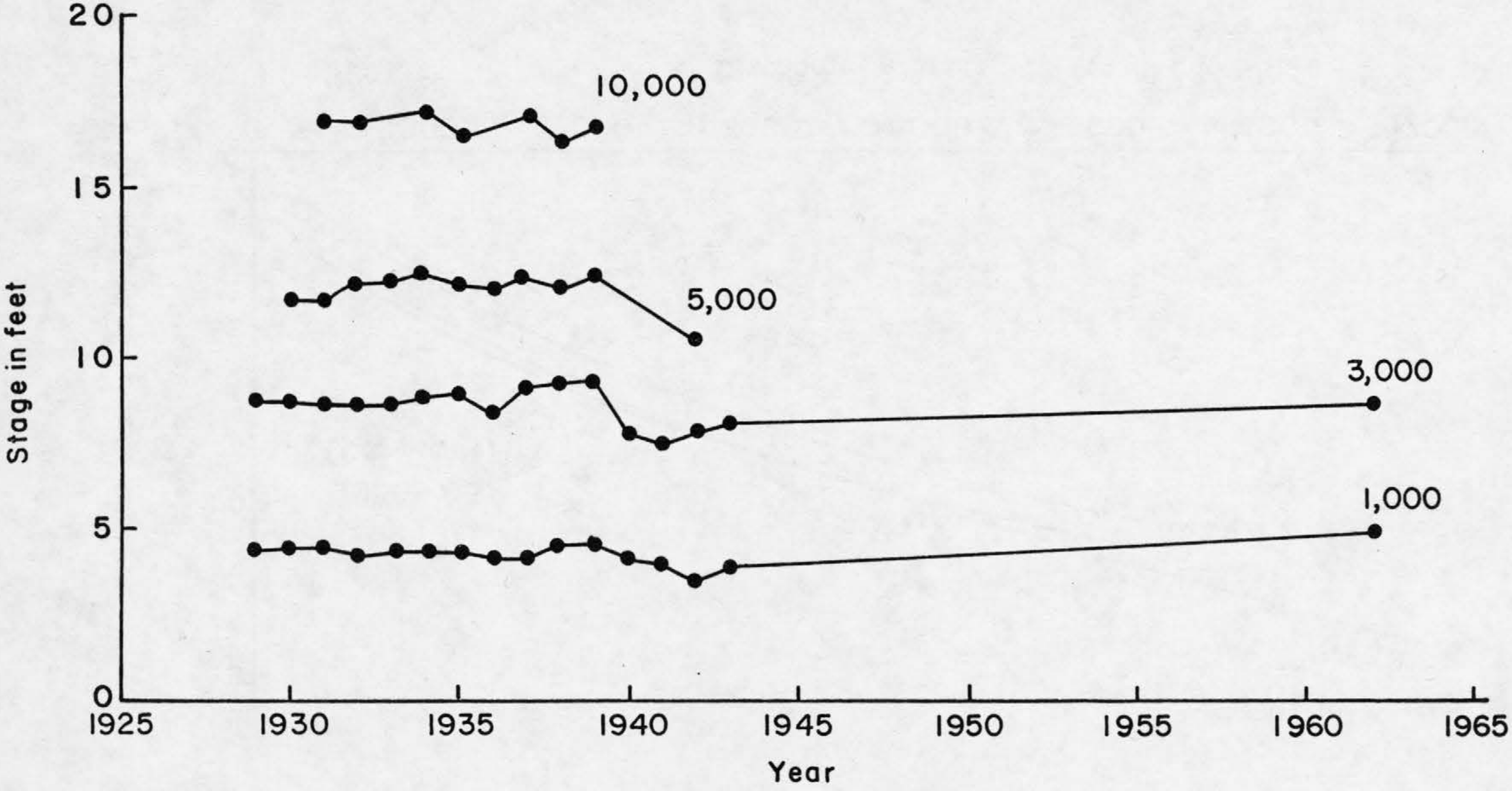


Figure 3.2. Specific gage record for Little Tallahatchie River at Belmont Bridge.

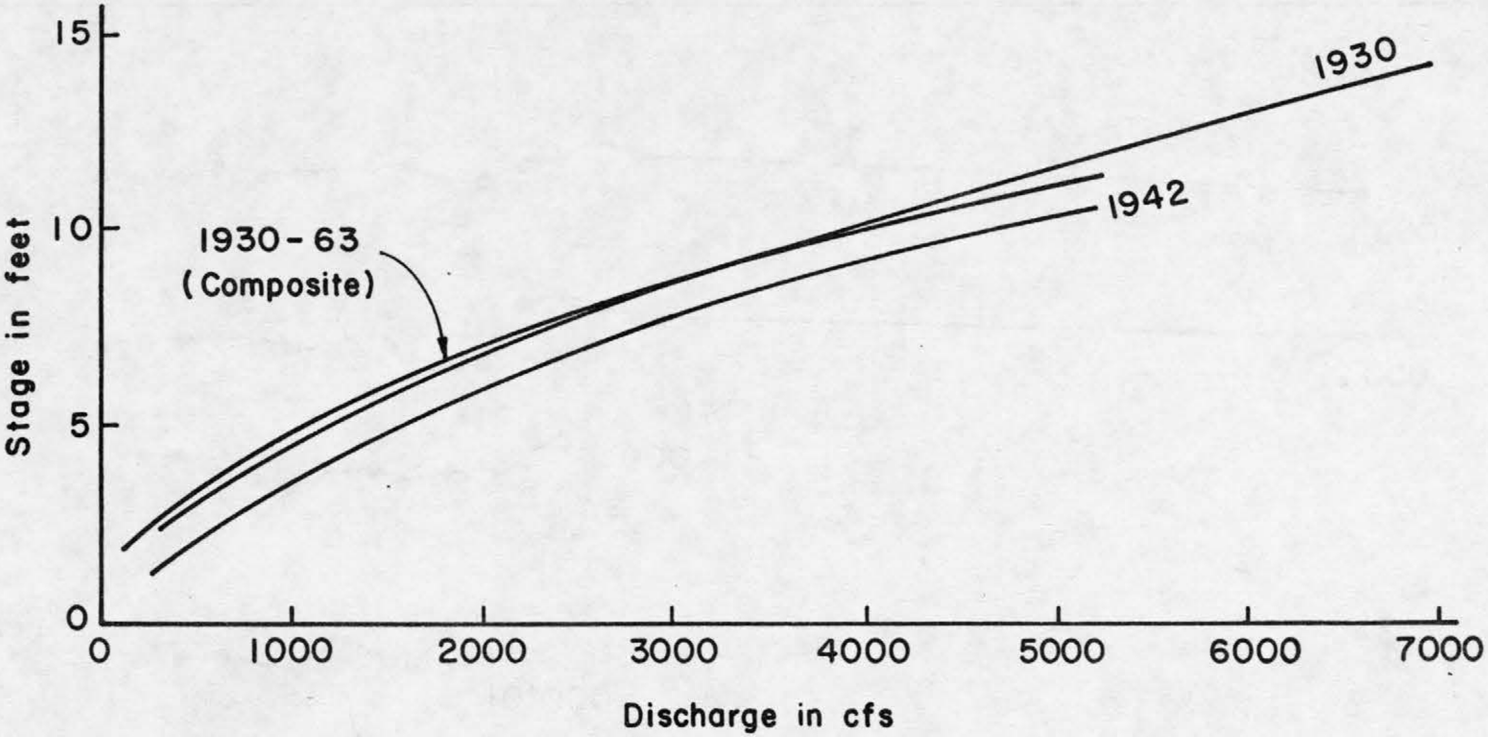


Figure 3.3. Stage discharge relationship for Little Tallahatchie River at Belmont Bridge.

short two- or three-year period of scour and degradation after the construction of Sardis Reservoir.

The other gage location is further downstream at Batesville near the river's junction with the Panola-Quitman Floodway. This gage location has a reasonably good record from 1940 to 1983. Figure 3.4 shows a trend of degradation commencing about three years after reservoir storage began. During the interim three-year period a moderate filling is indicated (1940-42). This was probably caused by the deposition of material from upstream degradation near the damsite. About 1944 the channel regime in the vicinity of Batesville stabilized and then shortly thereafter began to aggrade. The aggradation continued until about the early 1950's when a gradual trend of degradation commenced and still continues at the present time. From 1942 to 1946 the rating curve shifted downward for the lower range of discharges (0 to 8000 cfs) while it remained practically the same for the higher discharges as shown in Figure 3.5. This would indicate possibly a change in cross-sectional shape of a channel allowing for a deeper low water channel along with a wider channel for higher flows but with more roughness. The maximum drop in stage for a given discharge has been about three feet.

There are several possible reasons for the regime behavior of the Little Tallahatchie. The most obvious cause of degradation during the early 1940's was the construction of Sardis Reservoir. The aggrading of the channel during the late 1940's and early 1950's is much more difficult to explain. A preliminary comparison of over the last two decades reveals that the river has a long history of bank caving and pronounced meandering. There has also been much straightening of its tributaries below the dam which has forced more sediment into the parent stream.

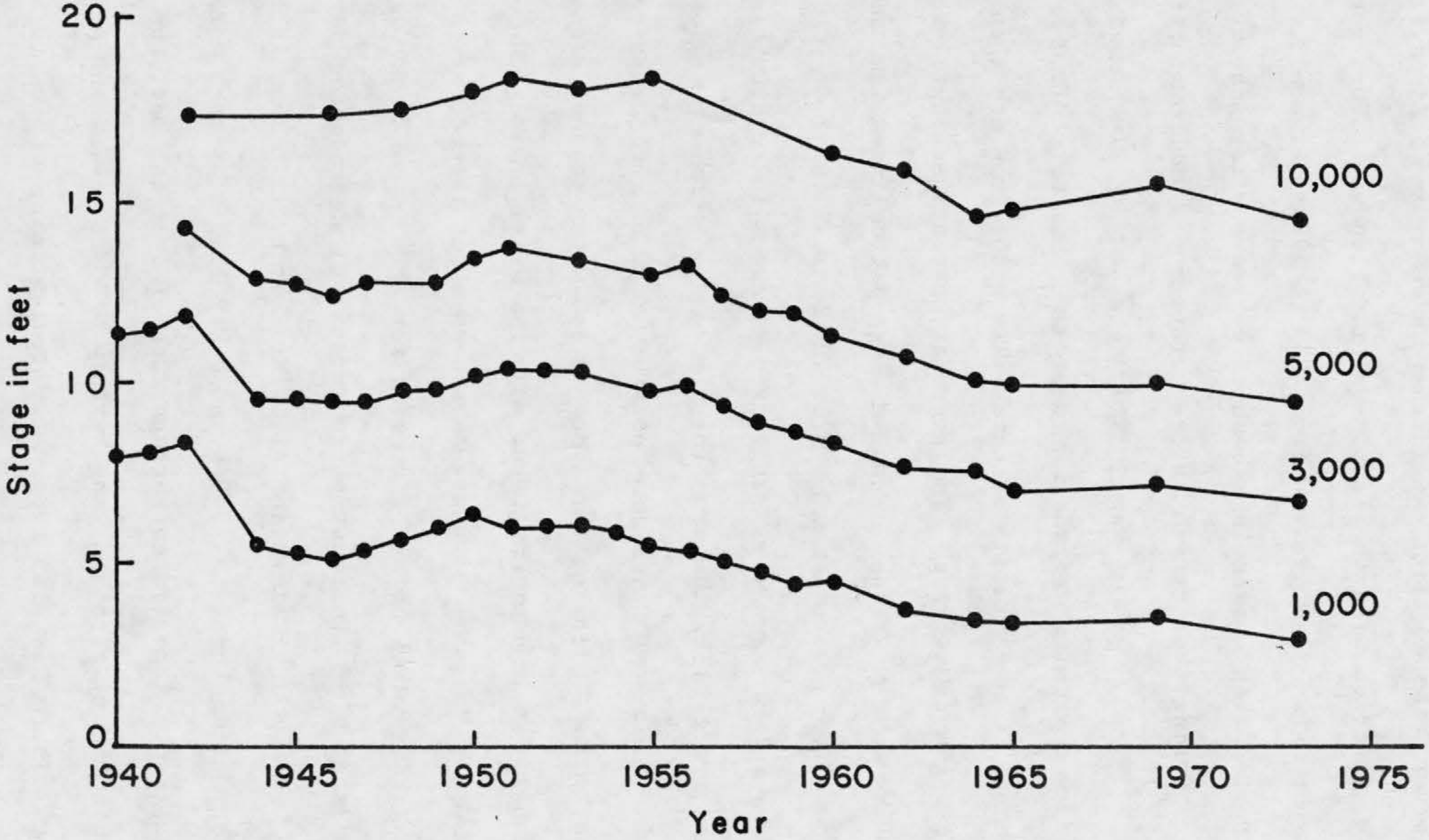


Figure 3.4. Specific gage record for Little Tallahatchie River at Batesville.

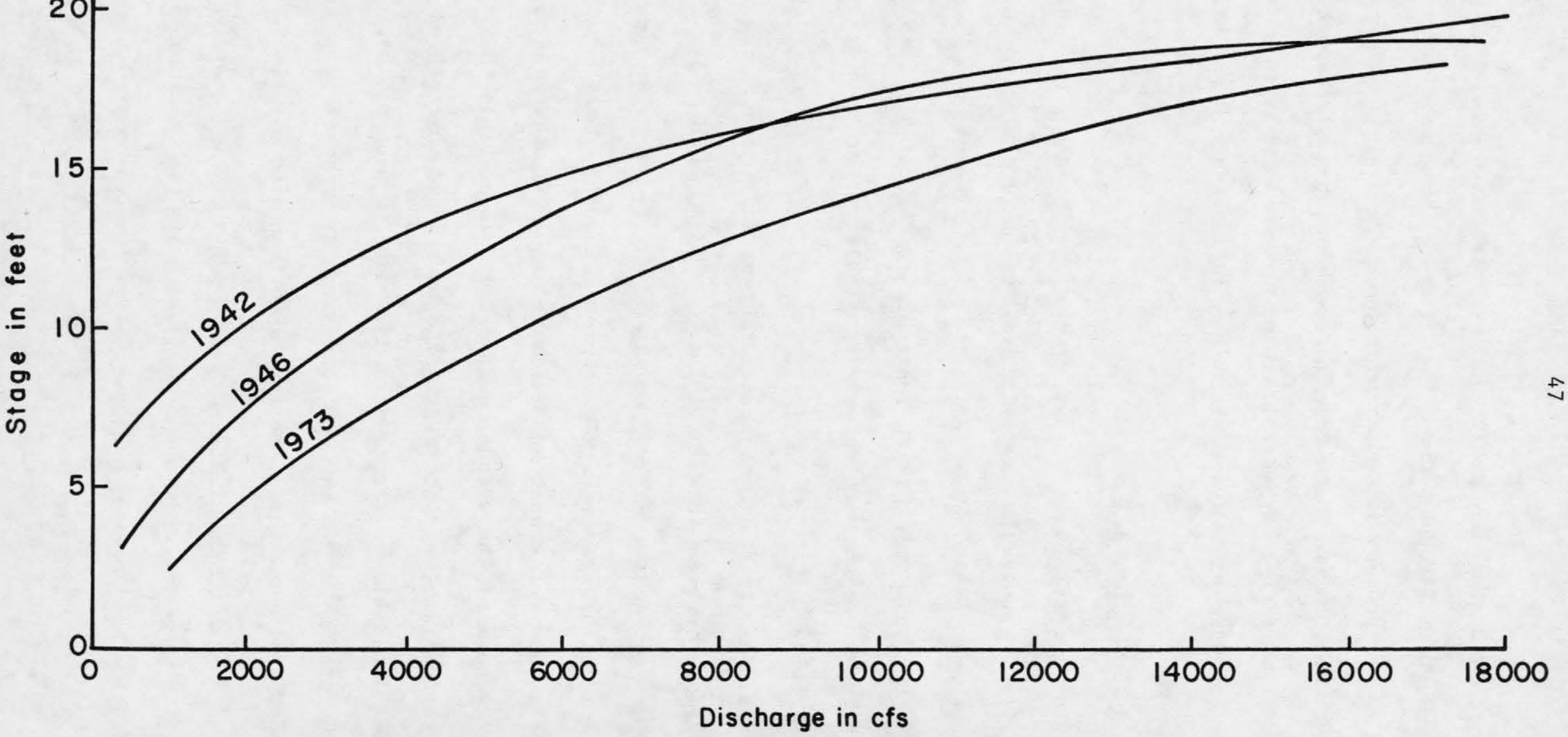


Figure 3.5. Stage discharge relationship for Little Tallahatchie River at Batesville.

The aggradation during the early 1950's corresponds to the filling of the Panola-Quitman Floodway about that time. The channel degradation occurring at the present time indicates a net removal of sediment from the channel near Batesville. This material has been transported into the Panola-Quitman Floodway which, at the present time is introducing a tremendous quantity of sediment into the Tallahatchie River below the Floodway mouth.

3.3.2 Yocona River

Data for specific gage analysis were available at the Enid gage located slightly above the present Enid Dam and are plotted in Figure 3.6. The record is very good from 1929 to 1951 but readings were discontinued after that year due to reservoir construction. From 1929 to 1944 the channel regime was reasonably stable. After 1944, pronounced degradation began a full three years before construction commenced on Enid Reservoir in 1947. The degradation was still continuing in 1951 but to a lesser degree than it did from 1944 to 1950. The downward shift of the rating curve due to degradation is shown in Figure 3.7. Construction on the reservoir was completed in 1955, however, the full effects of this event cannot be determined as no discharge data exist. The primary cause of the channel degradation was probably the straightening or channelizing of the river. The background information on this work is not available at the present time but it probably began around 1944. The straightening involved the complete channel from Enid Dam downstream to its outlet into the Panola-Quitman Floodway.

3.3.3 Yalobusha River

Adequate gage records were available at two locations on the Yalobusha. The bridge gage on Highway 51 is located on the outskirts of Grenada, Mississippi. The record is very good from 1929 to 1954, but

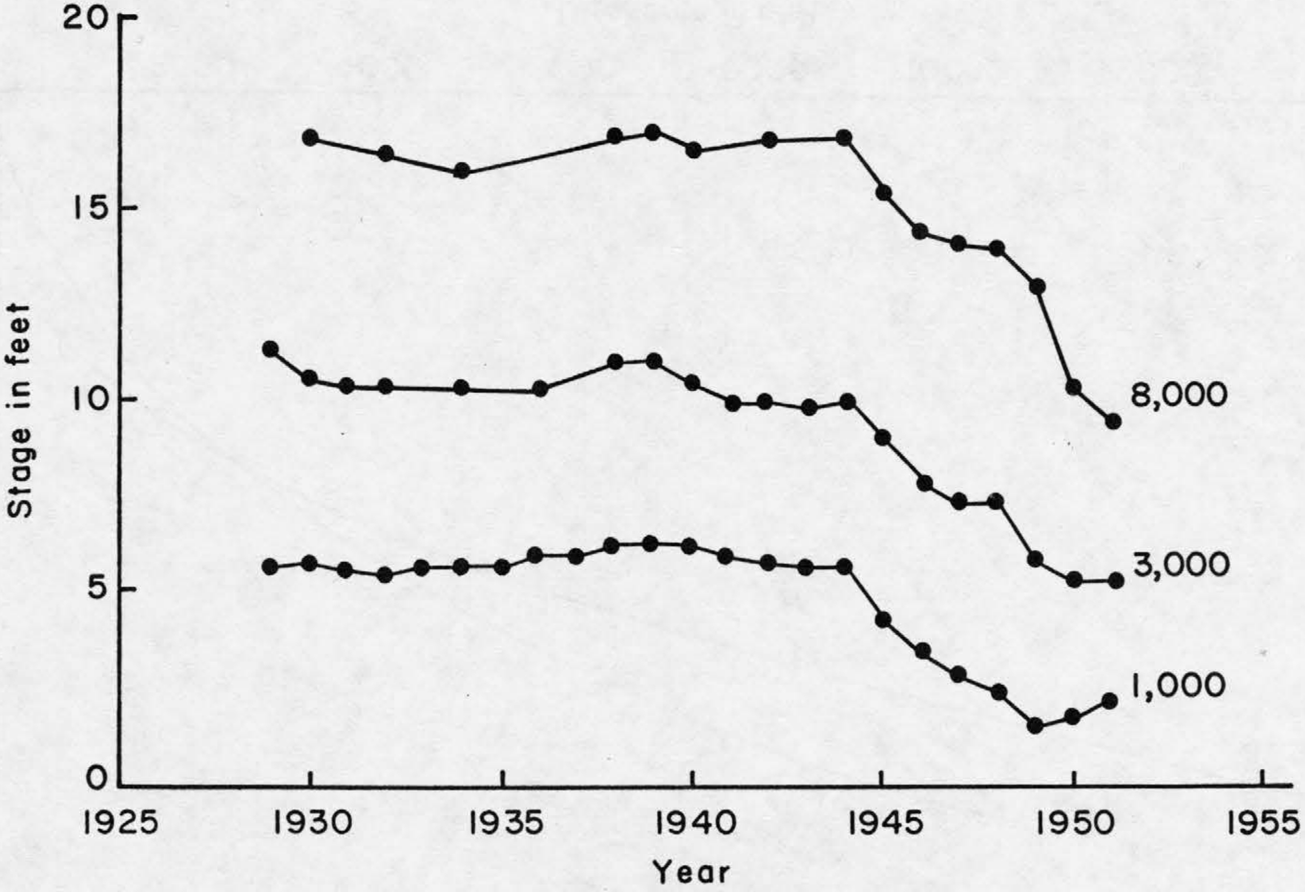


Figure 3.6. Specific gage record for Yocona River at Enid.

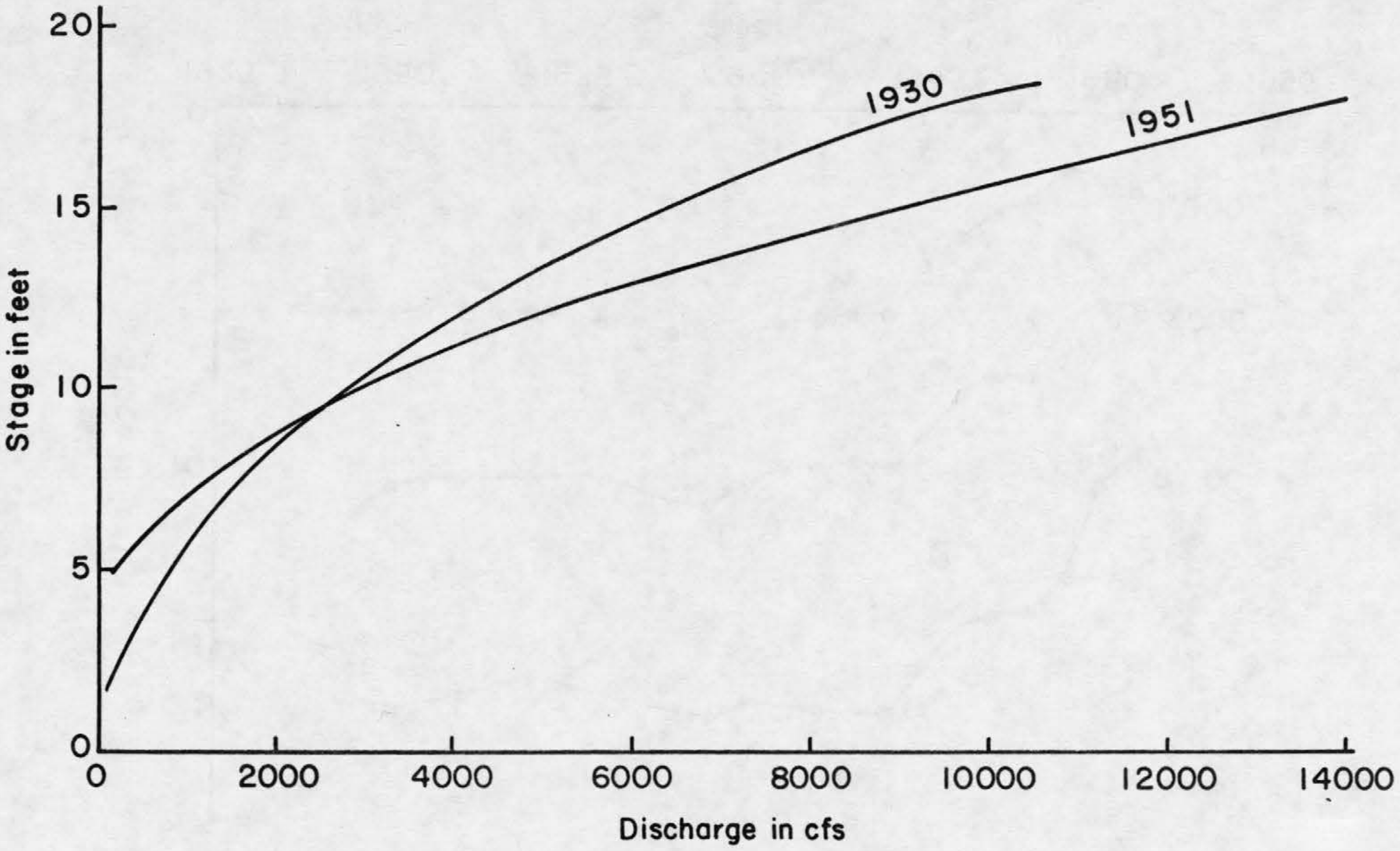


Figure 3.7. Stage discharge relationship for Yocona River at Enid.

from that time on discharge measurements were discontinued as shown in Figure 3.8. Degradation due to the dam, a major cutoff program, and channel work started about 1951. When it began, it was extreme, accounting for a drop in stage of about 5 feet in two years. Prior to 1951 there was a gradual trend of aggradation possibly a result of erosion in Topashaw Creek upstream (Walters 1977) which increased the sediment load to the Yalobusha as shown in Figure 3.9.

The other gage at Whaley, Mississippi, located well out into the Yazoo Delta did not show any degradation until 1953 as shown in Figure 3.10. Over the next three years the degradation amounted to about 4 to 5 feet. After this, a very gradual trend in aggradation commenced and by 1969 about 2 feet of channel capacity had been lost. Prior to reservoir construction aggradation had been the trend from 1938 to 1953 and was about 3 to 5 feet over that time period.

The rating curve comparison in Figure 3.11 shows that the 1973 curve has been displaced upward from its approximate position in 1939 indicating a loss in channel capacity.

3.3.4 Tallahatchie River

There are two gage locations on the Tallahatchie with discharge data sufficient enough to indicate a trend. The upstream gage is near Locopolis, Mississippi and is about two miles below the confluence of the P-Q Floodway and Tillatoba Creek with the Tallahatchie River. The record is intermittent, but extends from 1937 to 1973, as shown in Figure 3.12. From 1937 to about 1943 the trend was one of degradation which was more than likely due to the number of cutoffs made in this vicinity during the late 1930's and early 1940's.

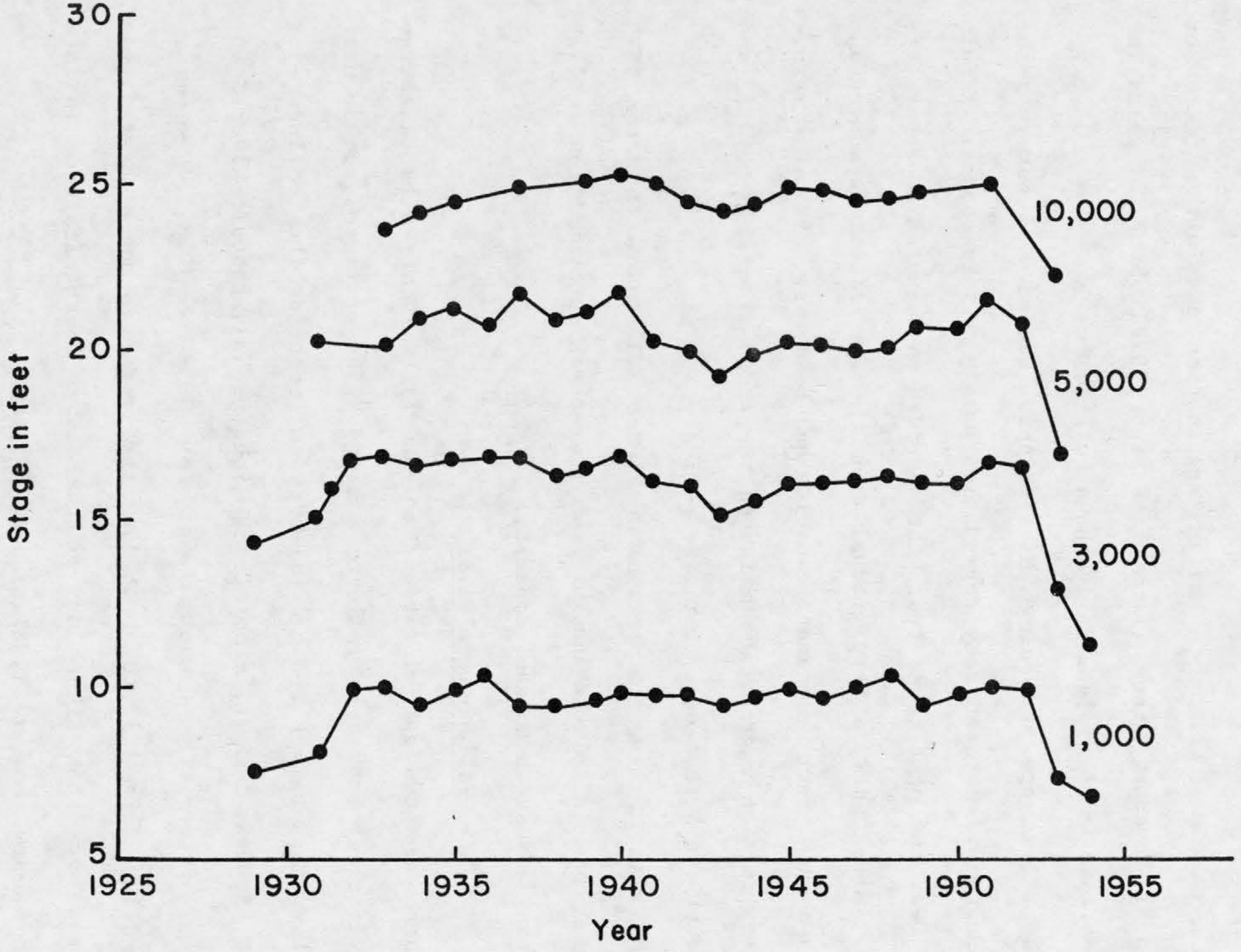


Figure 3.8. Specific gage record for Yalobusha River at Grenada.

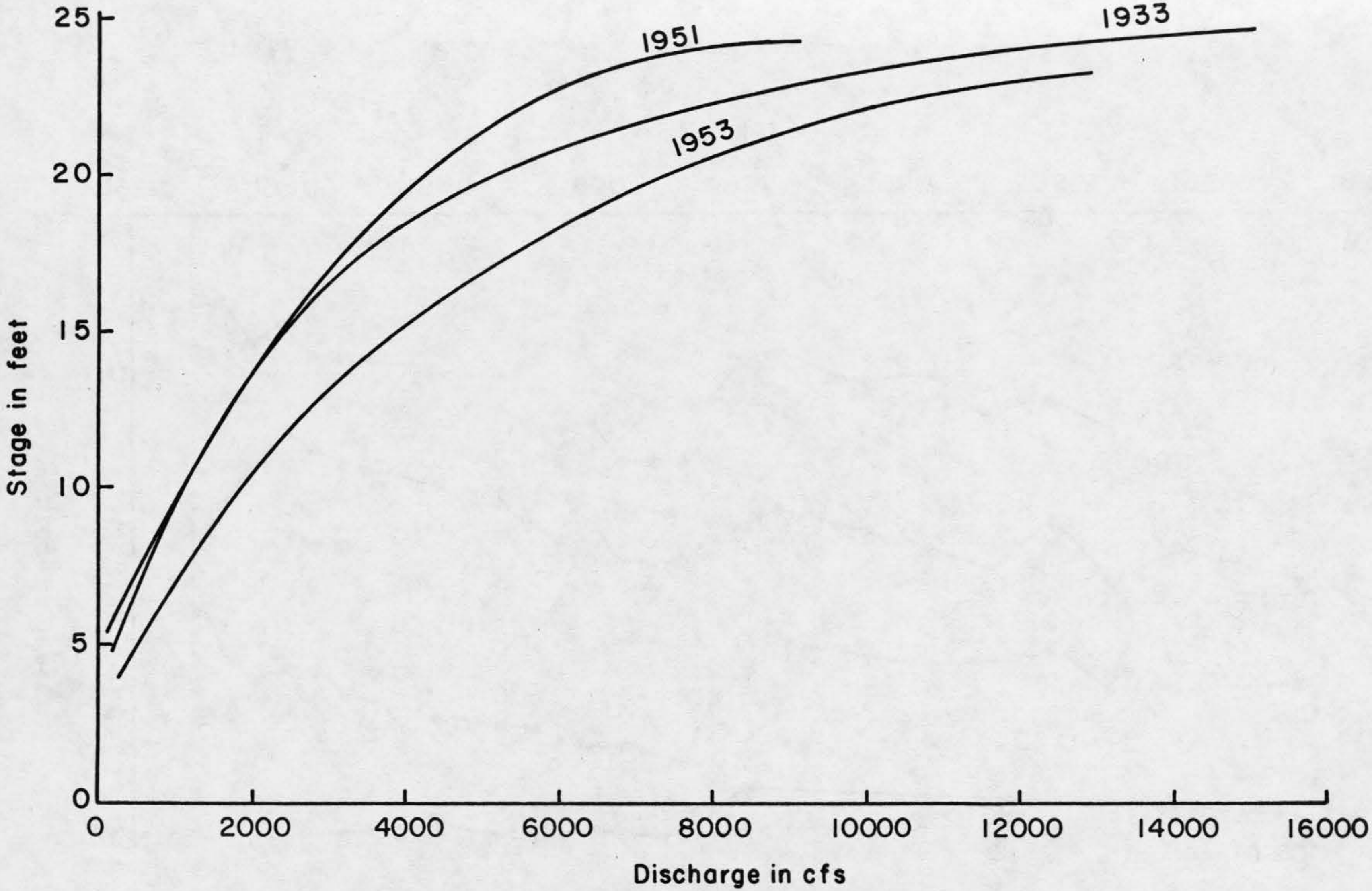


Figure 3.9. Stage discharge relationship for Yalobusha River at Grenada.

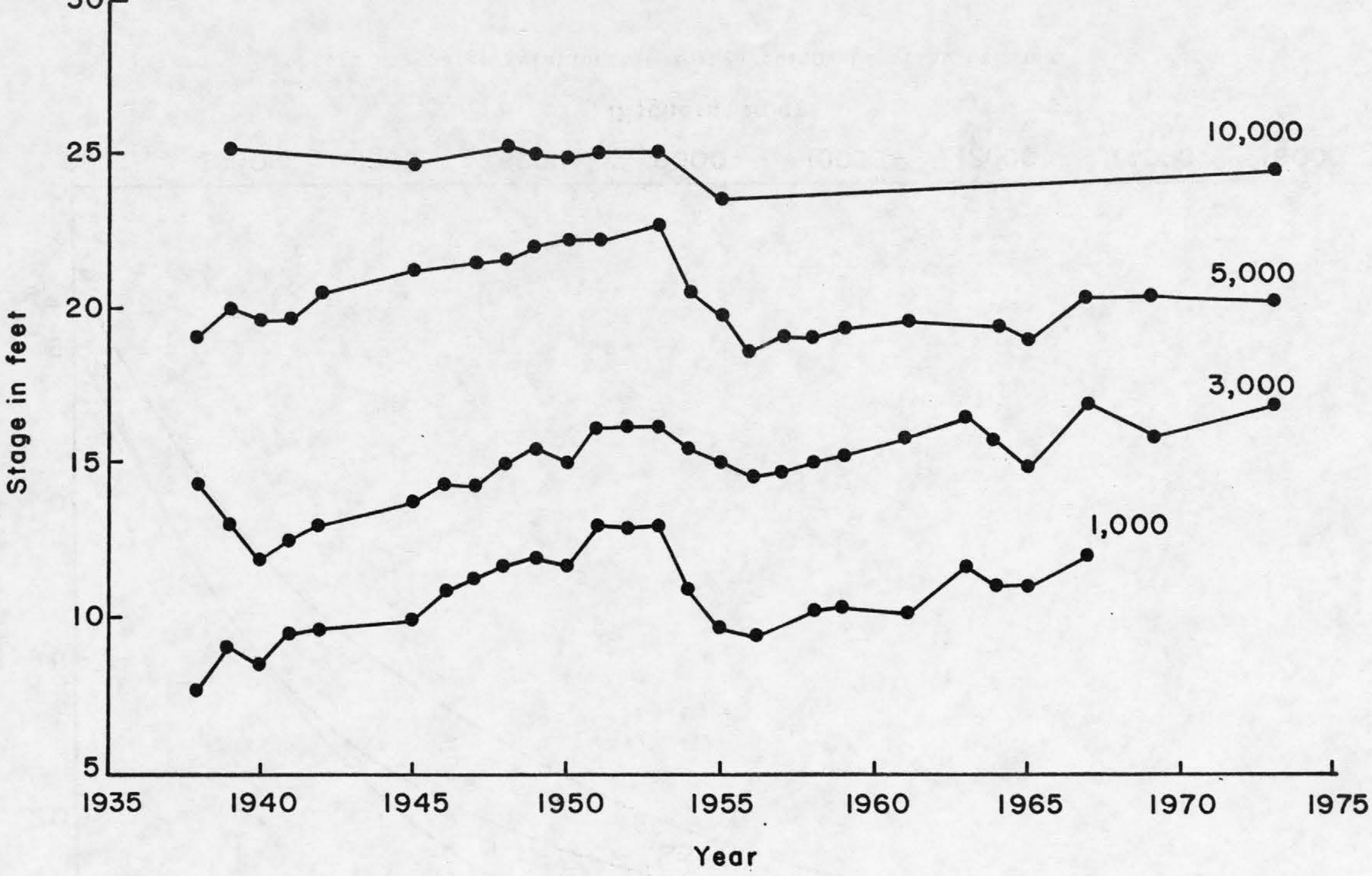


Figure 3.10. Specific gage record for Yalobusha River at Whaley.

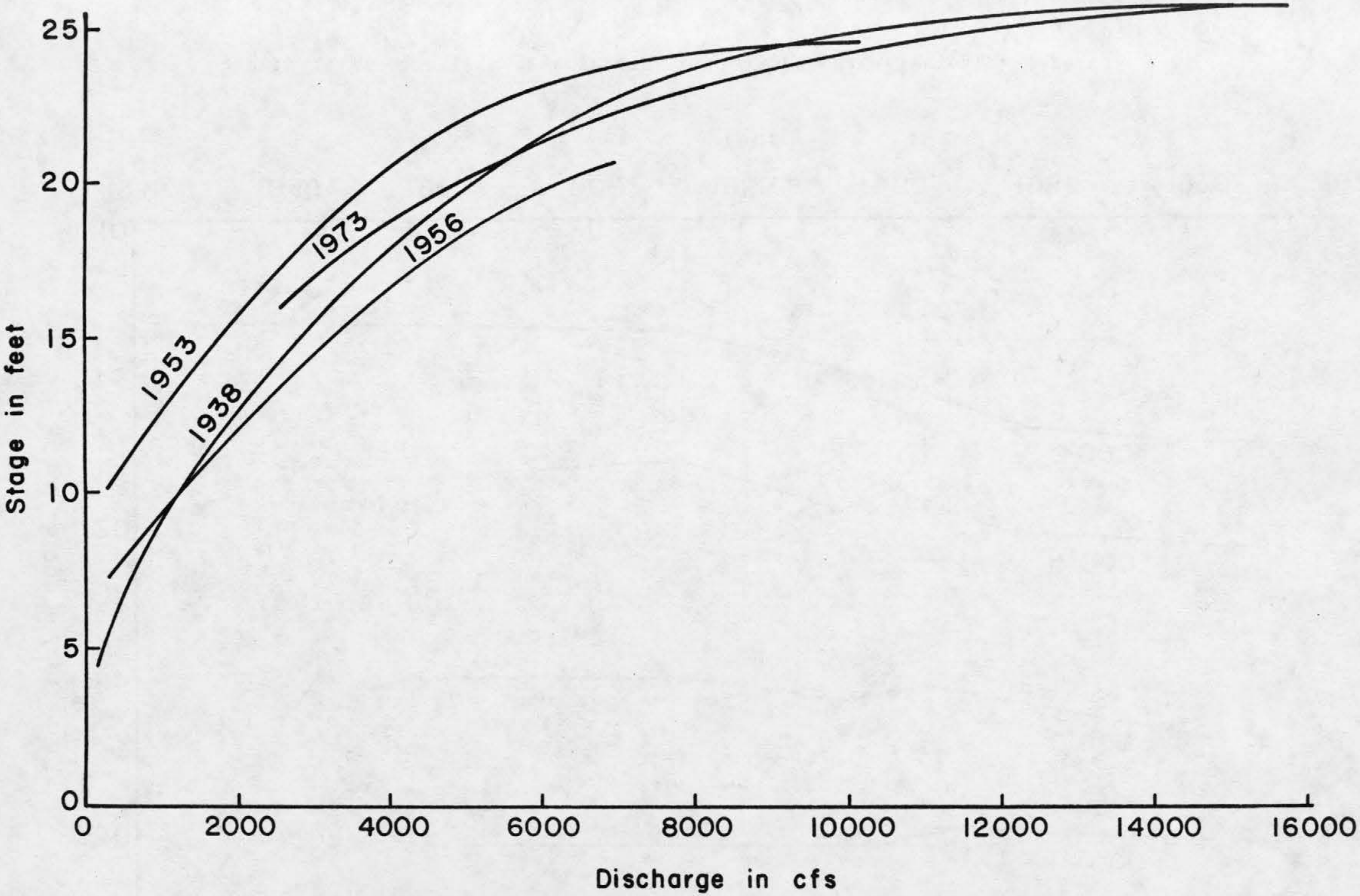


Figure 3.11. Stage discharge relationship Yalobusha River at Whaley.

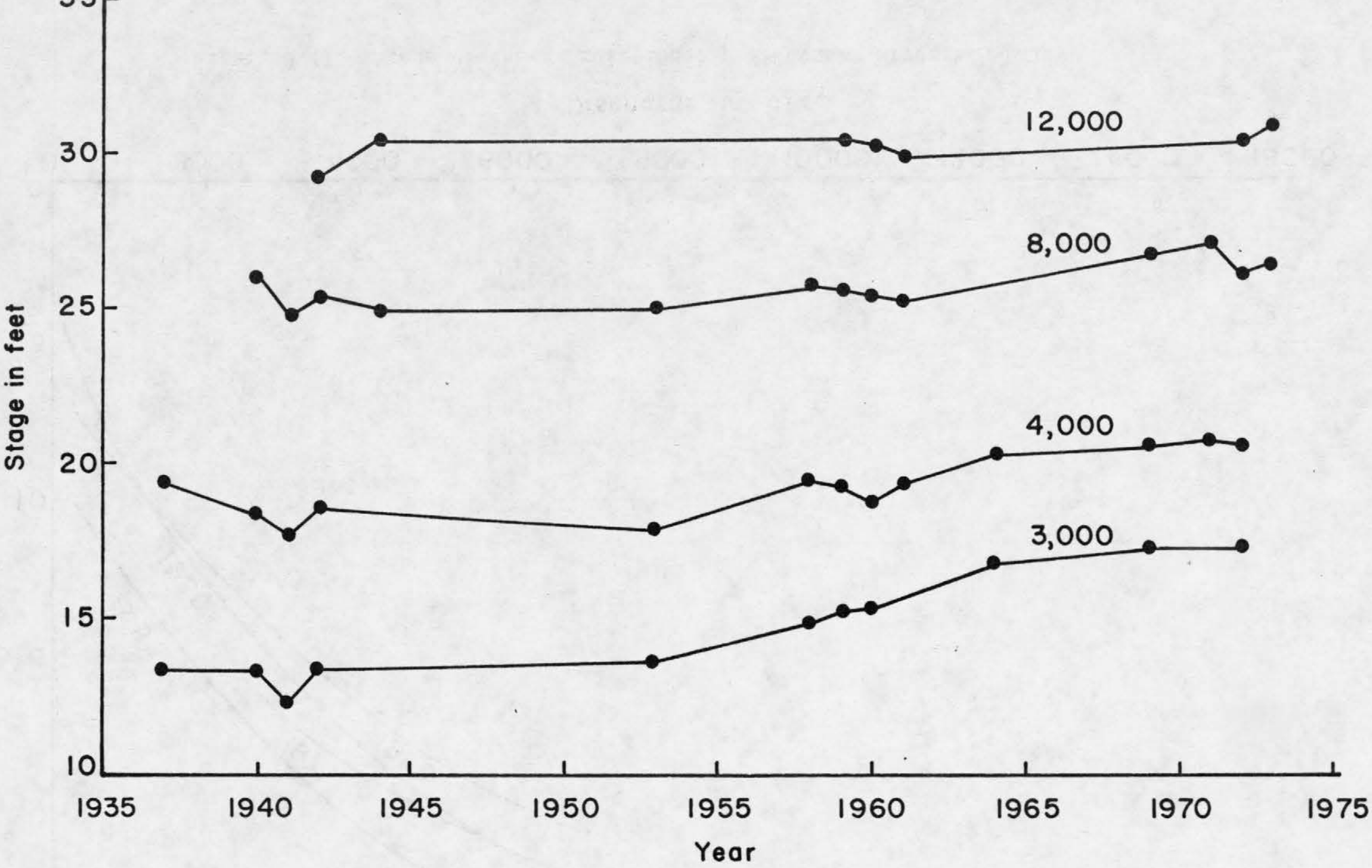


Figure 3.12. Specific gage record for Tallahatchie River at Locopolis.

Beginning about the 1950's a very gradual trend of aggradation commenced and continued through the available record to 1973. The amount of aggradation from about 1943 to the present is approximately 2 to 3 feet. The probability here is that the major portion of the sediment contributing to aggradation came from the Panola-Quitman Floodway which has had sedimentation problems from the onset of its existence. The other source of sediment is probably Tillatoba Creek as it has also been straightened and channelized. It is very doubtful that much sediment comes from the reach of the Tallahatchie above the Panola-Quitman outlet since its discharge has been greatly reduced as it only receives any sizable flow from the Coldwater River. The flow of both the Little Tallahatchie and the Yocona are now passed down the Panola-Quitman Floodway. The rating curve comparison in Figure 3.13 indicates that aggradation has occurred in this reach of river since the late 1940's.

The other gage is several miles downstream below the mouth of Cassidy Bayou near Swan Lake, Mississippi. The record here is very good extending from 1933 to 1973 as shown in Figure 3.14. A similar trend of degradation occurred from about 1937 to 1944 due primarily to the large number of cutoffs made on this reach of river. Then came a short period of aggradation from 1944 to 1947. From this point in time to 1973 the channel regime appears fairly stable with a possible return to aggradation during the last two or three years of record. From a comparison of rating curves presented in Figure 3.15 only degradation due to cutoffs has occurred. However, as illustrated by the 1973 curve some channel filling has occurred recently.

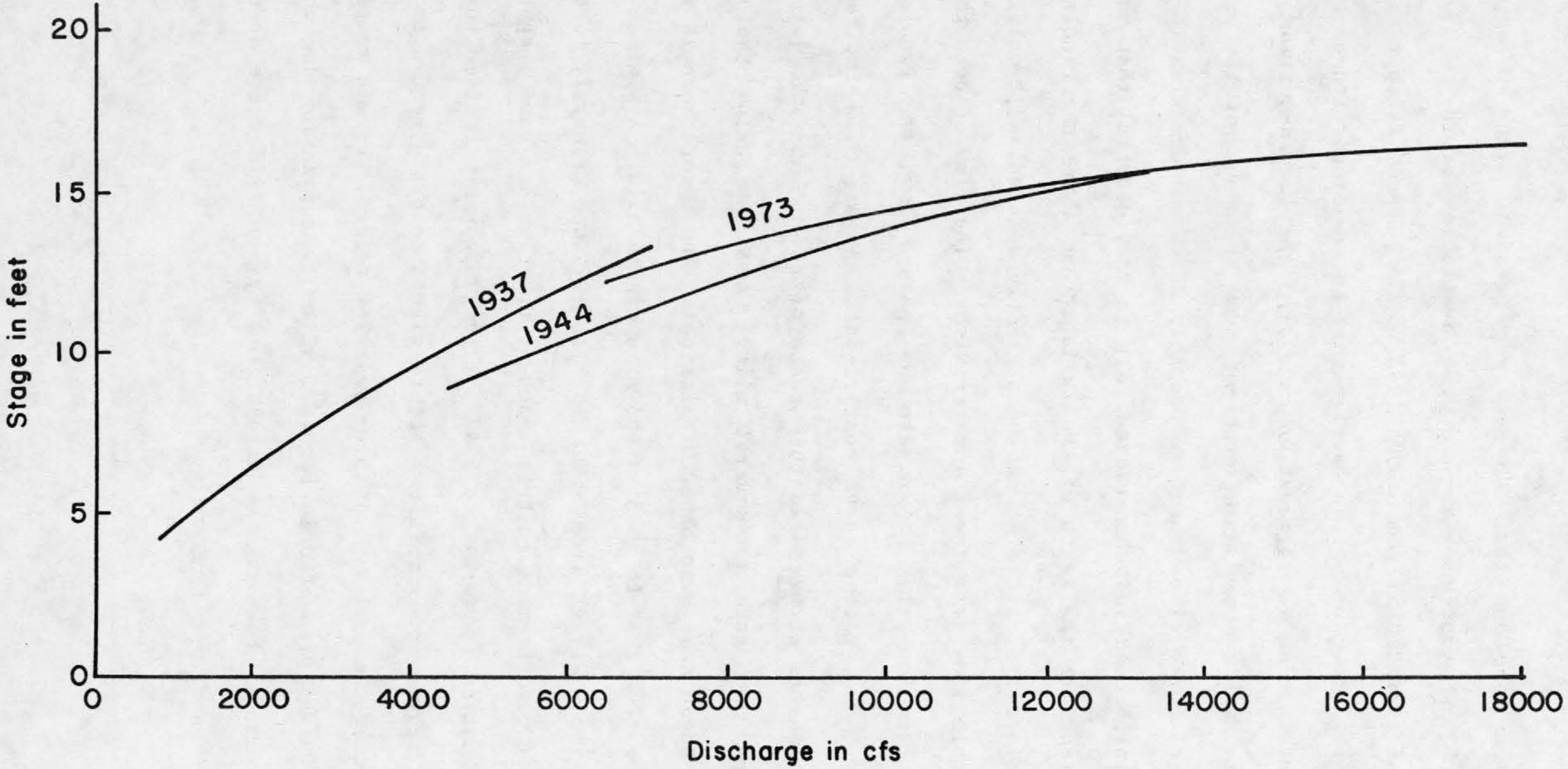


Figure 3.13. Stage discharge relationship for Tallahatchie River at Locopolis.

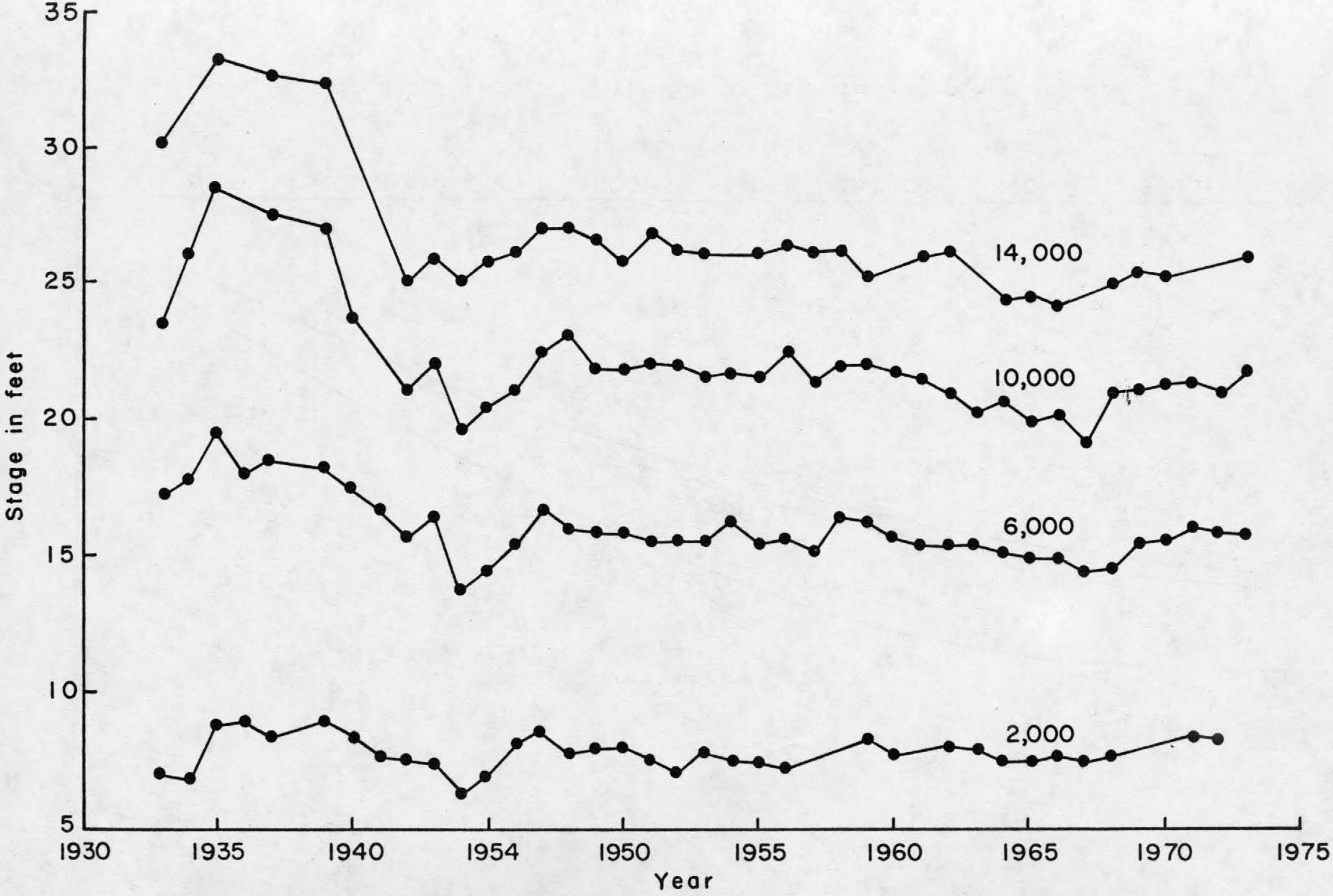


Figure 3.14. Specific gage record for Tallahatchie River at Swan Lake.

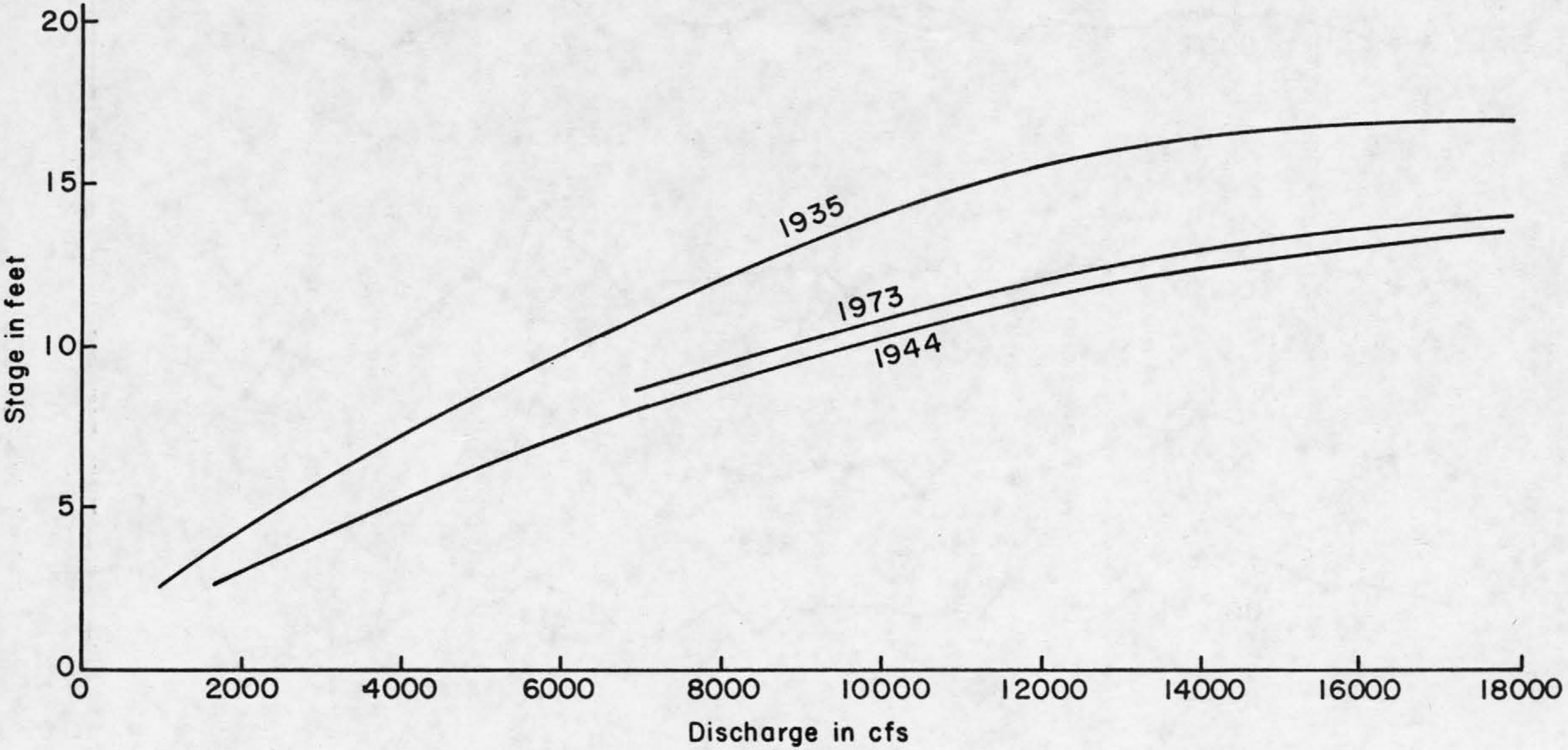


Figure 3.15. Stage discharge relationship for Tallahatchie River at Swan Lake.

3.4 Hydraulic Properties

Table 3.1 presents typical hydraulic properties for 11 locations on the mainstem and tributaries. These data were taken from the single year 1974, to show the magnitude and range of flow properties through the basin. The data were obtained from discharge measurements taken by the Corps of Engineers. As can be seen, depth of flow on most streams has a narrow range while the velocity at many stations varies over an

Table 3.1. Depths and Velocities for Yazoo River Basin*

Stream	Depth Range Low	Depth Range High	Ave. Depth	Vel. Range Low	Vel. Range High	Mean Velocity
Yazoo at Greenwood	13	32	22.41	0.42	1.19	0.724
Yazoo at Belzoni	22	43	30.81	2.42	3.23	2.827
Yazoo at Yazoo City	28	49	36.17	1.48	2.34	2.051
Yocona at Enid Dam	1	12	9.66	0.79	3.83	2.02
Coldwater at Arkabutla Dam	7	22	13.30	0.74	2.14	1.65
Coldwater near Crenshaw (Pompey Ditch)	5	27	16.25	0.81	4.56	2.93
Little Tallahatchie at Sardis Dam	13	20	17.78	1.05	2.41	1.82
Tallahatchie near Lambert	18	31	23.78	0.42	2.64	1.46
Tallahatchie near Locopolis	23	30	26.71	1.20	3.17	1.92
Tallahatchie Yazoo at Fort Pemberton Cutoff	30	50	40.60	1.62	2.50	2.08
Yalobusha at Grenada Dam	7	21	16.07	0.26	2.30	1.73

*1974 Discharge Measurement Data

order of magnitude. It can also be seen that all measured flows are sub-critical.

3.5 General Predicted River Response

A qualitative geomorphic analysis of the river system response to the planned modifications can be obtained by use of Schumm's relationships

$$Q \cong \frac{W,D,\lambda}{S} \tag{3.2}$$

$$Q_s \cong \frac{W,\lambda,S}{D,P} \tag{3.3}$$

where W is channel width, D is depth, λ is meander wave length, S is slope, P is sinuosity, Q is discharge and Q_s is sediment discharge. Schumm states that Q could be either the mean annual flood or the mean annual flow. The proposed Plan E or generally any flood control plan will have the four following direct effects:

1. Deepen the mainstem,
2. Widen the mainstem,
3. Decrease the mainstem width to depth ratio (W/D), and
4. Increase tributary slope due to base lowering.

Assuming the mean annual flow is constant and the peak flow volumes are not changed, Equation 3.2 shows that both the mainstem and tributaries will most certainly be out of balance.

For the mainstem, by increasing width and depth and keeping discharge constant the only way available to balance Equation 3.2. is to increase slope and/or decrease meander wavelength. It is not believed the meander wavelength will change without a change in discharge. With a mild slope stream the only way to increase slope is by channel straightening and cutoffs, but because of previous work little if any opportunity for that exists. Thus the river can only respond by decreasing width or depth. It has been the experience to date that the channel will reduce depth while maintaining width. The end result being a wider, shallower channel than initially.

On the tributaries the increase in slope will force an increase in width and depth. Thus the tributaries will degrade.

From another point of view, the effects on sediment transport through the system can be determined by Equation 3.3. For the mainstem the initial reduction in the width depth ratio (W/D) will cause a reduction of sediment transport in the mainstem, while on the tributaries the increased slope will increase sediment transport. The net effect will be to induce mainstem aggradation and tributary degradation which is the same conclusion reached with use of Equation 3.2.

Schumm has shown the importance of complex responses in the fluvial system. It is thus necessary to continue this analysis one step further. As the mainstem aggrades, most probably by depth reduction, Equation 3.3 shows the sediment transport will increase. This will reduce the rate of mainstem aggradation. More importantly as the mainstem aggrades the tributaries' base level will increase reducing their slope. This will induce the tributaries to reduce their width and depth and cause a reduction in their sediment transport. Harvey, Schumm and Watson (1983) have noted exactly this response on several basin tributaries. At some point the mainstem and tributary sediment transport will be balanced.

The balanced conditions the system reaches need not be the same as the initial conditions. Since it is necessary for the guarantee of success of the Upper Yazoo Project to know when and what balanced conditions will be achieved, the more detailed hydraulic modeling of the basin was carried out in this study.

IV. SYSTEM DESIGN

4.1 Overall System Design

As mentioned prevously, the Yazoo River Basin is composed of a main stem and numerous tributaries (refer to Figure 1.1). Analysis of the Basin simulates the river system as a whole rather than only selected areas.

In the Yazoo River Basin, tributaries to the main stem were divided into controlled, uncontrolled, and point source type streams. Controlled tributaries, the Yalobusha River, for example, are regulated by large storage reservoirs. The controlled tributaries significantly affect the response of the Basin. Uncontrolled tributaries are generally smaller than controlled ones and do not have large storage reservoirs; however, they are important in analysis. An example of this type of tributary is Tillatoba Creek. The third type of tributary is referred to as a point source and is generally smaller than the other two types. Point source tributaries are considered as a single point input. The potential impact of sediment inflow from point source tributaries to the main stem is small. However, in order to conserve flow continuity, these tributaries were included in the analysis of the Yazoo system as point source inputs. An example of this type of tributary is Peters Creek.

Classification of tributaries is based upon examining system response which is described in the next section. Controlled, uncontrolled, and point source tributaries are shown schematically in Figure 4.1. This figure also shows the relation of the tributaries to the main stem system. In addition, the nonpoint source contribution from additional uncontrolled areas was considered in order to conserve flow continuity in the total system.

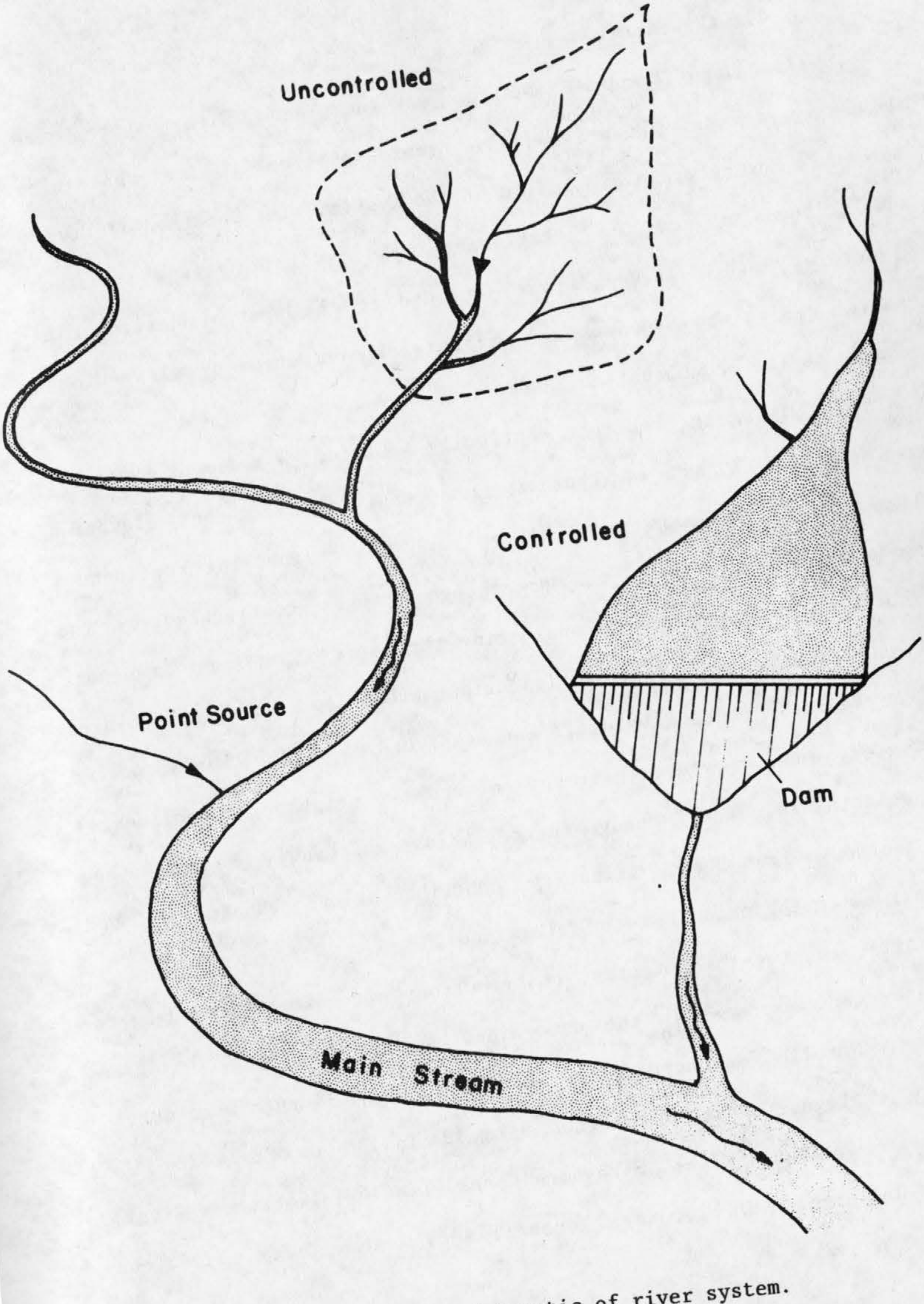


Figure 4.1. Schematic of river system.

4.2 Spatial Design

4.2.1 General

Spatial and temporal designs of the Yazoo River system are necessary to provide a realistic representation of the space-time structure for accurate simulation of the system. The location of rivers and tributaries and the location of all pertinent gaging stations, structures, and confluences are included in the spatial design. The spatial design was based on the potential contribution of all sediment sources to the bed elevation changes.

By applying the sediment continuity equation, a sediment transport equation, and a set of typical flow conditions, the bed elevation changes along the main stem between each two neighboring confluences were determined. Also, the percentage changes contributed by the tributaries were determined considering the ratio of sediment transport rates between the main stem and its tributaries. By summing all changes in the sediment storage volume (product of bed elevation change, wetted perimeter, and the space increment between two neighboring confluencs) and relating this total change to the individual change, the percentage of sediment from each tributary contributing to changes in bed elevations in the main stem was determined.

After ranking the potential contributions of sediment according to the computed percentages, the determination of important tributaries (either controlled or uncontrolled) and point source inputs were delineated. Fifteen of the tributaries were identified important for the analysis: Arkabutla Creek, Strayhorn Creek, Little Tallahatchie River, McIvor Drainage, P-Q Floodway, Yocona River, Peters Creek, Tillatoba

Creek, Yalobusha River, Potococowa Creek, Teoc Creek, Ascalmore Creek, Big Sand Creek, Abiaca Creek, and Pelucia Creek. The Old Coldwater River, Bobo Bayou, Burell Bayou, and all the tributaries below Belzoni such as Big Sunflower River, Little Sunflower River, Deer Creek, and Steele Bayou were excluded from analysis. Since the primary objective of the Phase II study was to evaluate the interaction of the main stem and seven major tributaries. These tributaries are the Little Tallahatchie River, P-Q Floodway, Yocona River, Tillitoba Creek, Big Sand Creek, Pelucia Creek and Yalobusha River, the spatial representation of Phase II did not extend below Belzoni. The ten other tributaries cited were considered as point sources.

4.2.2 Alternative Runs

Spatial representation of Alternative Run No. 1, existing conditions is shown in Figure 4.2. The proposed Plan E is the basic spatial design for other alternative runs. Run No. 2 is Plan E as proposed by the U.S. Army Corps of Engineers and represented in Figure 4.3. Alternative study Runs No. 3 and 4, have the same spatial design as Run No. 2. Runs No. 5 and 6 utilize a step channel. The step channel has a narrower bottom than Plan E but has a step 15 feet above the channel thalweg. Figure 4.4 shows the spatial representation of the step channel.

For simplicity, Plan E and the step channel have channel bottom elevations as specified in the design, even when the original bed elevation is lower than the design bed. A detailed index map of the cross sections and the associated bed profiles utilized in the model is shown in Appendix C.

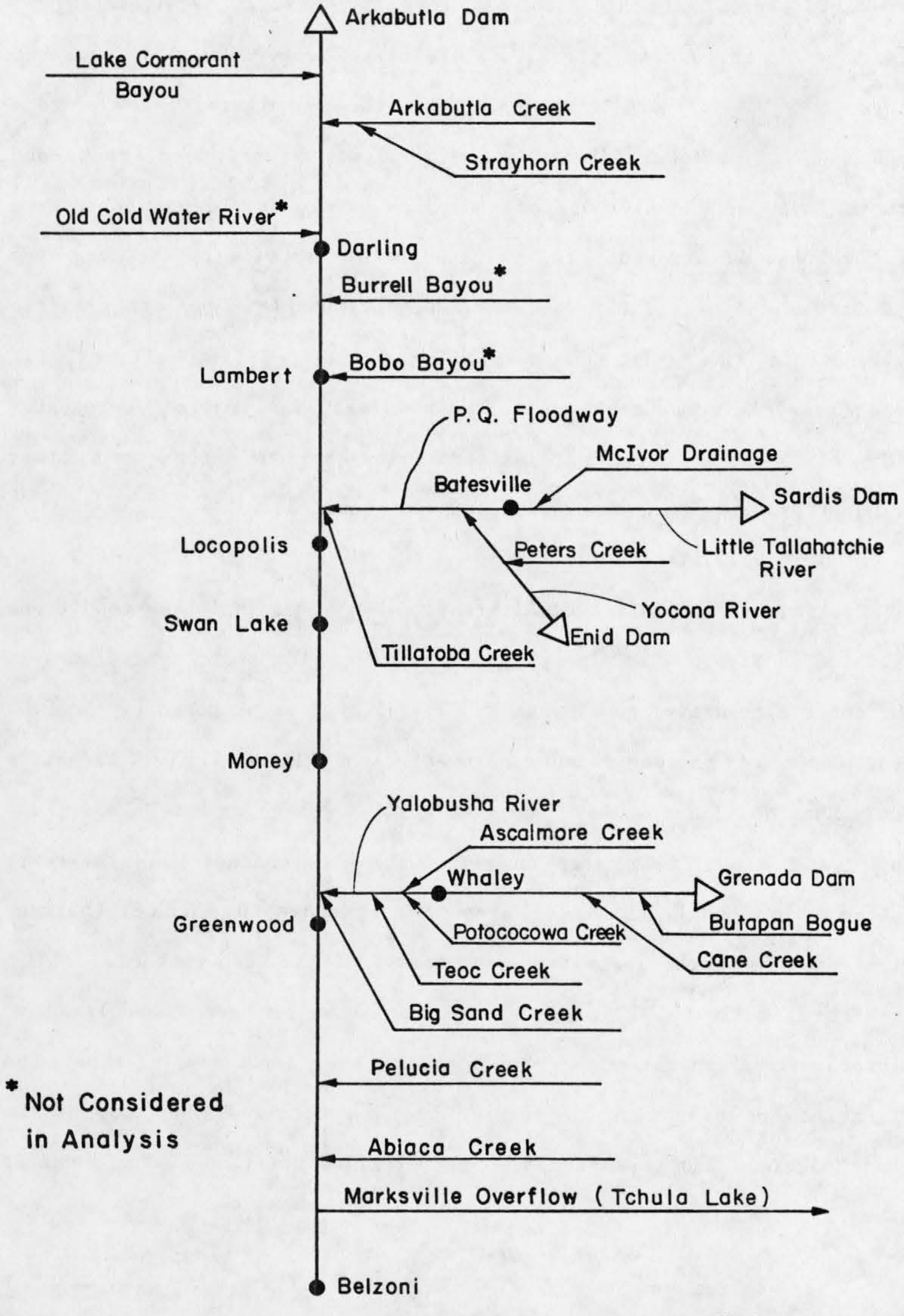


Figure 4.2. Spatial representation of the existing conditions (Run No. 1).

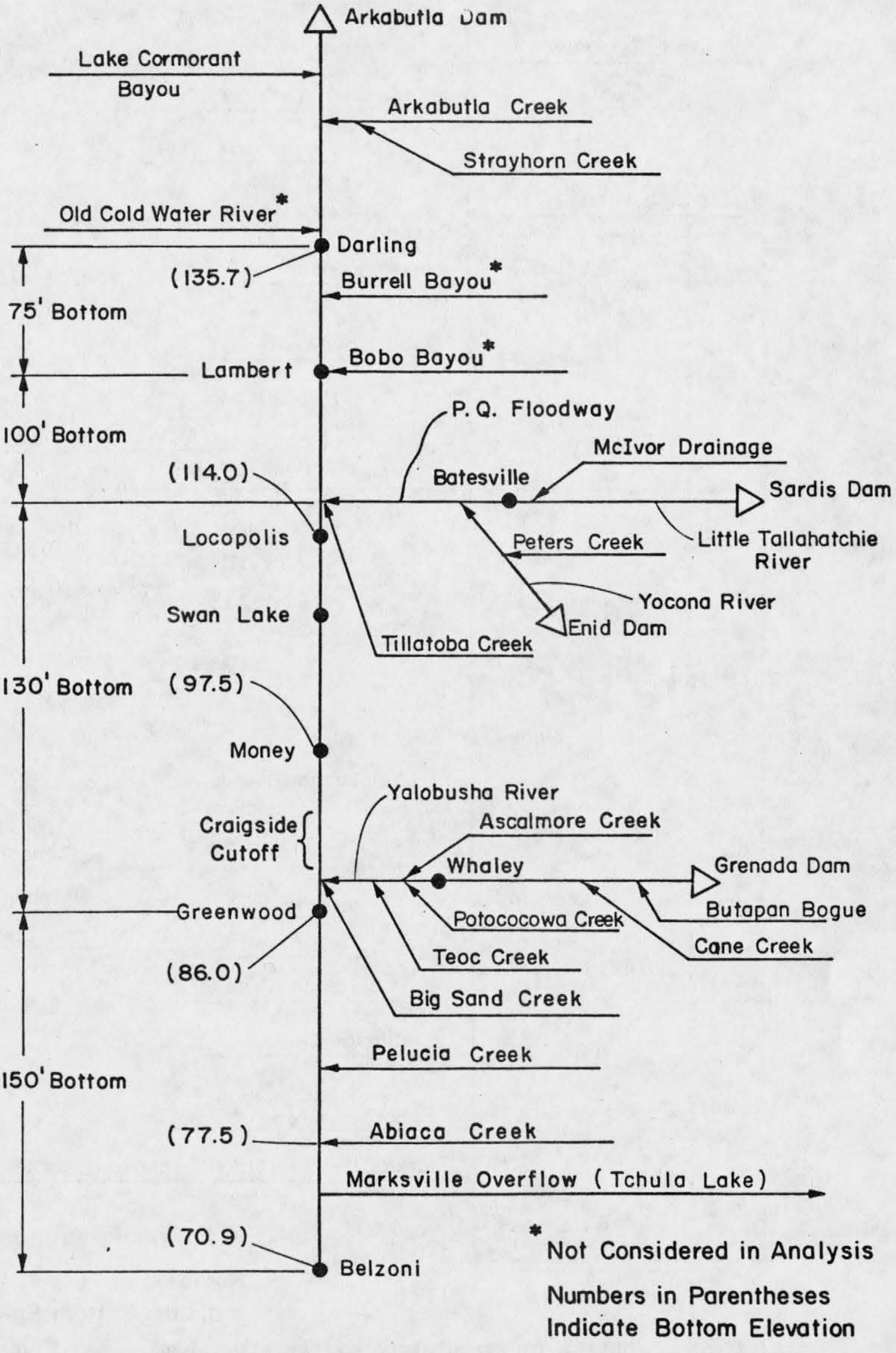


Figure 4.3. Spatial representation of Plan E conditions (Runs No. 2, 3 and 4).

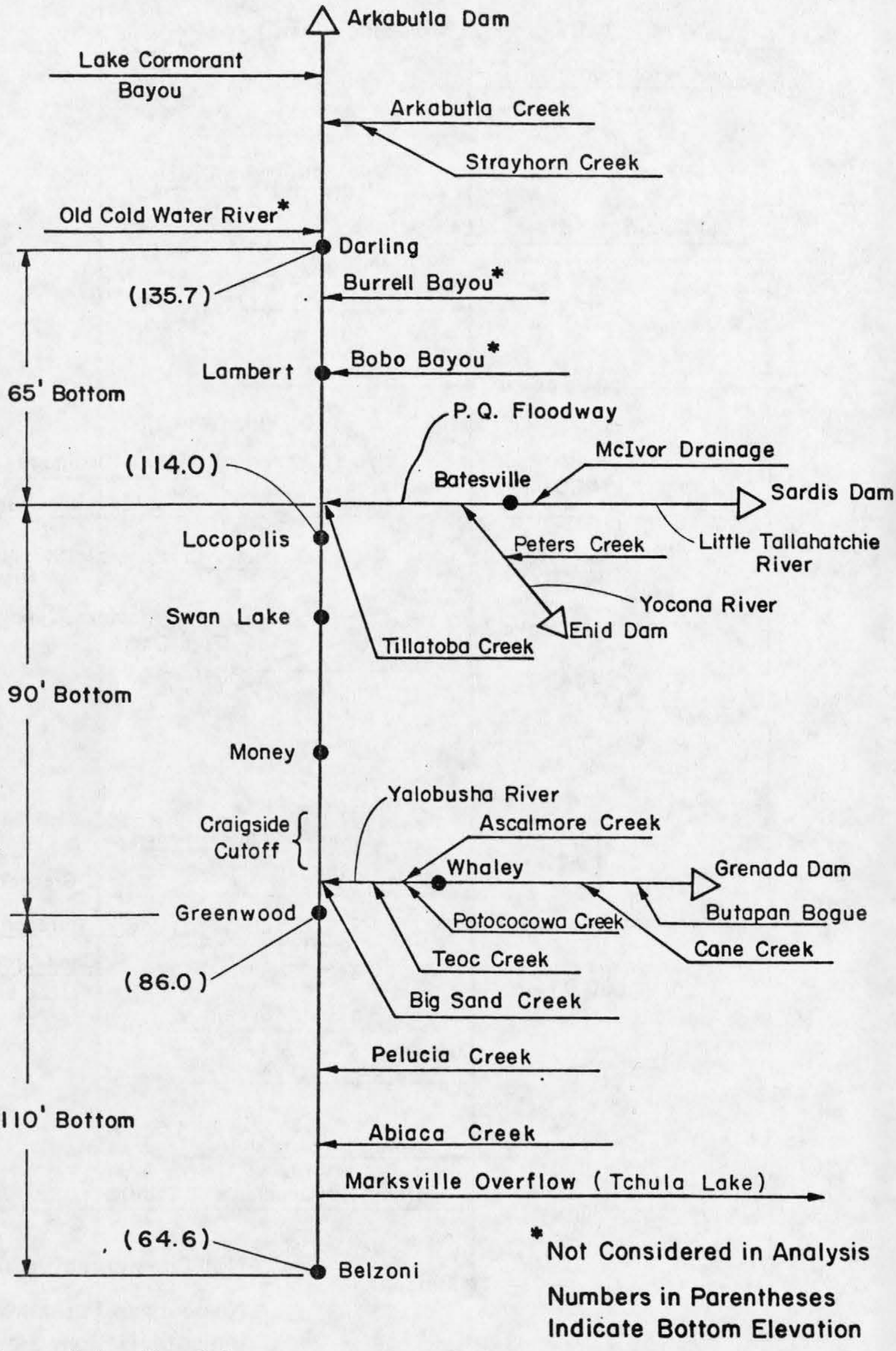


Figure 4.4. Spatial representation of the step channel for Plan E (Runs No. 5 and 6).

4.3 Temporal Flow Design

4.3.1 General

An accurate set of discharge records was necessary for modeling the Yazoo River Basin. These records were developed for key river locations for a consistent time span. Before the development was initiated, a thorough review of existing records followed by the delineation of realistic spatial and temporal frameworks were completed. Data review indicated what type of discharge information was available at specific locations. This information included daily discharge, instantaneous stage readings, peak discharge and intermittent measurements. Once data availability and adequacy were ascertained, the design was formulated by the selection of discharge stations. These stations are determined, in part, by the discharge of water and sediment past the site, and the overall stability of the channel reach surrounding the site. Data availability was then used to determine the method of record development for each site. At some stations, an adequate set of discharge or stage records existed, however, at other sites no data were available. In that case, a record was synthesized for that site.

The time span of record was important in modeling. The temporal design was again determined by the availability and duration of records at each site. Some had continuous records covering a long period of time while others had only intermittent records for a few years. Records were compared until the longest common time span was found allowing selection of the temporal design.

Appendix A presents the temporal design. The Phase II temporal design of 48 sites includes 24 sites with existing stage or discharge records, 9 ungaged sites, and 15 non-point sources. The period of record chosen was from January 1, 1964 to December 31, 1977. This 14-year period was used because of data availability for discharge or stage records at the 24 gaged sites. Flows at each site were constrained to average daily discharges. However, close proximity of the sites made water travel times between adjacent sites one day or less under most flow conditions. A total of 5,113 average daily flow values for the 14-year period formed the basic data.

Average weekly flow values (731) were developed from the 14-year data set. These 731 values were in turn folded to generate an extended record of an additional 36 years for all sites, a total of 2,609 values for 50 years. The sequence used for developing sets of 14 years of daily and 50 years of weekly discharge values is shown in Figure 4.5. At each point in the sequence checks to avoid unrealistic values or other errors were made.

4.3.2 Data Sources

The basic data requirement was for a set of daily discharge records at all sites included in the spatial design. For seven sites, Coldwater River near Lambert, Tallahatchie River near Swan Lake, Yazoo River at Greenwood and outflows for the four major reservoirs of Arkabutla, Sardis, Enid, and Grenada, daily discharges were obtained from the U.S. Geological Survey on magnetic tapes. These discharges were computed from stage readings supplied by the U.S. Army Corps of Engineers, Vicksburg District and are published by both the Corps and the USGS.

Stage records for the other 17 gaged stations were supplied by the Corps of Engineers, Vicksburg District on magnetic tape and printed report. Stage readings were at 0800 hours (8:00 AM) for each day.

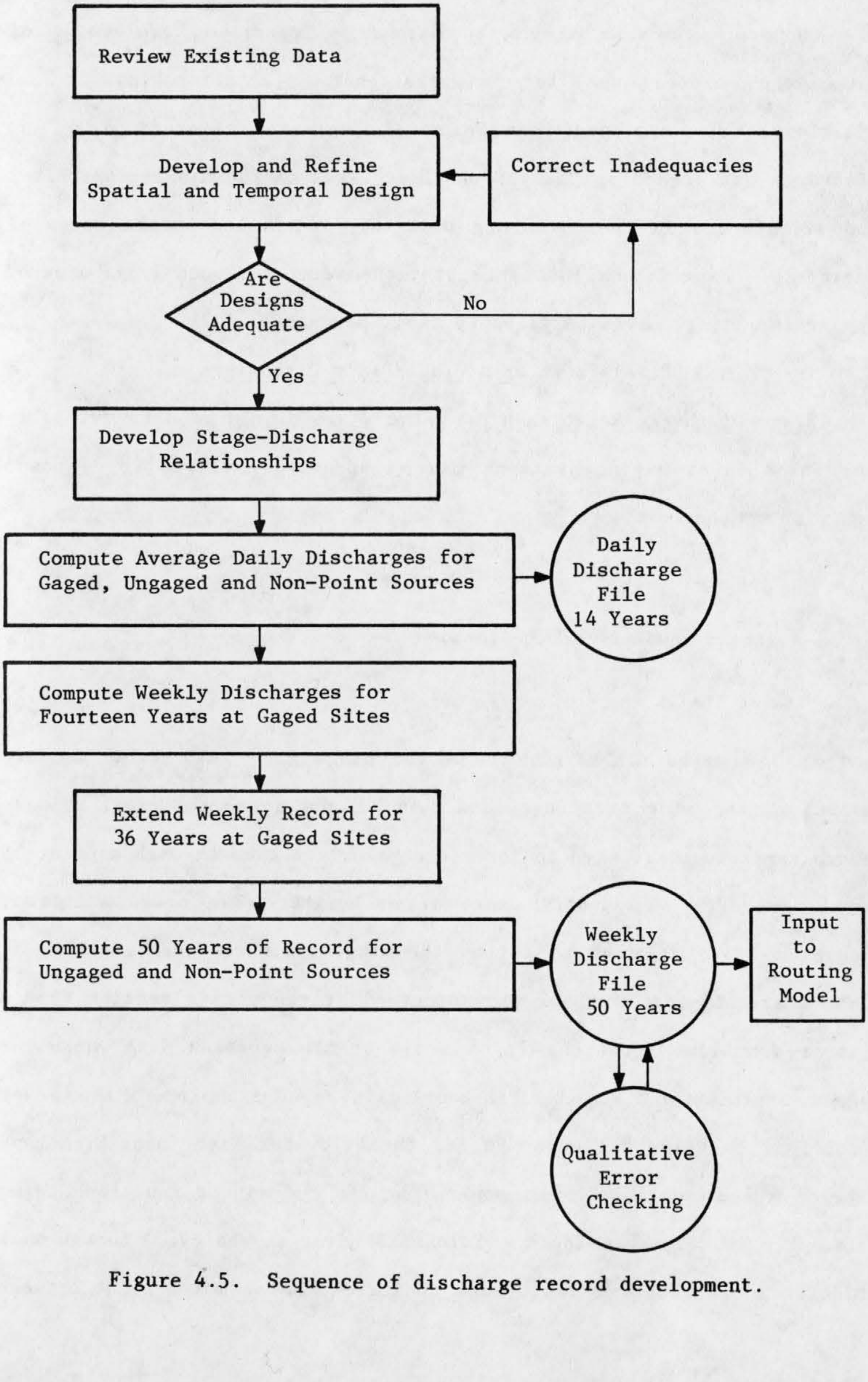


Figure 4.5. Sequence of discharge record development.

Conversion of the stages to discharges required development of mathematic expressions for stage-discharge relationships. Some relations were developed from Corps of Engineers observed stage and discharge data found in "Stages and Discharges of the Mississippi River and Tributaries in the Vicksburg District," published by the Corps of Engineers. Expressions for other stations were developed from Corps of Engineers rating curves supplied by their personnel.

4.3.3 Development of Average Daily Discharges

Stage-Discharge Relationships. The stage-discharge data available for Yazoo River gaging stations can be adequately related by a power equation of the form:

$$Q = a(S + c)^{b} \tag{4.1}$$

or by a linear equation of the form:

$$Q = mS + k \tag{4.2}$$

where Q is the discharge, S is the stage, c is a value used to transform the stage readings, and a, b, k and m are empirical values. The parameter c is used to force the power function through a point of zero discharge at relative zero stage height. The power function, Equation 4.1, was used to define the stage-discharge relationships at most stations. If overbank flow occurred at the gaging section then a linear function, Equation 4.2, was fit to the overbank data while the power function fit to the in-bank data. An example of the power function is shown in Figure 4.6 for the Coldwater River near Crenshaw. Figure 4.7 shows a combined power function and linear function stage-discharge relationship for the Yalobusha River at Whaley. Although bank full stage is about 21 feet, data indicated that a match point between

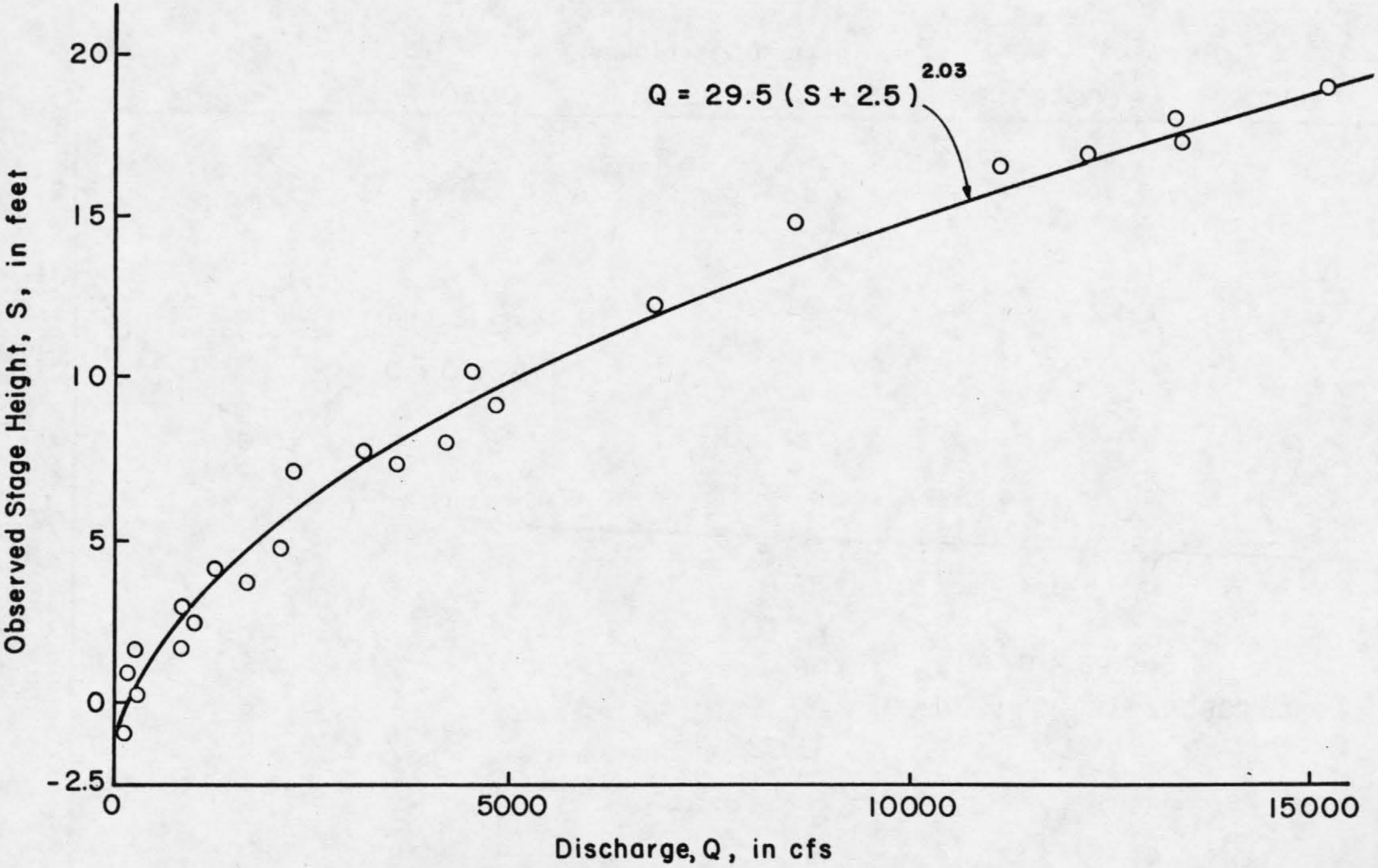


Figure 4.6. Power function fit for the Coldwater River near Crenshaw stage-discharge relationship.

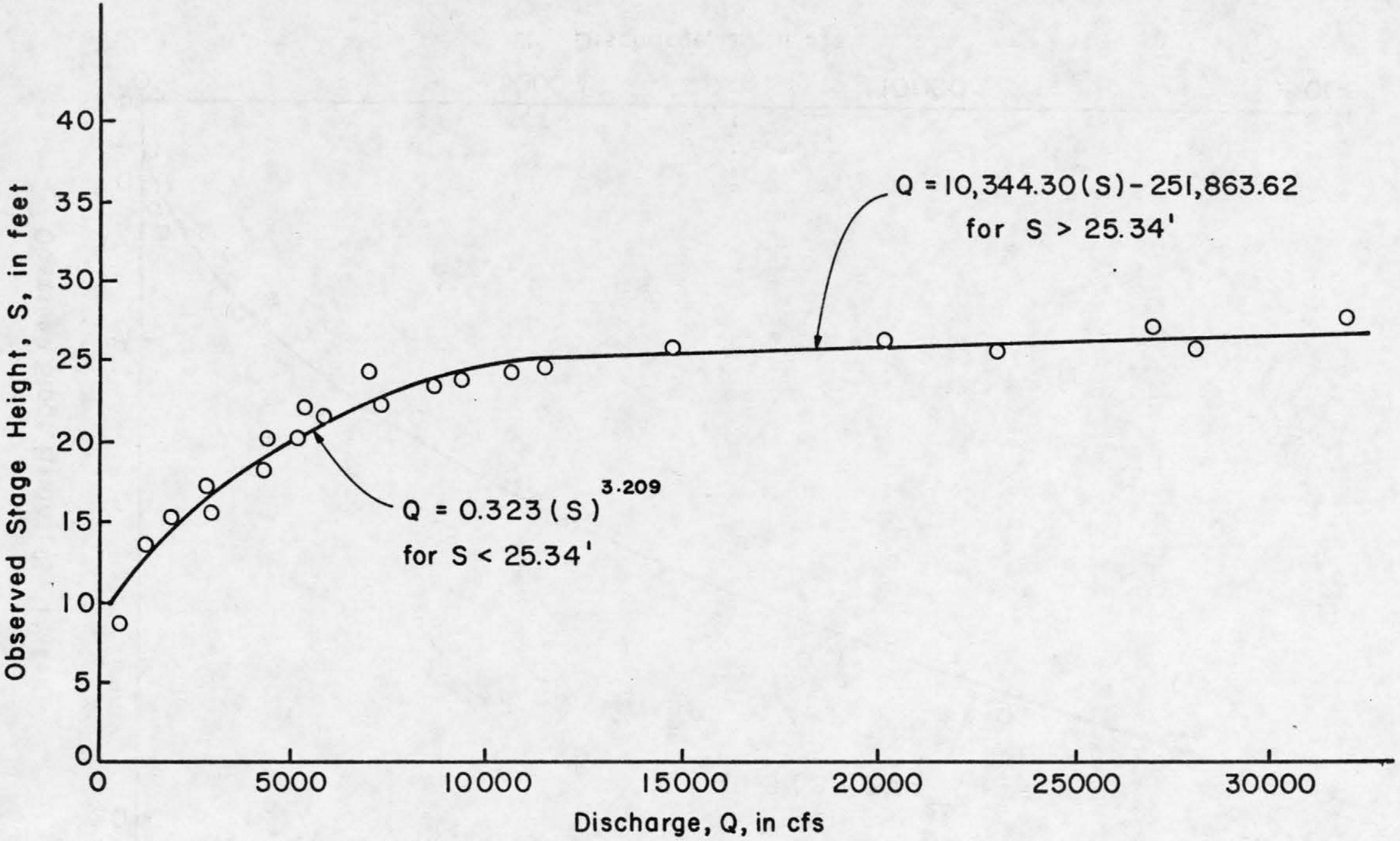


Figure 4.7. Power and linear function fits for Yalobusha River at Whaley stage-discharge relationship.

the two functions was nearer to 25 feet. Therefore, stages above 25 feet were used in computing the linear function and stages less than 25 feet were used for the power function. The two functions coincide at a stage of 25.34 feet. Above this stage the linear function was used, below this stage the power function was used. A complete set of stage-discharge relationship parameters is presented in Table 4.1.

Six stations required particular attention when dischages were computed. The first two stations where the computed stage-discharge relationship needed to be altered were on the Coldwater River near Prichard and near Marks. It was noted the original relationship for these stations produced discharges that yielded a relatively low average discharge over the 14-year base period. These average discharges were in fact less than the average discharge of the next upstream gaged site. It was also noted that the gain in average discharge between two sites was about one cfs per square mile. This observation was used to adjust the stage-discharge relationships at both stations to coincide with changes in average discharge observed elsewhere between the sites. Adjustment for the Marks relationship was facilitated by obtaining a Corps of Engineers rating curve for this site. Although different from the relationship computed from available data, it did provide the desired results. For Prichard, the parameter b in Equation 4.1 was increased slightly to produce the desired results. This increase had the effect of generating a higher estimated discharge at the same stage as compared to the original relationship. The adopted relationships for these two stations provide discharges consistent with other river sites.

A problem in converting stages to discharges was that of missing stage readings. Generally, only a few readings were missing from any particular

Table 4.1. Parameters for Yazoo River Basin Stage-Discharge Relationships $Q = a(S + c)^b$
$Q = MS + k$

Name	Parameter a	b	c	k	m	Breakpoint Stage*
Yazoo River at Belzoni	154.80	1.457	-	-	-	
Yazoo River overflow at Marksville[1]	399.972	1	-25	-	-	
Abiaca Creek near Pine Bluff	SEE APPENDIX F					
Pelucia Creek near Valley Hill	SEE APPENDIX F					
Yazoo River at Greenwood	discharge obtained for USGS					
Tallahatchie River at Money	57.808	1.704	-3	-	-	
Big Sand Creek[2] at Valley Hill	30.478	2.646	-1.5	-19571.43	1928.575	5.64
Ascalmore Creek[2] at Paynes	8.492	2.615	-1	-7339.465	1161.564	7.17
Yalobusha River at Whaley	0.492	3.209	-	-251863.62	10344.30	25.34
Yalobusha River at Grenada	3.392	2.921	-	-	-	
Yalobusha River at Grenada Dam	discharge already determined by USGS					
Tallahatchie River near Swan Lake	discharge already determined by USGS					
Tallahatchie River at Locopolis	65.578	1.717	-10	-145805.21	4953.34	32.14
Yocona River at Enid Dam	discharge already determined by USGS					
Little Tallahatchie River near Batesville	122.211	1.654	-	-91680.72	5880.49	18.09
Little Tallahatchie River at Sardis Dam	discharge already determined by USGS					
Tallahatchie River near Lambert	discharge already determined by USGS					
Coldwater River at Marks	6.301	2.280	-10	-	-	
Coldwater River near Darling	5.940	2.347	-3	-	-	
Coldwater River near Sledge	27.573	1.860	2	-	-	
Coldwater River near Crenshaw	25.549	2.030	2.5	-	-	
Coldwater River near Sarah	74.880	1.594	1.2	-32552.65	2181.99	19.07
Arkabutla Canal[2] near Arkabutla	2.944	2.566	-	43900	2700	17.90
Coldwater River near Prichard	24.096	1.970	-7	-	-	
Coldwater River at Arkabutla Dam	discharge already determined by USGS					

Key -
*Stage at which dual stage-discharge relationships match.

[1] Linear relationship only of $Q = 399.972(S-25)$ for $S \geq 25$.

[2] Note comments in Section 4.4.

site. In such cases, linear interpolation was used to estimate the discharges between two computed values as

$$\hat{Q}_i = Q_1 + [\frac{Q_n - Q_1}{t_n - t_1}] [t_i - t_1] \tag{4.3}$$

where $\hat{Q}_i$ is the interpolated value, Q_1 is the last computed 8:00 AM discharge before the missing record, Q_n is the next computed discharge after the missing record, and t_i, t_1, and t_n are the corresponding times in days from beginning of record on a slightly fluctuating stream. One problem site, Arkabutla Canal (Creek) southwest of Arkabutla did not meet these criteria. Discharge in Arkabutla Canal can fluctuate highly during a single day. This fluctuation, combined with missing records of four days or more duration, produced some odd interpolated values. Of particular concern were four consecutive days in March of 1965 that had extremely high 8:00 AM stage readings for the last and next values. Linear interpolation produced a set of high discharges that were unmatched in any previous or subsequent set of records. These high values were discovered upon inspection of the record and a different approach for interpreting the missing values was used. For this site, stages were related to the stages at Coldwater River near Sarah. Although lower, the resulting discharges were still higher than what is considered realistic. Manual adjustment of the discharges was finally used to correct these abnormally large values.

Computation of Daily Flow Values. Because only 8:00 AM discharges were available, an interpolation scheme was needed to define the hydrograph during the 12 midnight to 12 midnight period of the day in question. The scheme utilized here interpolated the discharge for the previous and post 12 midnight times relative to the 8:00 AM discharge and then averaged these two values. Special attention was given to end points, i.e., first and last days. Computation of daily discharge for all days was of the form:

$$\bar{Q}_i = \frac{Q_{Pi} + Q_{Ni}}{2} \tag{4.4}$$

where $\bar{Q}_i$ is the average daily flow for day i, Q_{Pi} is the previous 12 midnight discharge and Q_{Ni} is the subsequent or next 12 midnight discharge. For days 2 through 5113, Q_p and Q_N were computed as:

$$Q_{Pi} = Q_i - \frac{(Q_i - Q_{i-1})}{3} \tag{4.5}$$

and

$$Q_{Ni} = Q_i + \frac{2}{3}(Q_{i+1} - Q_i) \tag{4.6}$$

where Q_{i-1}, Q_i, and Q_{i+1} are 8:00 AM discharges before, during and after day i, respectively. First and last day values required extrapolation formulations. For first day values these were:

$$Q_{P1} = Q_1 - \frac{(Q_2 - Q_1)}{3} \tag{4.7}$$

and

$$Q_{N1} = Q_1 + \frac{2}{3}(Q_2 - Q_1) \tag{4.8}$$

Similarly, for last day values:

$$Q_{P5114} = Q_{5114} - \frac{(Q_{5114} - Q_{5113})}{3} \tag{4.9}$$

and

$$Q_{N5114} = Q_{5114} + \frac{2}{3}(Q_{5114} - Q_{5113}) \tag{4.10}$$

Development of daily discharge records for gaged sites allowed creation of weekly flow records for gaged sites and computation of daily and weekly flow values for ungaged and non-point sources.

4.3.4 Development and Generation of Weekly Discharges

Weekly discharges are found by computing the average daily discharge for seven day periods. For example, days 1 through 7 would have a single average daily discharge and days 8 through 14 another. A seven day period was chosen since it represented average time necessary for water to travel from Arkabutla Dam to Vicksburg. Seven days also produced exactly 731 time steps from the original 14 years of daily discharges. Because the sedimentation model for the main stem Yazoo River is operated as a predictive or management aid, realistic long term records beyond the original 731 values were required. This necessitated extension of the 14-year discharge base to 50 years, an addition of 36 years

4.3.5 Generation of Fifty-Year Hydrograph

In Phase I the 11 years of measured discharge data were extended 39 years by using time series techniques. While the generated data proved adequate, it has been felt by both the authors and the Corps that the data were too regular when compared to the measured period. During the project three additional years of data have become available, and it has become feasible to replace the generated data by "folding over" or repeating the measured record. During Phase I folding was considered inappropriate, since with 11 years most years would appear five times. But with 14 years of record, even after extracting one year, 1973, each year only appears three or four times. Also since Phase I, a folded record was used successfully in the sedimentation study of Abiaca Creek and Pelucia Creek (Appendix F), thus it is estimated that the folded hydrograph will be as good if not better than the generated data.

The 1973 data only appear twice in the 50-year hydrograph, since it was a flood year with an approximate return period of 50 years. Table 4.2 lists the sequence of historical years in the 50-year hydrograph.

4.3.6 Ungaged Sources

An ungaged source is an important watershed of definable area that lacks continuous stage or discharge data. Ungaged sources are listed in Table 4.3.

These nine sources were computed using flow records from nearby stations. Two types of relationships were used. If nearby, similar gaged sites existed, the discharge value for the ungaged site was computed as:

$$Q_{UG} = \frac{A_{UG}}{n} \left(\sum_{J=1}^{n} \left(\frac{Q_G^J}{A_G^J} \right) \right) \qquad (4.11)$$

where Q_{UG} is discharge at the ungaged site, A_{UG} is area of the ungaged watershed contributing to the site, Q_G^J is discharge at gaged site J, A_G^J is watershed area contributing to gaged site J, and N is the number of sites used. Four of the nine ungaged sources were computed using Equation 4.11. Teoc, Potococowa and Cane Creek discharges were based on Big Sand and Ascalmore Creeks while Strayhorn Creek flows are developed from Arkabutla Creek only.

One drawback to this approach is that those ungaged sources with records developed from the same nearby stations will have identical hydrograph timing, e.g., the peak and low flows will occur on the same day. This may not be unrealistic, however, as such groups of watersheds are close to each other and have similar characteristics. The other type of relationship used to estimate ungaged sources was flow

Table 4.2. Sequence of Years in Fifty-Year Hydrograph

Model Year	Historical Year	Model Year	Historical Year
1	1964	24	1976
2	1965	27	1977
3	1966	28	1964
4	1967	29	1965
5	1968	30	1966
6	1969	31	1967
7	1970	32	1968
8	1971	33	1969
9	1972	34	1970
10	1973	35	1971
11	1974	36	1972
12	1975	37	1974
13	1976	38	1975
14	1977	39	1976
15	1964	40	1977
16	1965	41	1964
17	1966	42	1965
18	1967	43	1966
19	1968	44	1967
20	1969	45	1968
21	1970	46	1969
22	1971	47	1970
23	1972	48	1971
24	1974	49	1972
25	1975	50	1973

Table 4.3. Ungaged Sources for the Yazoo River Basin Study Phase II

Stream	Computed by
Teoc Creek	Adjacent Stream
Potococowa Creek	Adjacent Stream
Cane Creek	Adjacent Stream
Batupan Bogue	Continuity
Tillatoba Creek	Continuity
Peters Creek	Continuity
McIvor Drainage	Continuity
Strayhorn Creek	Adjacent Stream
Lake Cormorant Bayou	Continuity

continuity between a gaged site above the ungaged source inflow and a site below the inflow. Again, discharge per unit area was employed as:

$$Q_{UG} = A_{UG} \left[\frac{Q_{Above} - Q_{Below}}{A_{Below} - A_{Above}}\right] \tag{4.12}$$

where Q_{Above} is the daily or weekly discharge at the site upstream of the ungaged inflow, Q_{Below} is discharge downstream of site and A_{Below} and A_{Above} are the drainage areas contributing to the two sites. Five sources were estimated using this approach. Batupan Bogue was estimated by Yalobusha River at Grenada Town (Highway 51), downstream, and Yalobusha River at Grenada Dam, upstream. Tillatoba, Peters and McIvor Drainage utilized the Panola-Quitman Floodway near Batesville and Little Tallahatchie River at Sardis Dam while Lake Cormorant Bayou used Coldwater River near Prichard and Coldwater River at Arkabutla Dam. If there was a loss between gaged stations at any particular time, a default value was used for the ungaged source discharge. Addition of these 9 ungaged sources to the 24 gages sites produced a set of point source or specific site inputs or outputs. Non-point or undefined sources completed the flow records.

4.3.7 Non-Point Sources

Non-point source (NPS) inflows or outflows are comprised of several hydrologic units. Notable non-point sources are groundwater flow, overbank flow, low gradient backwater swamps, channels or bayous, small tributaries, or overland flow. To account for each of these sources would be an enormous task not worthwhile for this study. Therefore, each of these small or diffuse sources were lumped into non-point sources. Fifteen non-point sources were determined for this study, one for each reach or subreach as noted in the temporal design. Non-point source flows were computed by flow continuity or:

$$Q_{NPS} = Q_{OUT} - \sum_{i=1}^{n} Q_{IN_i} \qquad (4.13)$$

where Q_{NPS} is the weekly or daily discharge for the non-point source, Q_{OUT} is the outflow station of the reach being processed, Q_{IN_i} are the individual inflows to the reach and n is the number of inflows. For example, the reach from Belzoni to Greenwood has an outflow site at Yazoo River at Belzoni and inflows from Abaica and Pelucia Creeks and Yazoo River at Greenwood, all other sources and sinks are considered as part of non-point source flows. Because non-point sources can be either inflows or outflows there was no constraint upon discharge being positive or negative.

4.4 Sediment

4.4.1 General

In the preceding studies of the Yazoo River Basin, empirical relations of the form:

$$Q_s = aV^bD_e^cW_e \qquad (4.14)$$

where Q_s is the sediment transport rate in cfs, V is the flow velocity, D_e and W_e are the effective depth and effective width, respectively, and a, b and c are coefficients used to compute the bed material transport rate at each cross section in the main stem and major tributaries. These equations were derived from the Yazoo River sediment discharge measurements. The main stem equation used in the Phase I study was:

$$Q_s = 4.48 \times 10^{-6} V^{3.16} D_e^{.94} W_e \qquad (4.15)$$

The sediment input from point source (minor) tributaries was computed using a sediment rating curve of the form

$$Q_s = a Q^b \qquad (4.16)$$

where Q is the water discharge.

In this study, refinement of the tributary sediment equation begun in the previous Phase II studies using the data collected by Water Environmental Consultants and compiled in "Yazoo Basin Tributaries Data Collection" of October 1980, was completed.

In performing the analysis, the stage, discharge and cross-section data were used to generate the hydraulic flow paramters for each data set. These parameters were then used with the suspended sediment measurements and bed material size fractions to generate the bed material discharge using the Modified Einstein Method. Regression analysis was then performed using these results to obtain the sediment discharge equations for each tributary.

4.4.2 Major Tributaries

Yalobusha River. For the Yalobusha River, data were available for four cross section locations corresponding to river miles 0.50, 12.19, 38.53 and 55.10 (1937 Standard River Mile). Using these 16 data sets, the hydraulic flow parameters were generated and the bed material transport rates were computed using the Modified Einstein Method. The resulting sediment transport rates were then correlated with the flow parameters (V, D_e, W_e) to find the coefficients defined by Equation 4.14. Due to the limited number of data points, the powers of the effective depth and effective width were assumed to be 0.94 and 1.0, respectively, as in the Phase I study. Simple linear correlation in the log-log domain was performed to find the a and b coefficients for the relation:

$$\frac{Q_s}{D_e^{0.94} W_e} = aV^b \ . \tag{4.17}$$

In performing the regression, it was found that much better correlation was obtained by dividing the data into two sets, one for the two upper cross sections and a separate set for the two lower cross sections. The resulting sediment equations were:

Lower Yalobusha $Q_s = 6.618 \times 10^{-6} V^{3.141} D_e^{0.94} W_e$ (4.18)

Upper Yalobusha $Q_s = 1.247 \times 10^{-5} V^{2.711} D_e^{0.94} W_e$ (4.19)

The coefficient of correlation for both equations was very high, $r = 0.83$ and .997, respectively, indicating excellent correlation.

Two pertinent observations should be made here. First, for the range of conditions under consideration, the equation for the upper cross sections predicts a higher sediment transport rate for a given set of hydraulic conditions than that for the lower. Secondly, these equations compare quite favorably with the relation used for the main stem in the Phase I study.

Yocona River. For the Yocona River, four data sets were available to derive the sediment equation. Due to the limited amount of data, the exponents b and c in Equation 4.14 were assumed equal to those derived for the entire Yalobusha River where $b = 2.93$ and $c = 0.94$. The coefficient a was then determined by computing its value for each of the four data sets and averaging. The resulting sediment equation used in this study was:

$$Q_s = 1.30 \times 10^{-5} V^{2.93} D_e^{0.94} W_e \tag{4.20}$$

Tillitoba Creek. Eight data sets were available for Tillatoba Creek. The regression analysis for those data sets indicated a sediment transport equation of:

$$Q_s = 2.94 \times 10^{-4} V^{2.10} D_e^{0.94} W_e \tag{4.21}$$

P-Q - Little Tallahatchie. It was determined that the transport equation derived for the overall reach of the Yalobusha River using the data compiled by Water and Environmental Consulting, Inc. (WEC) would predict more realistic sediment transport rates for the P-Q Floodway than the old main stem equation (Equation 4.15) used in the Phase I study. The new equation used in this study was:

$$Q_s = 9.10 \times 10^{-6} V^{2.93} D_e^{0.94} W_e \tag{4.21}$$

A summary of the updated sediment transport equations and tributary rating curves based on the WEC data is presented in Tables 4.4.

Table 4.4. Summary of Sediment Transport Equations

Main Stem (Phase I)	$Q_s = 4.48 \times 10^{-6} V^{3.16} D_e^{0.94} W_e$
Yalobusha River (Lower)	$Q_s = 6.618 \times 10^{-6} V^{3.141} D_e^{0.94} W_e$
Yalobusha River (Upper)	$Q_s = 1.247 \times 10^{-5} V^{2.711} D_e^{0.94} W_e$
P-Q Floodway - Little Tallahatchie River	$Q_s = 9.10 \times 10^{-6} V^{2.93} D_e^{0.94} W_e$
Yocona River	$Q_s = 1.30 \times 10^{-5} V^{2.93} D_e^{0.94} W_e$
Tillatoba Creek	$Q_s = 2.94 \times 10^{-4} V^{2.10} D_e^{0.94} W_e$
Abiaca Creek	$Q_s = 5.85 \times 10^{-5} V^{3.04} D_e^{0.9} W_e$
Pelucia Creek	$Q_s = 2.63 \times 10^{-4} V^{2.24} D_e^{0.94} W_e$

Point Source Tributaries. Analysis for Cane and Teoc Creeks yielded equations for Q_s versus Q as follows:

$$\text{Cane Creek} \qquad Q_s = 2.3 \times 10^{-6} Q^{1.52} \tag{4.22}$$

$$\text{Teoc Creek} \qquad Q_s = 3.92 \times 10^{-6} Q^{1.5} \tag{4.23}$$

The coefficient of correlation for Equation 4.22 is also very high (r=0.99). However, due to the limited number of data sets (four) it was not possible to obtain a reasonable regression equation for Teoc Creek. Therefore, based primarily upon the analysis of Cane Creek, Abiaca Creek and Pelucia Creek the exponent "b" in Equation 4.16 was assumed to be 1.5. The coefficient "a" was then determined by computing the value of "a" for each data point and taking the average. While there is still considerable spread (standard deviation = 3.92×10^{-6}), it is felt that the resulting relation predicts realistic sediment transport rates for the range of discharges used in the model.

Two data sets were available for Strayhorn Creek. Again, due to the limited amount of data, the new rating curves were developed by assuming the exponent b in Equation 4.16 to be 1.5 as indicated by the analysis of the other hill tributaries in the watershed. The resulting rating curve for the tributary was:

$$\text{Strayhorn Creek} \qquad Q_s = 2.5 \times 10^{-5} Q^{1.5} \qquad (4.24)$$

Comparison of this relation with that from the Phase I study ($Q_s = 1 \text{x} 10^{-8} Q^{2.4}$) indicates that the new relations predict significantly higher transport rates for the average flows.

In view of the exponents obtained from analyzing the WEC data, it was determined that an adjustment should be made to the original point source sediment rating curves in the Phase I study for those tributaries for which no sediment data were available. The adjustment was made by again assuming the exponent "b" in Equation 4.16 to be 1.5 and computing the coefficient "a" based on the 50-year mean discharge. As shown qualitatively in Figure 4.8, this adjustment has the effect of decreasing the sediment transport rate for high flows and increasing the rate for lower flows.

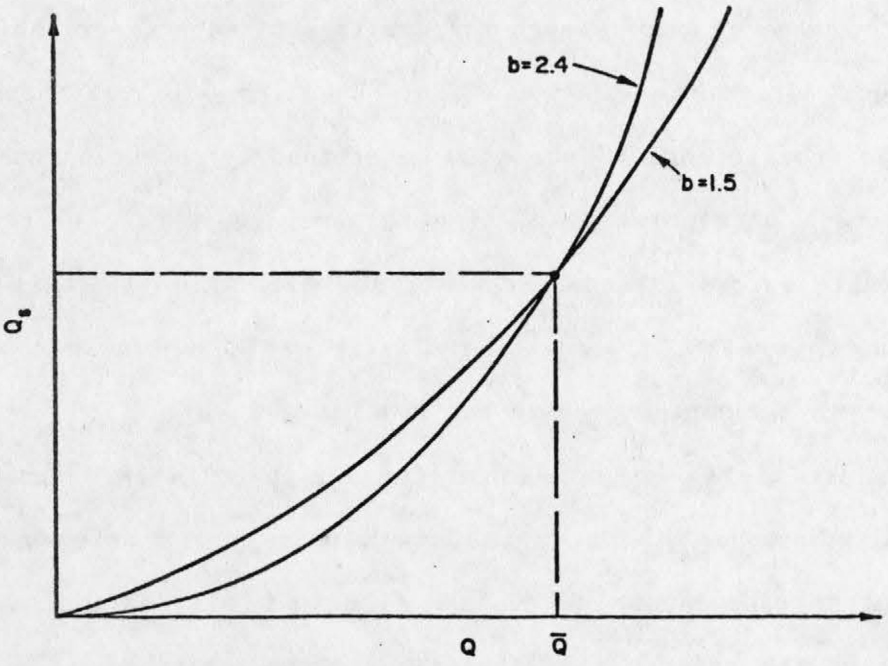


Figure 4.8. Qualitative comparison of sediment rating curves for varying exponents.

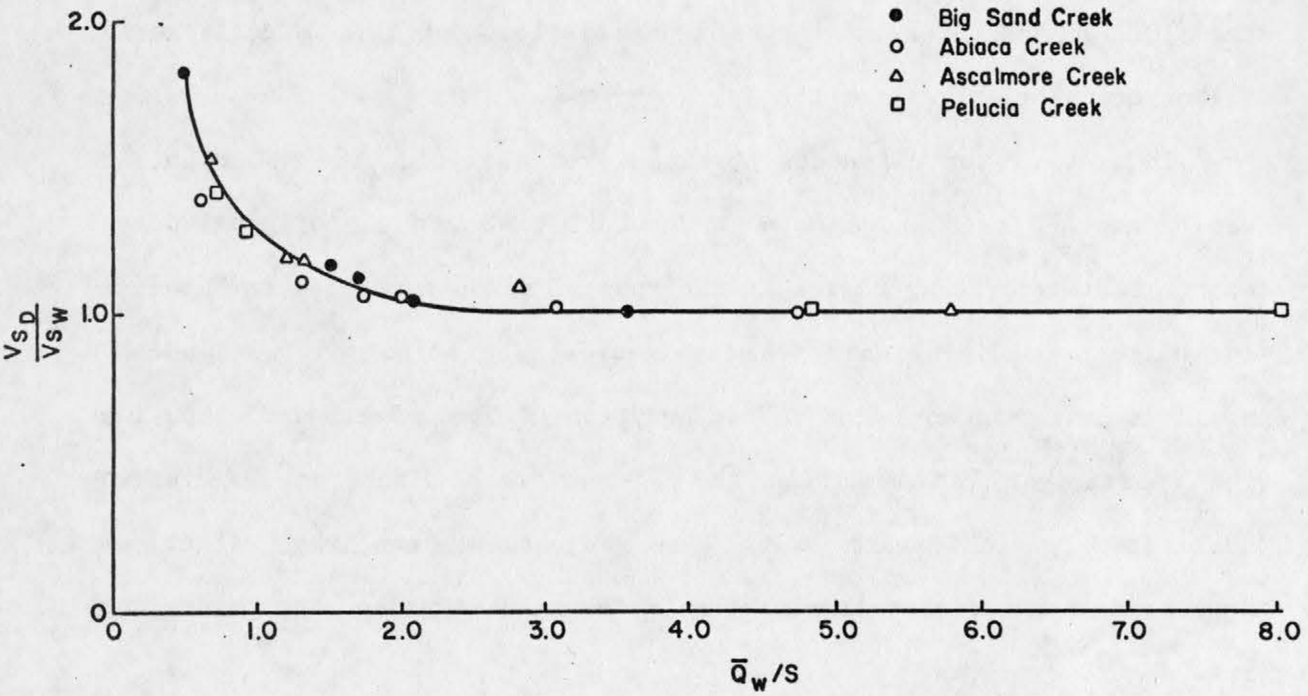


Figure 4.9. Ratio of sediment discharges for daily flows to sediment discharges for average weekly flows.

In comparing the resulting equations for Potococowa and Ascalmore Creeks with the new relation for Teoc Creek, it was found that the coefficient a was quite low. Therefore, an adjustment was made to these two rating curves based on the ratio of the old and new coefficient for Teoc Creek.

Adjustment for Average Flows. A further analysis was made of the effect of using average weekly discharges to predict the sediment loading from the point source tributaries in leiu of daily flows. As one would expect, since the sediment rating curves are power functions, the effect of averaging out the peaks in the daily flows tends to reduce the sediment input from the tributaries. In order to determine the magnitude of this discrepancy, 23 weekly flows were selected at random from the hydrographs for the four gaged streams, Abiaca, Pelucia, Ascalmore, and Big Sand Creeks. The total sediment discharge V_{s-w} for each data point was computed using the appropriate sediment rating curve and the average weekly discharge. The total sediment discharge V_{s-d} for each week was then recomputed as the sum of the daily sediment discharges obtained from the same rating curve using the average daily discharges for the corresponding 7-day period. The ratios of these values were then computed and plotted versus the ratio of the average weekly discharge $\bar{Q}$ to the standard deviation S. This plot is shown in Figure 4.9. As can be seen, the data points indicate a reasonably regular curve. Using this plot and the 50-year average weekly flow statistics for the tributaries in this study, an additional adjustment was applied to the coefficient a in the sediment rating curves. The final adjusted coefficient used in the model, along with the parameters used to compute them, are presented in Table 4.5.

Table 4.5. Adjustment of Sediment Rating Curve Coefficient a in the Equation Q_s = aQb

Tributary	b	$\bar{Q}$* (cfs)	S	$\frac{\bar{Q}}{S}$	$\frac{V_{S-D}}{V_{S-W}}$	a_{old}	a_{new}
Teoc Creek	1.5	136	146	0.93	1.35	5.38×10^{-6}	7.26×10^{-6}
Potococowa Creek	1.5	266	284	0.93	1.35	9.12×10^{-6}	1.23×10^{-5}
Ascalmore Creek	1.5	135	105	1.28	1.20	4.96×10^{-6}	5.95×10^{-6}
Cane Creek	1.517	85	91	0.93	1.35	2.30×10^{-6}	3.11×10^{-6}
Batupan Bogue	1.5	283	472	0.60	1.68	8.88×10^{-7}	1.49×10^{-6}
Strayhorn Creek	1.50	67	283	0.24	2.0	2.50×10^{-6}	5.0×10^{-6}
Arkabuta Creek	1.50	150	626	0.24	2.0	2.50×10^{-6}	5.0×10^{-6}
Peters Creek	1.50	93	174	0.53	1.65	2.50×10^{-6}	5.0×10^{-6}
McIvor Drainage	1.50	115	154	0.75	1.40	2.50×10^{-6}	5.0×10^{-6}
Lake Cormorant	1.5	204	390	0.52	1.7	2.50×10^{-6}	5.0×10^{-6}

*Unadjusted by qualitative analysis (see section 4.4)

Symbol explanation

b = power coefficient (b) for tributary sediment equation (see Table 4, Phase II)
$\bar{Q}$ = 50-year average weekly discharge in cfs (for 23 weeks)
S = standard deviation of average weekly flows
V_{S-D} = total sediment flow volume using daily sediment discharge
V_{S-W} = total sediment flow volume using weekly sedment discharge
a_{old} = coefficient (a) for tributary sediment equation (see Table 4, Phase II)
a_{new} = adjusted coefficient (a) based on ratio of V_{S-D}/V_{S-W}

4.5 Qualitative Analysis

4.5.1 General

A thorough check of the Phase II temporal design was performed after all the previous analysis. The objective of the check was to determine if any errors had been made in the adoption of discharge rating curves, calculation of the river and tributary water discharges or the tributary sediment rating curves.

In the analysis two types of errors were found. The first type was "numerical" errors. Numerical errors are mathematical errors made in the complex procedure of converting stage records to discharge, daily records to weekly records, or gaged stations to ungaged stations. These errors were easily corrected.

The second type was stage-discharge rating curve errors. At 24 stations in the temporal design, stage-discharge relationships were used to generate water discharge from stage records. The stage-discharge relationships were either supplied by the Corps or developed from Corps data. On the mainstem and major tributaries considerable data were available to develop the curves, but on most of the minor tributaries only limited data were available. As could be expected, the stream flows produced from well-defined rating curves produced relatively good values, as documented by the error check, while the discharges generated from ill-defined rating curves caused problems. On four of the tributaries when the stage-discharge relationship was applied to the stage record, the total annual volume of water generated did not come close (two to three times as much) to what could be expected from the watershed. This occurred even when no error could be found in the rating curve. The best, but not the only, explanation for these errors is that the rating curves are based on medium to high flows and overpredict low flows. On two tributaries, trends in the stage hydrograph showed that the bed was aggrading with time, thus the stage-discharge relationships which were based mainly on old measurements overpredicted the recent discharges.

The importance of these errors to Phase I analysis should not be overestimated. For the most part these errors should have caused only minor local inaccuracies in the modeling results. This is due to two self-correcting features in the sedimentation study. The first feature is the inclusion of nonpoint sources in the temporal design. There are good estimates of discharge on the mainstem and major tributaries, at 25 locations. From these stations and the gaged and ungaged tributaries water continuity shows that in a given reach water may be gained or lost. Groundwater discharge or small tributaries can produce a gain in stream flow while groundwater recharge or outflows to the Big Sunflower basin can produce channel losses. In stream channel storage can produce gains when stage falls and losses during rising stages. In the temporal design each reach between major stations was defined to have an NPS so that water continuity would be maintained. When a gaged or ungaged tributary discharge was too high due to errors, the NPS for the reach was automatically reduced to compensate. Thus no water discharge error is carried out of the reach, and within the reach it is dampened. The second feature of the study which tends to dampen errors is in Phase I, where the sediment rating curves for the minor tributaries were calibrated to match existing conditions (Simons et al., 1978). Thus even though the sediment discharges were calculated with high discharges, the total sediment load they input to the stream was correct.

The following sections outline the error analysis and checking performed on the water and sediment discharges.

4.5.2 Water Discharge

Three principal methods were used in the error check of the discharge files. These methods were (1) numerical checks, (2) mean trend analysis, and (3) calculation of unit runoff. With these methods most, if not all, errors can be identified.

Nine of the minor tributaries are ungaged. Four of the hydrographs are determined by transfer of flow from adjacent gaged tributaries, while five are determined from flow continuity between gaged sites. Likewise, all of the nonpoint sources were calculated from flow continuity once the tributaries were determined. Each of these calculations was checked. The discharges for three tributaries, Peters Creek, Tillatoba Creek, and Batupan Bogue were found to be in error and were corrected.

A trend analysis was performed by calculating the annual mean discharge for each station and comparing it to the 14 year mean. A steady rising or falling mean would indicate a possible error. The analysis showed a trend in two tributaries, Abiaca and Pelucia Creeks. These trends had been previously discovered and the daily records corrected (Appendix F) and it was a simple matter to correct the weekly data. No other trends could be detected for any tributary or mainstem stations. One nonpoint source, NPS-5, shows an increase with time. Its mean value for 1964 is -922 cfs, which increased to 973 cfs in 1971 and then declines. This nonpoint source is the difference on the Tallahatchie River between Swan Lake and Money. Table 4.6 presents the mean annual discharge for these stations and the three year running mean

Table 4.6. Mean Annual Discharge for Money, Swan Lake and NPS 5.

Year	Money	Swan Lake	NPS 5	Three Year Running Mean
1964	7,062	7,984	-922	-
1965	6,560	6,840	-279	-459
1966	4,160	4,333	-172	-333
1967	4699	5,248	-548	-142
1968	4,803	8,508	294	-11
1969	8.372	8,150	222	449
1970	9,452	8,621	830	675
1971	7,101	6,127	973	837
1972	5,581	4,874	707	774
1973	14,355	13,710	644	654
1974	13,407	12,797	610	632
1975	11,627	10,985	642	590
1976	6,461	5,943	517	670
1977	5,570	4,719	850	-

for NPS-5. Neither of these stations shows a clear trend, only their difference, NPS-5. One possible explanation for this phenomenon is that a large slug of bed material was passed through the system.

If its peak was moving from Swan Lake in 1964 to Money in 1971 the discharge at the two stations, as calculated by constant stage-discharge relationships, would be out of phase with one another. Swan Lake would have a gradually decreasing discharge, and the discharge at Money would gradually increase. Since these are relatively small changes, they would not show up in the actual records, only in the differences. Nonpoint sources 6, 7, 9, 11, 12 and 13 show similar, but not as pronounced, trends. Since the nonpoint sources are small relative to the stations and it would be difficult to accurately correct the records, it was decided not to make any adjustments to improve the non-point sources.

The mean annual runoff for each of the 48 upper stations was calculated by dividing the mean station discharge for the 14 years of record by the station drainage area. The result was converted to inches of runoff per year. For the general hydrology of the area it is known that the runoff should be in the range of 15 to 25 inches per year. All of the mainstem and major tributary stations have values that range from 16.6 for Grenada Dam to 22.9 in/yr for Sardis Dam. Most of the mainstem stations have values near 20 in/yr.

Four gaged tributaries, Big Sand, Ascalmore, McIvor and Arkabutla had values of runoff which exceeded 30 in/yr. The stage-discharge relationships for these tributaries were checked and no errors could be found. It is unknown why the correct stage hydrograph and stage-discharge relations give such high total flow for all four stations. It may be that since the stage hydrographs were developed for medium to high flows they overpredict low flows, but this cannot be proved by the available data. To correct the hydrographs for Big Sand, Ascalmore and McIvor it was decided to simply reduce each weekly value by a constant, so that the mean annual runoff would be approximately 20 in/yr. For Arkabutla Canal it was found that by reducing its runoff to 14.4 in/yr NPS 14 could be driven to about zero. The corrected Abiaca and Pelucia runoffs were somewhat high, 27 and 22 in/yr, respectively but they are still in the reasonable range.

Table 4.7 presents the new flow statistics for each of the 48 upper basin stations, along with the old mean value. In the review of the nonpoint sources it is important to remember that they are a "lump" variable. While they primarily represent flow contribution for tributaries not included in the temporal design, they are also used to correct for other flows which are difficult to define. Thus nonpoint sources include losses out of the river system, such as overflow to the

Table 4.7. New Flow Statistics, Mean Weekly Discharge 1964-1977

Station or Stream	Old Mean (cfs)	Mean (cfs)	Minimum (cfs)	Maximum (cfs)	Standard Deviation (cfs)	Runoff (in./yr)	Remarks on Changes
Belzoni	11,232	11,233	1,466	28,114	5,761	19.5	No change
Abiaca Creek	456	223	48	1,979	251	27.1	Stage-discharge corrected
Pelucia Creek	309	108	2.7	2,078	205	22.9	Stage-discharge corrected
Greenwood	11,605	11,605	1,065	40,857	6,416	21.1	No change
NPS 1*	-1,087	-703	-14,363	6,873	1,798	-46.8	Change due to Abiaca and Pelucia
Money	8,086	8,086	56	22,419	4,668	21.0	No change
Big Sand Creek	284	158	4.5	3,935	311	19.5	Discharge reduced by 44%
Teoc Creek	145	58.3	11.9	832	76.1	19.8	Change due to Big Sand and Ascalmore
Potococowa Creek	284	113.7	23.2	1,624	113.7	19.8	Change due to Big Sand and Ascalmore
Ascalmore Creek	151	47.3	2.2	503	46.5	20.1	Discharge reduced by 69%
Whaley	2,876	2,876	295	19,427	2,316	19.9	No change
Cane Creek	91	36.4	7.4	520	47.6	19.8	Change due to Big Sand and Ascalmore
Grenada	1,922	1,922	54.6	12,813	1,755	16.6	No change
Butupan Bo.	351	233	0.1	8,183	678	19.5	Numerical error corrected
Grenada Dam	1,850	1,850	5.0	5,685	1,356	19.0	No change
NPS 2	-125	425	-9,049	3,488	1,114	48.5	Change due to tributaries
NPS 3	807	756	-4,313	15,953	1,339	40.2	Change due to tributaries
NPS 4	-226	-161	-1,122	4,445	545	-24.8	Change due to tributaries
Swan Lake	7,774	7,774	774	36,428	4,656	20.6	No change
NPS 5	312	312	-14,816	5,514	1,430	46.6	No change
Locopolis	7,085	7,085	108	29,802	4,735	19.5	No change
NPS 6	689	689	-2,489	6,626	767	44.6	No change
Lambert	2,791	2,791	116	14,571	2,606	19.1	No change
Tillatoba Creek	495	205	0.1	2,285	383	17.8	Numerical error corrected
Enid Dam	916	916	1.2	3,925	728	22.2	No change
Peters Creek	224	93.1	0.1	1,033	173	17.8	Numerical error corrected
Batesville	3,034	3,034	52.5	13,815	1,816	22.9	No change
Sardis Dam	2,391	2,391	15.0	10,997	1,553	21.0	No change

Table 4.7. continued

Station or Stream	Old Mean (cfs)	Mean (cfs)	Minimum (cfs)	Maximum (cfs)	Standard Deviation (cfs)	Runoff (in./yr)	Remarks on Changes
McIvor Dr.	239	114	0.1	1,191	154	20.5	Discharge reduced by 41%
NPS 7	-349	44.7	-5,164	5,094	1,218	1.7	Change due to Tillatoba Creek
NPS 8	547	527	-672	5,659	748	-39.6	Change due to McIvor Dr.
Marks	2,981	2,981	219	14,854	2,692	22.4	No change
NPS 9	-190	-190	-2,045	2,005	538	-15.2	No change
Darling	2,352	2,352	154	14,686	2,474	19.7	No change
NPS 10	628	628	-1,222	2,854	451	44.9	No change
Sledge	2,014	2,014	100	11,091	1,678	19.5	No change
NPS 11	337	377	-1,095	9,275	945	21.2	No change
Crenshaw	2,007	2,007	16.7	13,631	1,770	19.5	No change
NPS 12	7.7	7.7	-7,233	2,954	503	104.1	No change
Sarah	1,892	1,892	77.4	13,949	1,630	18.4	No change
NPS 13	115	115	-1,493	2,798	375	195.6	No change
Strayhorn Creek	102	49.9	0.1	2,716	208	14.4	Change due to Arkabutla Creek
Arkabutla Creek	187	110	0.1	6,010	460	14.4	Discharge reduced 41%
Prichard	1,734	1,734	24.1	13,030	1,649	19.4	No change
NPS 14	-214	-3.0	-7,223	1,901	683	-1.4	Change due to tributaries
L. Cormorant	204	204	0.1	2,770	390	27.5	No change
Arkabutla Dam	1,314	1,314	5.0	7,676	1,139	17.8	No change
NPS 15	214	214	-190	3,099	445	25.8	No change

*NPS 1 includes Marksville overflow

Big Sunflower, groundwater recharge and discharge, and most importantly small errors in the calculated discharge at the mainstem stations. Several of the nonpoint sources have large positive or negative runoff values. These large values are primarily due to the fact that the nonpoint sources have such small drainage areas that any small error in a mainstem gaging station discharge can cause a large change in the nonpoint source runoff value. Since the actual flows are small, it was decided not to change any mainstem discharges to improve the nonpoint source runoff values. As a note, it is possible to improve NPS 3 and 4 by increasing the Grenada discharge (runoff = 16.6 in/yr) and improve NPS 9 and 10 by decreasing flow at Marks (runoff = 22.4 in/yr).

4.5.3 Tributary Sediment

Point-source tributary sediment yield is the most important input parameter to the known-discharge sediment routing model (Brown, 1982), therefore considerable time was spent checking the sediment rating curves for the tributaries once the new discharges were determined. In the first phase the tributary sediment rating curves were estimated from channel properties and then calibrated using the sediment routing model to match existing conditions. As part of the second phase, data on the tributary sediment transport were collected and the rating curves were improved. The new rating curves are much better, but since they are based on only a few data points they must be used with care.

Previous sections detailed the development of new rating curves for Abiaca, Pelucia, Teoc, Potococowa, Ascalmore, Cane, Batupan, Tillatoba and Strayhorn. Peters, McIvor, Arkabutla and Lake Cormorant do not have the data to develop curves of their own, so their rating's are estimated from the other streams.

The principal method of checking the sediment yields was to calculate an annual yield in tons per acre using the newest discharges. The annual yields were then compared to documented yields in the basin. It is important to note that the yields given by the rating are for bed-material load, not total load.

Watson (1982) states that the total sediment load for bluff line tributaries in the basin currently is 5-10 tons per acre. The U.S. Army Corps of Engineers found the deposition behind Sardis Reservoir (1966a) to average 1.32 tons per acre, and behind Grenada Reservoir (1966b) to be 2.46 tons per acre, but these values are probably low for total load since substantial unmeasured deposition can occur in the channel upstream of the flood pool.

It is impossible to calculate bed load from annual total data or a few sediment measurements, but through the use of geomorphic principals an estimate can be made. The Yazoo tributaries exhibit the channel shape and bank material of mixed load to bed-load streams as defined by Schumm (1977), and thus it would be reasonable then to expect bed load to be 5 percent to 50 percent of total load. When these values are applied to Watson's total load we can estimate annual bed load yield to be 0.25 to 5 tons per acre. The 0.25 value would probably occur only on stable streams, while the 5.0 value would occur on streams undergoing active channel erosion. It is estimated that the tributaries considered here should range from 0.5 tons per acre to 5.0 tons per acre. One exception would be Lake Cormorant Bayou, which originates from the delta.

Using the new rating curves and discharge hydrographs the mean annual sediment yield was calculated. The rating curves were then adjusted when necessary to bring the calculated yield into the expected range. Table 4.6 presents the new sediment rating curves, the new yield, and the yield from Phase I. As can be seen, the new yields from Abiaca and Pelucia Creeks are somewhat high, but they are based on the best data, and since they are actively eroding they can be expected to be the highest producers. Teoc, Potococowa and Strayhorn Creeks did not require adjustment, while Ascalmore, Cane and Batupan had to be increased.

Table 4.8. Point Source Tributary Sediment Yields* (yields given for 14 years of record)

Tributary	Phase I Yield tons/yrx10^3	Phase II		New Ratig Curve $Q_s = axQ^b$ (cfs)		Remarks on Coefficients
		tons/yrx10^3	tons/ac-yr	a	b	
Teoc	18	23	0.90	1.00×10^{-5}	1.56	Calculated from new data
Potococowa	176	59	1.18	1.28×10^{-5}	1.50	Calculated from new data
Ascalmore	15	14	0.67	1.29×10^{-5}	1.50	Calculated from new data *2
Cane	23	12	0.73	1.29×10^{-5}	1.50	Calculated from new data *4
Butupan	97	94	0.90	3.56×10^{-6}	1.50	Calculated from new data *2
Peters	4	11	0.25	2.50×10^{-6}	1.50	Estimated
McIvor	239	122	2.50	2.50×10^{-5}	1.50	Estimated
Strayhorn	17	17	0.57	5.00×10^{-6}	1.50	Calculated from new data
Arkabutla	82	85	1.28	7.50×10^{-6}	1.50	Estimated
L. Cormorant	4	8	0.12	5.00×10^{-7}	1.50	Estimated

*Bed load only.

V. KNOWN DISCHARGE MODEL

The known discharge, uncoupled, sediment routing model developed in Phase I was used in this study (Brown, 1982). The model was designed to take advantage of three basic basin characteristics: 1) no significant widespread bed armouring occurs, 2) the majority of flows are subcritical and 3) all channels have relatively small width to depth ratios. Several improvements were made in the model for Phase II. The resulting model, after the modification, is an effective tool in simulating water and sediment movement in the hill tributaries. This model can also be used to evaluate the effect of channelization, downstream dredging, and the installation of sediment control structures. The following section includes a brief description of the model and changes made for Phase II.

5.1 Model Features

5.1.1 Known Discharge

This program is a known discharge or steady flow model. It assumes that during any one time period, water discharge is constant along a reach of river, except where lateral inflows occur. Although a model of this type cannot predict the dynamic effects that an unsteady model can, it requires considerably less computer time. However, the model is still able to calculate flood stages and provide a practial method to model sediment movement over long time periods. The time increment on the input hydrographs may vary from a few hours to a month or longer depending on the flow conditions and the required accuracy of the results. In this study a constant value of seven days was used.

5.1.2 Uncoupled Routing

Water and sediment routing were uncoupled. This makes the bed profile constant during any one time increment with changes in the bed profile due to the sediment movement introduced at the end of each time increment.

5.1.3 Sediment Transport

The bed material sediment transport at each cross section was calculated by a transport equation that was derived from the Yazoo River sediment discharge measurements. The equation is:

$$Q_s = a\ W_e\ V^b\ D_e^c \tag{5.1}$$

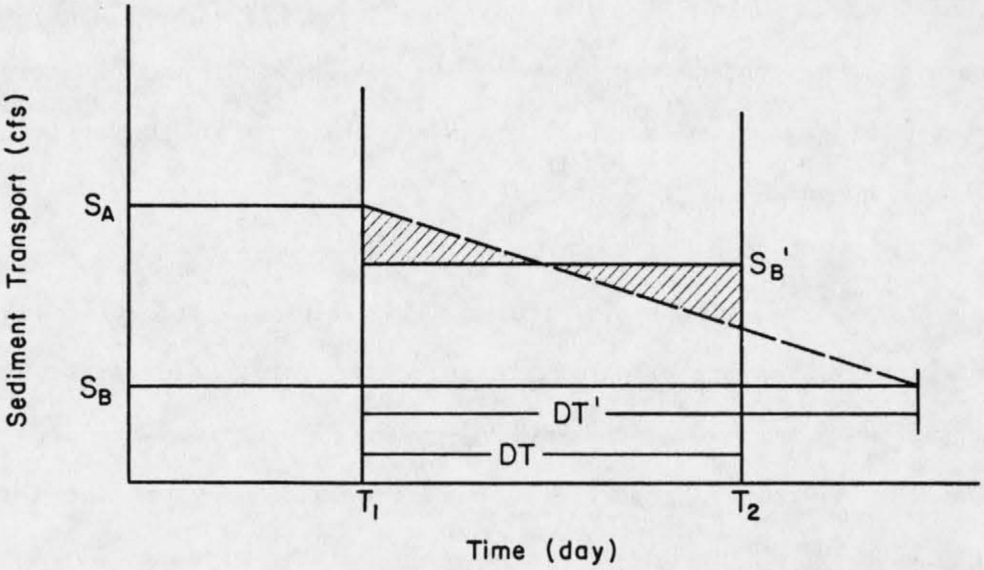
where Q_s is the sediment transport in cfs, W_e is the effective channel width in feet, V is the average water velocity in feet per second, D_e is the effective channel depth in feet, and a, b and c are calibrated coefficients. In Phase I, sediment transport capacities for the cross sections were represented solely by Equation 5.1. This is adquate in the main stem where sediment continuity based on the transporting capacities can be attained between cross sections of small sediment transport rate deviation. However, in the tributaries, sediment balance based on the transporting capacity might not exist due to limited sediment supply, large channel geometry changes, and aggradation or degradation.

A bed material transport rate which is out of balance between two sections considering the transporting capacities is resolved by the following scheme. First, the time needed to reach a sediment transport balance between upstream and downstream sections is calculated. Second, using proportions, the time needed to reach sediment balance and the time increment of routing are used to establish the instantaneous downstream transport rate at the end of the routing period. The final average transport rate of the routing period is then estimated as an average of the initial upstream value at the start of the routing period and the instantaneous downstream value at the end of the routing period. Figure 5.1 shows two cases of the average transport rate calculation. Case I assumes that the time required for sediment balance, DT' exceeds the routing time increment DT. In Case II balance is assumed to be reached prior to the end of the routing time increment. S_A and S_B represent the bed material transport rates for upstream section A and downstream section B, and T_1 and T_2 are the start and end of the routing time increment. Final averaged outgoing bed material transport rate is represented by S_b'.

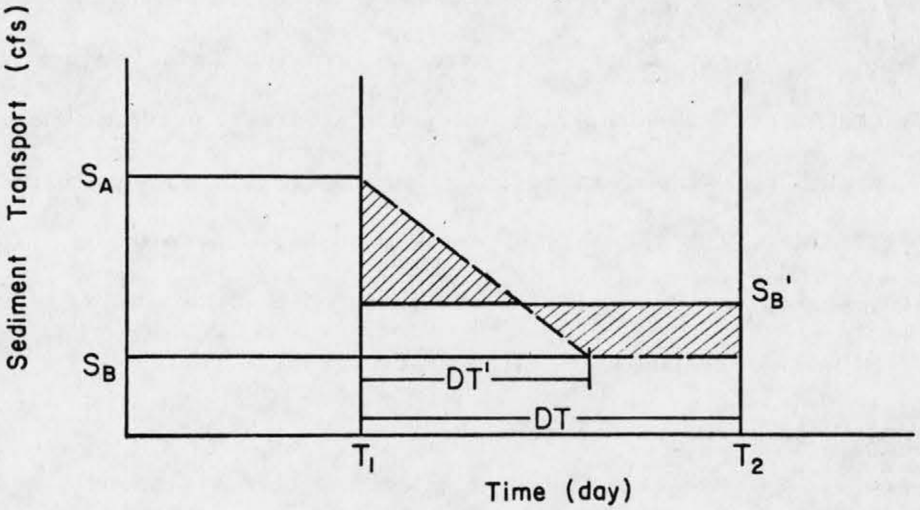
The ability of the model to calculate a new sediment transport rate for a nonbalanced sediment condition considering the transport capacities greatly improves the model's applicability to tributary sediment routing. Again, this modification considers the importance of limited sediment supply and sources.

5.1.4 Channel Geometry

River geometry data required by the model includes digitized channel cross sections, river distance between cross sections, horizontal location of the banks, and the Manning's n value for the main channel and overbank areas. The model uses this digitized geometry data to determine geometry equations for each cross section. These geometry equations define conveyance, width, depth, and area of the channel as a function of the maximum depth. The program uses these channel geometry equations for backwater calculations.



CASE I DT' > DT



CASE II DT' < DT

Figure 5.1. Average sediment transport rate for a unit time increment.

In a tributary, variation of the cross section geometry is greater than the variation in the main stem, and generally the tributary's bed slope is steeper. Large local flow area variations, plus the steeper slopes, cause the tributary flow regime to approach the critical flow condition. The method of "least squares through a fixed point" was used to improve the continuity of the thalweg depth power function. Consistency of the power function was thus achieved in the region of bankfull elevations.

5.1.5 Backwater Calculations

The backwater curve was calculated by using an iterative first order Newton-Raphson approximation to solve the total head equation at each cross section. Since the channel geometry equations are used to describe the hydraulic properties, the first derivative of the total head equation can be evaluated analytically. This makes the backwater calculations up to 10 times faster than most trial and error methods.

In Phase I, energy slope was used to provide trial values for unknown water-surface elevations. In the tributary program, normal depth and channel bed slope, in addition to energy slope, were used to provide an estimation for the first-order Newton-Raphson solution. This modification worked well at locations where the water surface was controlled by backwater and where large grade breaks occur.

5.1.6 One-Dimensional Simulation

This program is one-dimensional. This means that it can only model water and sediment in the longitudinal direction along the river. It cannot precisely model lateral phenomenon such as meandering or sediment distribution across the river cross section. While this is a limitation, there are no practical methods presently available to model multidimensional flow. However, in order to account for the lateral changes in the cross section, the degradation and aggradation were assumed to be distributed according to the relative magnitude of conveyance at a subsection in the cross section.

5.1.7 Average Velocity

Overbank flow occurs frequently in the tributaries. As the flow depth exceeds the channel bank, the relative width of the channel becomes proportionally less than the width of the inundated flood plain. Average velocity calculated by the discharge and flow area as in Phase I, are no longer representative of the true velocity within the main channel, thus causing an inaccurate sediment rate calculation. In Phase II, the average velocity is calculated by:

$$V = \frac{Q}{D_e W_e} \tag{5.2}$$

where Q is the discharge and D_e and W_e are the effective depth and width, respectively. Effective depth is a weighted depth based on conveyance, and the effective width is the result of equal section factors:

$$D_e = \frac{\sum_{i=1}^{n} (d_i \; K_i)}{\Sigma \, K_i} \tag{5.3}$$

and

$$W_e = \frac{\sum_{i=1}^{n} (a_i \; r_i^{2/3})}{D_e^{5/3}} \tag{5.4}$$

where d_i, K_i, a_i, and r_i are the corresponding depth, conveyance, area and hydraulic radius between individual cross section points. Velocity, so derived, will give more weight to the velocity in the main channel and will result in a more accurate value for the sediment transport rate calculation.

5.1.8 Simulation Procedure

Figure 5.2 shows a short flow diagram of the program operation. The program is set up in modular forms for easy updating, correction, and revision.

5.2 Calibration

5.2.1 General

During Phases I and II of this study the known discharge model has been calibrated and verified whenever possible. The extent of calibration and verification has been limited by the amount of suitable data available, but the results to date have shown that calibration for any given reach has required only minor changes in initial estimates of Manning's n value or sediment transport. From the results to date and observations in the basin, it can be shown that the model is able to accurately simulate the physical responses of the river system with a minimum of calibration or detailed input data.

The model was calibrated and verified for the mainstem in Phase I (Simons et al., 1978) and that calibration is used here. The calibrations of Abiaca and Pelucia Creeks are presented in Appendix F. The Yalobusha and Little Tallahatchie Rivers have been calibrated in Phase II and their results are presented in the following sections. No data were available for calibrating the Yocona River and Tillatoba Creek. Manning's n values of 0.03 for main channel and 0.15 for overbank areas were assumed.

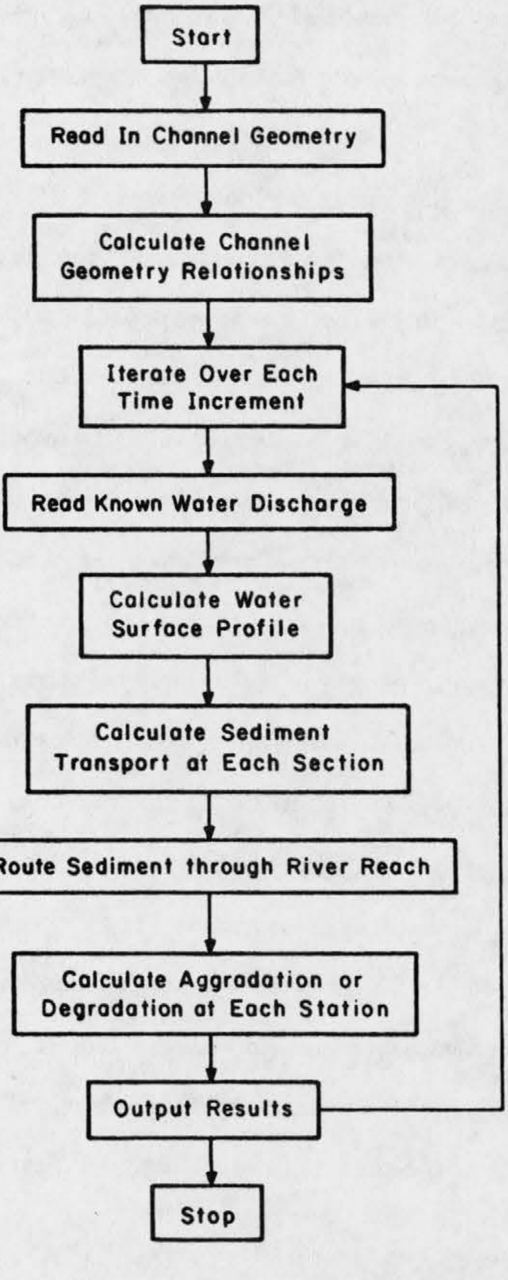


Figure 5.2. Flow chart illustrating program operation of the known discharge model.

5.2.2 Yalobusha River

The flow resistance for the Yalobusha River was calibrated by adjusting Manning's n so that the water surface elevation at Whaley and Grenada predicted by the model matched, as closely as possible, the water surface elevation predicted by the appropriate stage-discharge relation.

To accomplish the calibration, several discharges covering a range of low to high flows were selected from the first 11 years of the discharge hydrograph. The water surface profile was then computed for each discharge, adjusting the n value until the computed water surface elevation matched, within a reasonable tolerance, the water surface predicted by the appropriate stage-discharge relation. A plot of n versus Q was then constructed for each of the two sites and a power curve of the form, $n = aQ^b$ was fitted to the points (see Figure 5.2). The resulting errors in water surface elevatons for discharges used in the calibration are shown in Table 5.1. Considering the wide range of flows, the mean error of 0.23 feet is considered excellent. The Manning's n relationship at Whaley requires two curves, as shown in Figure 5.3. For modeling purposes the river was divided into two reaches, the lower reach from the mouth to River Mile 20 (1980 Standard) uses the whole relationships, while the upper reach from River Mile 20 to Grenada Dam uses the Grenada relationship. The divide point at River Mile 20 was selected based on the change in river slope at that approximate location.

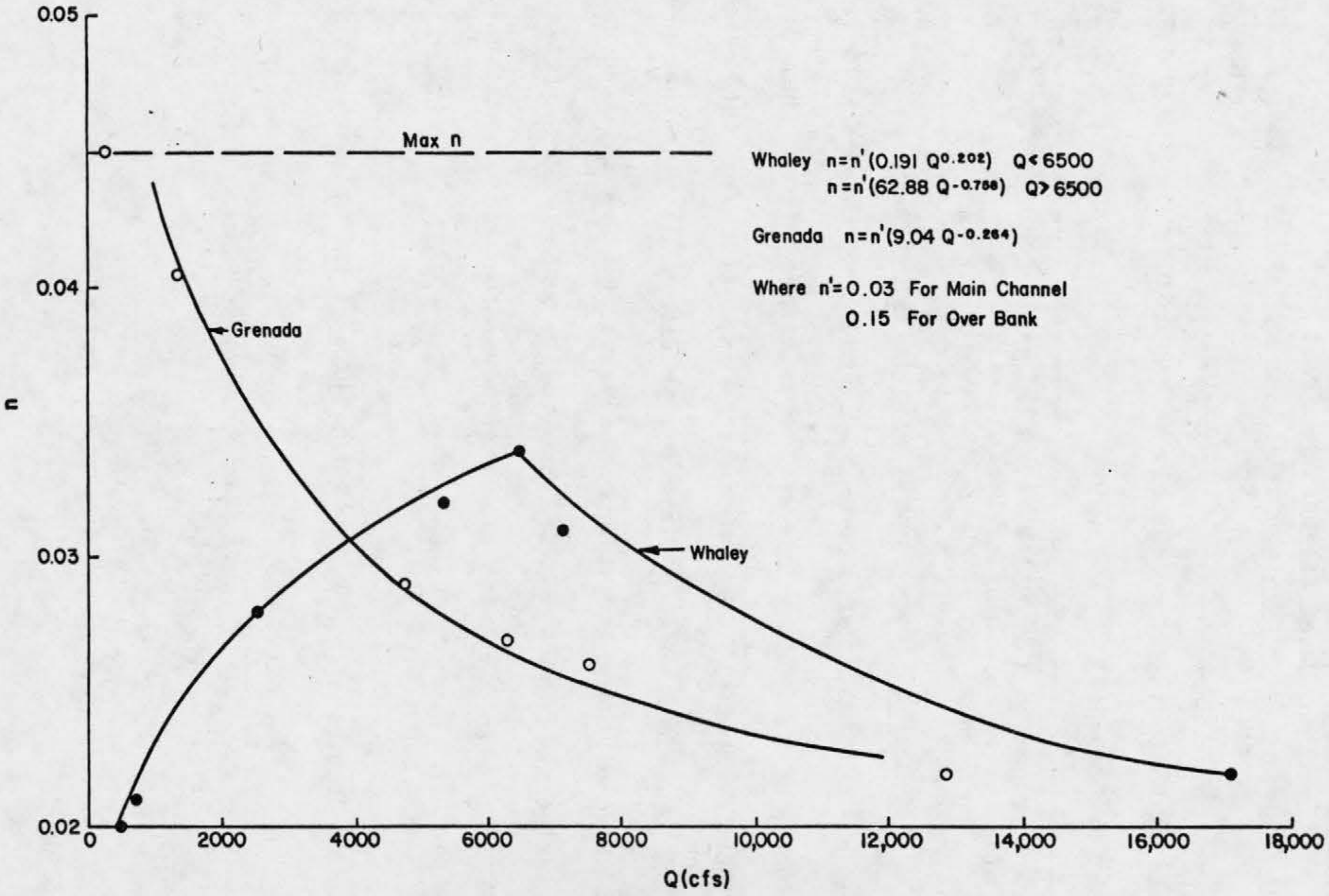


Figure 5.3. Manning's n calibration curves for Yalobusha River.

Table 5.1. Error in Computed and Predicted Stage for Yalobusha River
Error in Water Surface Elevation (ft)

	Minimum	Mean	Maximum
Yalobusha at Whaley	0.02	0.23	0.52
Yalobusha at Grenada	0.00	0.23	1.21*

*This corresponds to a very low flow (230 cfs) and is due to the upper limit of 0.045 established for the n value.

5.2.3 P-Q Floodway, Little Tallahatchie River

Again, the value of Manning's n used for the P-Q Floodway was determined by selecting several discharges from the discharge hydrograph, computing the water surface profile for the reach, and comparing the water surface elevation at Batesville with that predicted by the stage discharge relation. The value of n was adjusted until the water surface elevation matched as closely as possible. It was found that allowing n to vary with discharge according to the relation:

$$n = 0.03\ (0.0865\ Q^{0.254}) \qquad (5.5)$$

(within the limits of n = 0.02 to 0.042), gave the best results.

VI. RESULTS OF ANALYSIS

6.1 General

The spatial designs of the various runs differ slightly in the number of cross sections used or the location of weirs but the results of all runs can be catagorized into eleven river segments. Referring to Figure 4.2, River Segment No. 1 extends from Belzoni to just below Greenwood Bendway. The Greenwood Bendway is River Segment No. 2. River Segment No. 3 extends from immediately upstream of the Bendway to Arkabutla Dam. The P-Q Floodway and Little Tallahatchie River are River Segment No. 4. The Yocona River is defined as River Segment No. 5. Tillatoba Creek is River Segment No. 6. The Yalobusha River from its confluence with the Tallahatchie to River mile 20 (1982 conditions) is River Segment No. 7 and upstream to the Grenada Dam is River Segment No. 8. Big Sand Creek is River Segment No. 9. The Ft. Pemberton cutoff at Greenwood is River Segment No. 10 and Pelucia Creek is River Segment No. 11.

These river segments have no special meaning except that they minimize the input and computation time. Other segments could be defined that are subsets or combinations of these segments. In any case, the final results would be the same.

Results for the volume of aggradation or degradation in each river segment for each run are summarized in Table 6.1.

6.2 Run 1 (Existing Conditions)

The results of the simulation after calibration indicate that the Lower Mainstem, Belzoni to Greenwood Bendway (Reach 1) is relatively stable. Figure 6.1 shows the total aggradation to 1.19 million cubic yards (MCY) at the end of 50 years. The upper mainstem from the bendway

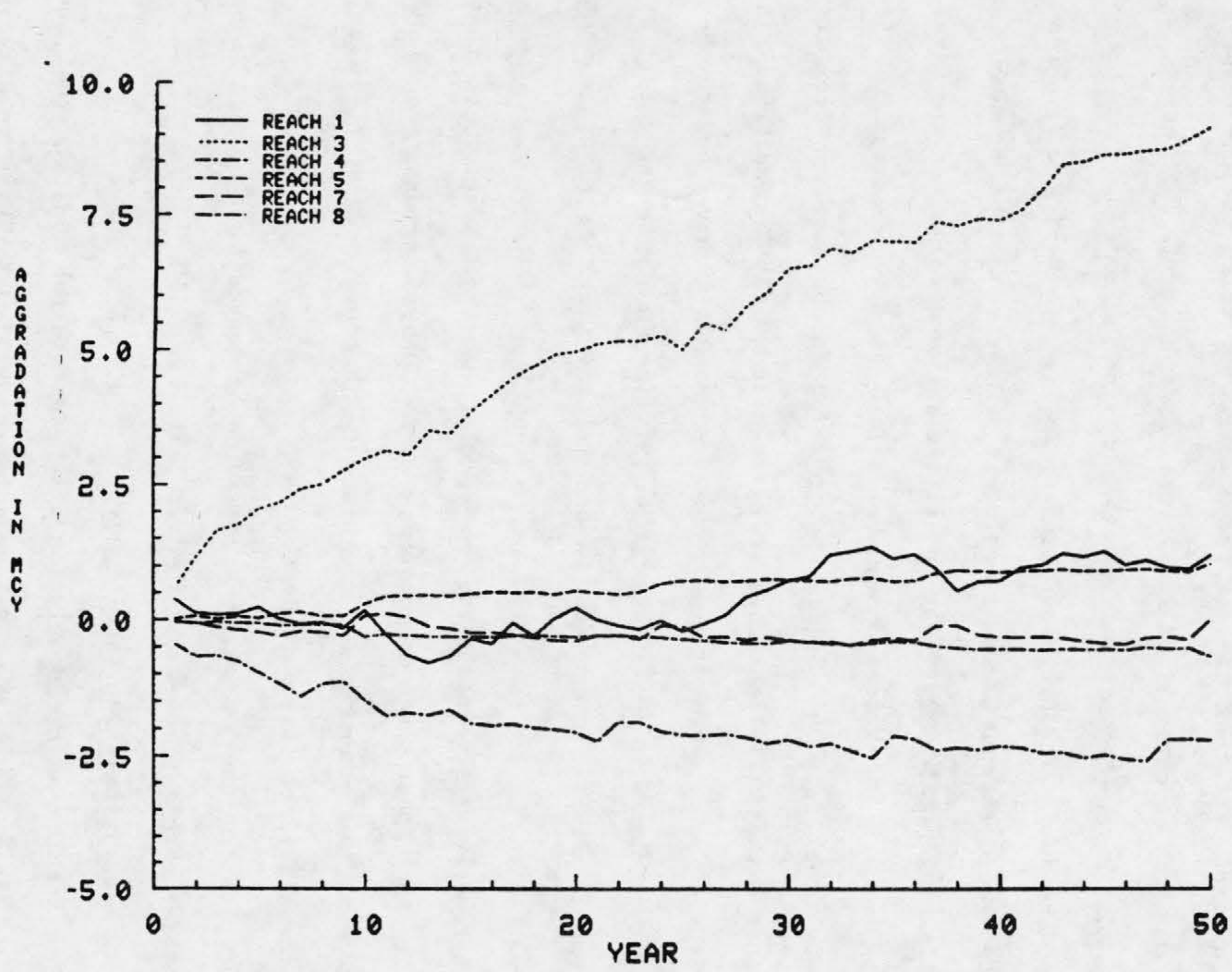


Figure 6.1. Volume of aggradation for on River Reaches 1, 3, 4, 7 and 8 for existing conditions (Run 1).

Table 6.1. Net Degradation and Aggradation for 50 Years Under Different Design Conditions in 10^6 cubic yards.

	Run Number					
	1	2	3	4	5	6
River Segment	Exist.	Plan E	Grade Control	Trib. Control	Step Channel	Max Sed. Control
1 Yazoo	1.19	9.63	9.18	8.97	10.3	9.98
2 GW Bend	-1.32	-1.28	-1.37	-1.31	-2.00	-.407
3 Tall-CW	9.12	21.1	20.3	19.8	17.1	2.81
4 P.Q. L Tall	-2.22	1.56	1.73	1.08	-3.70	3.35
5 Yocona	1.03	1.57	1.30	1.22	.773	.803
6 Tillatoba	.658	1.17	1.13	1.12	.470	-.087
7 L Yal	.001	1.99	1.76	1.41	-.744	-1.49
8 U Yal	-.682	.055	-.232	-.619	-1.24	-2.32
9 B Sand	.038	.043	.044	.044	.038	.039
10 Cut off	.087	-.474	-.454	-.465	-.237	.061
11 Pelucia	.361	1.67	1.71	1.8	1.95	1.92

to Arkabutla Dam (Reach 3) shows steady aggradation during the 50 years to 9.12 MCY. The majority of the aggradation occurs below the confluence of the P-Q floodway. The Ft. Pemberton cutoff (Reach 10) is relatively stable until year 36 where it undergoes a slight aggradation.

The P-Q Little Tallahatchie (Reach 4) undergoes steady degradation. Aggradation occurs in the P-Q while the upper Little Tallahatchie has considerable bank erosion. The total net degradation for the reach is 2.22 MCY. On the Yocona River (Reach 5) there is aggradation with a total of 1.03 MCY for 50 years. Tillitoba Creek (Reach 6) also experiences steady aggradation with a 50 year total of .658 MCY. The lower Yalobusha (Reach 7) is stable with only .001 MCY aggradation while the Upper Yalobusha degrades .682 MCY. The Greenwood Bendway (Reach 2) undergoes considerable degradation in the first six years due to the cutoff regulation and then oscillates with time. Big Sand Creek aggrades to .087 MCY and Pelucia Creek aggrades to .361 MCY. Figures 6.2 to 6.7 present the final bed elevation and maximum water surface for the mainstem, P-Q - Little Tallahatchie, Yocona, Tillatoba, Yalobusha, and Pelucia, respectively.

In general the run shows that the mainstem and the lower reaches of the tributaries will be stable or will aggrade slightly if existing condition continue. The upper reaches of the Little Tallahatchie and Yalobusha Rivers will degrade by bank and bed erosion. Flood stages along the mainstem will remain constant or increase.

6.3 Run 2 (Plan E Conditions)

Run 2 simulated Plan E conditions with few sediment control features. The Plan E channel was assumed in place, the plug in the Greenwood Bendway cutoff was only open for flow greater than 25,000 cfs, Pelucia Creek flows through a borrow excavation and Abiaca Creek flows through Matthews brake.

The Plan E run shows significant aggradation on the mainstem compared to the existing conditions run as shown in Figure 6.8. This aggradation is due to two factors. First the Plan E channel significantly reduces the sediment transporting ability of the channel. An example of this is Reach 1, the Yazoo River, from Belzoni to the Greenwood Bendway. At P.R. 119.3 located just above Belzoni, for the existing run 48 MCY of sediment were transported past the section while with Plan E only 23 MCY were transported. This is a 48 percent reduction. The reduction in transport occurs throughout the reach. At the

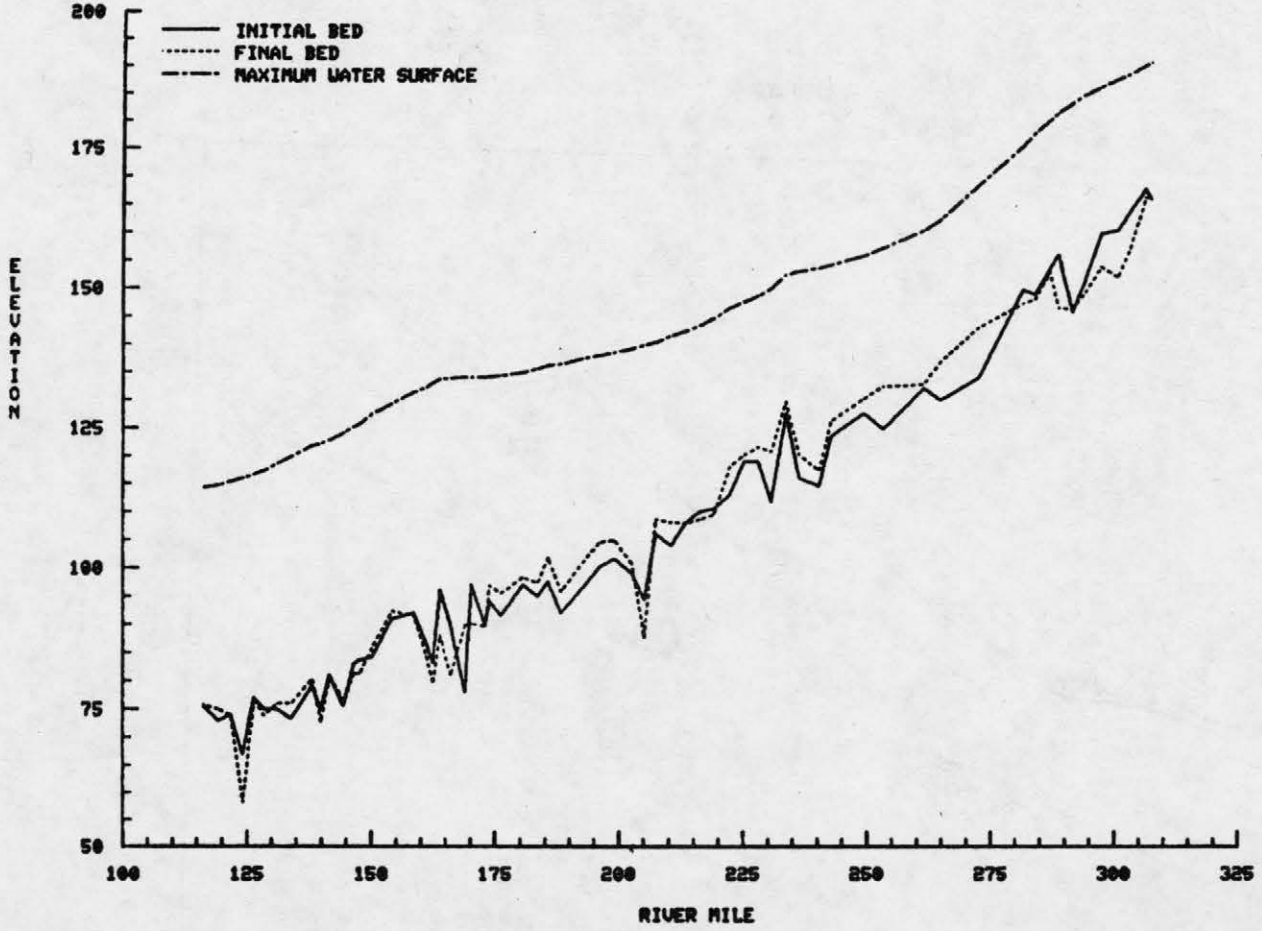


Figure 6.2. Profiles on mainstem for existing conditions (Run 1).

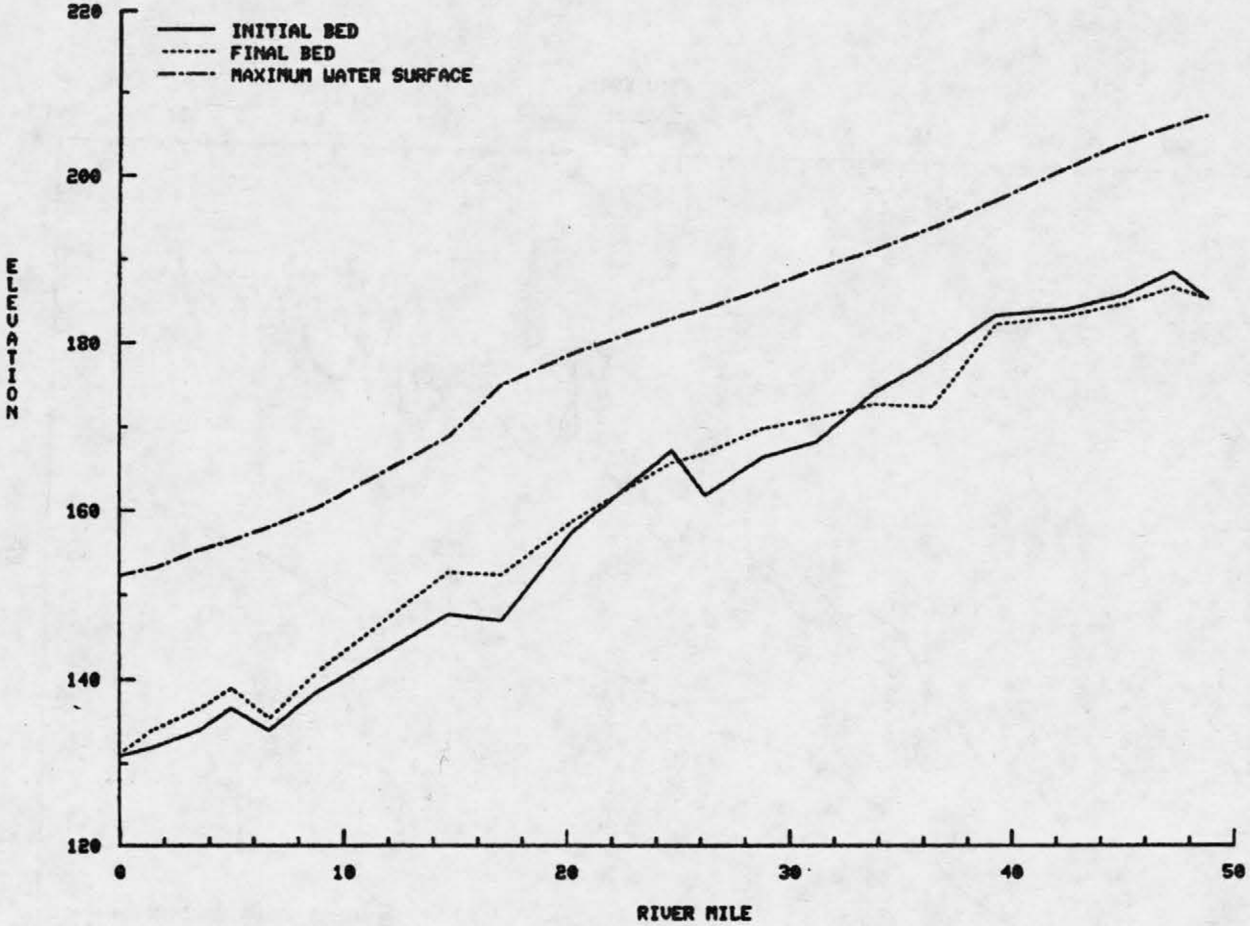


Figure 6.3. Profiles on P-Q, Little Tallahatchie existing conditions (Run 1).

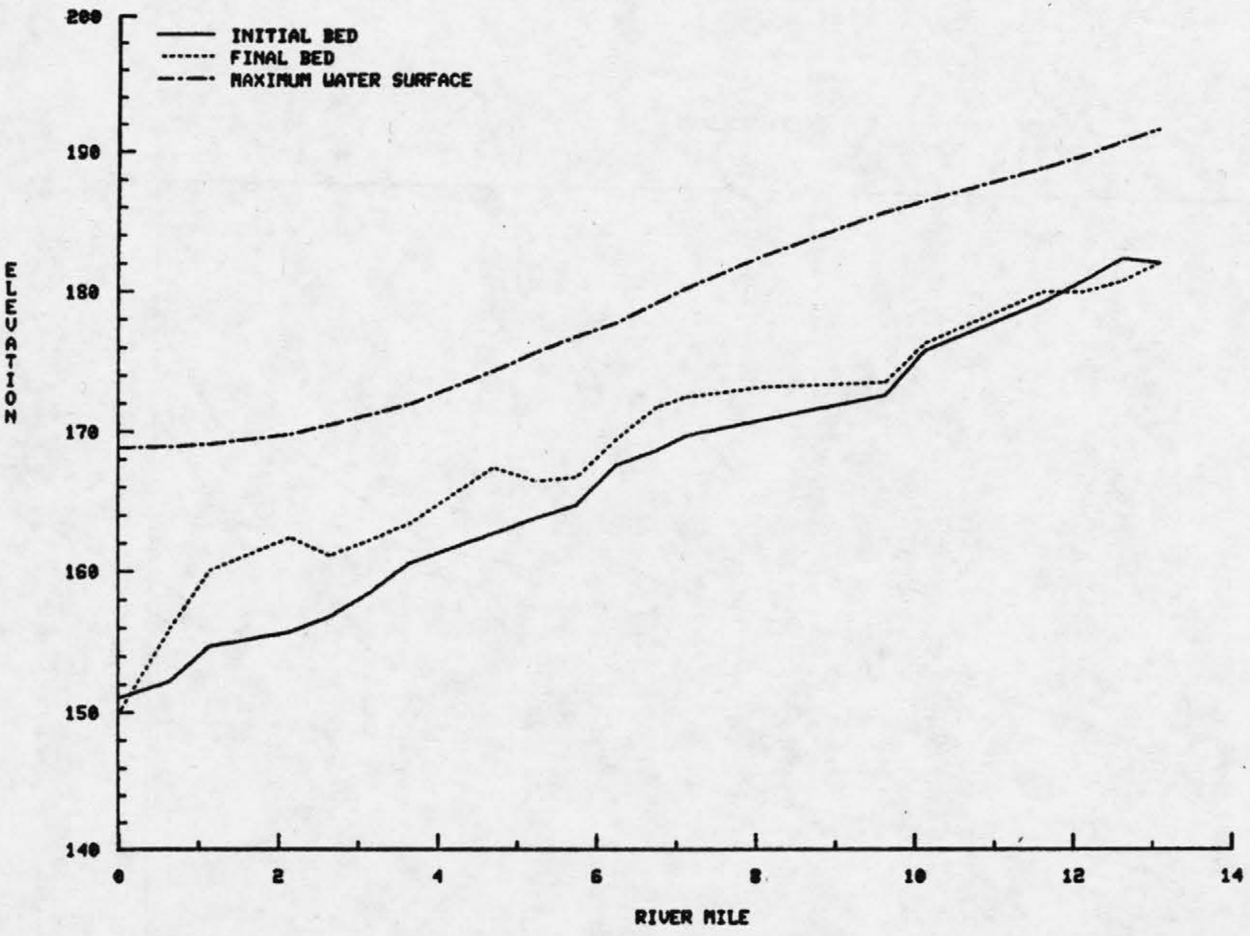


Figure 6.4. Profiles on Yocona River, existing conditions (Run 1).

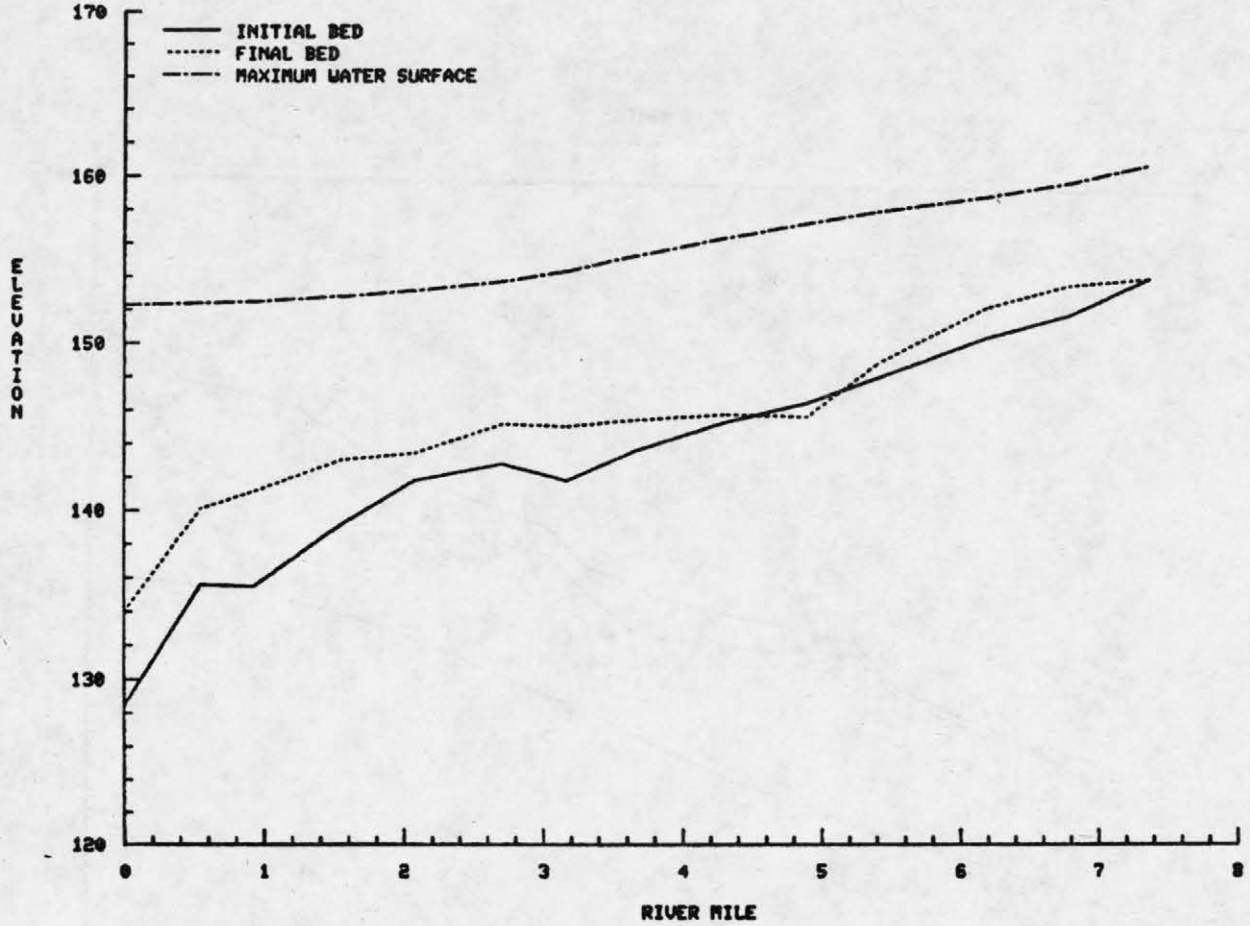


Figure 6.5. Profiles on Tillatoba Creek, existing conditions (Run 1).

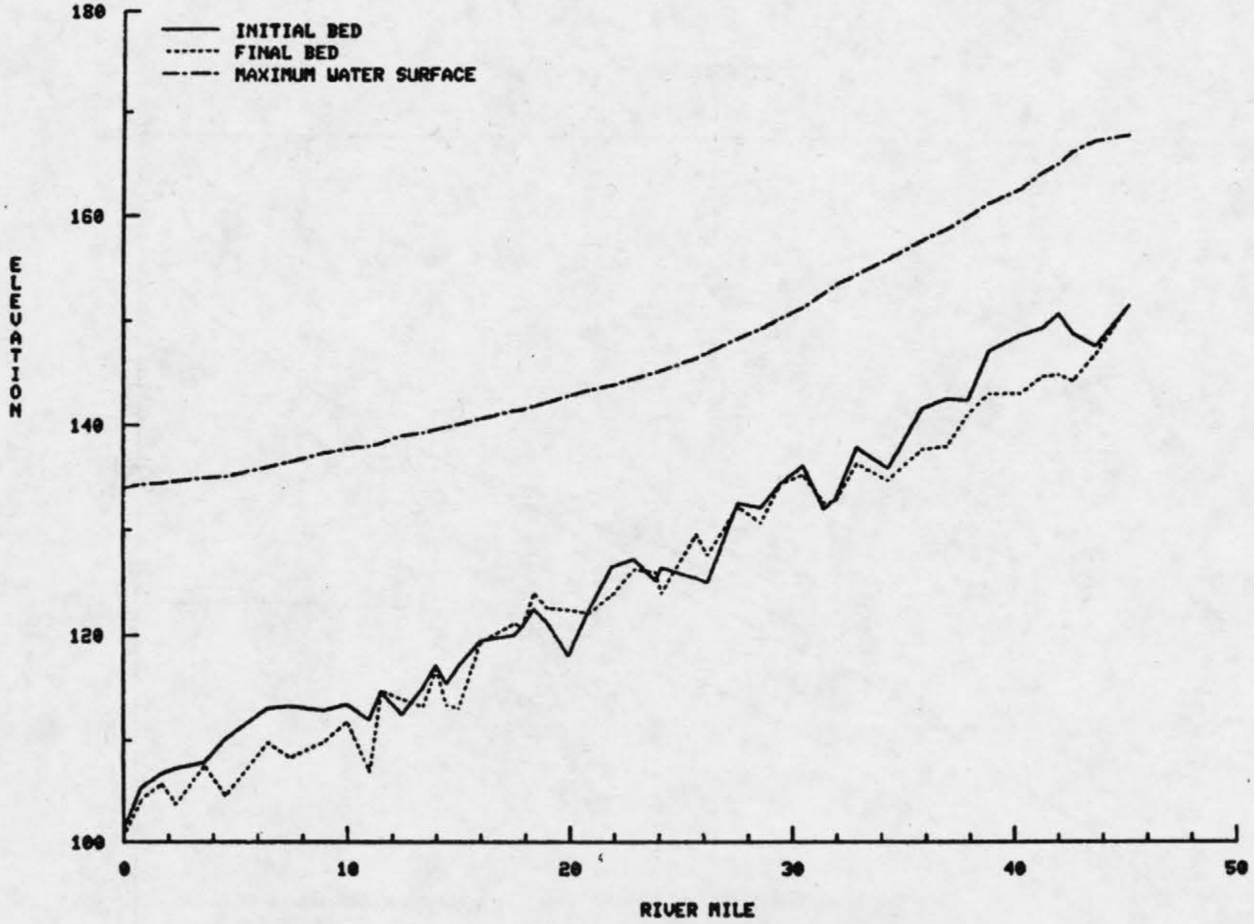


Figure 6.6. Profiles on Yalobusha River, existing conditions (Run 1).

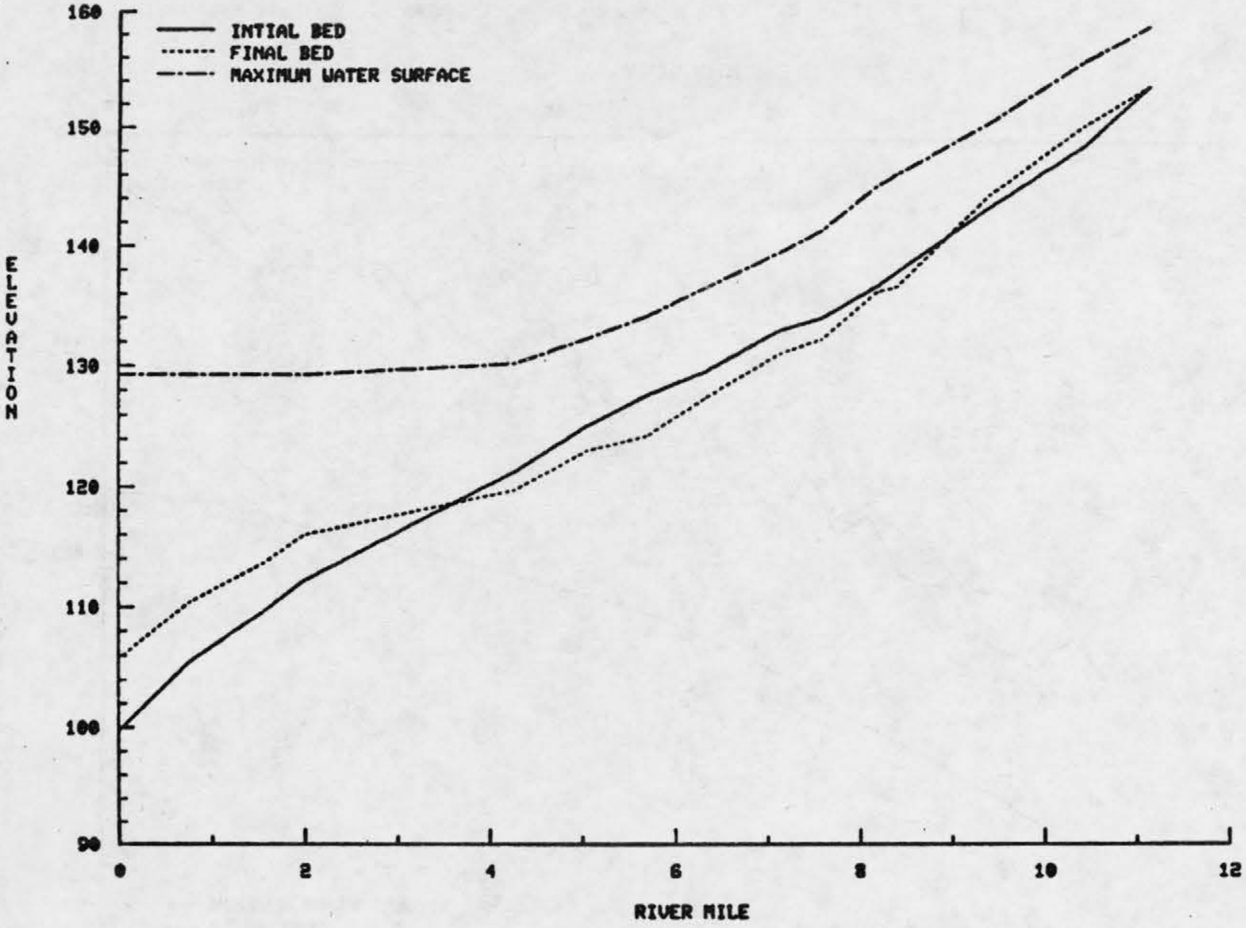


Figure 6.7. Profiles on Pelucia Creek, existing conditions (Run 1).

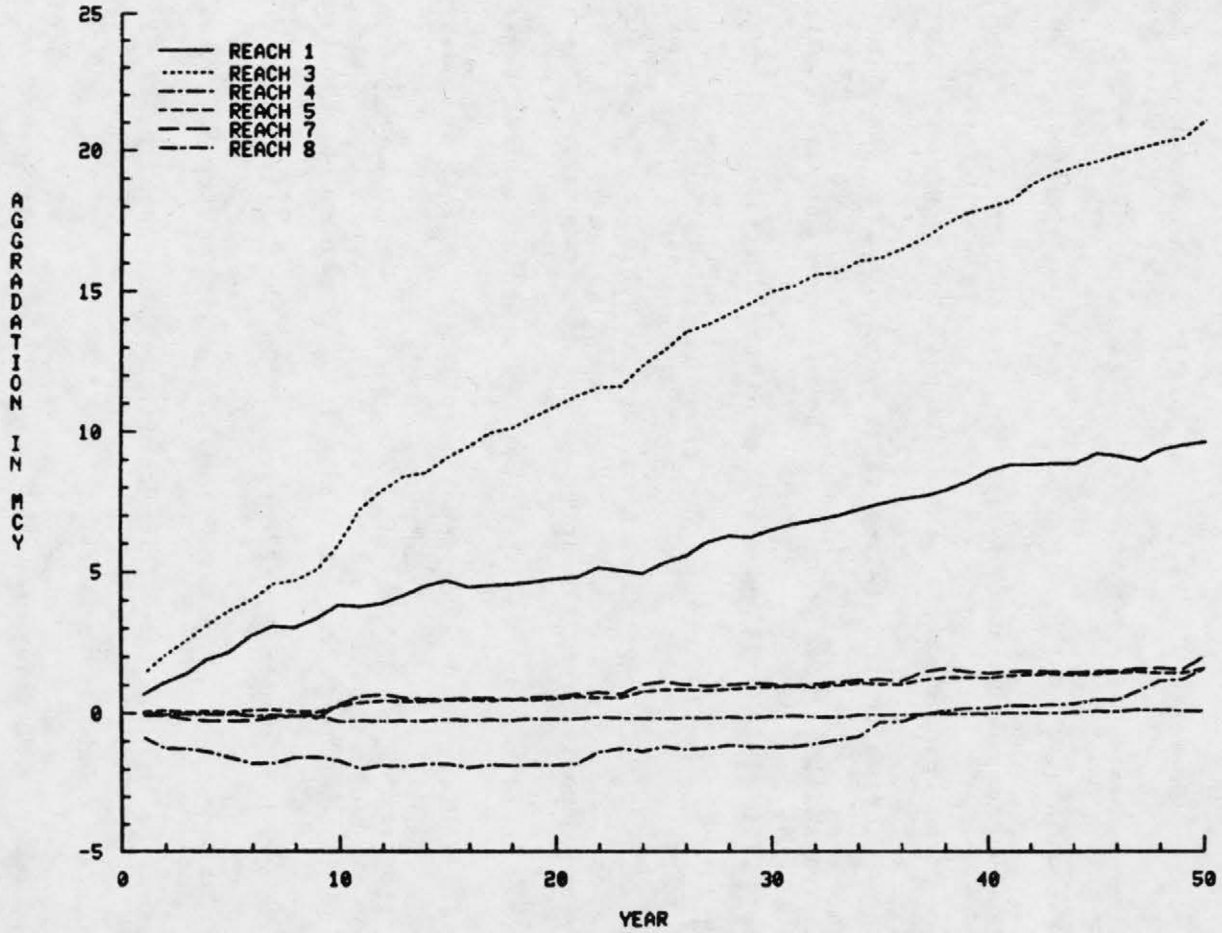


Figure 6.8. Volume of aggradation for River Reaches 1, 3, 5, 6, 7 and 8 for Plan E (Run 2).

was reduced by only 15 MCY. The sediment input from Abiaca Creek was 3.1 MCY (Appendix F) for both runs. The sediment input from Pelucia was 4.9 MCY under existing conditions and 3.5 MCY with the borrow excavation in Plan E. Thus the transport out of the reach was reduced more than the supply and aggradation resulted. Similar results were obtained on the other mainstem reaches. Figure 6.9 presents the volume of total transport versus mainstem river mile for existing and Plan E conditions.

The second factor which added to the mainstem aggradation was an initial head cutting on the tributaries, particularly the P.Q. Floodway, Yocona River and Pelucia Creek. Examination of the model results shows that most of the major tributaries experience an initial head cutting which started at their confluence with the mainstem and moved upstream with time. This head cutting was due to the initial base lowering caused by Plan E. The sediment eroded from the tributaries deposited in the mainstem forming a plug which then induced a high backwater on the tributary and deposition in the lower end of the tributary. This is a classic example of a complex response system where an initial degradation on a tributary produces a final aggradation in both the mainstem and the tributary.

As on the Existing Run, with Plan E the upper end of the Little Tallahatchie and Yalobusha Rivers degrade. On the Little Tallahatchie the degradation starts at River Mile 33.84 while on the Yalobusha it starts at River Mile 35.84. This degradation increases the supply of sediment to the downstream reaches.

The Greenwood Bendway and Cut-Off are well maintained by the regulation of the cut-off. The reduction of sediment from Pelucia Creek which was computed based on the Pelucia Project consisting of borrow

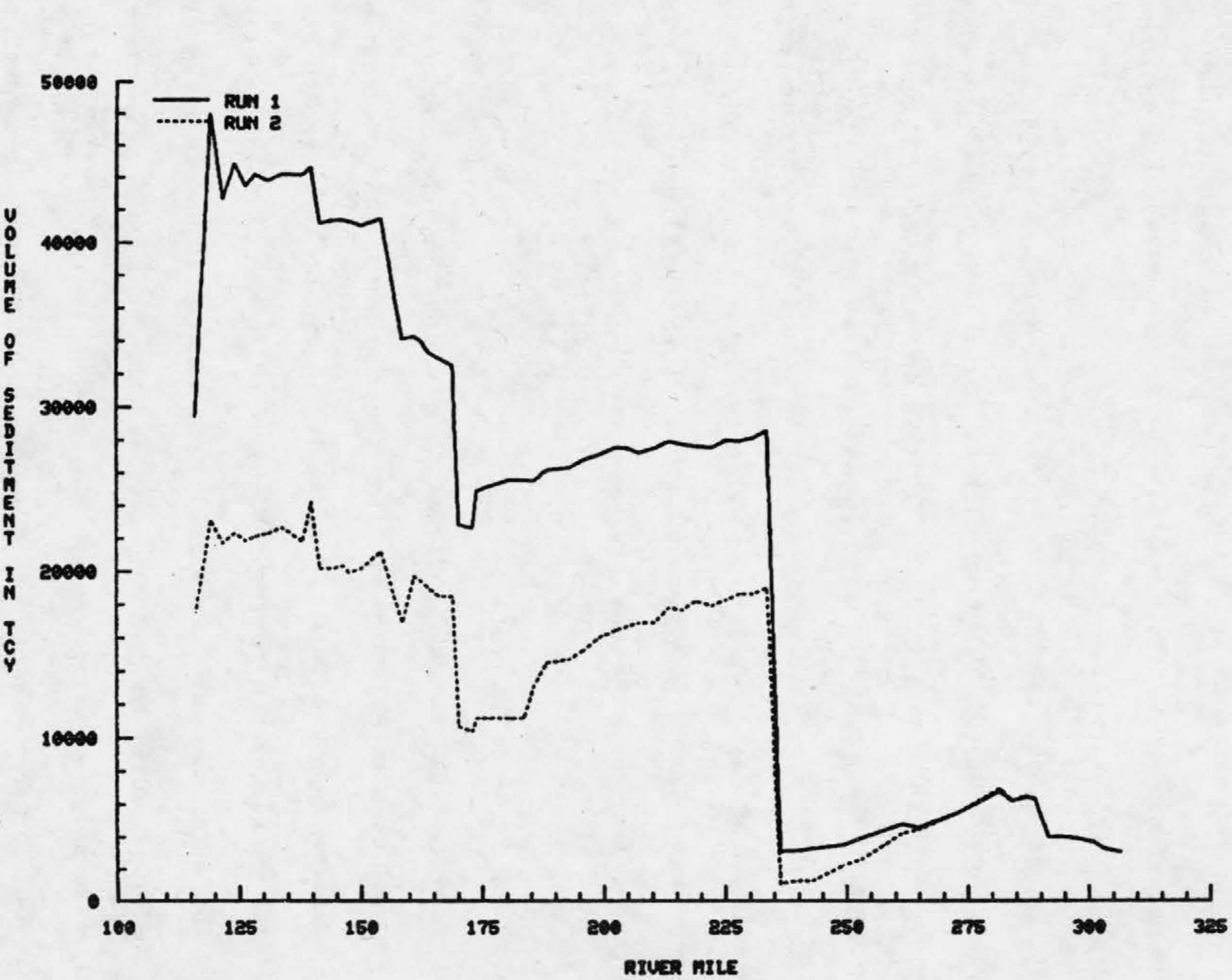


Figure 6.9. Volume of sediment transport on mainstem for Runs 1 and 2.

excavation within the leveed floodway also helped maintain the Plan E channel below the cutoff. The Cut-Off degrades in both cases since it is only used on high flows. Figures 6.10 through 6.15 present the initial and final bed profiles and the maximum water surface elevation for the mainstem, P-Q, Little Tallahatchie, Yocona, Tillatoba, Yalobusha and Pelucia, respectively.

It is important to note that if the Plan E channel is allowed to accumulate sediment for 50 years without maintenance, the flood stage reduction for Plan E will be lost. This is demonstrated by Figure 6.16 which compares the maximum water surface elevations for Plan E and Existing Conditions at Greenwood. As can be seen for the 50 year period Plan E will have stages equal to or slightly higher than existing. Plan E is more stable above the Bendway as is shown by Figure 6.17. The figure shows that Plan E stage reduction is only reduced by one-half after 50 years.

6.4 Run 3 (Grade Control)

A grade control run was performed to evaluate the effectiveness of grade control structures in controlling the aggradation and degradation on the mainstem and tributaries. After reviewing the Existing and Plan E runs eight structures were located and sized to minimize the problems seen in the first two runs. The grade control structures are listed in Table 1.3 (page 10). As the table shows, the structures were placed only slightly above existing grade. The sections at the structures were modified to represent conditions after a typical sheet pile structure placement. The banks were slightly widened and the bottom lowered even with the structure. Thus the flow area at the structure was kept roughly constant. This design was chosen to minimize any backwater the

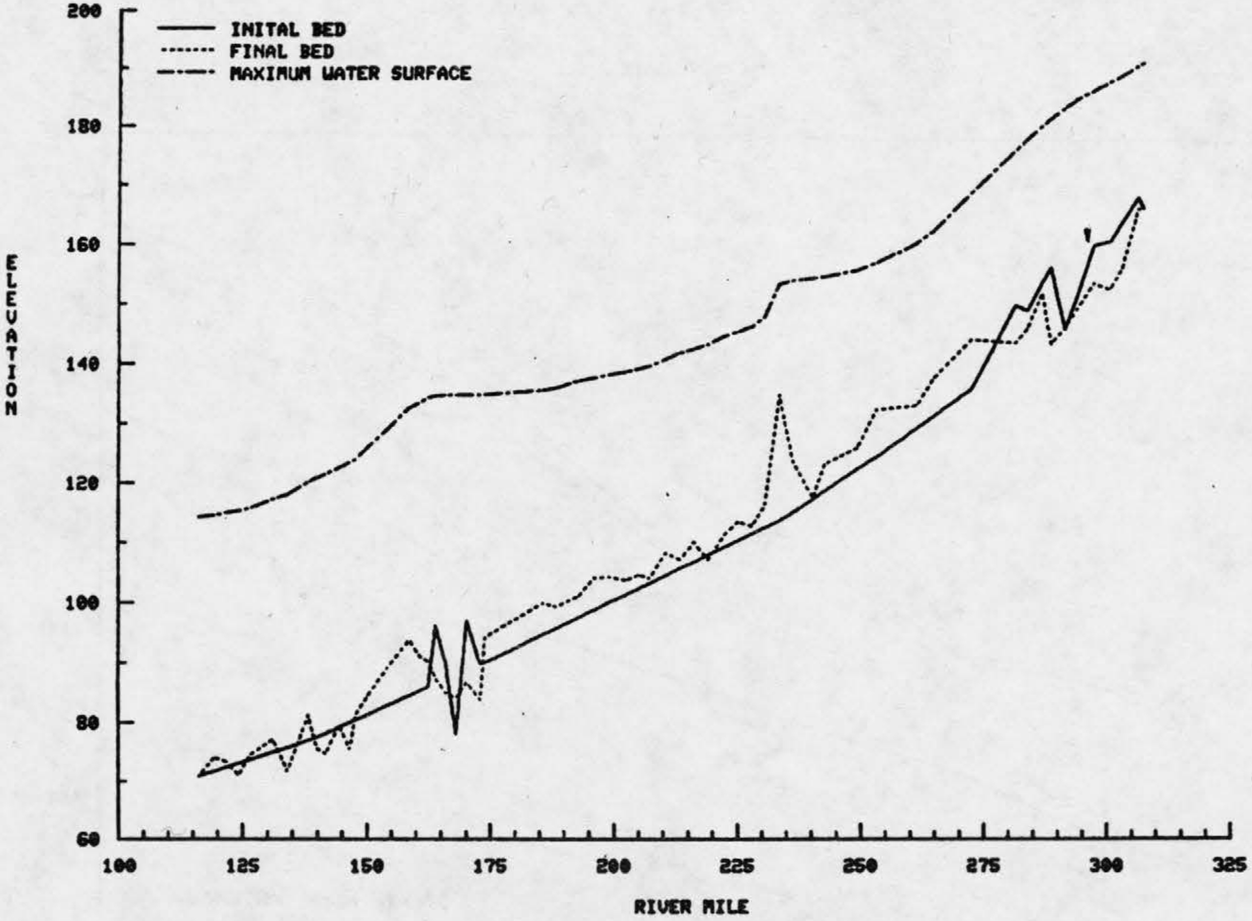


Figure 6.10. Profiles on mainstem for Plan E conditions (Run 2).

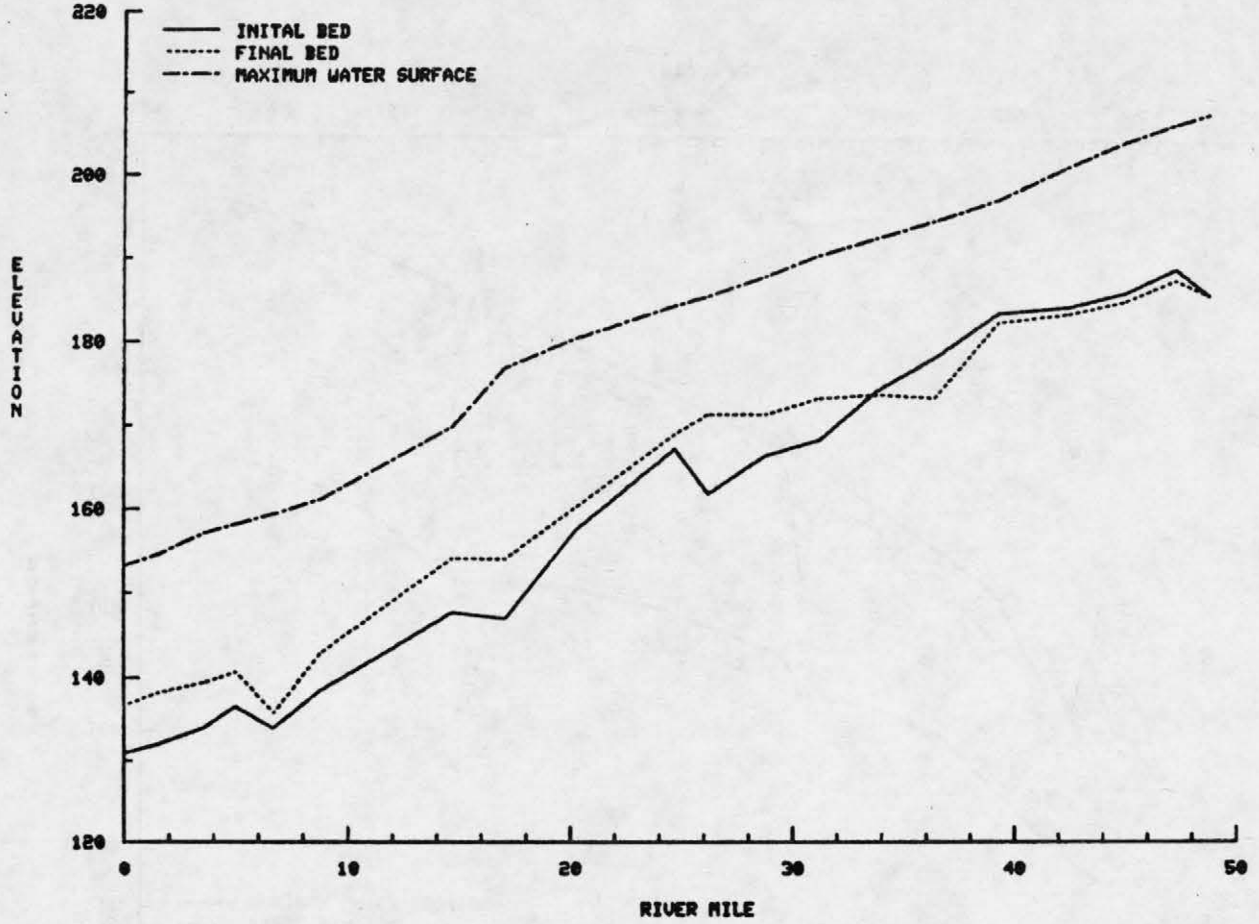


Figure 6.11. Profiles on P-Q, Little Tallahatchie Plan E conditions (Run 2).

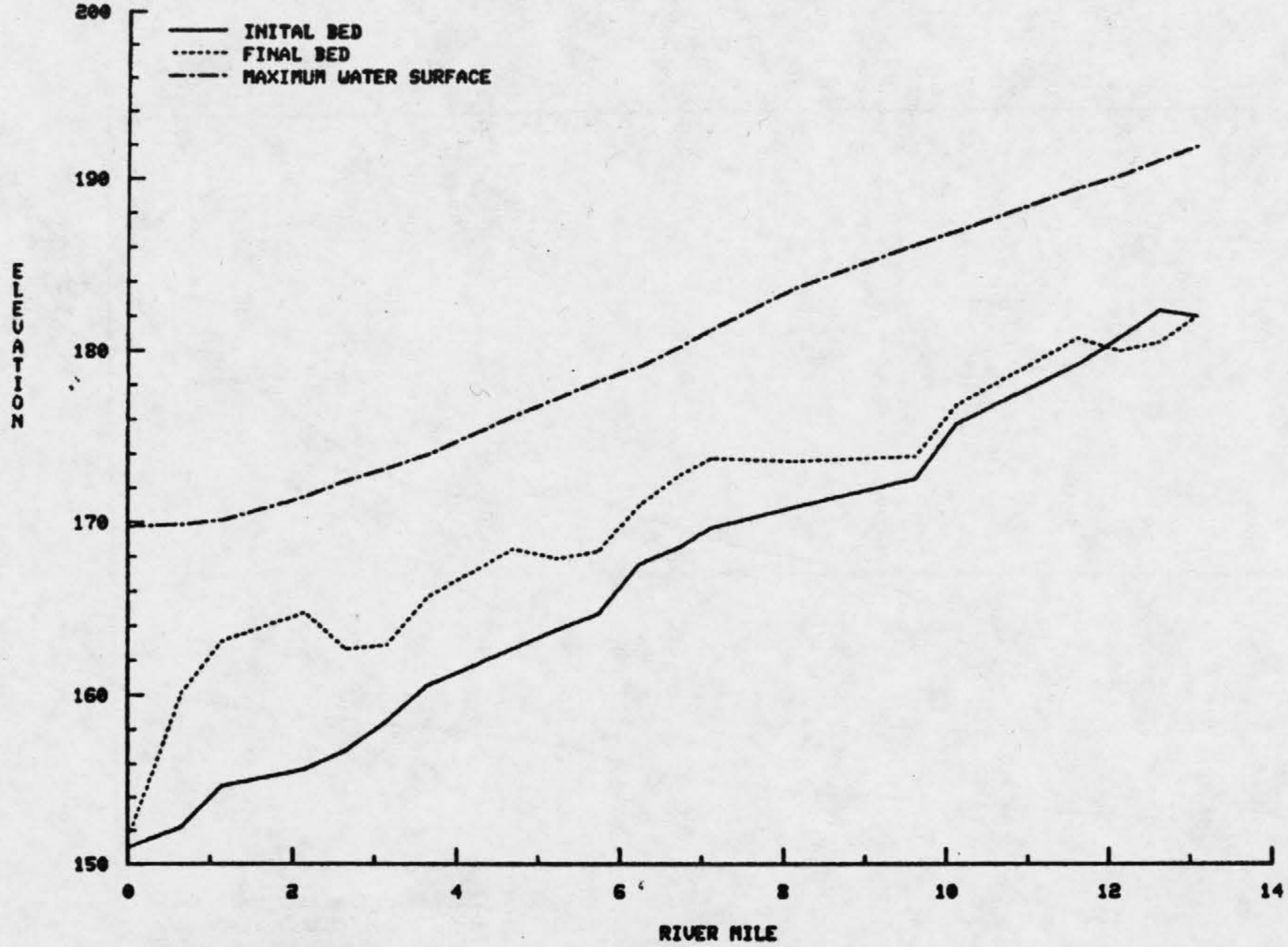


Figure 6.12. Profiles on Yocona River Plan E conditions (Run 2).

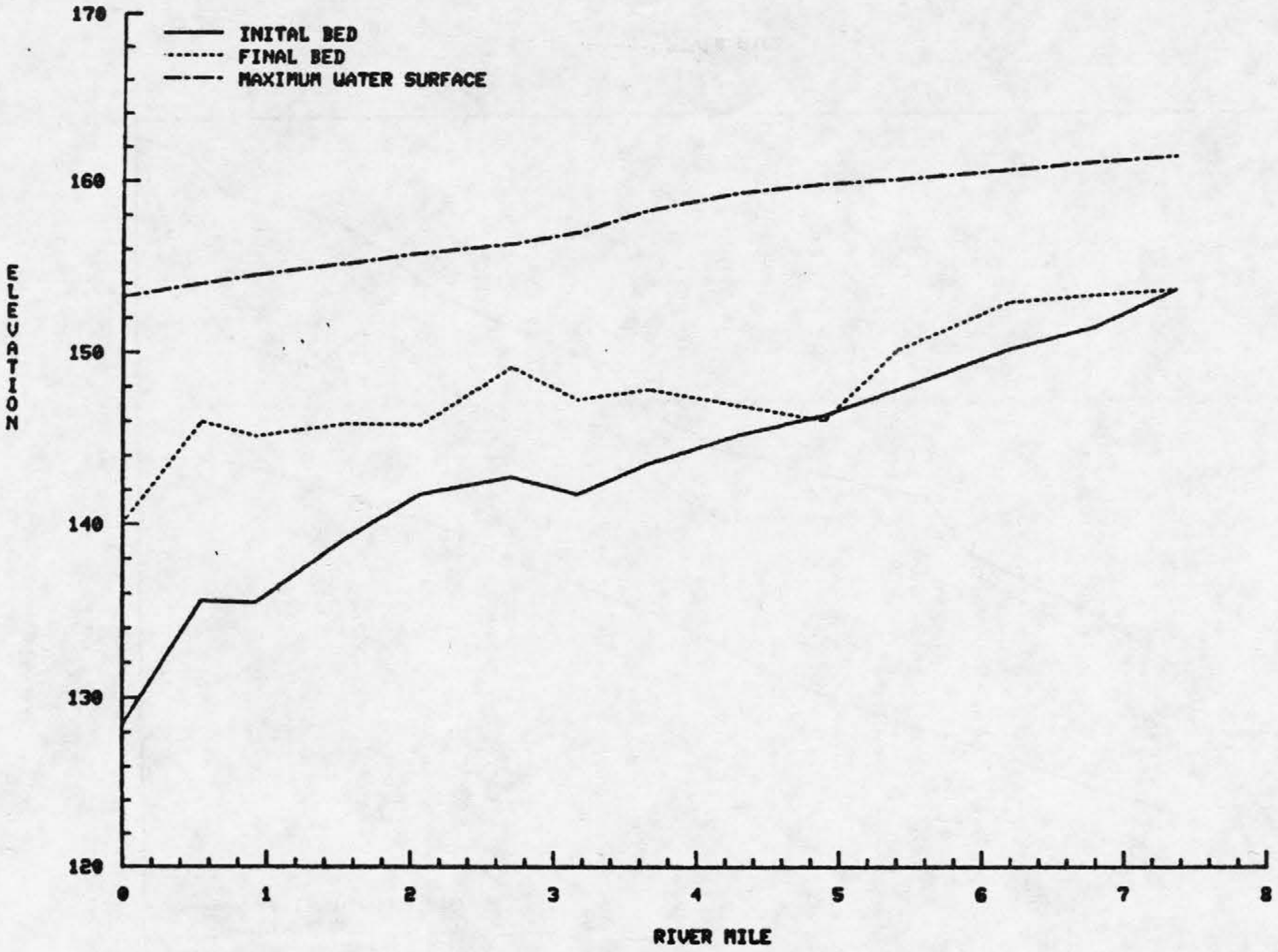


Figure 6.13. Profiles on Tillatoba Creek Plan E conditions (Run 2).

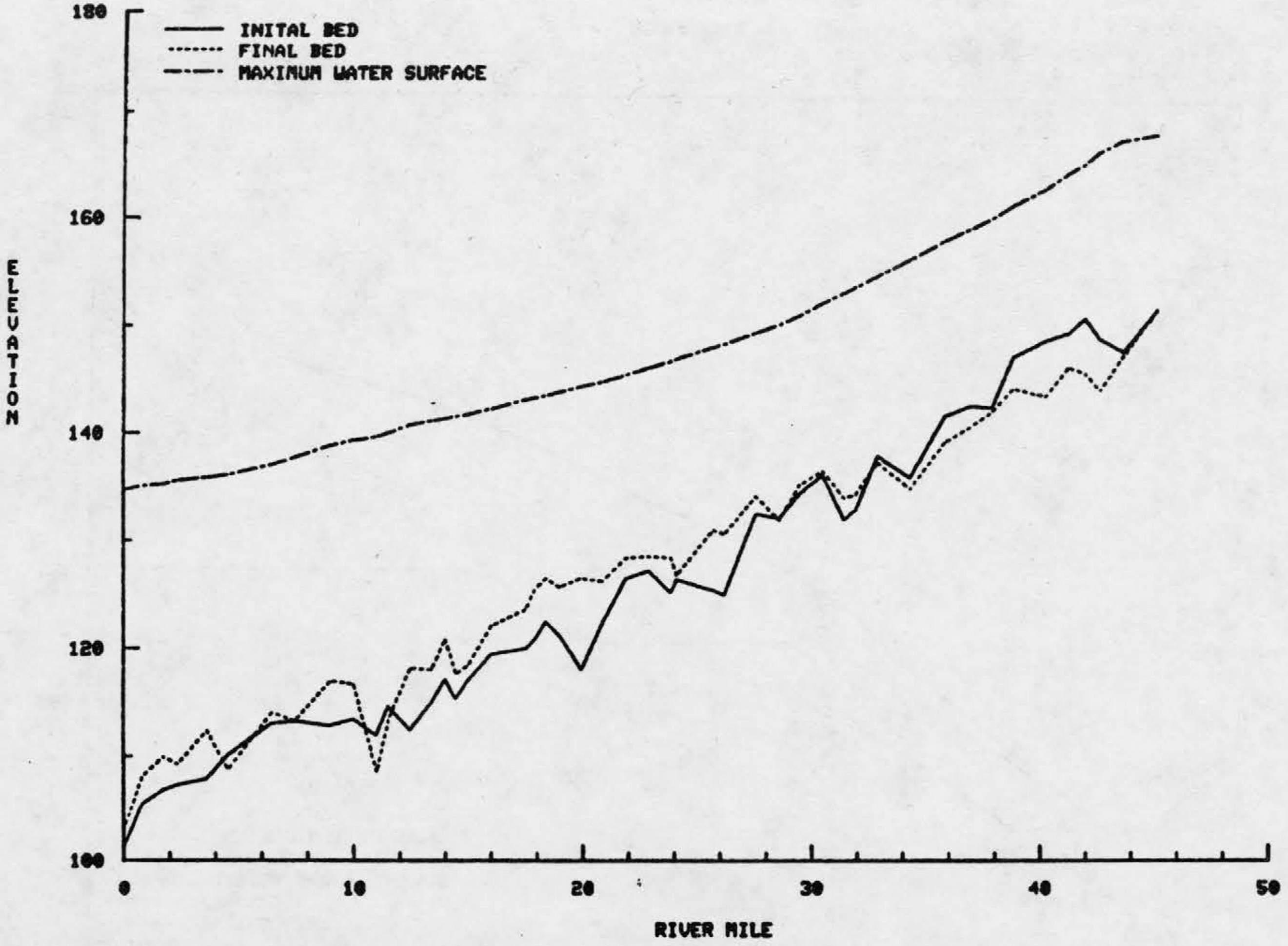


Figure 6.14. Profiles on Yalobusha River Plan E conditions (Run 2).

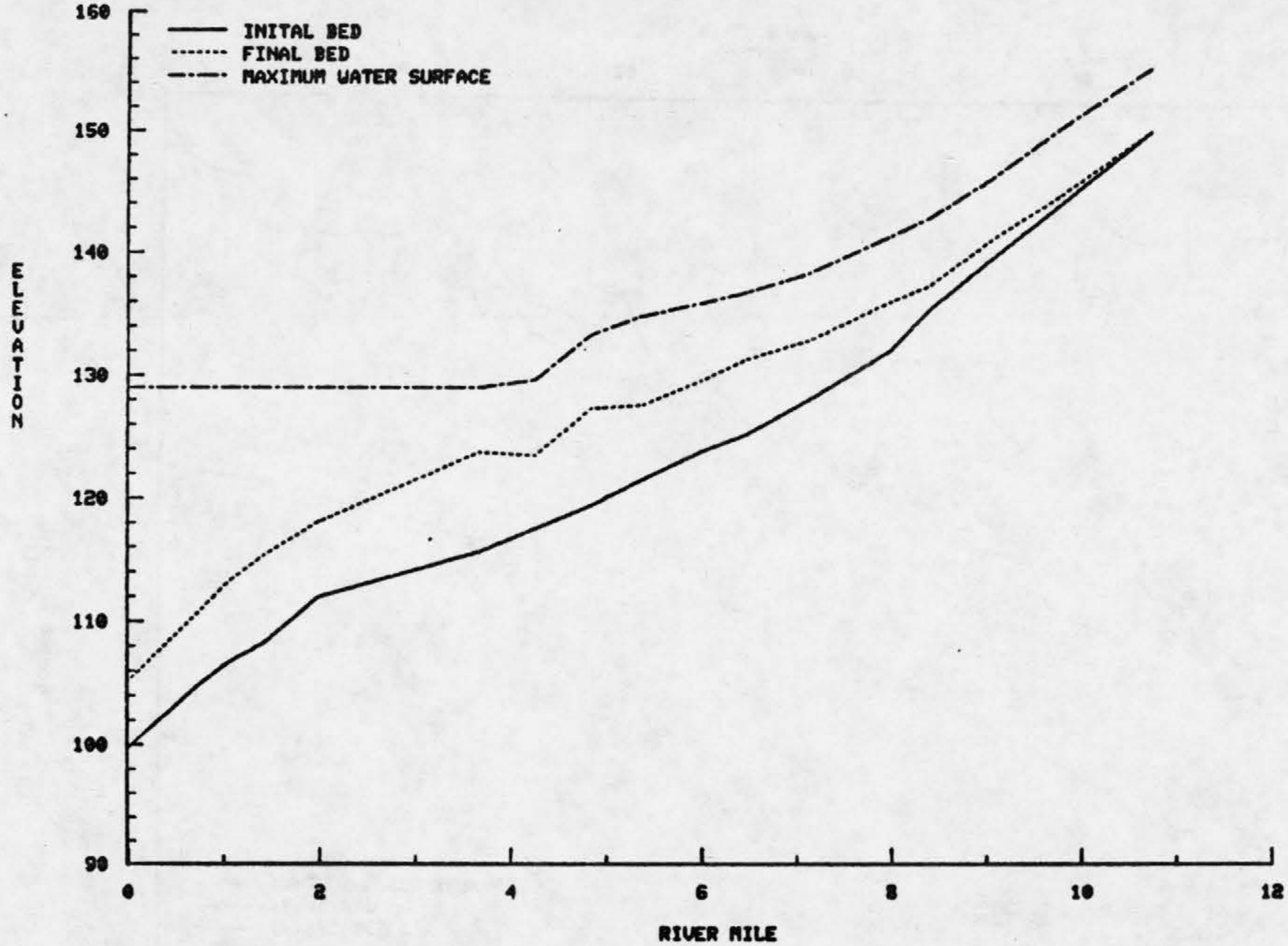


Figure 6.15. Profiles on Pelucia Creek Plan E conditions (Run 2).

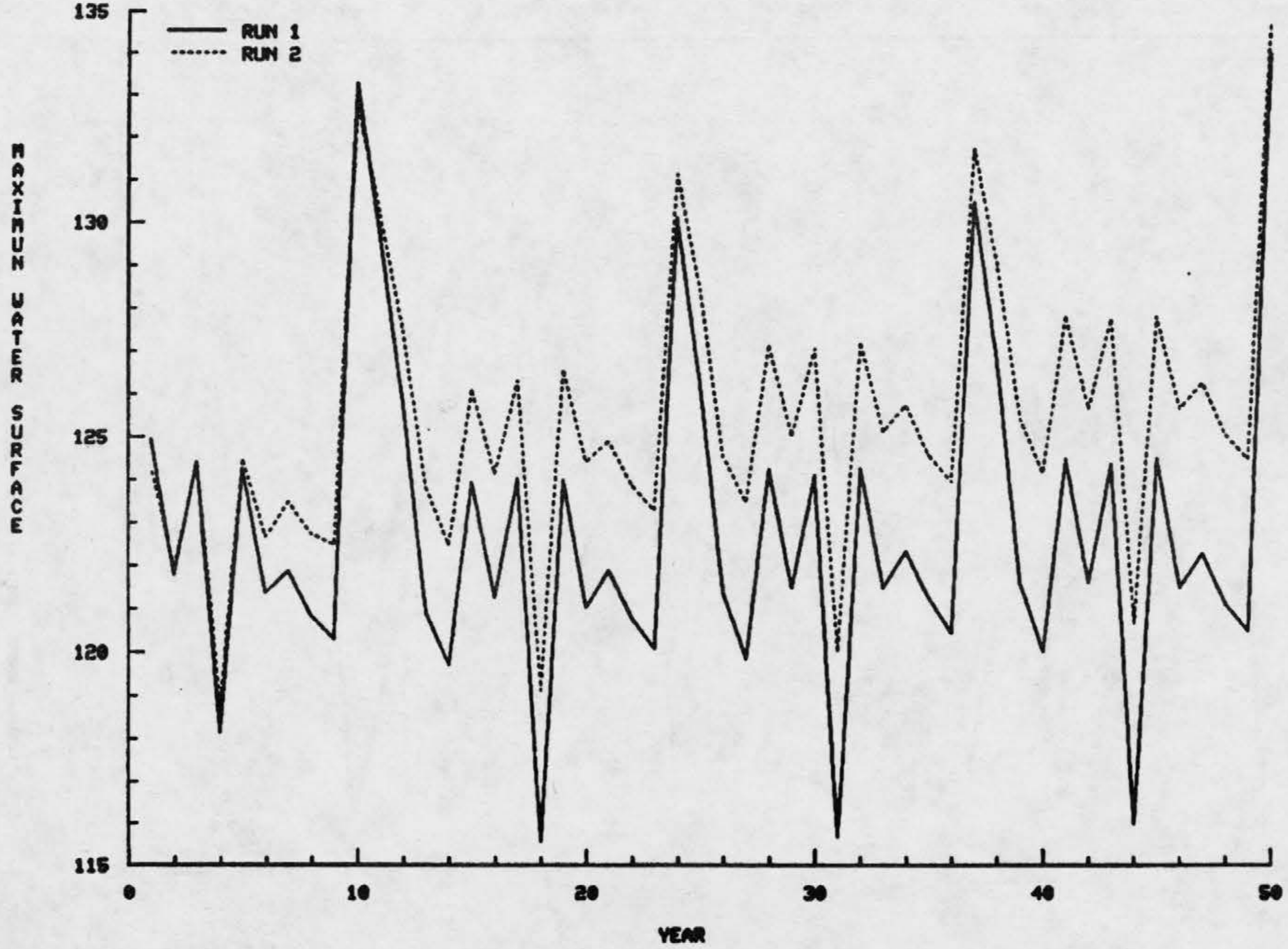


Figure 6.16. Annual maximum water surface at Greenwood.

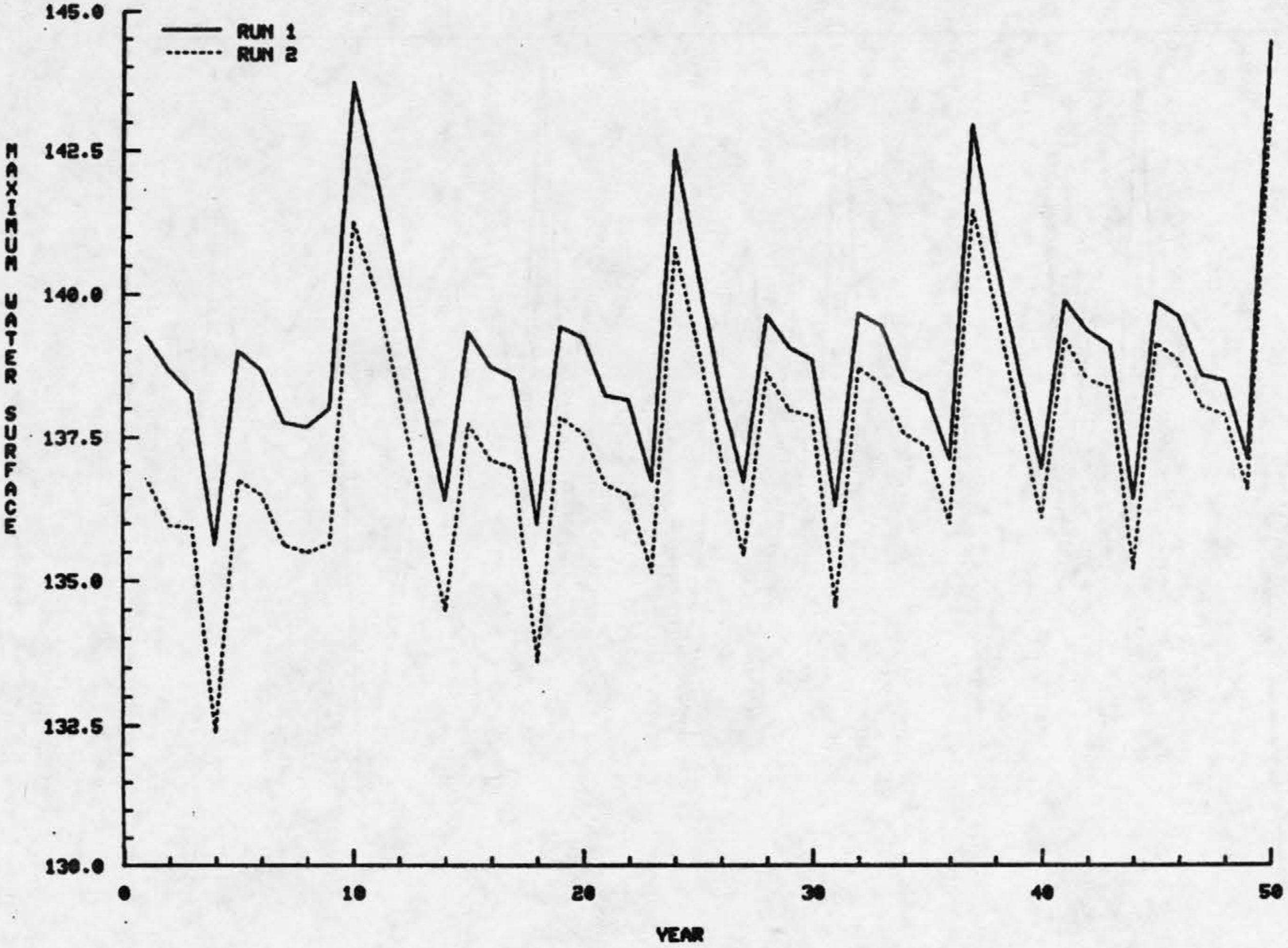


Figure 6.17. Annual maximum water surface at Swanlake.

structures would cause. Structures were placed at the mouths of the P-Q, Tillatoba, Yocona, and Pelucia Creek to minimize head cutting. Two structures each were placed on the Little Tallahatchie and Yalobusha to minimize the upstream erosion. Except for the structures the grade control run used the same spacial and temporal design as the Plan E run. Figure 6.18 shows the volume of aggradation in the major river reaches. Figures 6.19 to 6.24 show the initial and final bed profiles and the maximum water surface elevation for each reach. Vertical lines indicate position of weirs.

As can be seen in Table 6.1 the structures only reduced aggradation slightly. Table 6.2 lists the volume of sediment that passed over each structure and the corresponding location in the Plan E run. The table shows that only the Little Tallahatchie structures were effective in reducing total sediment transport. This is due to their height above the existing bed compared to the other structures. All four of the

Table 6.2 Performance of Grade Control Structures

Stream	River Mile	Sediment Transport Plan E 10^6 yrds	 Grade Control 10^6yrds	Buried	Year Last Exposed ft
P-Q	0.00	15.5	15.2	9.9	7
Little Tallahatchie	33.84	14.3	10.2	0.0	50
	39.34	13.9	9.80	0.1	50
Yocona	0.00	3.23	3.53	0.8	50
Tillatoba	0.00	4.95	4.97	7.4	4
Yalobusha	34.31	7.36	7.04	0.9	1
	40.26	7.24	6.87	0.0	50
Pelucia	0.00	3.52	3.45	4.4	40

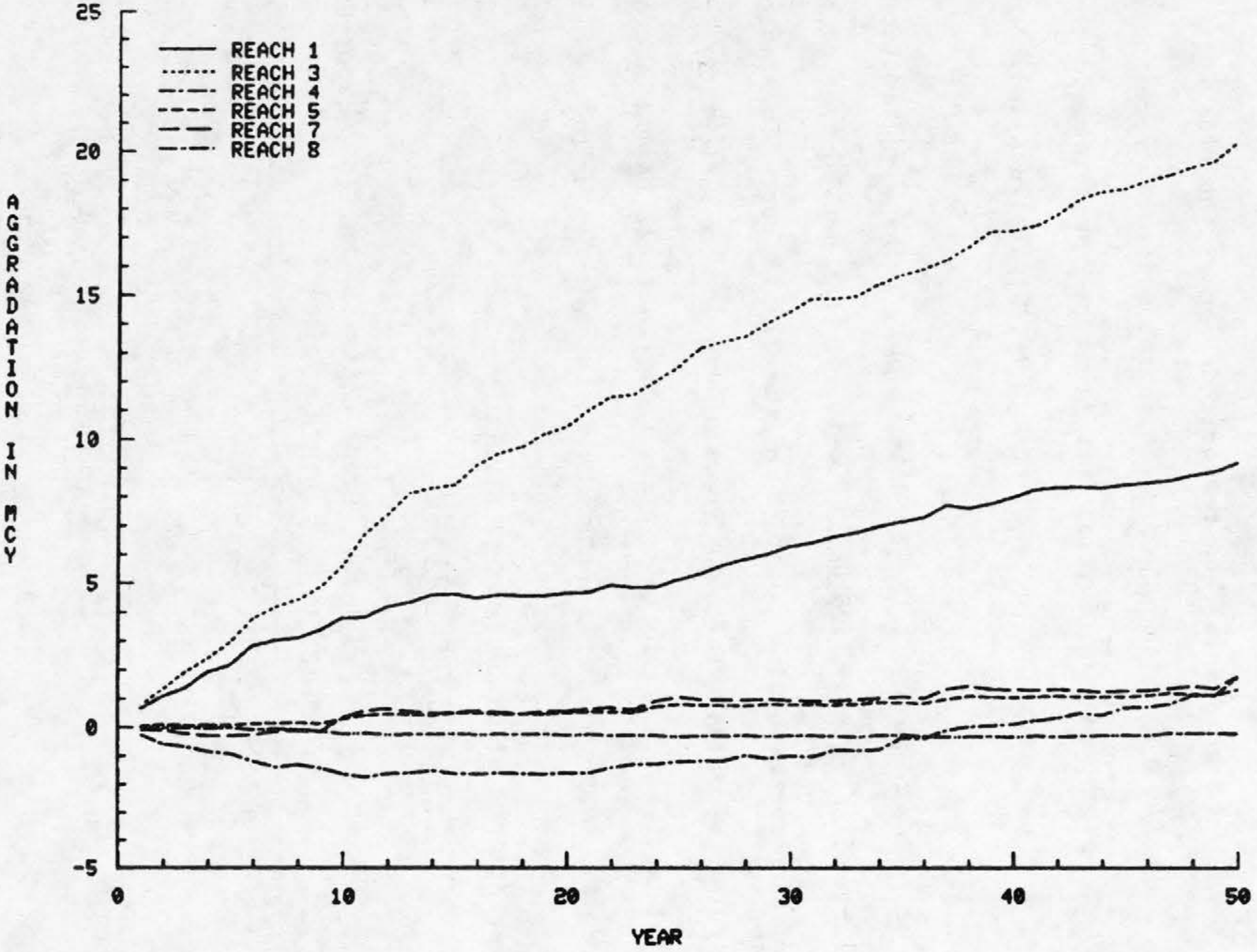


Figure 6.18. Volume of aggradation for river reacher 1, 3, 4, 5, 6, 7 and 8 for grade control (Run 3).

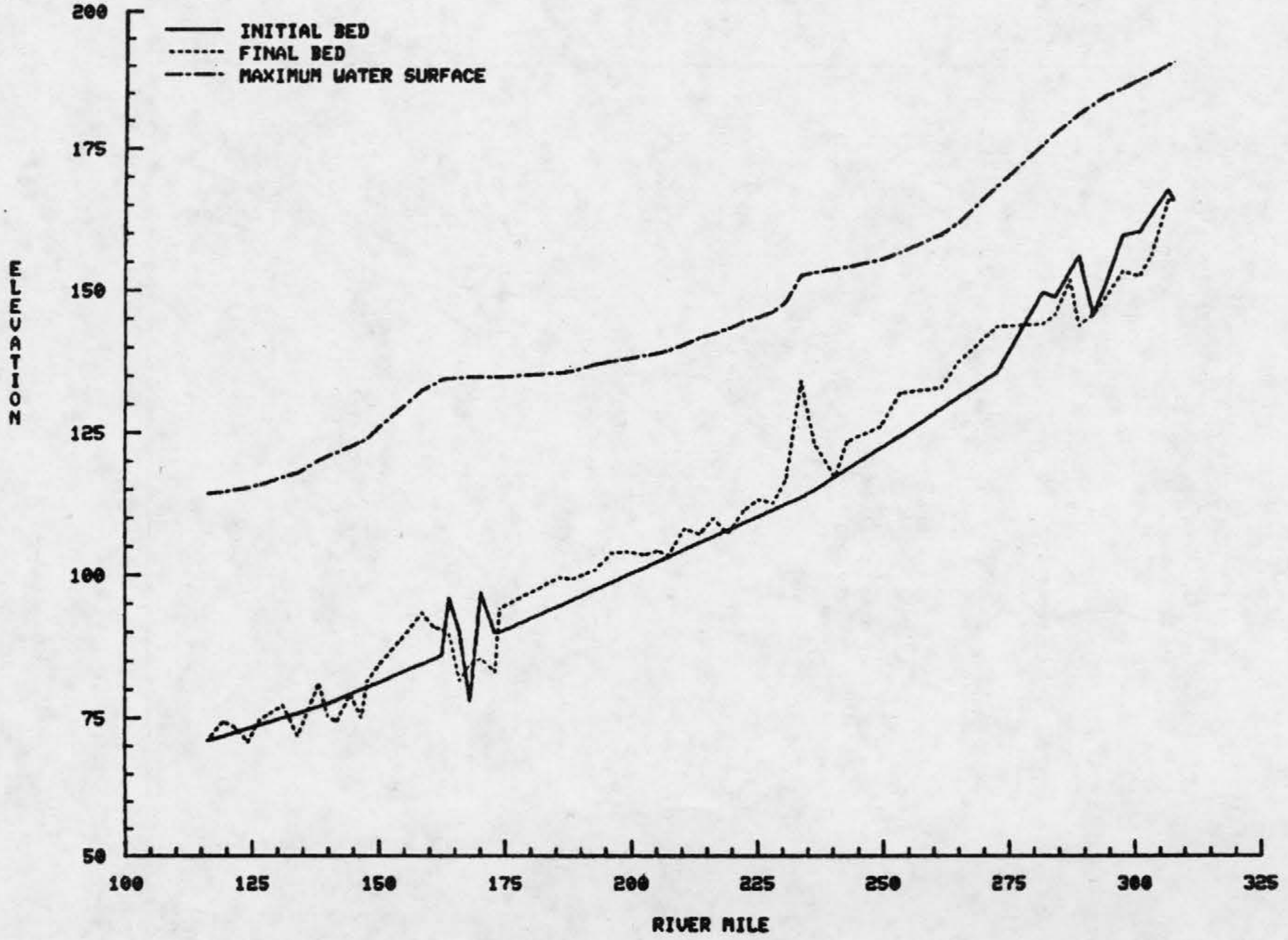


Figure 6.19. Profiles on mainstem for grade control conditions (Run 3).

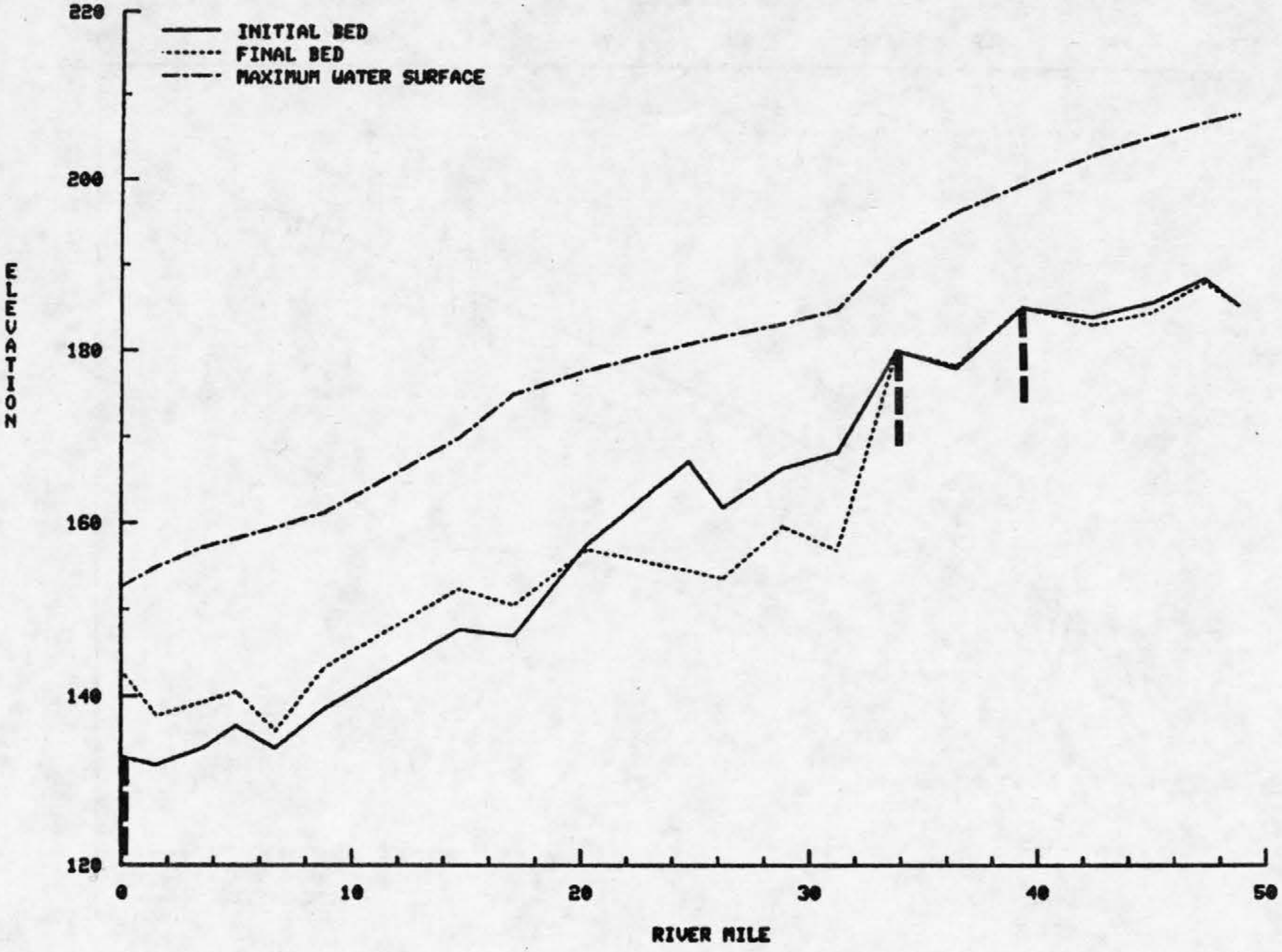


Figure 6.20. Profiles on P-Q, Little Tallahatchie for grade control conditions (Run 3).

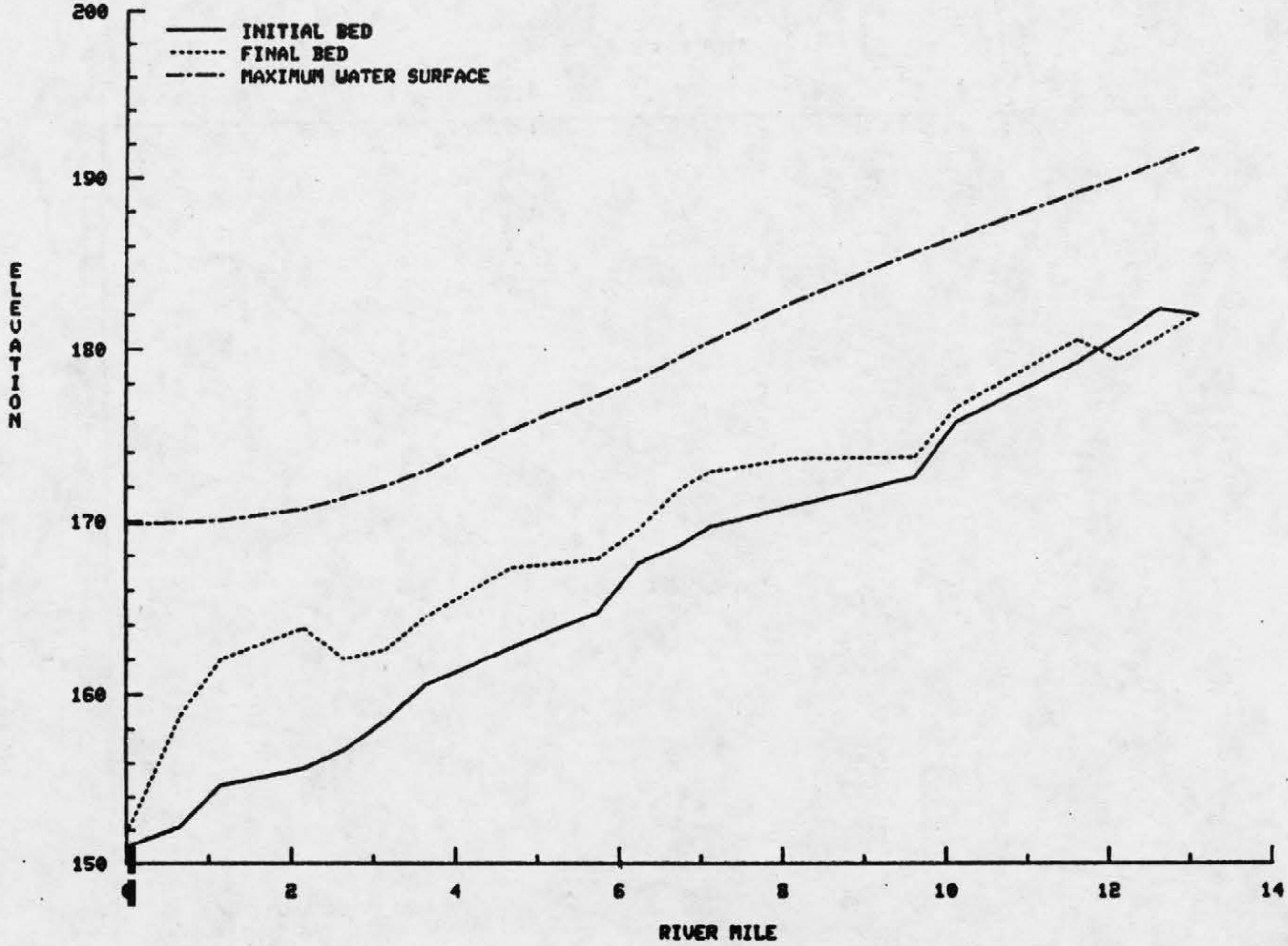


Figure 6.21. Profiles on Yocona River for grade control conditions (Run 3).

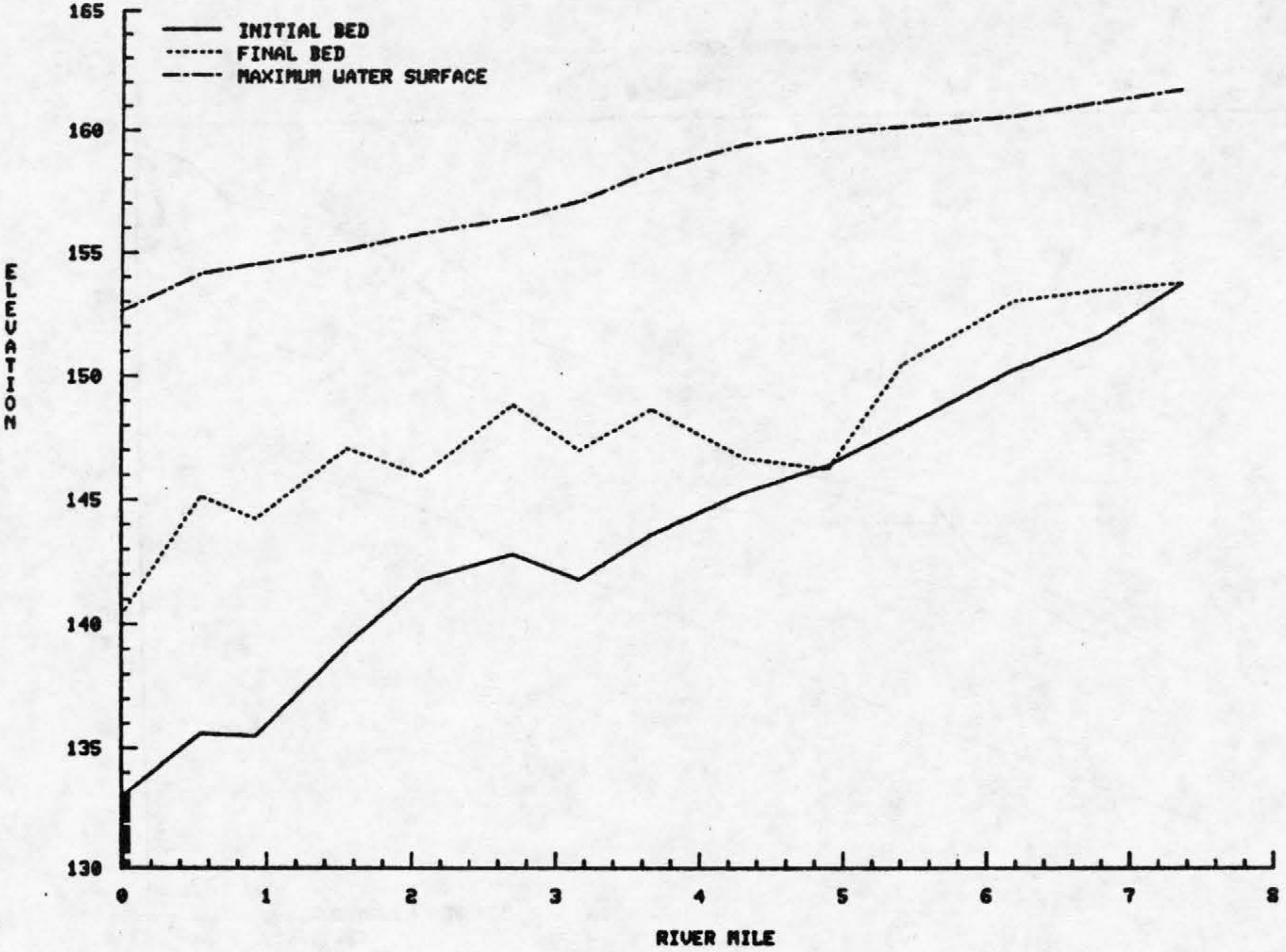


Figure 6.22. Profiles on Tillatoba Creek for grade control conditions (Run 3).

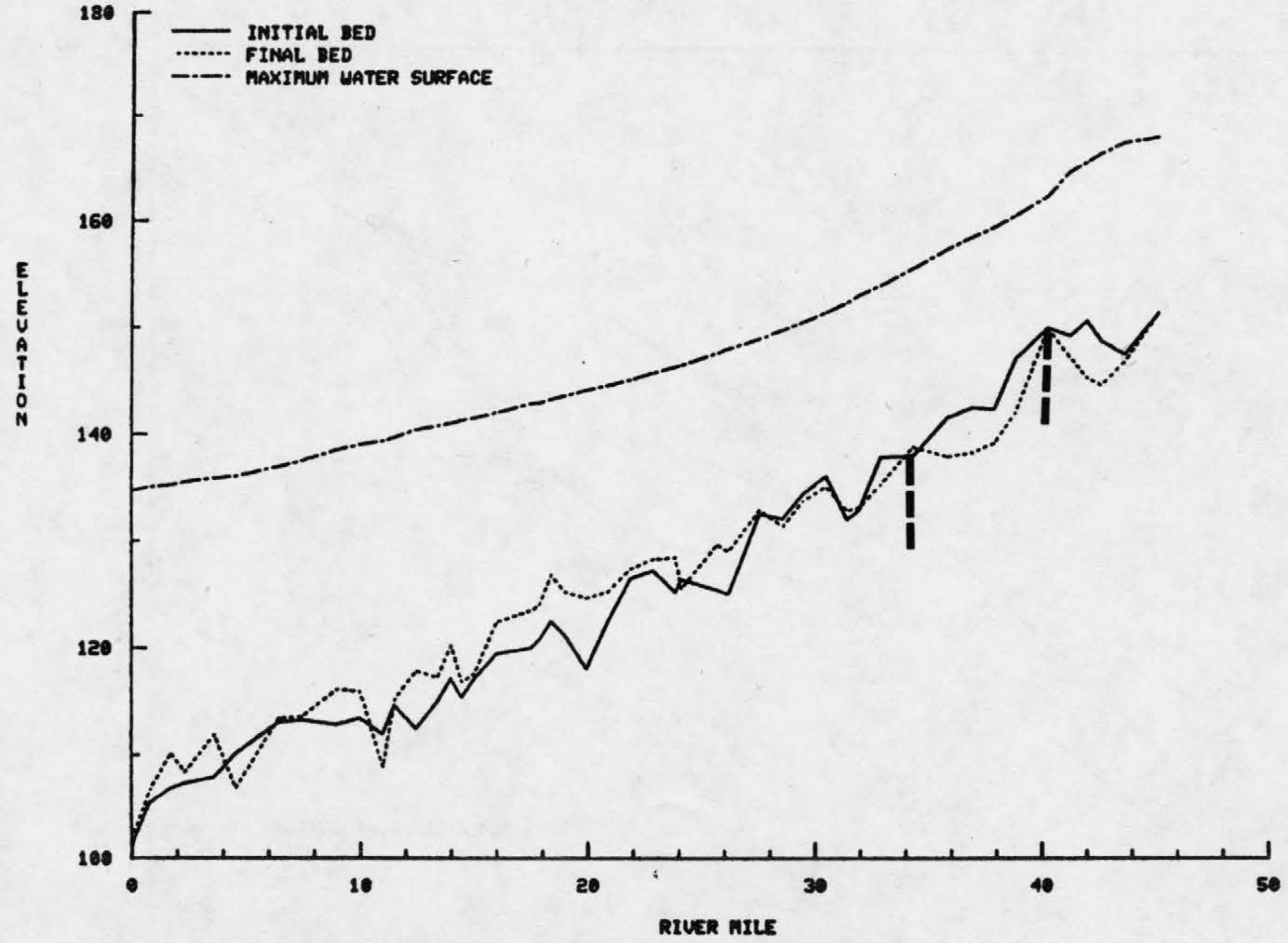


Figure 6.23. Profiles on Yalobusha River for grade control conditions (Run 3).

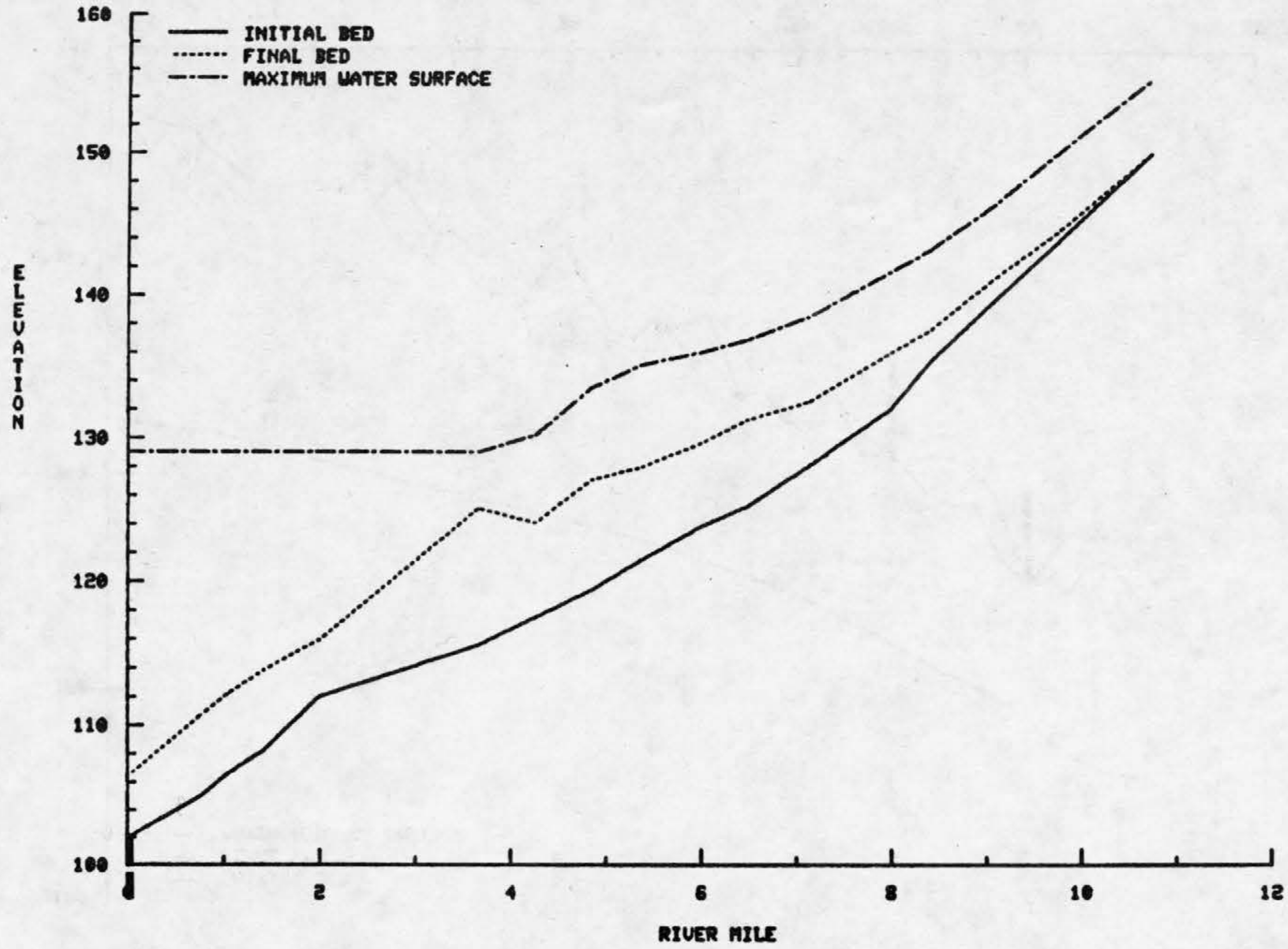


Figure 6.24. Profiles on Pelucia Creek for grade control conditions (Run 3).

structures at the tributary mouths were buried at the end of the simulation and only the structures on the Yocona and Pelucia were active throughout the simulation as shown by the year last exposed. These four structures would be more effective if raised.

The two structures on the Upper Yalobusha were effective at their locations in stopping erosion but the erosion was simply moved downstream. Figure 6.23 shows the scour below each structure on the Yalobusha River. For grade control to work on this reach additional structures would be required. Maximum water surface elevations on the mainstem were similar to Plan E conditions with only a slight reduction in stage above the P-Q Floodway as shown by Figure 6.25.

6.5 Run 4 (Tributary Control)

Considerable work has been performed by the USDA Soil Conservation Service in the watersheds of small tributaries to the mainstem and major tributaries to reduce soil and bank erosion. This work is undoubtably of value in the actual watershed but has had unknown impact to reducing sedimentation in the mainstem. Run No. 4 was performed to determine the effectiveness of large scale tributary sediment reduction. The simulation was similar to Run No. 3 except the sediment input from the point source tributaries was reduced by 25%. The specific structures required to achieve this reduction was not determined, but it is felt that a major construction program involving detention dams, grade control and bank stabilization would be required.

Figure 6.26 shows the volume of aggradation for the larger reaches over the 50 years of simulation. Figures 6.27 to 6.32 show the initial and final bed profiles and the maximum water surface elevation for each reach for the tributary run. Table 6.1 shows that the tributary

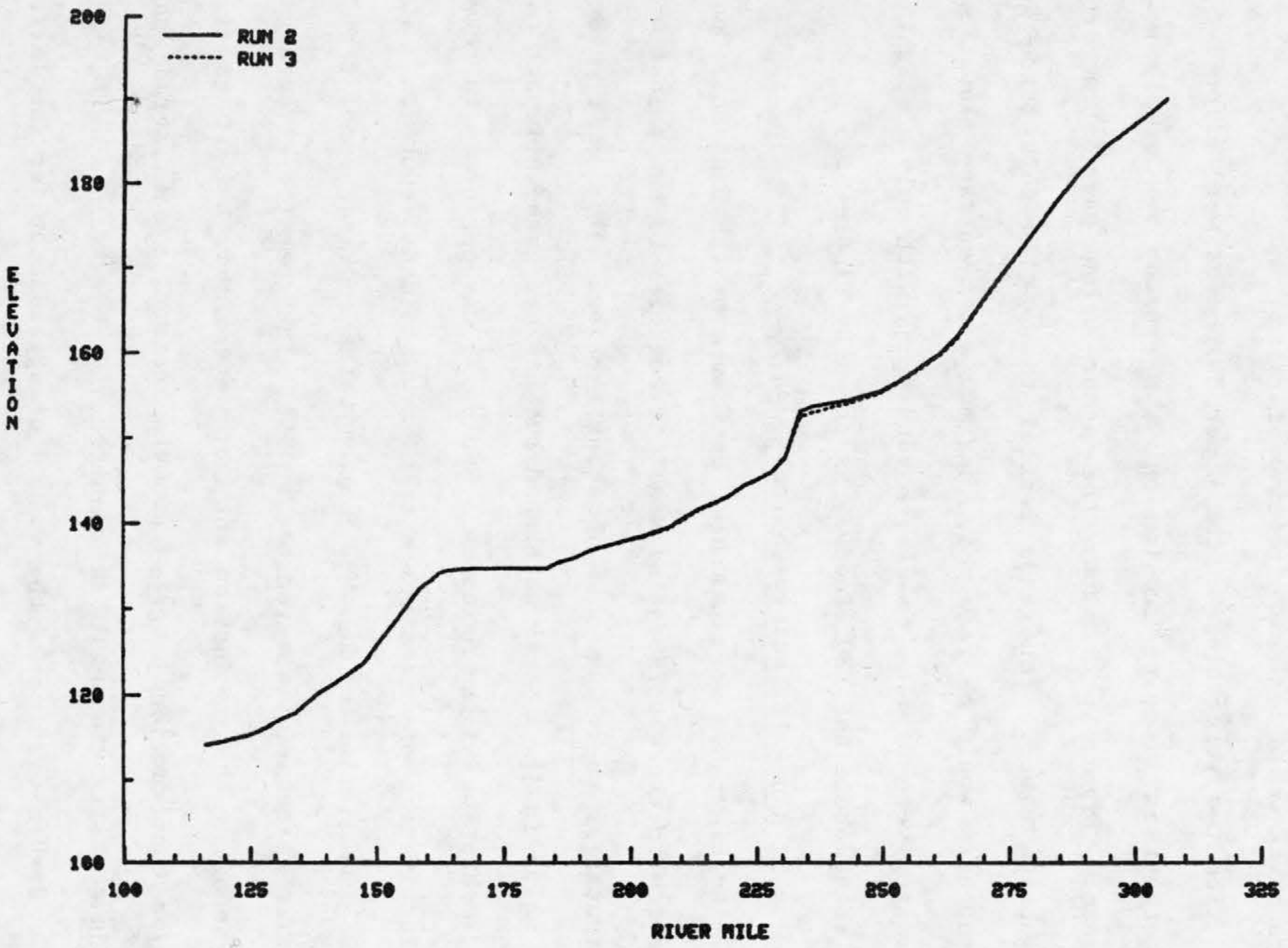


Figure 6.25. Maximum water surface on mainstem for Plan E and grade control condition.

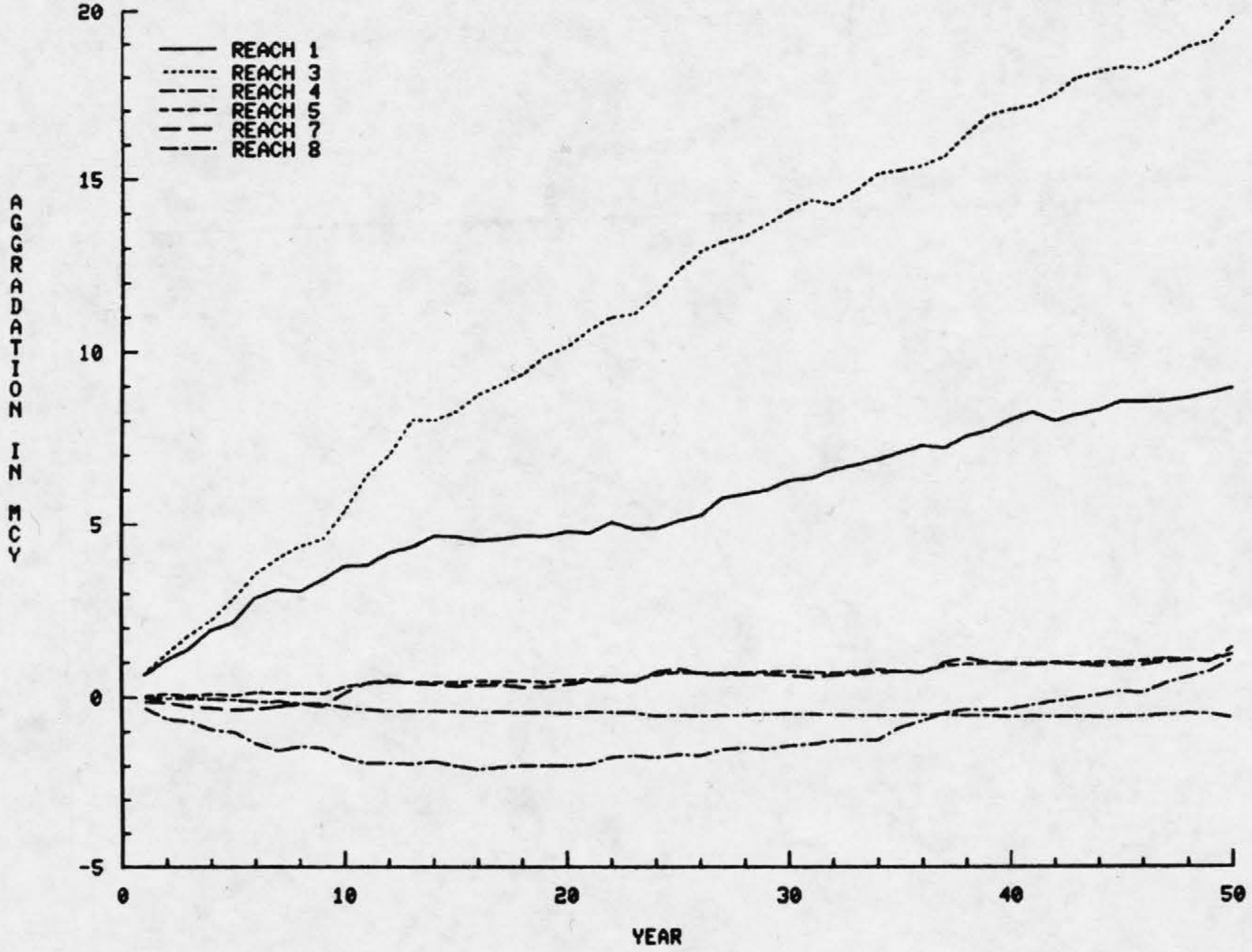


Figure 6.26. Volume of aggradation for river reaches 1, 3, 4, 5, 7 and 8 for tributary control (Run 4).

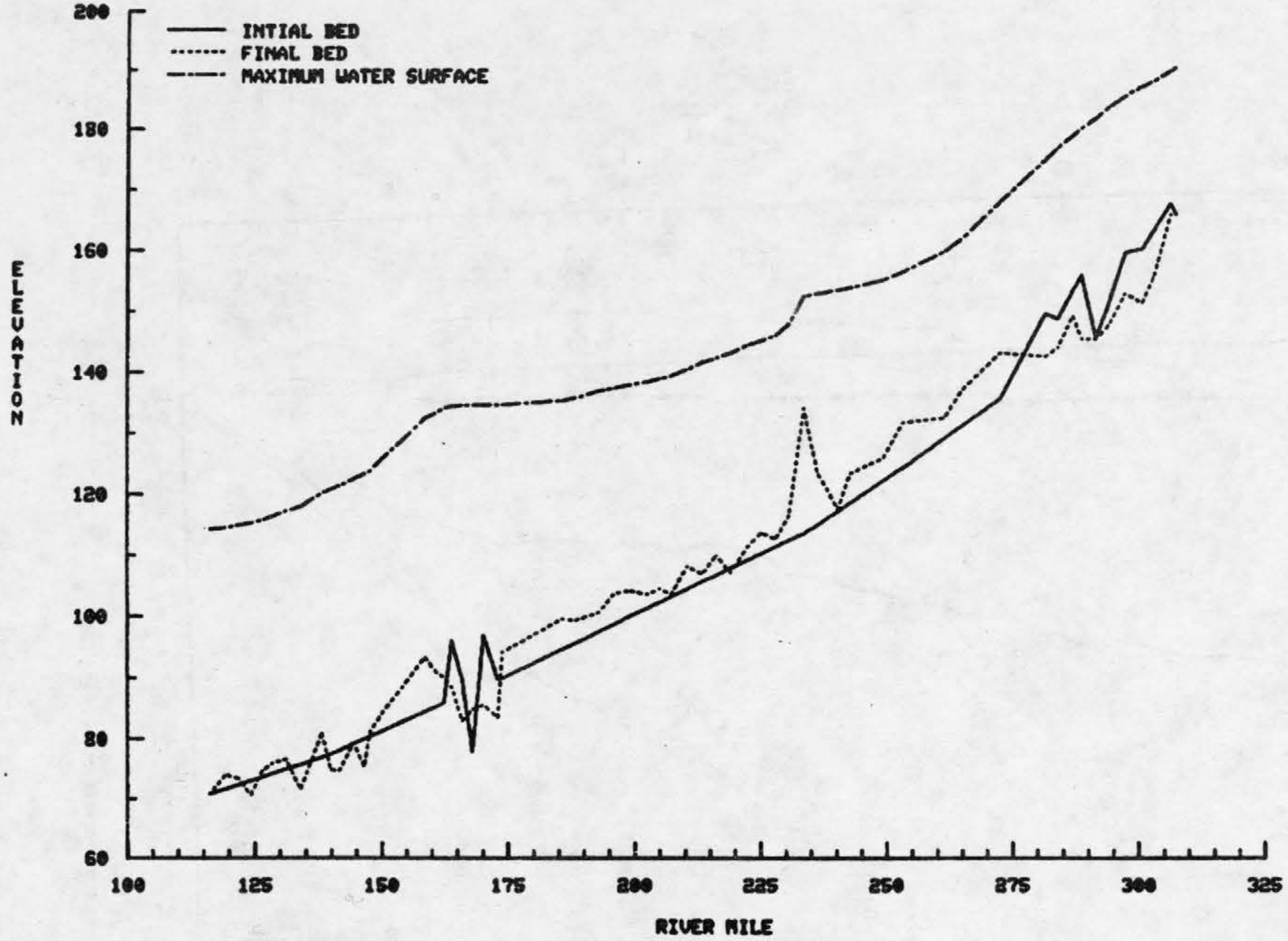


Figure 6.27. Profiles on mainstem for tributary control condition (Run 4).

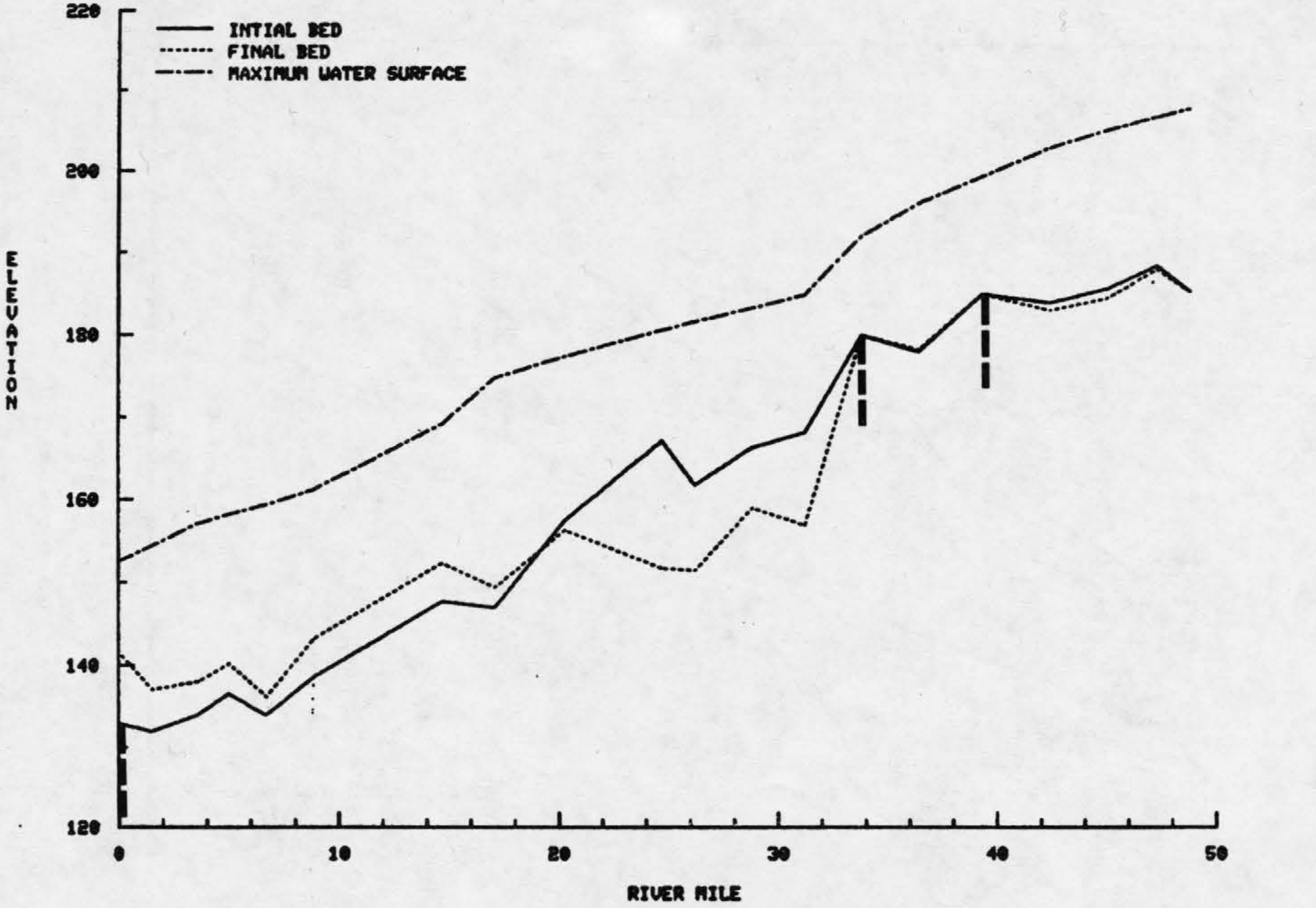


Figure 6.28. Profiles on P-Q, Little Tallahatchie for tributary control condition (Run 4).

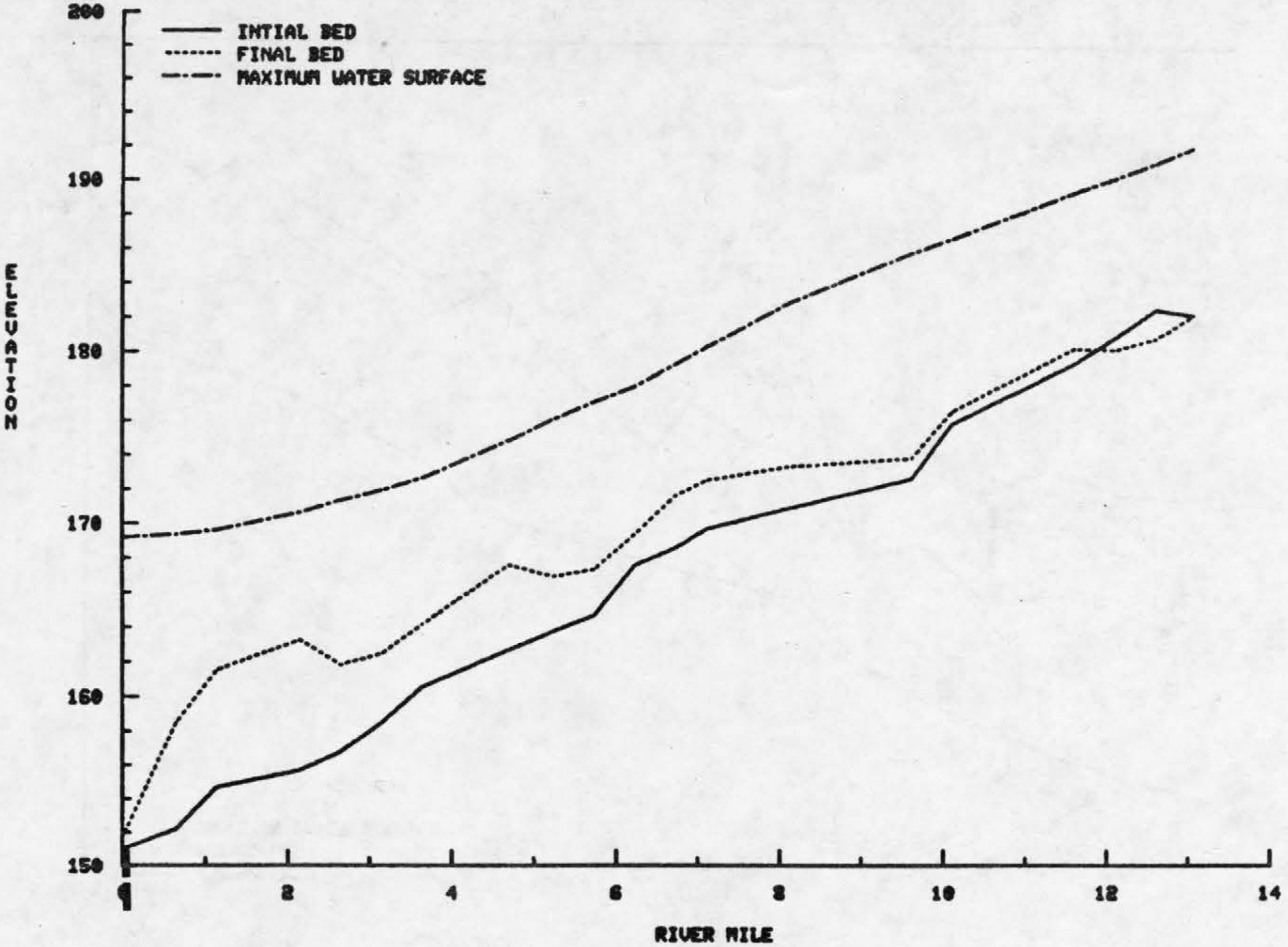


Figure 6.29. Profiles on Yocona River for tributary control condition (Run 4).

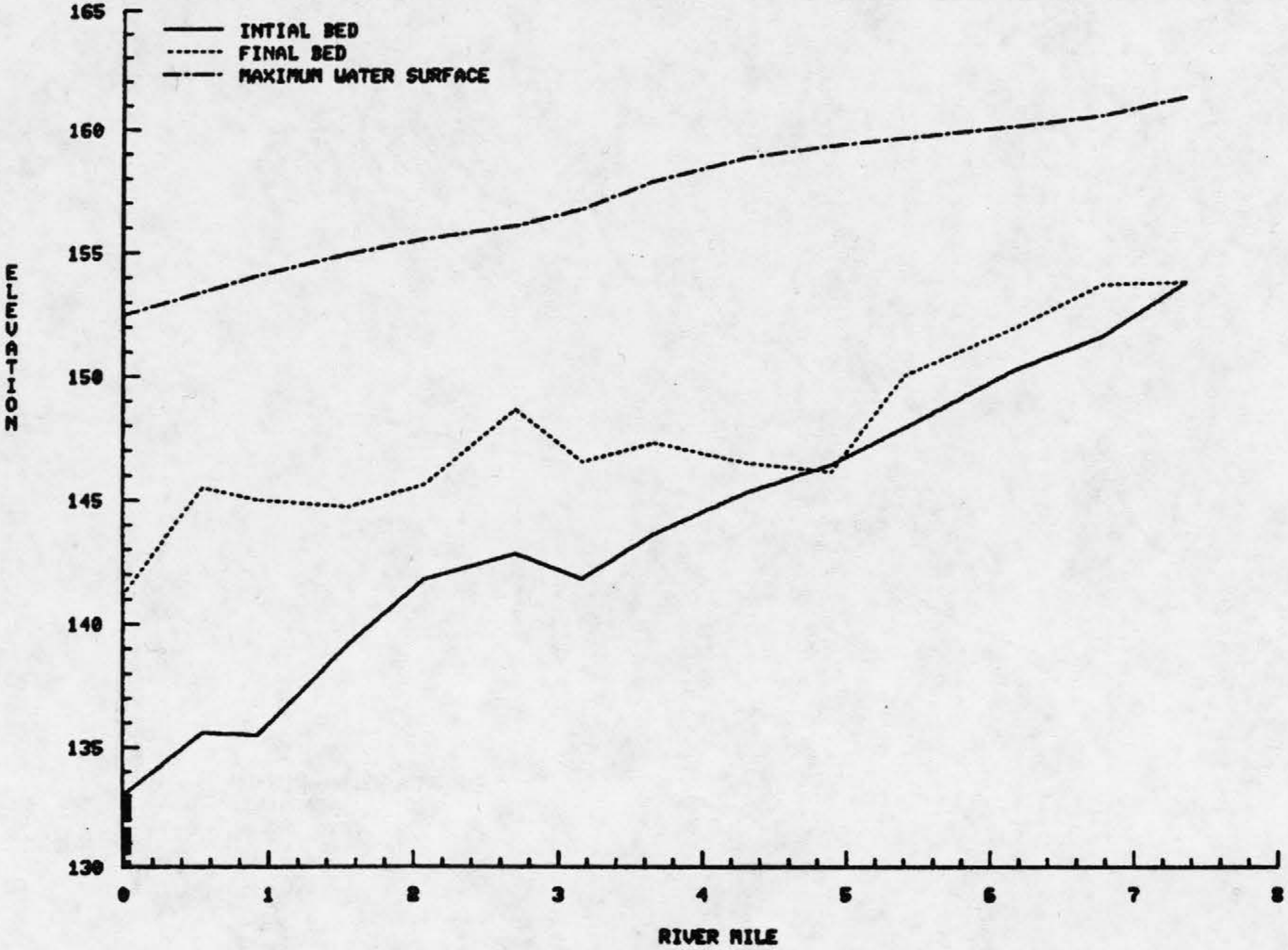


Figure 6.30. Profiles on Tillatoba Creek for tributary control condition (Run 4).

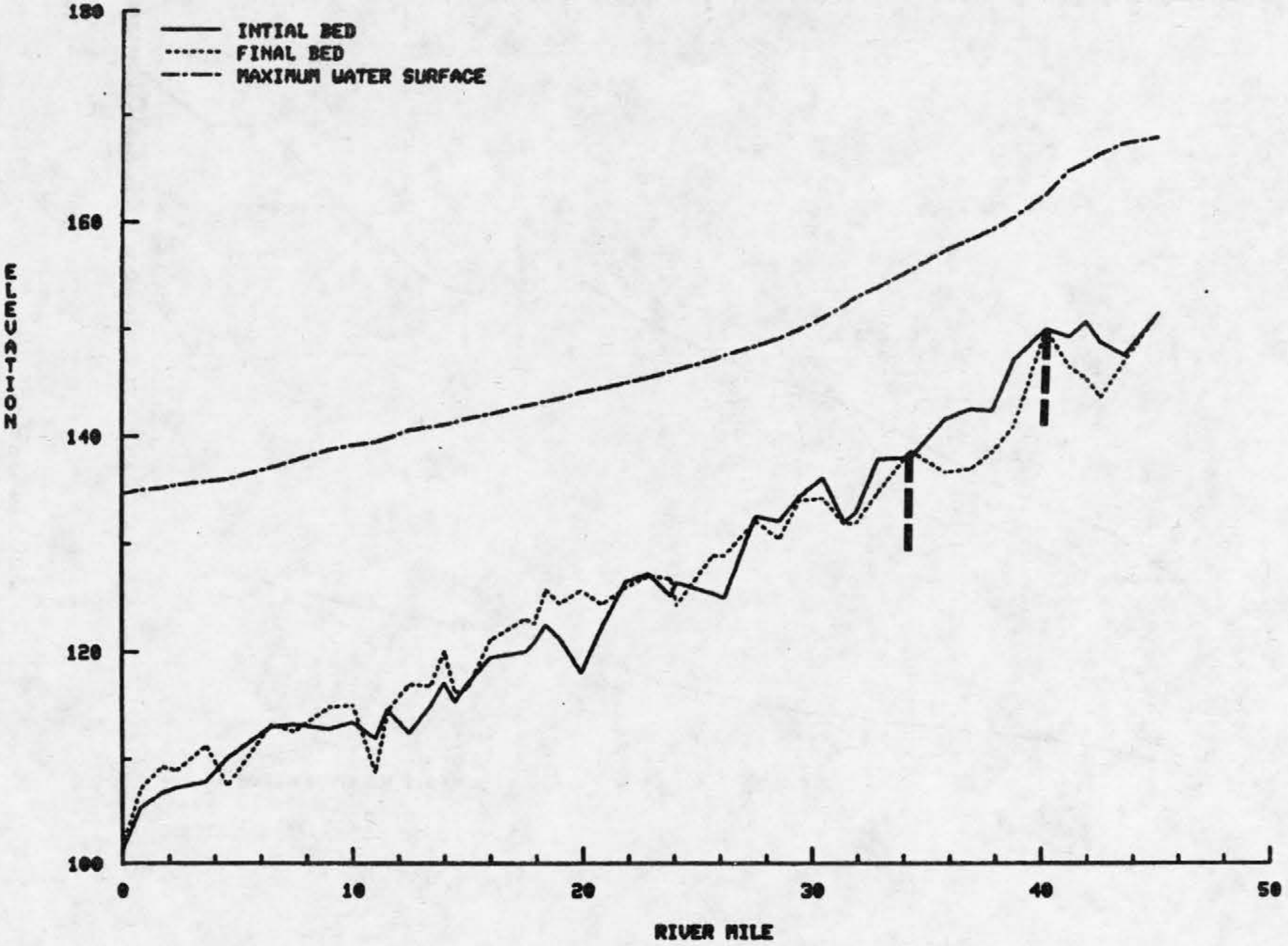


Figure 6.31. Profiles on Yalobusha River for tributary control condition (Run 4).

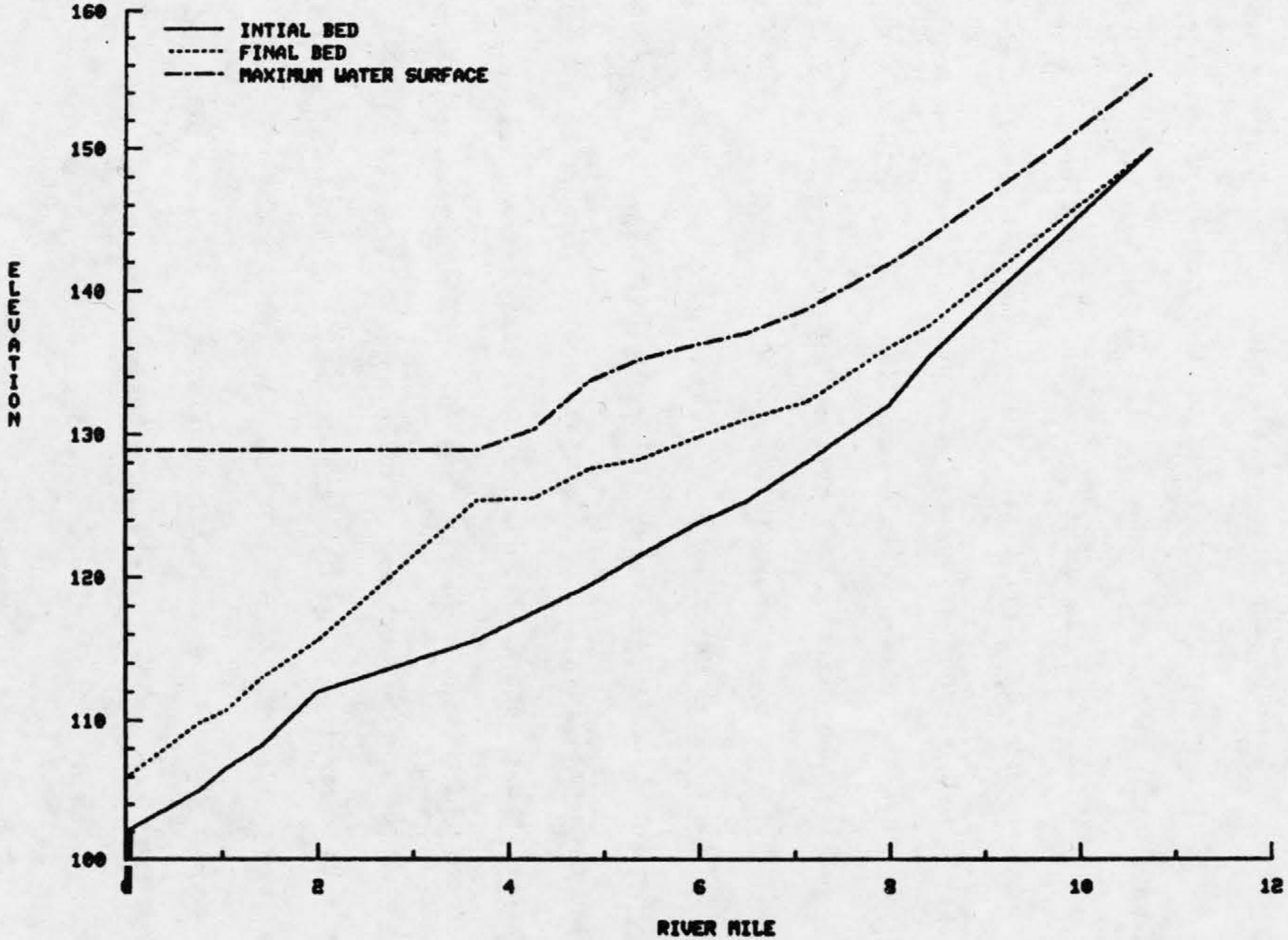


Figure 6.32. Profiles on Pelucia Creek for tributary control condition (Run 4).

sediment control only slightly reduced aggradation in the mainstem. Mainstem (Reaches 1 and 3) aggradation was reduced by only 2%. Control was more effective on the major tributaries. On the Little Tallahatchie (Reach 4) aggradation was reduced by 38% and the lower Yalobusha (Reach 7) by 20%. Generally the effects of reducing tributary sediment were only seen in the region adjacent to the tributary confluence. An important point to note is that on the Upper Yalobusha (Reach 8) the reduction in tributary sediment increased degradation by 167%. It is therefore concluded that tributary sediment control measures should only be carried out after considering possible detrimental effects to the mainstem. Maximum water surface profiles were similar to Run No. 3 except on the Upper Little Tallahatchie and Yalobusha Rivers where they were slightly lowered as shown in Figures 6.33 and 6.34.

6.6 Run 5 (Step Channel)

As pointed out previously, the principal cause of aggradation in the Plan E channel is a reduction in sediment transport in the mainstem. To counter this effect a step channel was designed and tested. The step channel concept is shown in Figure 6.35. Generally instead of widening the channel bottom to gain extra conveyance a step is cut on one bank. This has the effect of only lowering stages at high flows, and maintaining existing sediment transport at low flows.

The step channel was designed using the criteria outlined by the Corps of Engineers. The criteria for design were:

1. Channel bottom elevation and grade approximately the same as in Plan E.
2. Channel side slopes of 3 (horizontal) to 1 (vertical).
3. The step not to exceed 75 feet in bottom width.

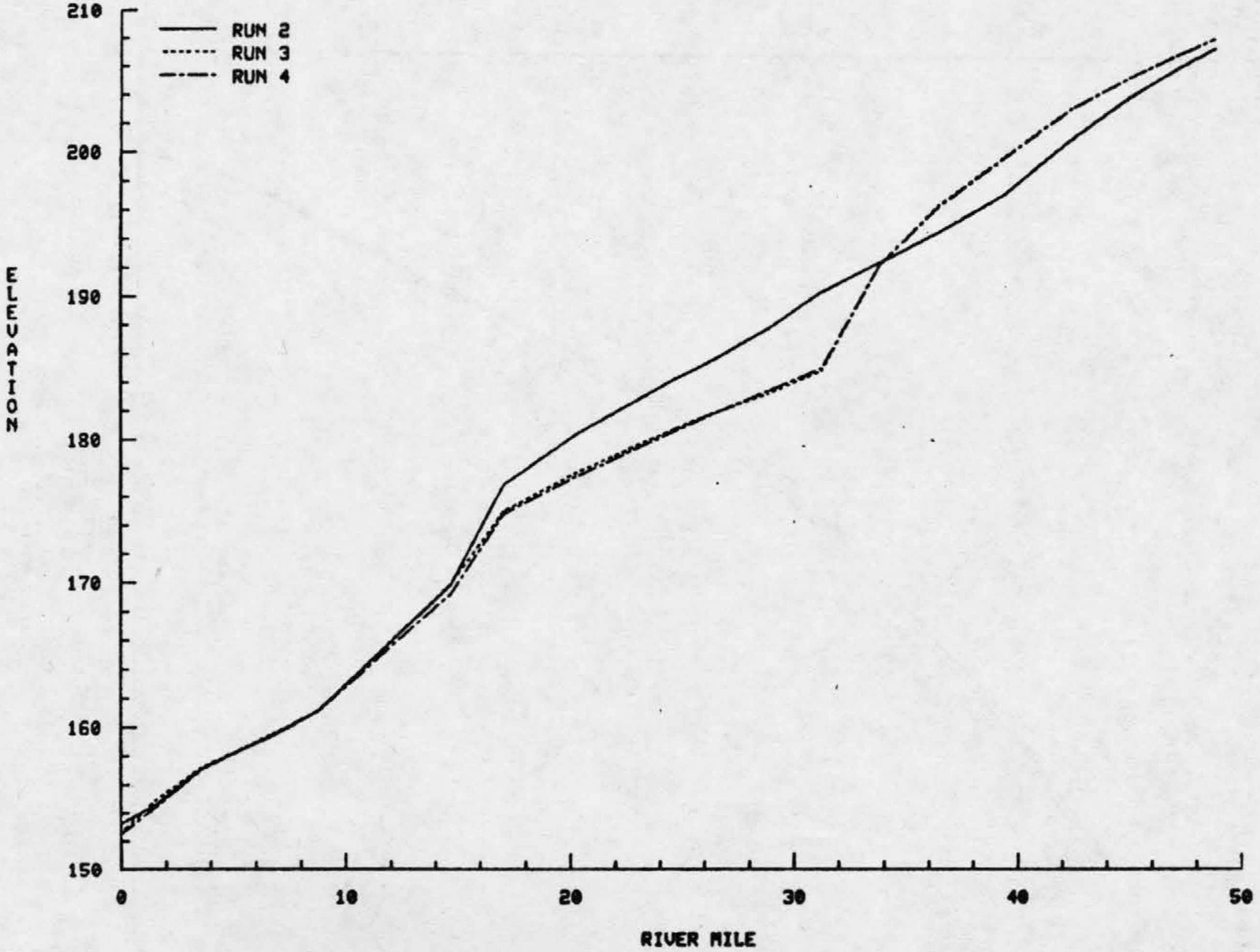


Figure 6.33. Maximum water surfaces on P-Q Little Tallahatchie for Runs 2, 3, and 4.

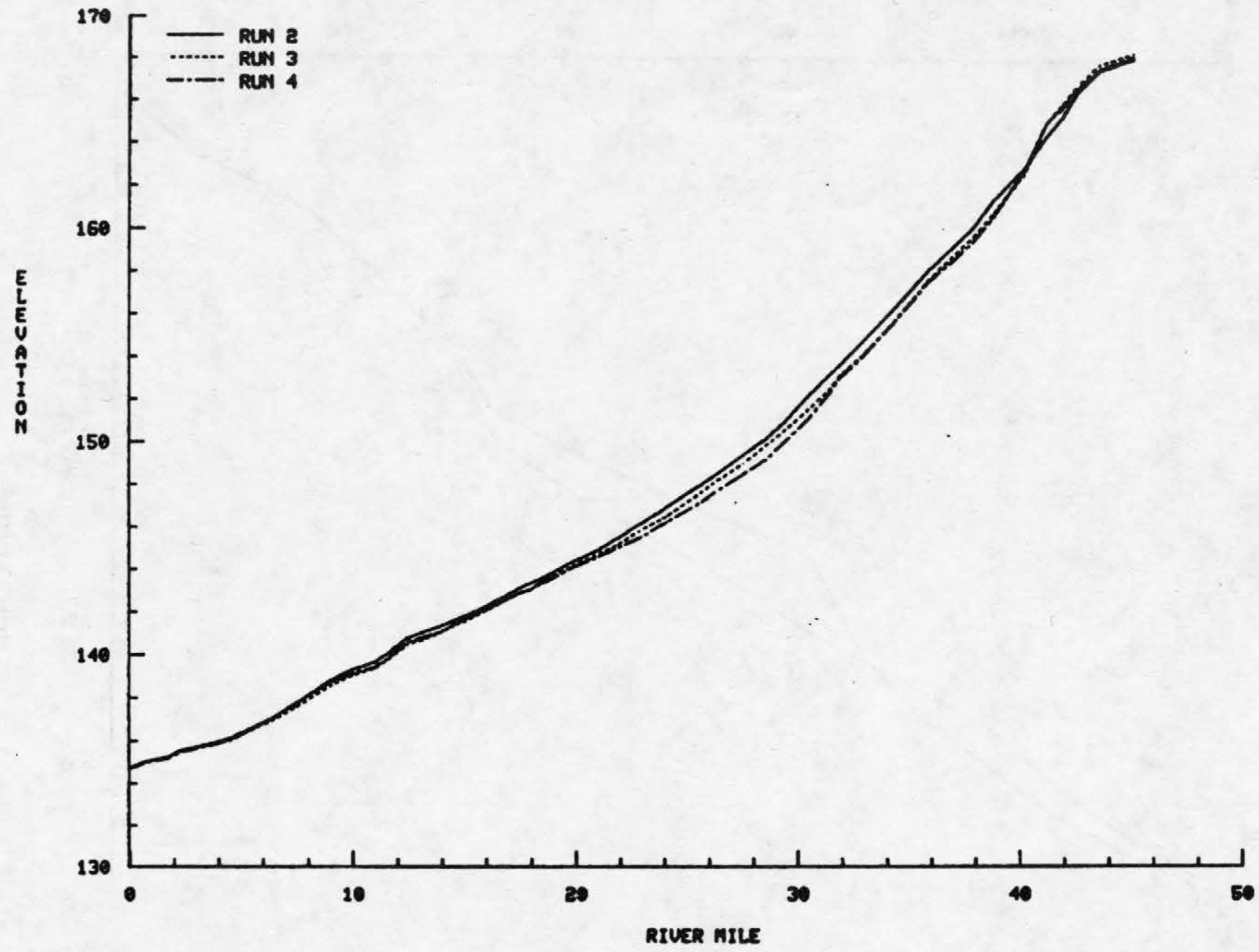


Figure 6.34. Maximum water surfaces on Yalobusha River for Runs 2, 3, and 4.

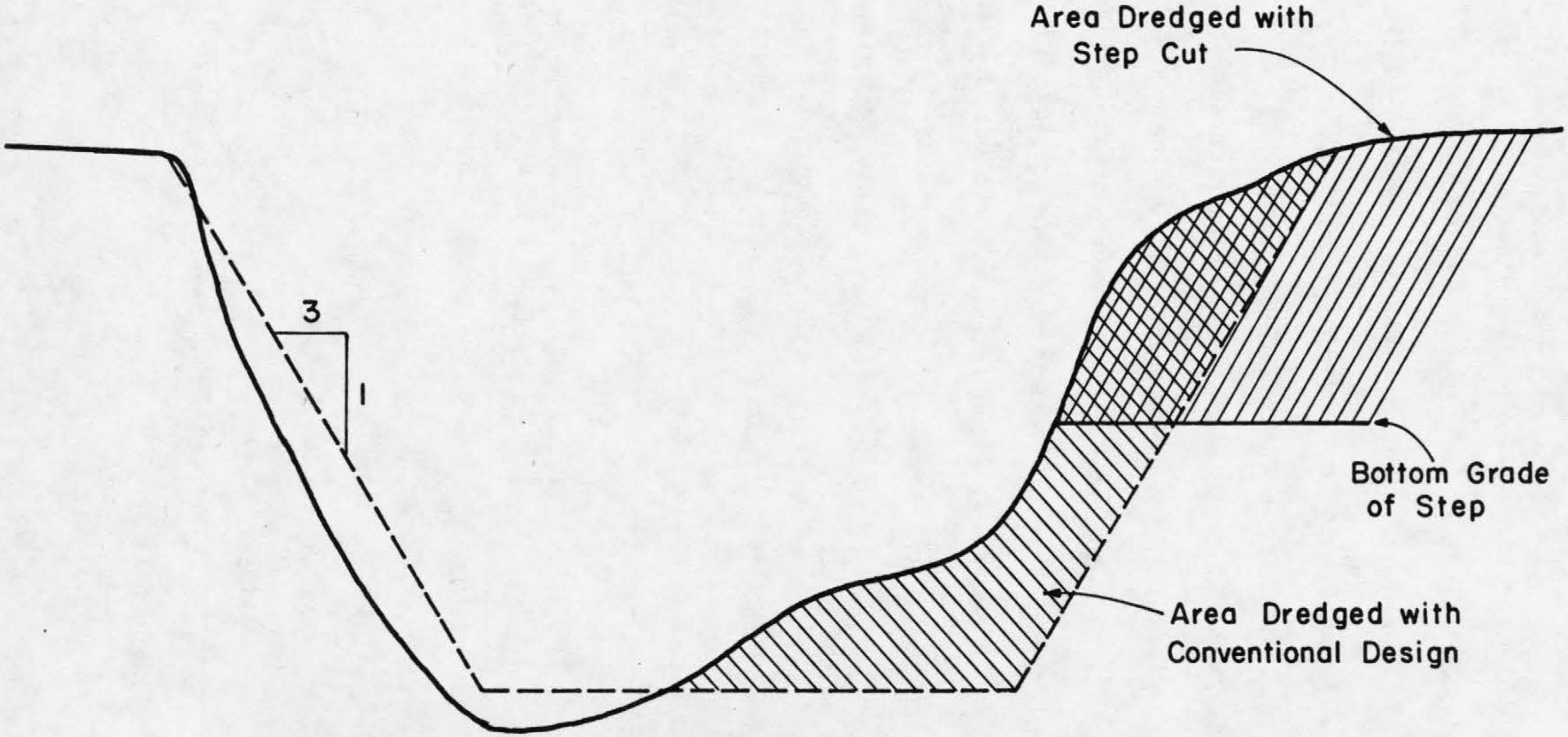


Figure 6.35. Step channel concept (after Banks, 1983).

4. Channel conveyance to be approximately equal to the Plan E value for reservoir emptying stages.

Using these criteria the channel detailed in Table 1.2 was designed. As the table shows the bottom width was substantially reduced but a bottom cut is still required. With this reduction, the sediment transport at low flows is increased significantly over Plan E Levels. It should be noted that this design only changes channel size and slope at the confluences of the Yalobusha River, P-Q Floodway and Old Coldwater River. Table 6.3 presents the conveyance of the existing Plan E and step channels for reservoir emptying stages at four locations. As can be seen, the step channel slightly exceeds the Plan E value.

Structures at the tributary mouths are under 20 ft of water during high mainstem stages. These structures could be raised and cause no increase in maximum stage for the tributaries. Table 6.4 presents

Table 6.3. Channel Conveyances

Location	River Mile	Stage (ft)	Elevation (ft)	Conveyance* ft^3/sec x 10^6) Existing	Plan E	Step
Belzoni	116.2	20	96.1	1.39	2.00	2.08
Below Greenwood	162.5	24	116.1	1.98	2.40	2.60
Swan Lake	219.08	21	134.4	1.10	1.70	1.73
Lambert	253.19	25	148.8	0.97	1.20	1.17

*Where conveyance, K is defined by Mannings Equation

$$Q = K\ S^{1/2}$$
$$K = \frac{1.48}{n}\ A^{5/3}\ P^{-2/3}$$

n is assumed to be 0.03.

Table 6.4. Grade Control Structures

		Weir Elevation		Grade Elevation		Raised Weirs				Maximum
Stream	Location	Runs 3&4	Run 5	Minimum	Overbank	Depth and Width at Overbank (ft)	(ft)	Slope ft/ft	Q[1] cfs	Q[2] cfs
P-Q	0.00	133	135	131	145	10	200	0.00183	14,078	17,740
Yocona	0.00	151	156	151	168	12	140	0.000284	9,000	3,926
Tillatoba	0.00	133	135	128	145	10	90	0.00285	4,300	2,285
Yalobusha	0.00	-	106	101	128	22	120	0.000066	10,200	19,290
Pelucia	0.00	102	112	99.7	122	10	100	0.000629	7,000	2,079

1. Calculated discharge based on normal depth rectangular channel, slope taken from grade control run.

2. 7-day mean 1964 to 1977.

information on five tributary mouth structures. For Run 5 the four structures on the P-Q, Yocona, Tillatoba and Pelucia were raised and a structure on the Yalobasha was added. Approximate, conservative calculations were performed to determine the water discharge which these structures could pass before the stage goes overbank. As can be seen the raised structures on the Yocona, Tillitoba and Pelucia have more than adequate capacity while the structures on the P-Q and Yalobusha can pass a large percentage of the maximum flow. Figure 6.36 shows the volume of aggradation in the larger river reaches. Figures 6.37 through 6.42 show the initial and final bed profiles and the maximum water surface profiles for the step channel run.

The step design was very successful in reducing stages along the mainstem and tributaries. Figures 6.43 through 6.46 show the stage frequency relationship for the 50 years of simulation for each of the five runs at Greenwood, Swan Lake, Batesville and Whaley. The stages at Greenwood, Whaley and Batesville were greatly reduced compared to all other runs while at Swan Lake the stage was only slightly reduced from runs 2, 3, and 4 but was still approximately three feet below existing conditions. To further illustrate these stage reductions, Figures 6.47 to 6.52 show the maximum water surface profiles on the mainstem and major tributaries for Plan E and the step channel.

The step channel was unable to prevent an increase in sediment transport from the tributaries into the mainstem. The stage reduction on the mainstem reduces the base level of the tributaries causing increased sediment input to the mainstem and degradation on the tributaries. The Tallahatchie and Yalobusha had significant degradation below their grade control structures, as shown in Figures 6.38 and 6.41. More structures

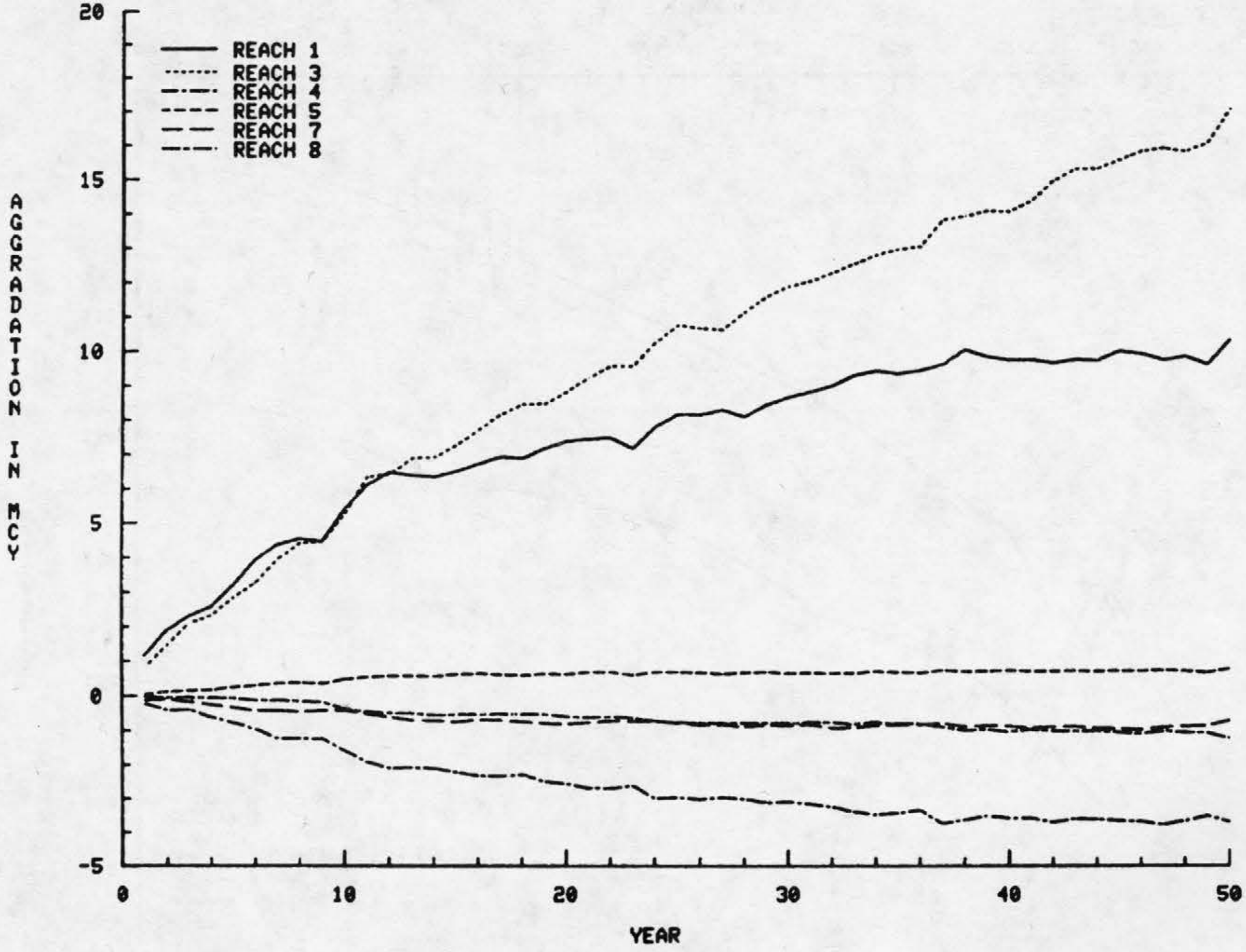


Figure 6.36. Volume of aggradation for river reaches 1, 3, 4, 5, 7 and 8 for step channel (Run 5).

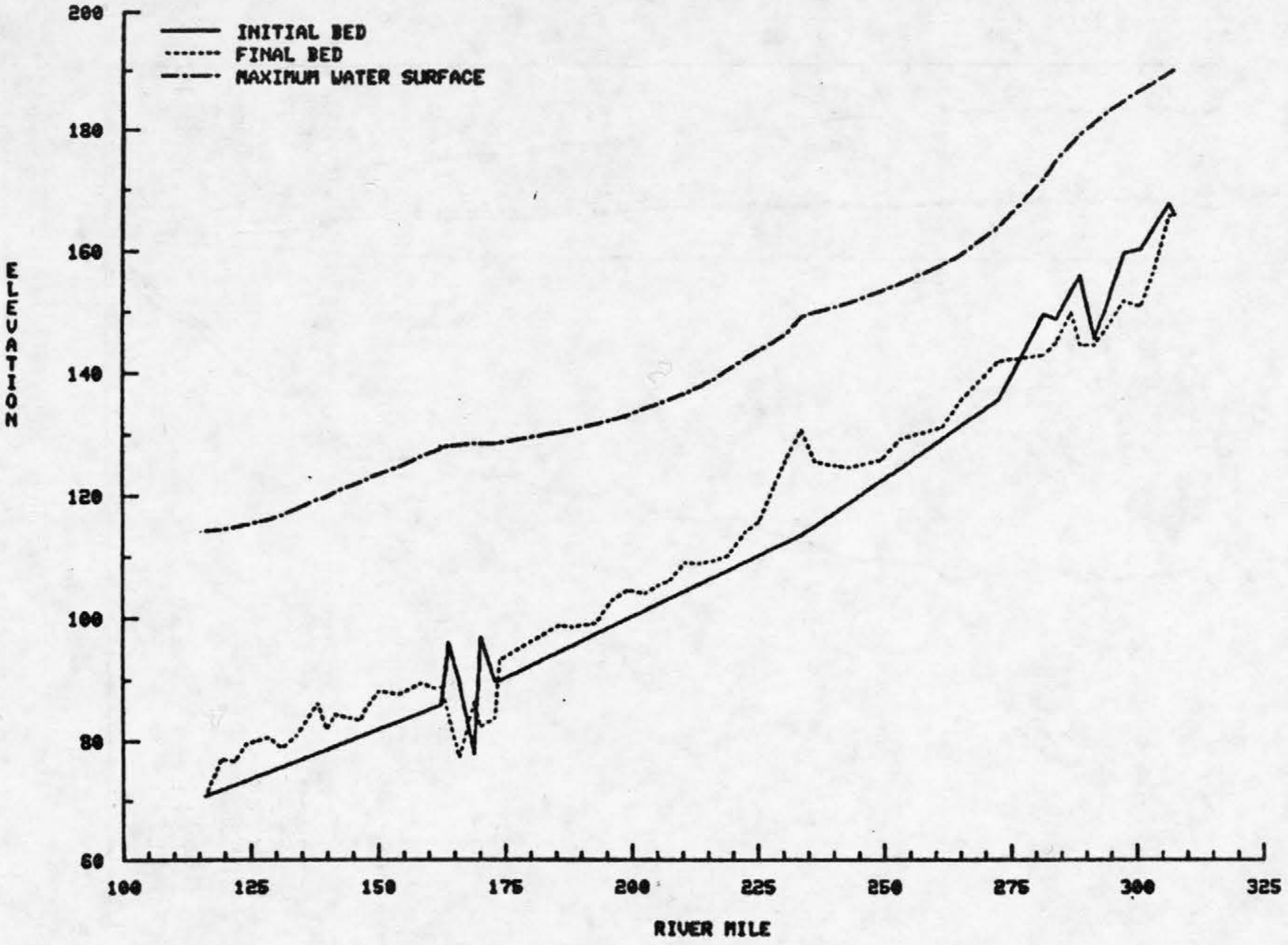


Figure 6.37. Profiles on mainstem for step channel conditions (Run 5)

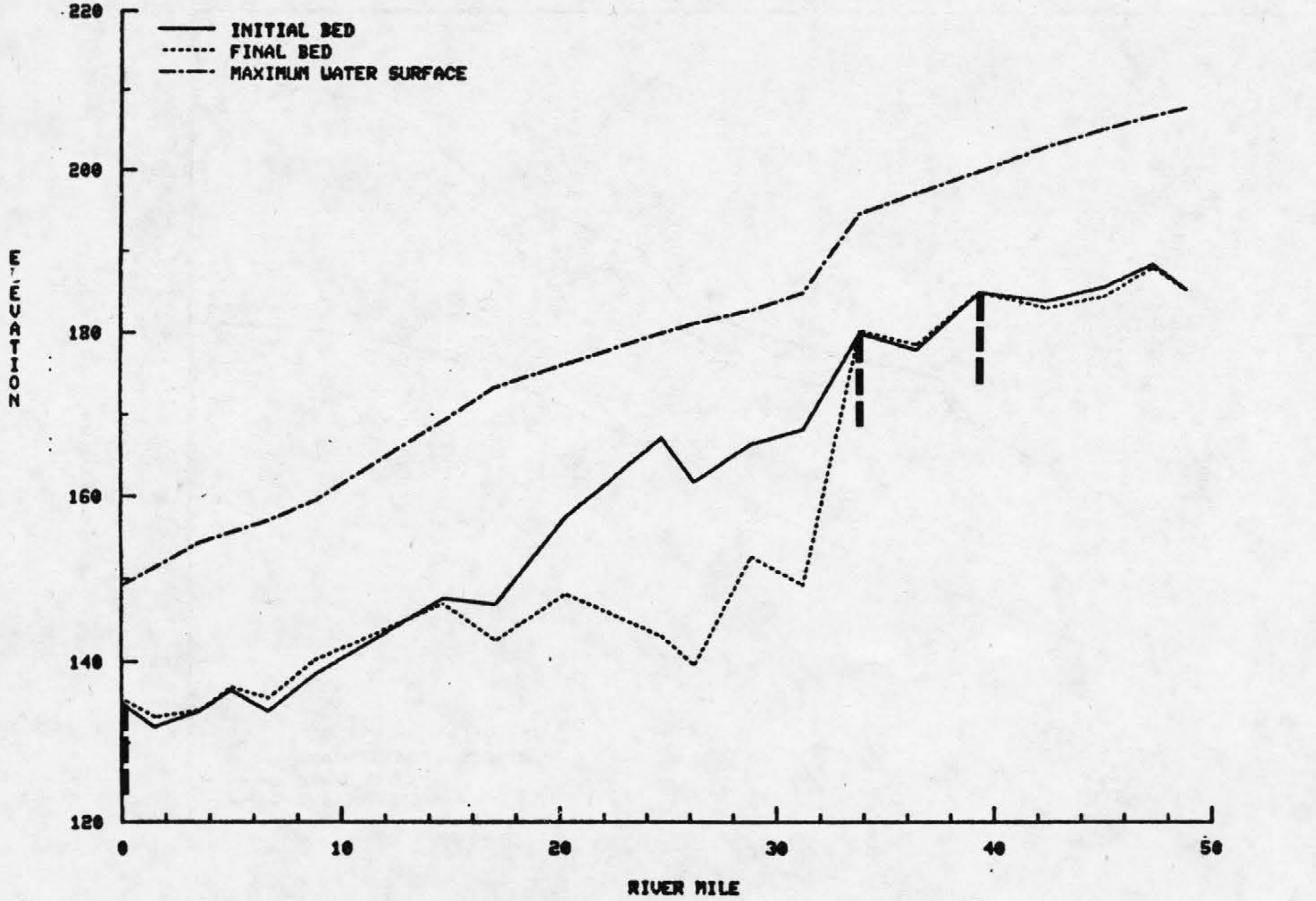


Figure 6.38. Profiles on P-Q, Little Tallahatchie for step channel conditions (Run 5).

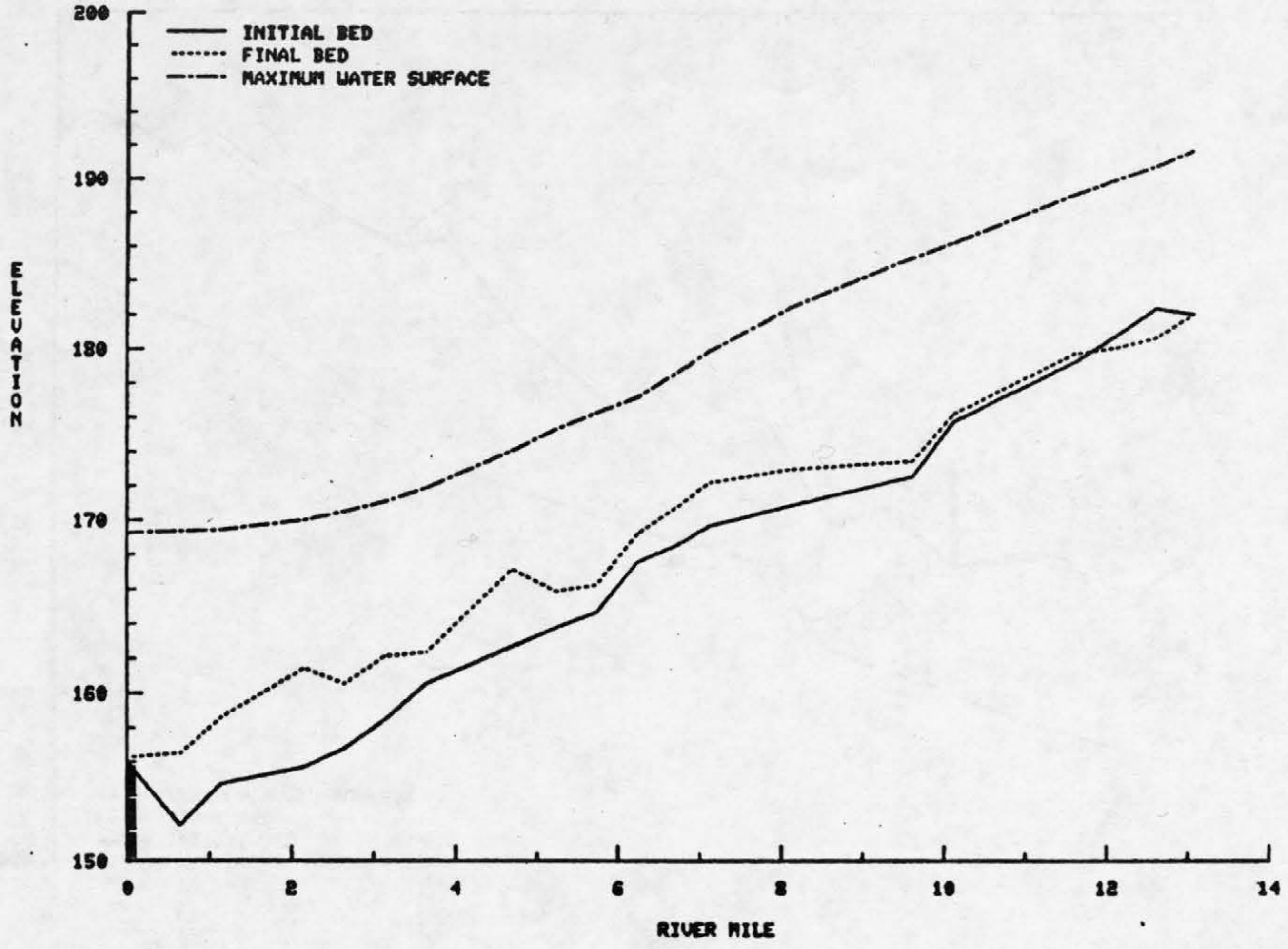


Figure 6.39. Profiles on Yocona River for step channel conditions (Run 5).

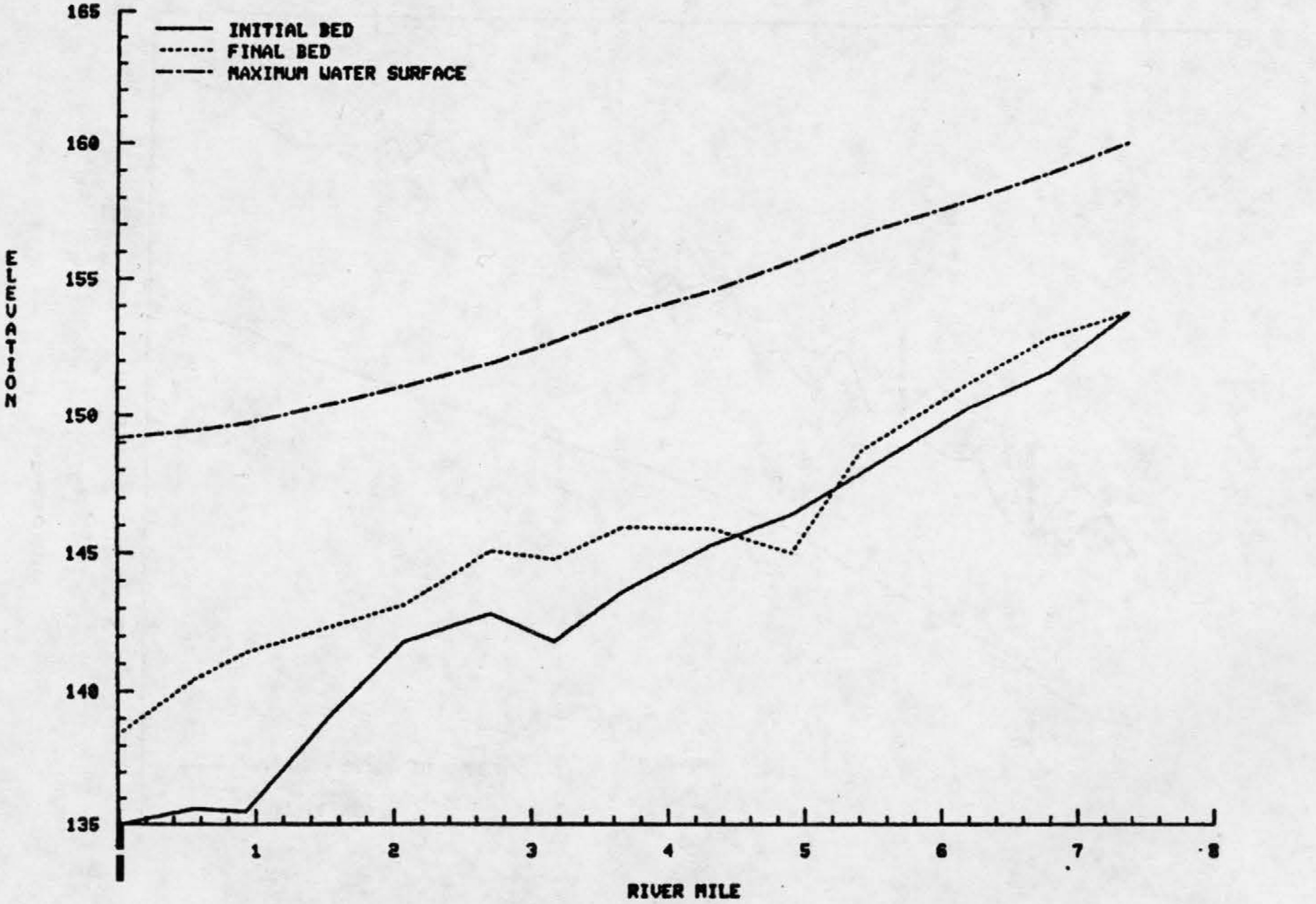


Figure 6.40. Profiles on Tillatoba Creek for step channel conditions (Run 5).

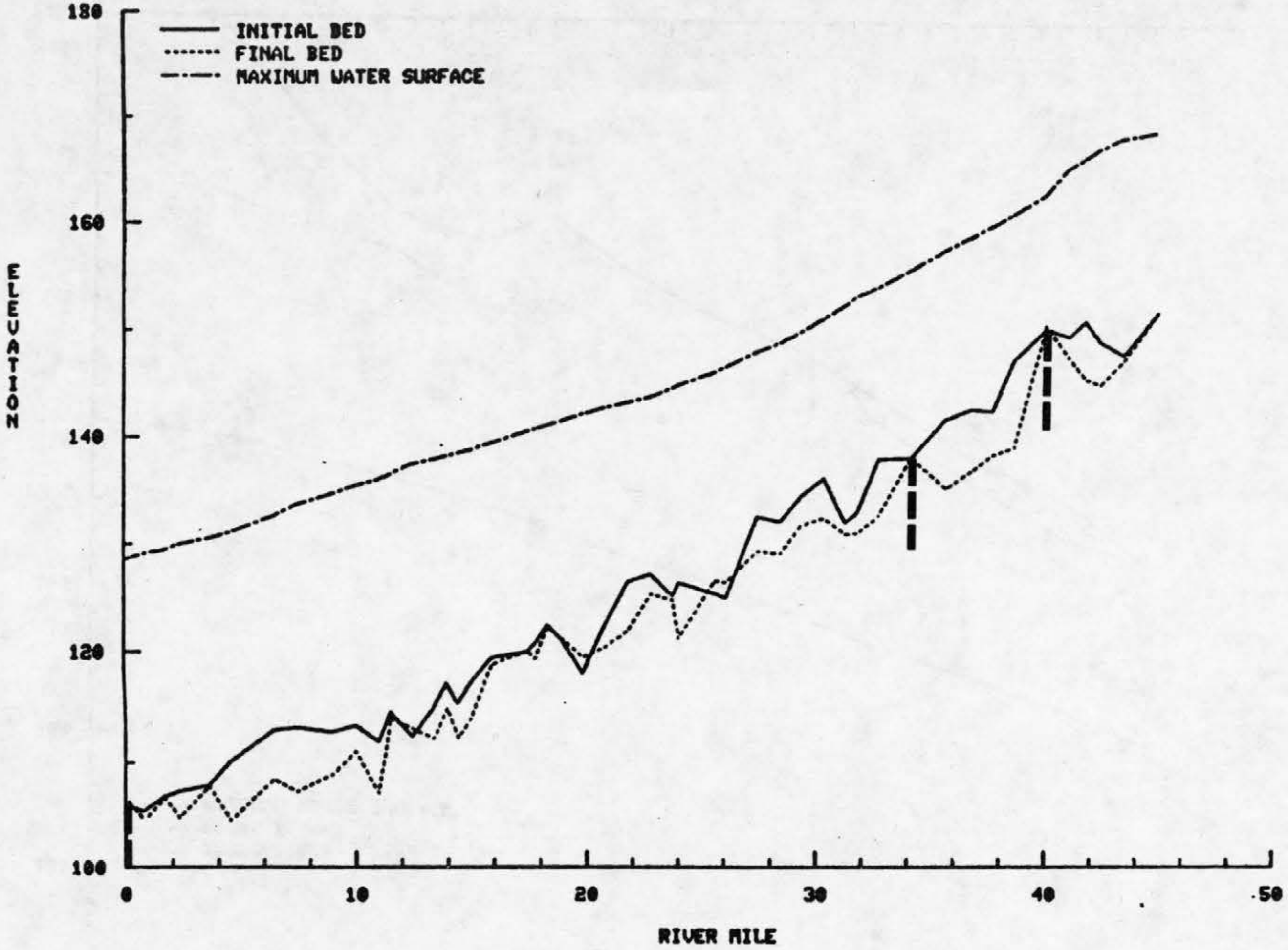


Figure 6.41. Profiles on Yalobusha River for step channel conditions (Run 5).

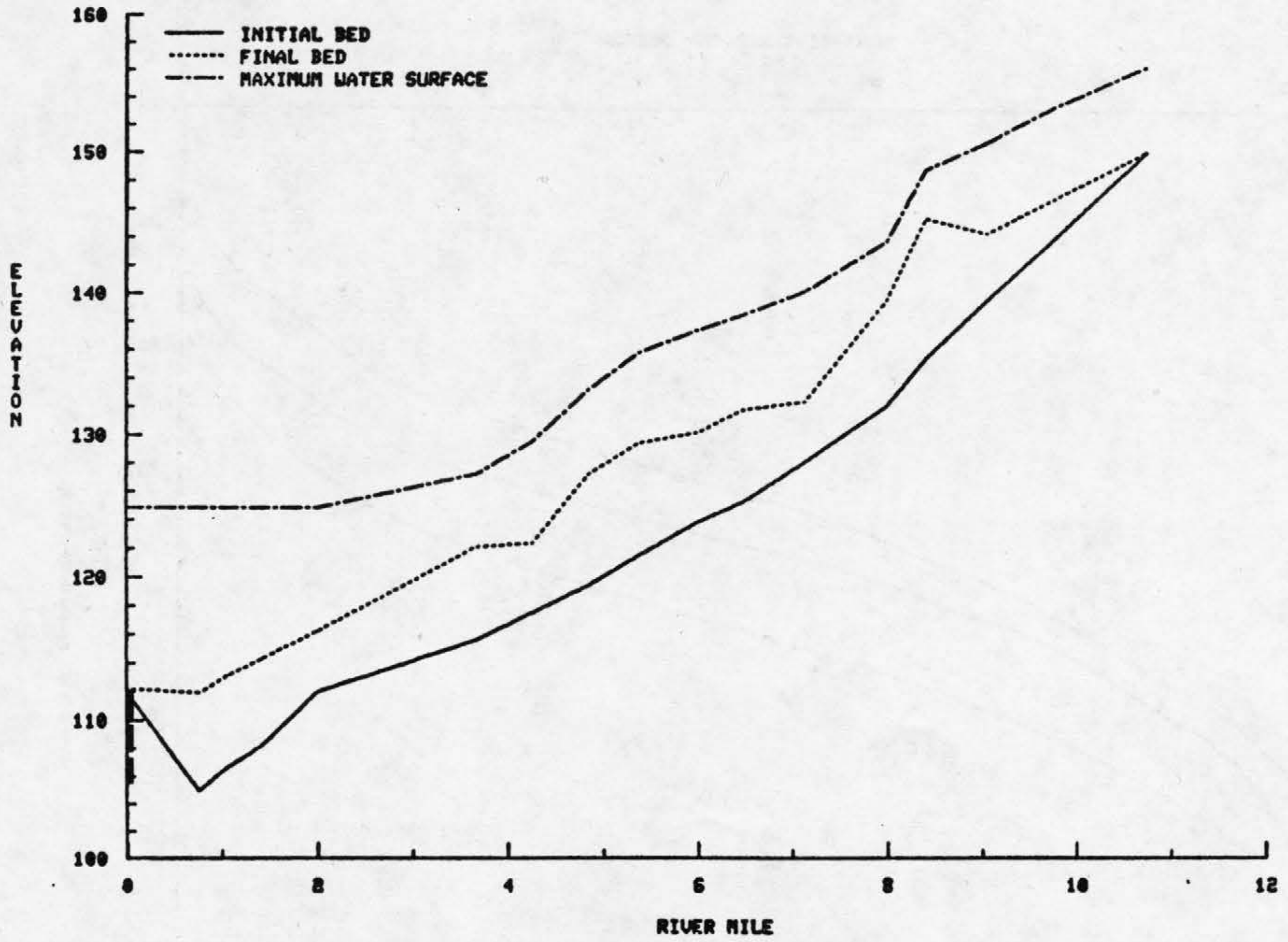


Figure 6.42. Profiles on Pelucia Creek for step channel conditions (Run 5).

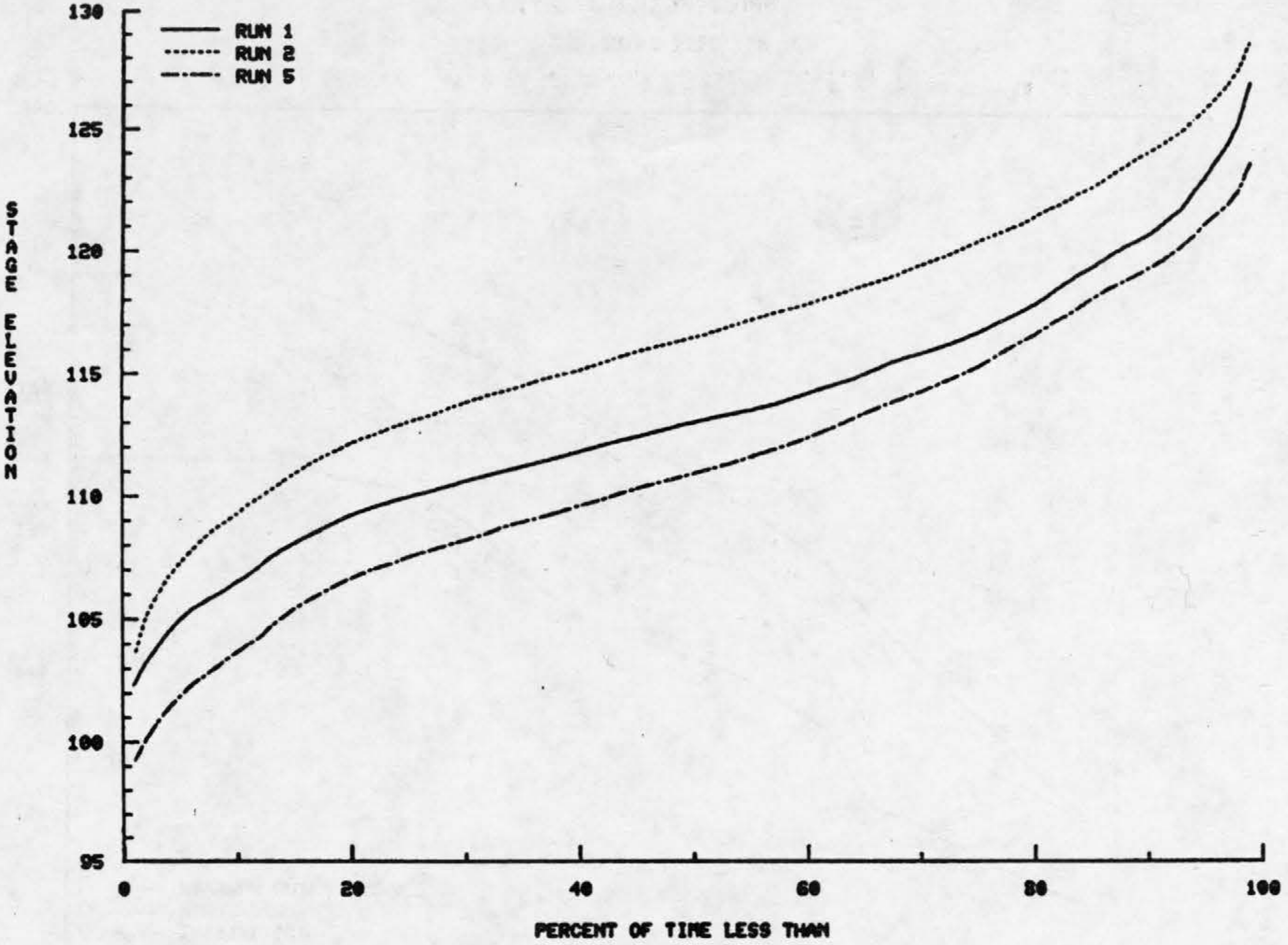


Figure 6.43. Stage duration at Greenwood for Runs 1, 2 and 5.

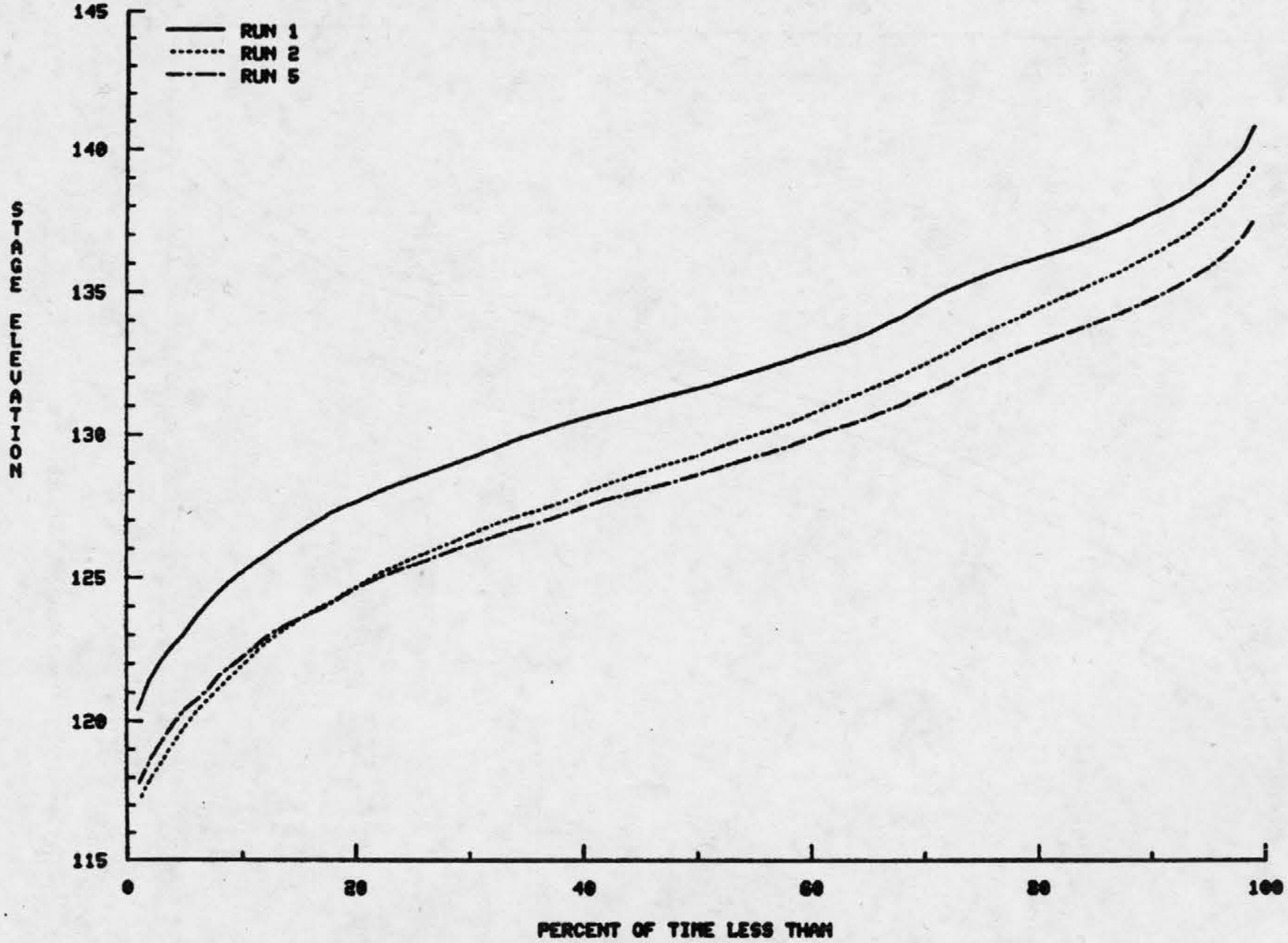


Figure 6.44. Stage duration at Swan Lake for Runs 1, 2 and 5.

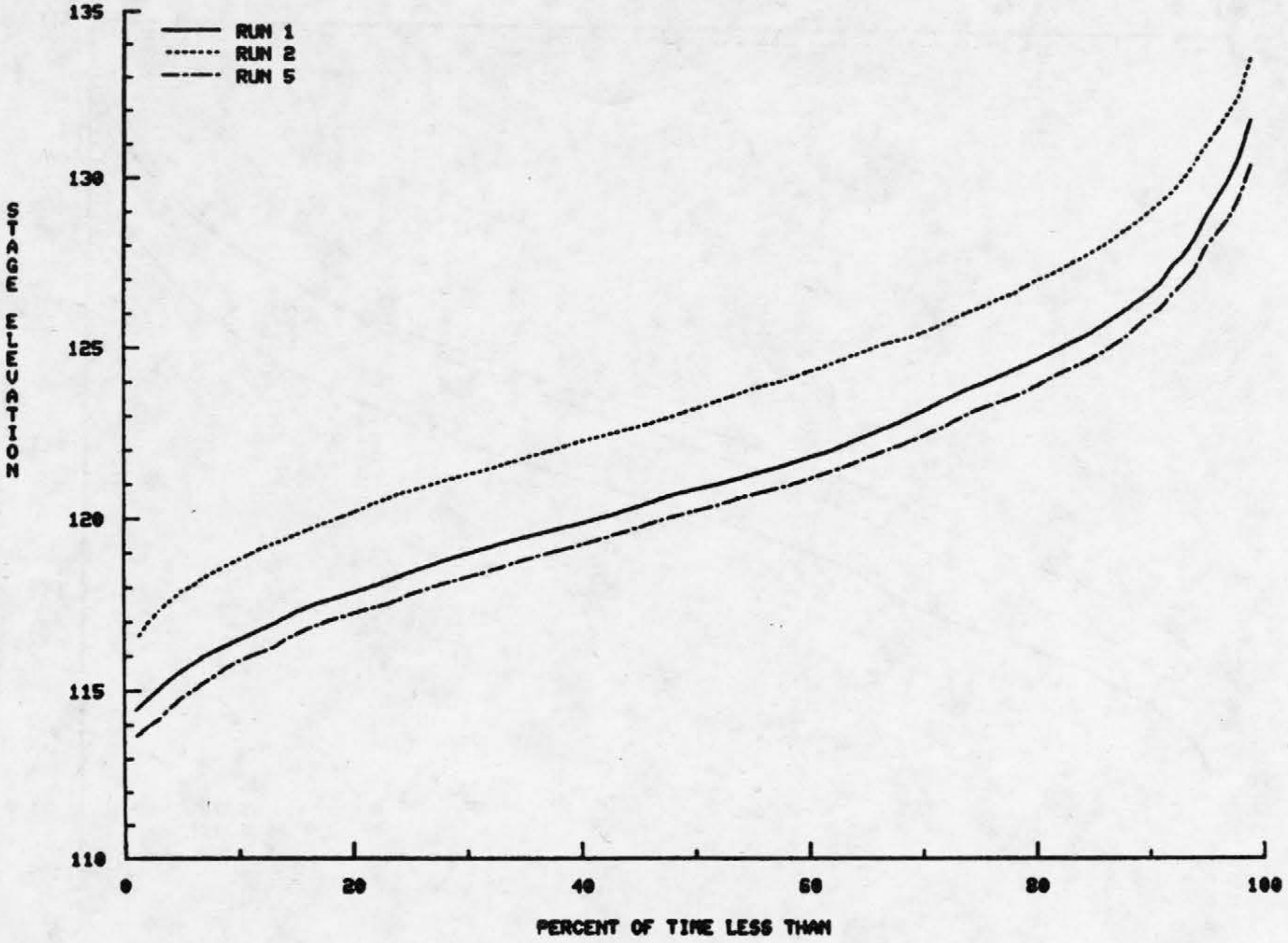


Figure 6.45. Stage duration at Whaley for Runs 1, 2 and 5.

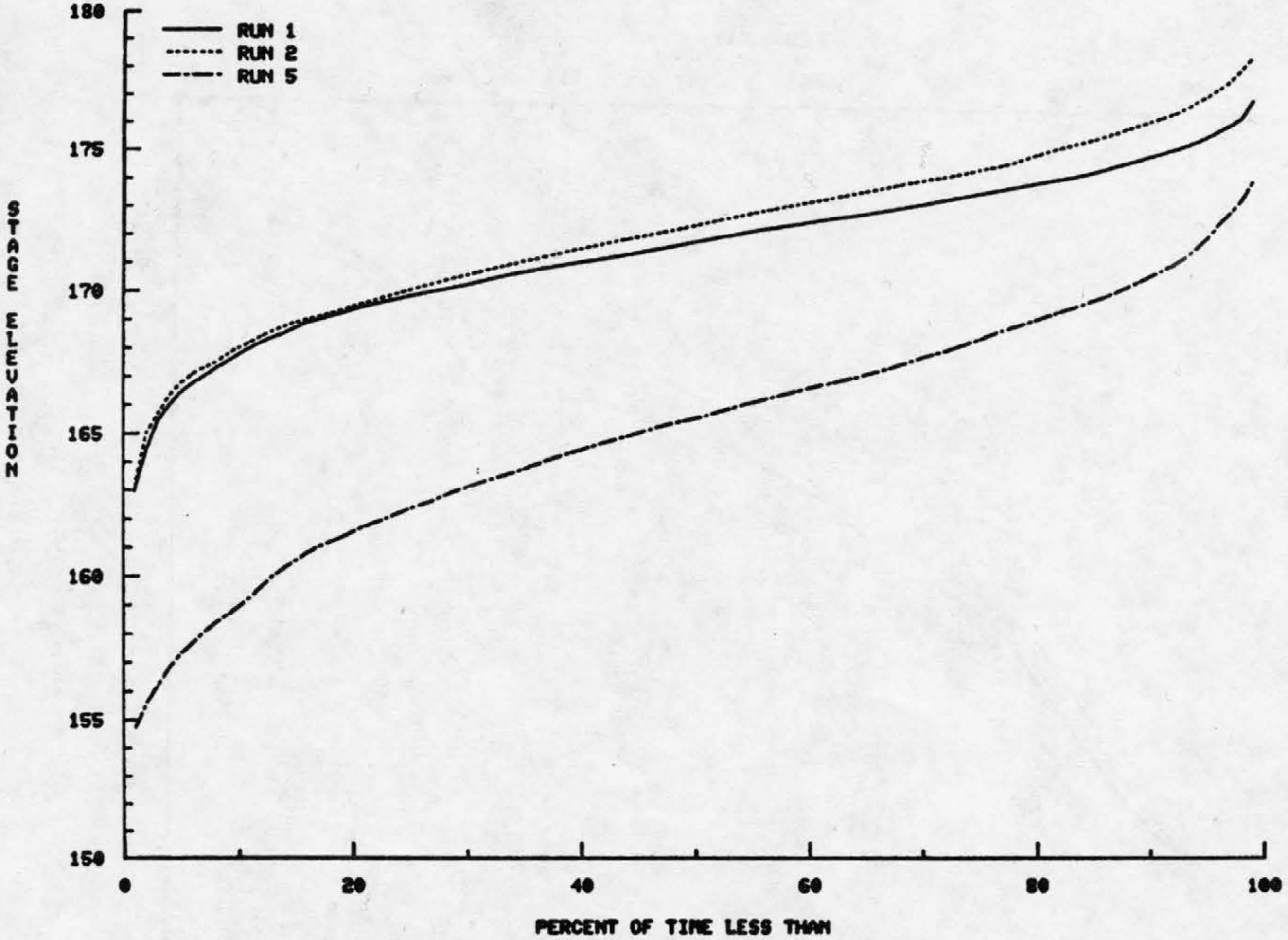


Figure 6.46. Stage duration at Batesville for Runs 1, 2 and 5.

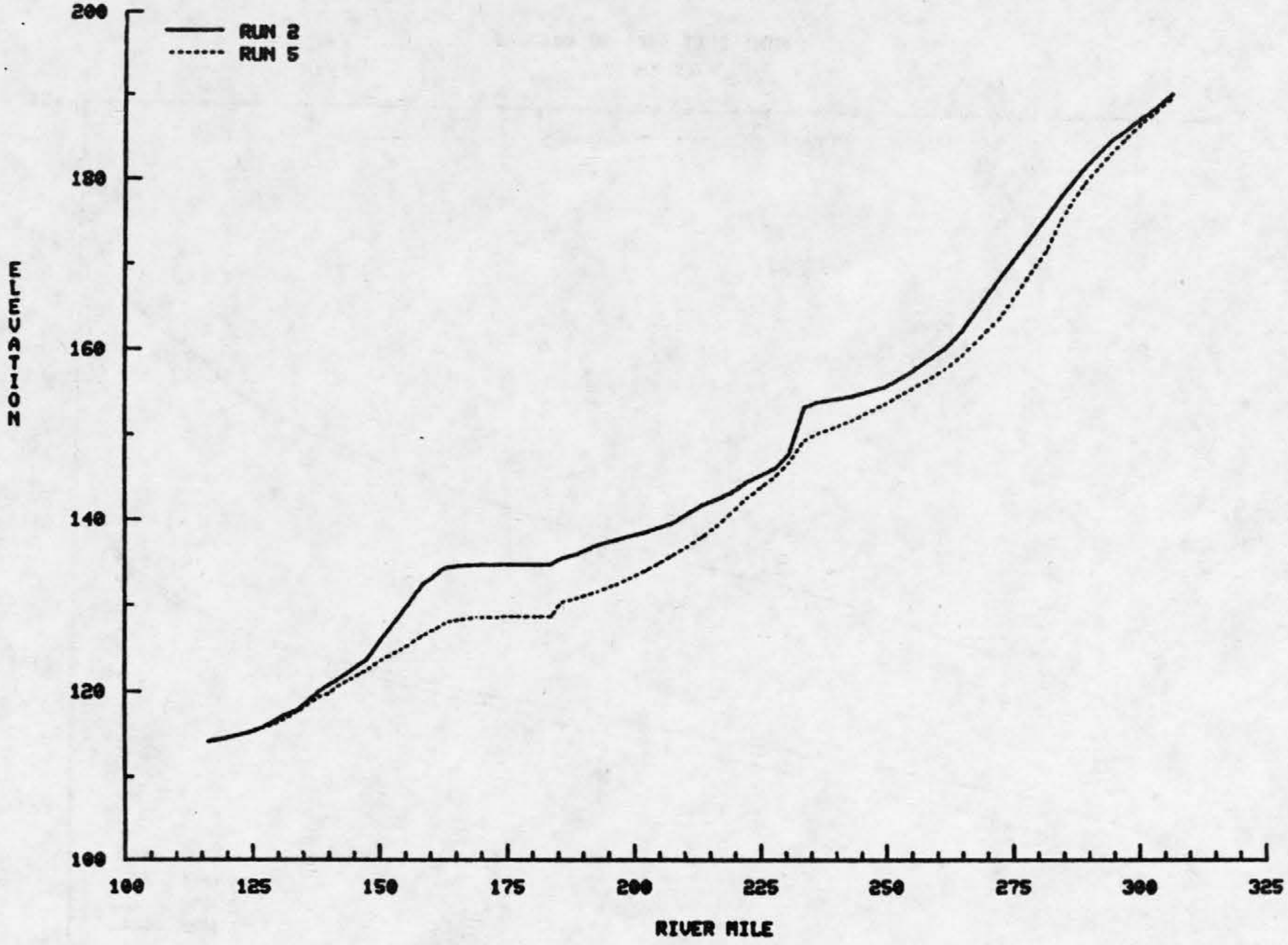


Figure 6.47. Maximum water surface on mainstem for Runs 2 and 5.

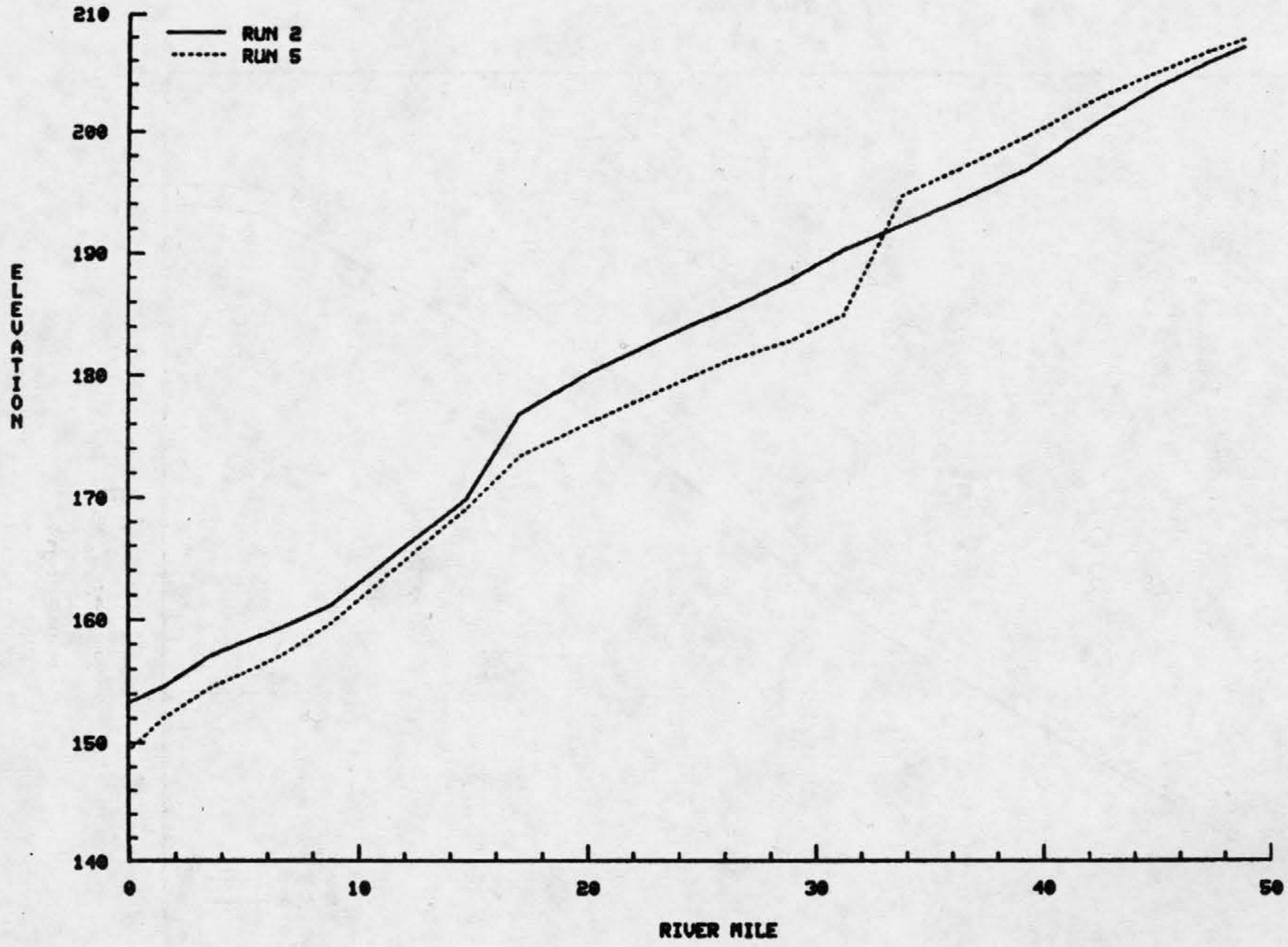


Figure 6.48. Maximum water surface on P-Q, Little Tallahatchie for Runs 2 and 5.

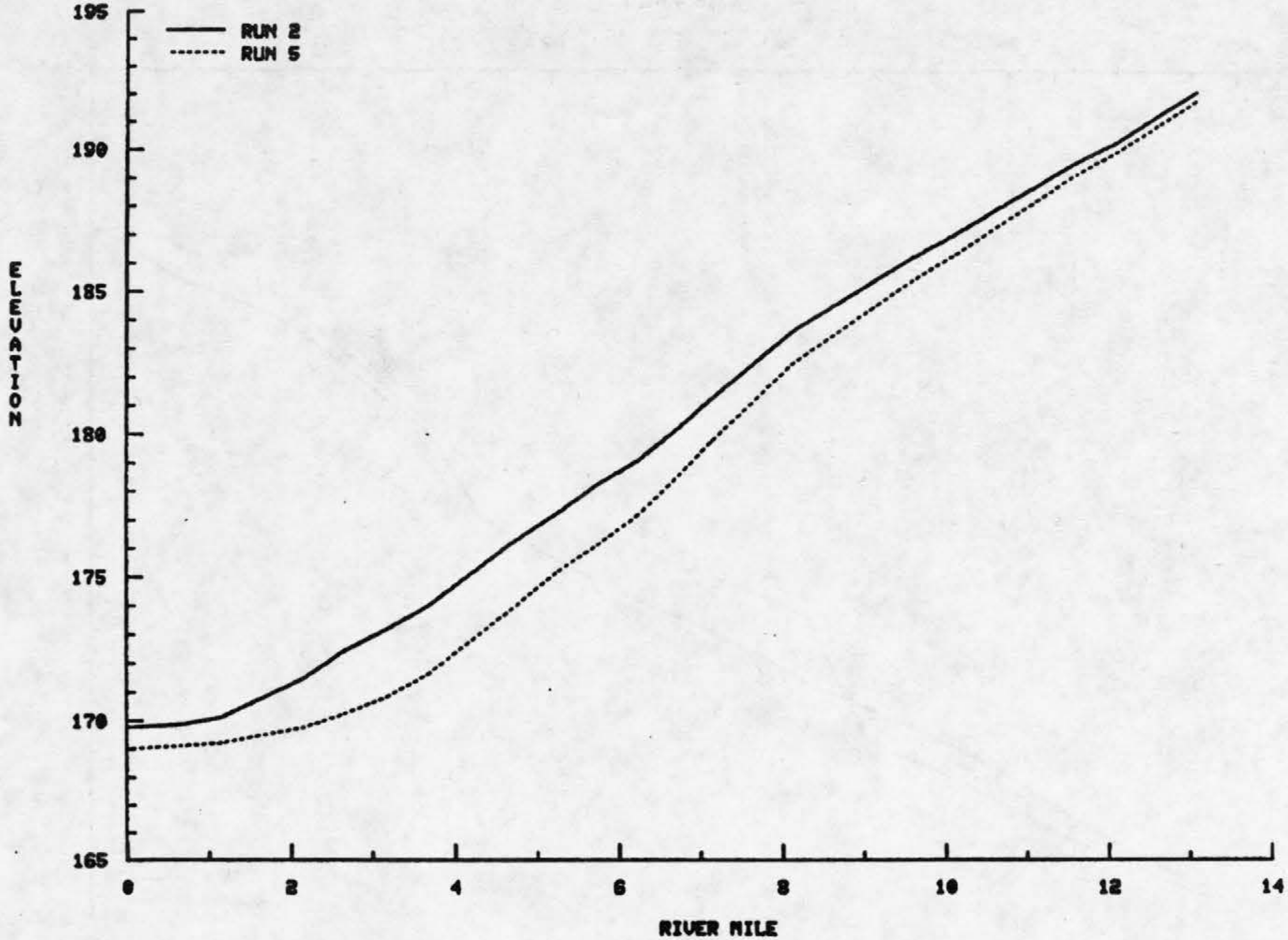


Figure 6.49. Maximum water surface on Yocona River for Runs 2 and 5.

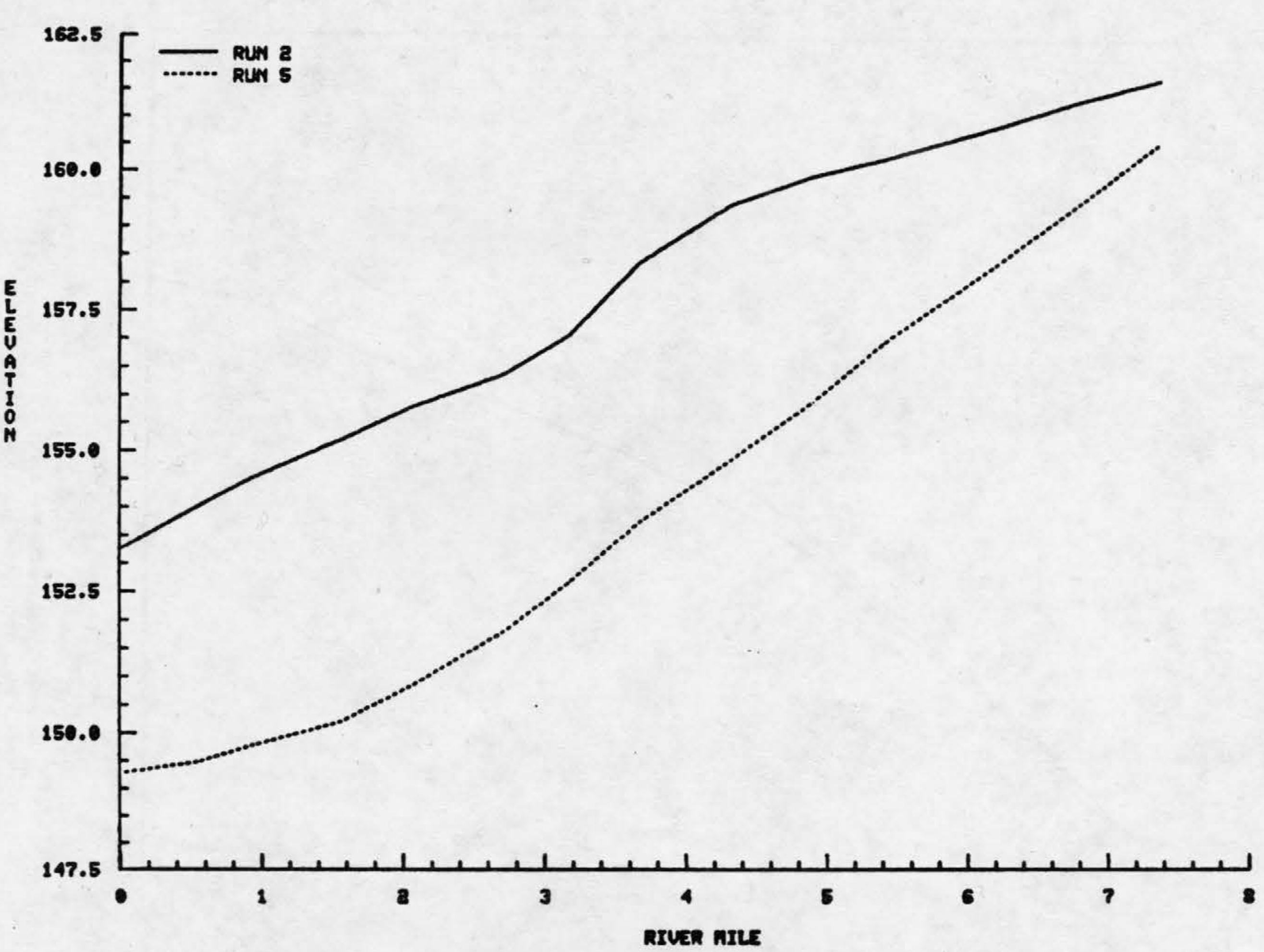


Figure 6.50. Maximum water surface on Tillatoba Creek for Runs 2 and 5.

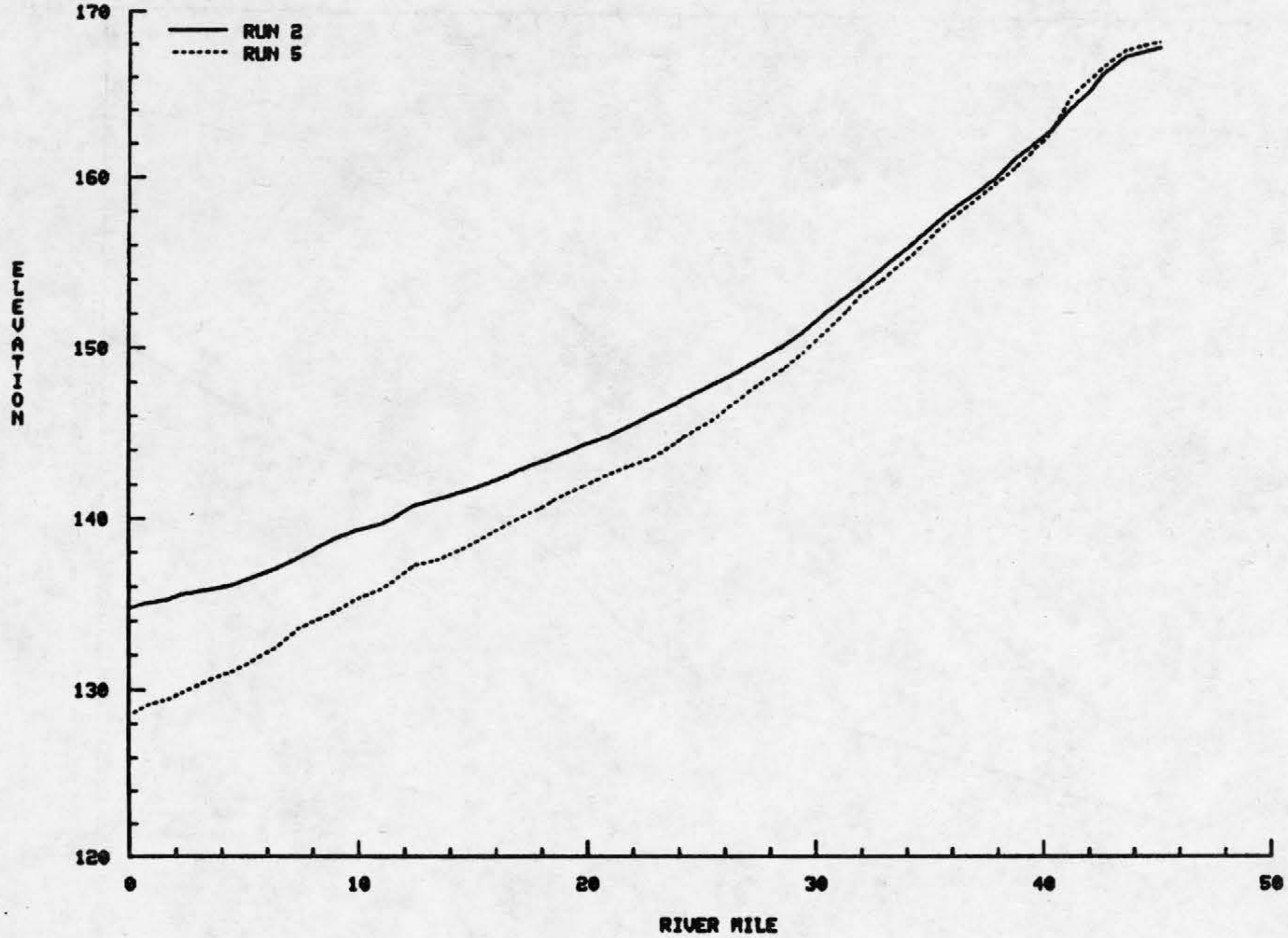


Figure 6.51. Maximum water surface on Yalobusha River for Runs 2 and 5.

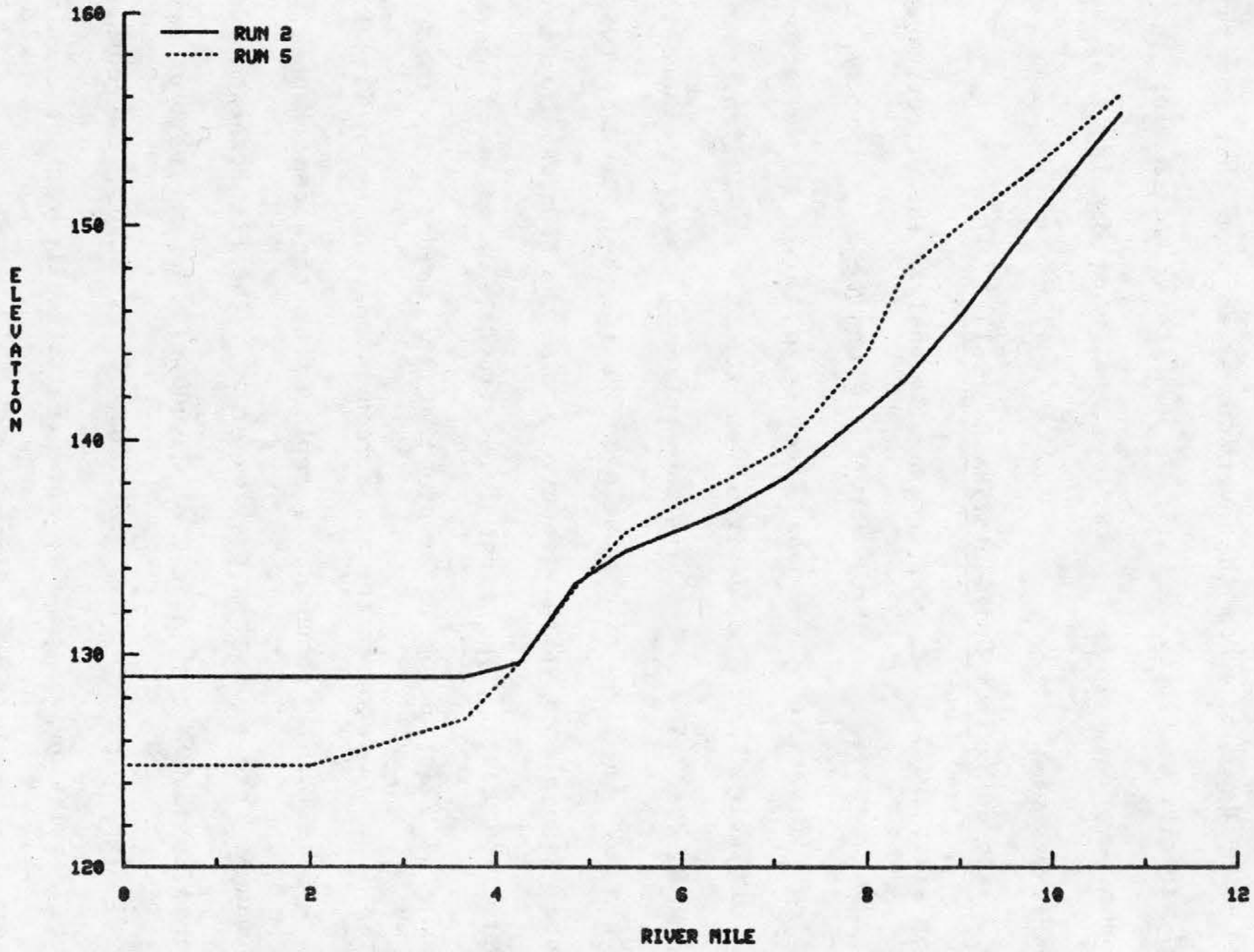


Figure 6.52. Maximum water surface on Pelucia Creek for Runs 2 and 5.

are needed on these rivers. Figures 6.47 through 6.52 show that maximum stages with the step channel are reduced throughout the basin.

The step channel was able to reduce stages even though the channel aggradation was not reduced due to two factors. First, the step channel induced more deposition on the overbank areas such that not as much channel capacity was lost. Second, the wide total bottom width provided more operating channel (with its lower value of Manning's n) at the higher discharges.

6.7 Run 6 (Maximum Sedimentation Control)

The sixth and last run was designed to analyze the effectiveness of placing numerous grade control structures on the P-Q Floodway, Little Tallahatchie River and Yalobusha River. To this end the structures listed in Table 1.3 were designed on the Little Tallahatchie and Yalobusha Rivers. The structures were placed on a grade close to the existing grade on five mile spacing. On the P-Q Floodway two high structures were placed which effectively turn the Floodway into a sediment detention basin. The first tall structure was placed above the confluence of Black Bayou to ensure that the major agricultural area above the Floodway receives the stage reductions provided by Plan E. As in Run 5, the Plan E channel was replaced by the step channel. Two other changes were made from previous runs. The Ft. Pemberton Cutoff was opened at 15,000 cfs instead of 25,000 cfs and the weir on Pelucia Creek was lowered 3 feet to elevation 109 ft NGVD. The change of structure regulation was made to more realistically reflect regulation as indicated by the Vicksburg District.

Figure 6.53 shows the volume of aggradation for the larger river reaches for Run 6. Figures 6.54 through 6.59 show the initial and final

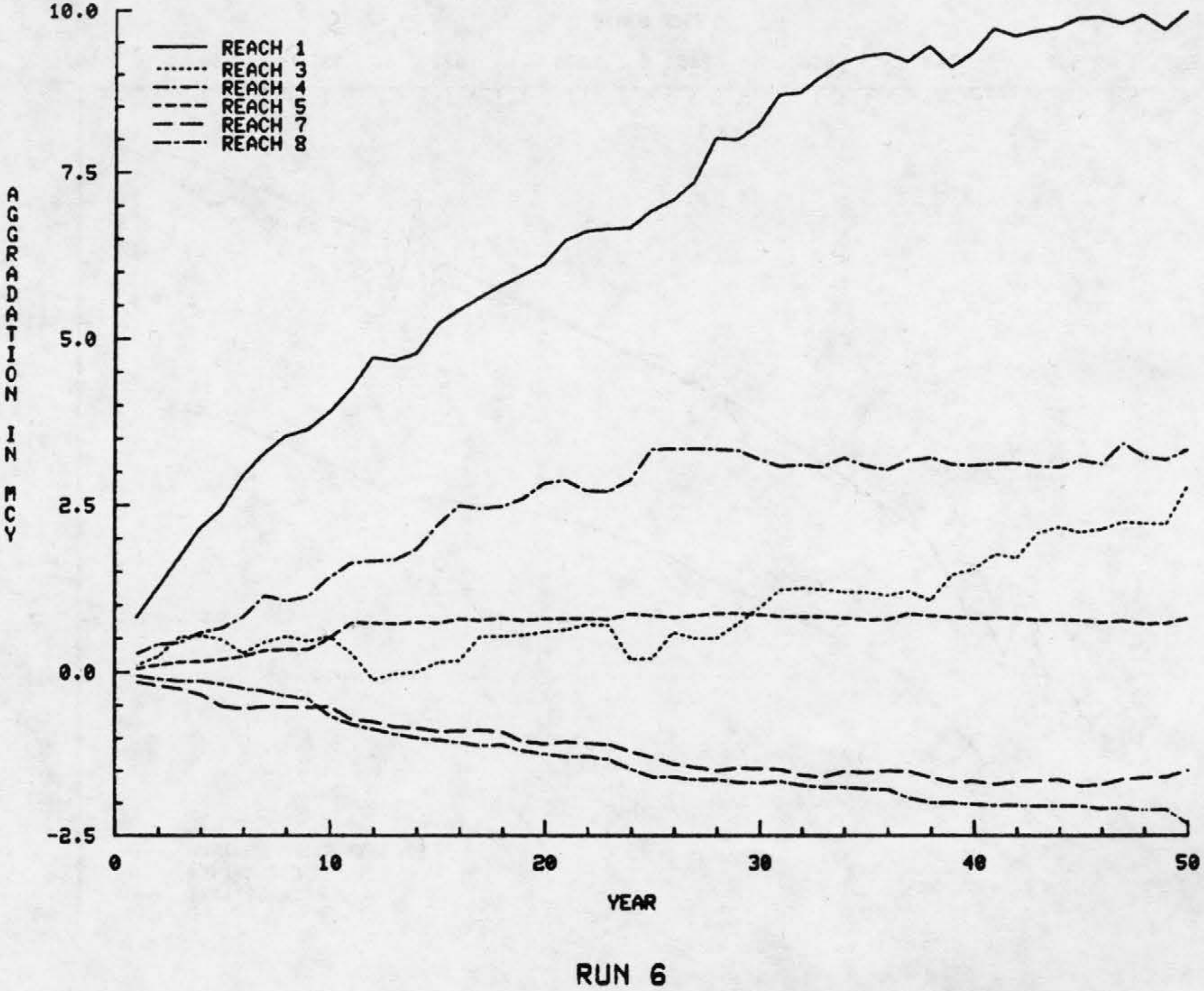


Figure 6.53. Volume of aggradation for river reaches 1, 3, 4, 5, 7 and 8 for maximum sediment control (Run 6).

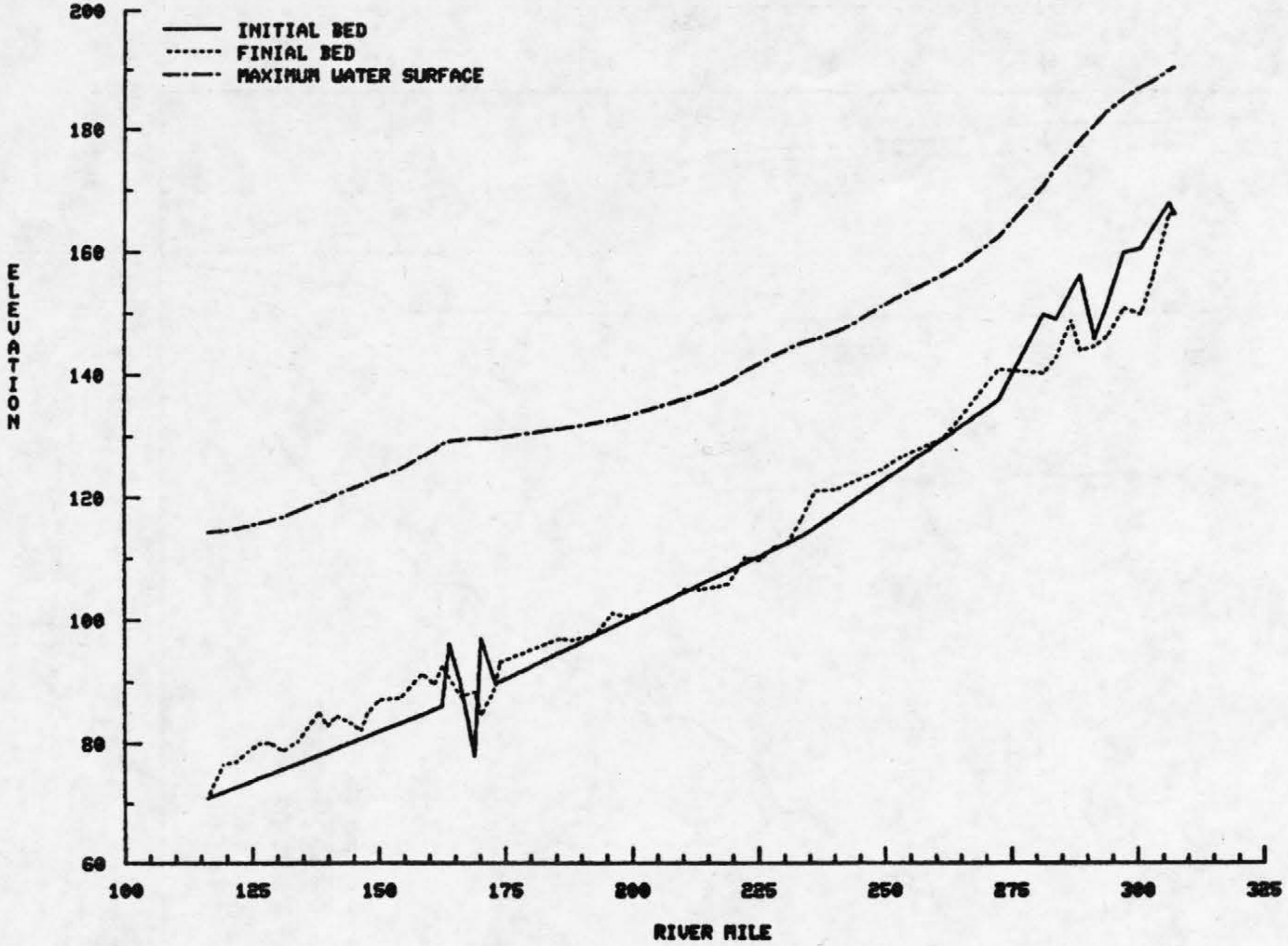


Figure 6.54. Profiles on mainstem for maximum sediment control conditions (Run 6).

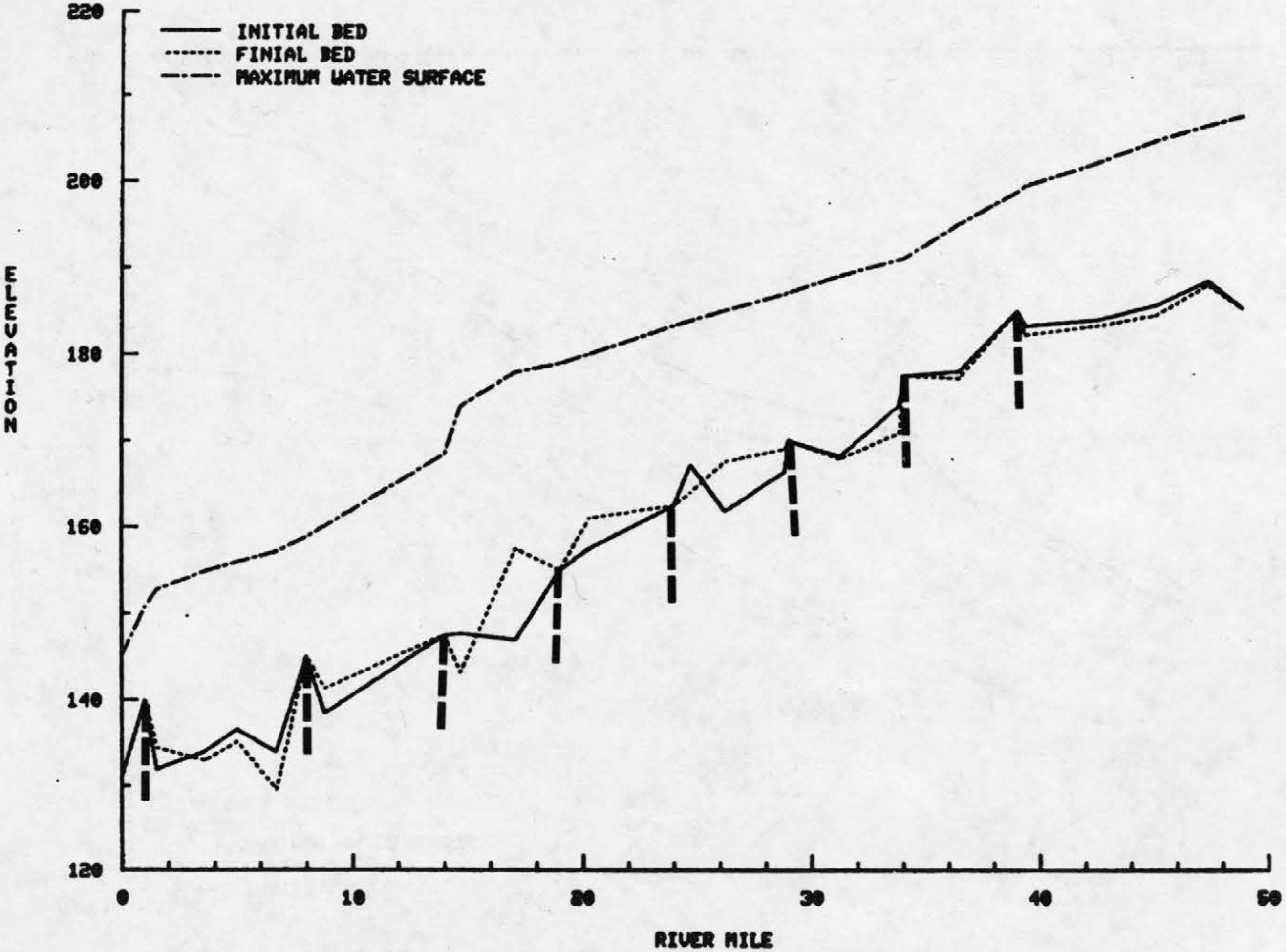


Figure 6.55. Profiles on P-Q, Little Tallahatchie for maximum sediment control conditions (Run 6).

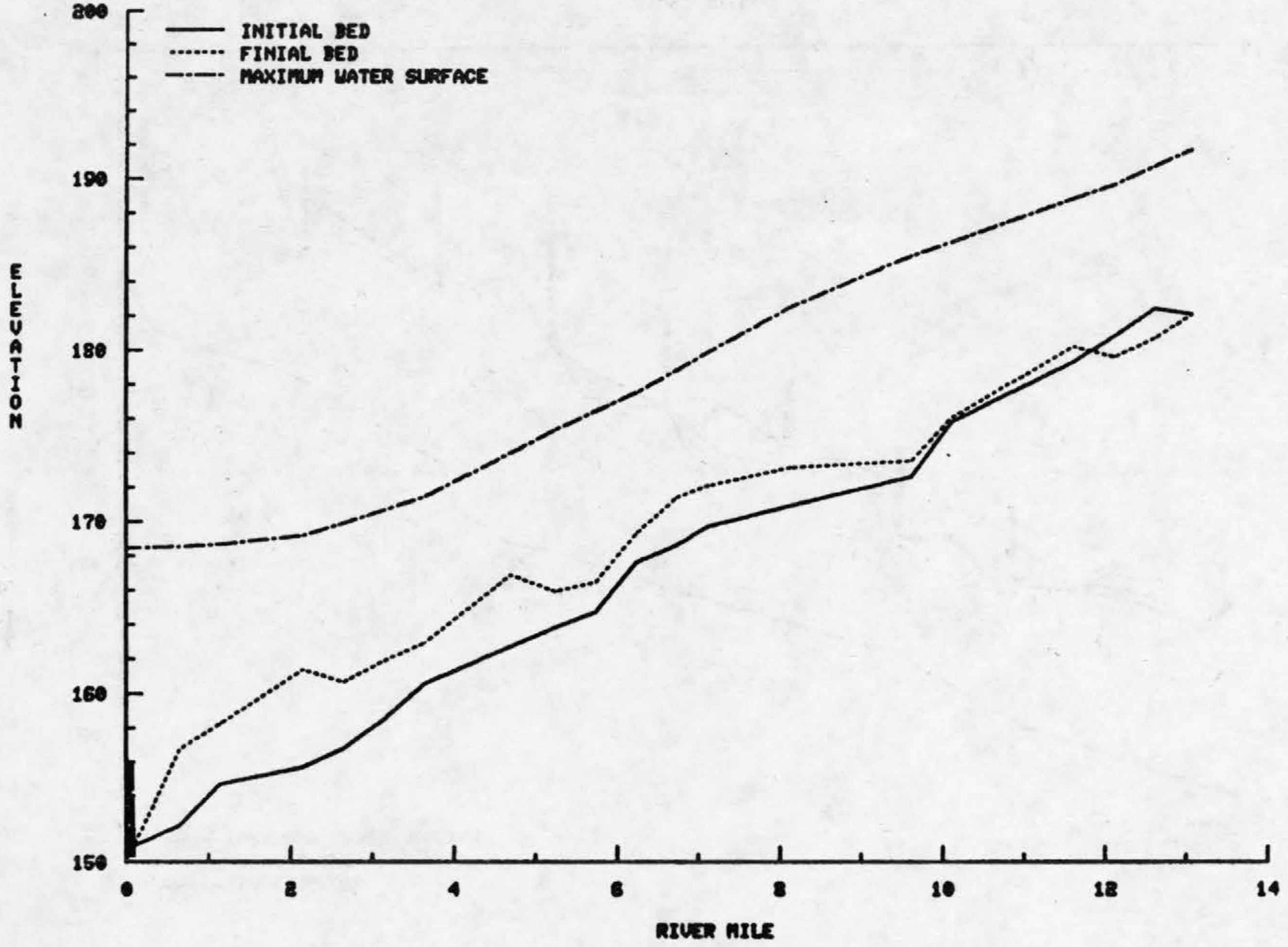


Figure 6.56. Profiles on Yocona River for maximum sediment control conditions (Run 6).

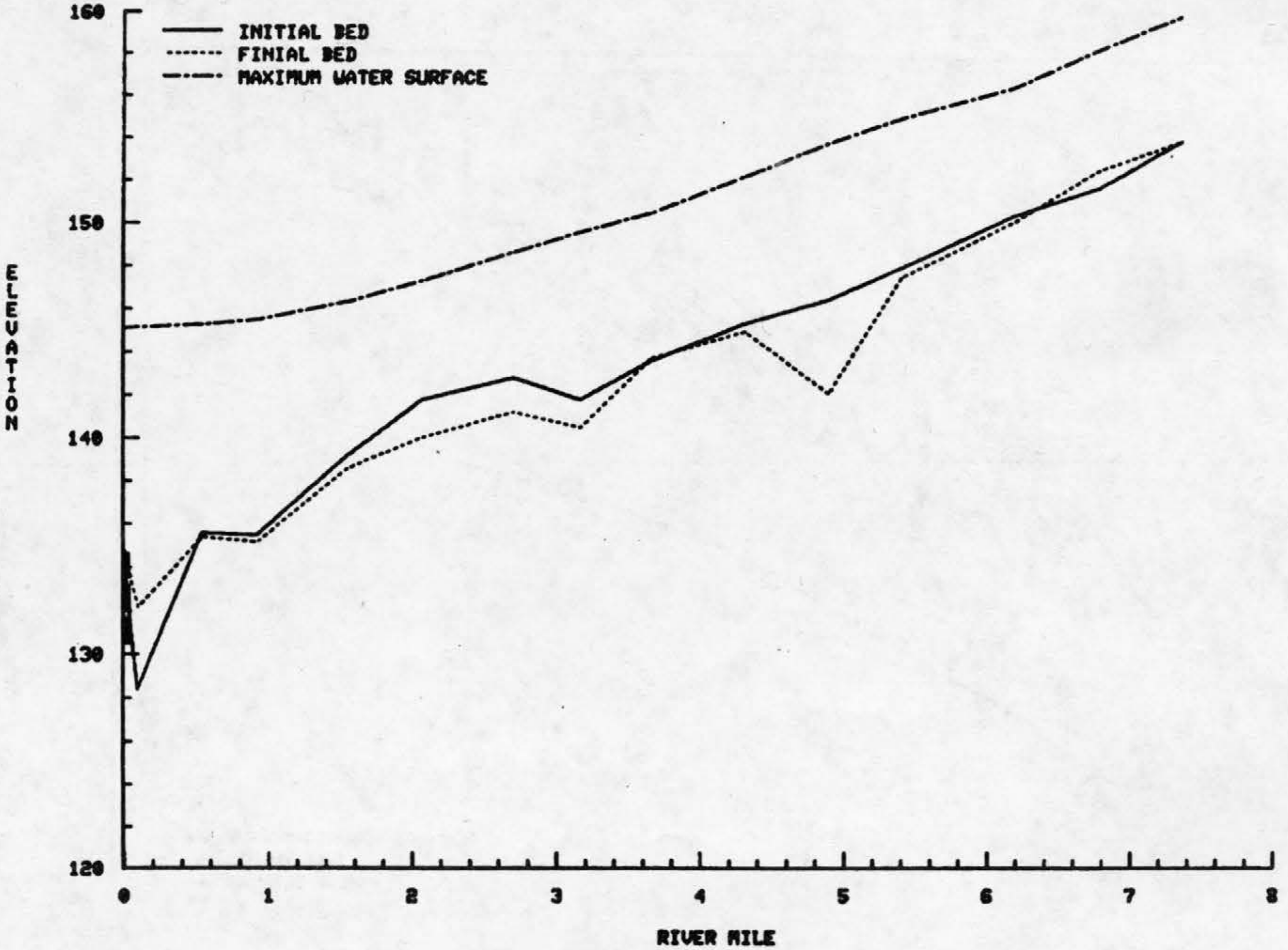


Figure 6.57. Profiles on Tillatoba creek for maximum sediment control conditions (Run 6).

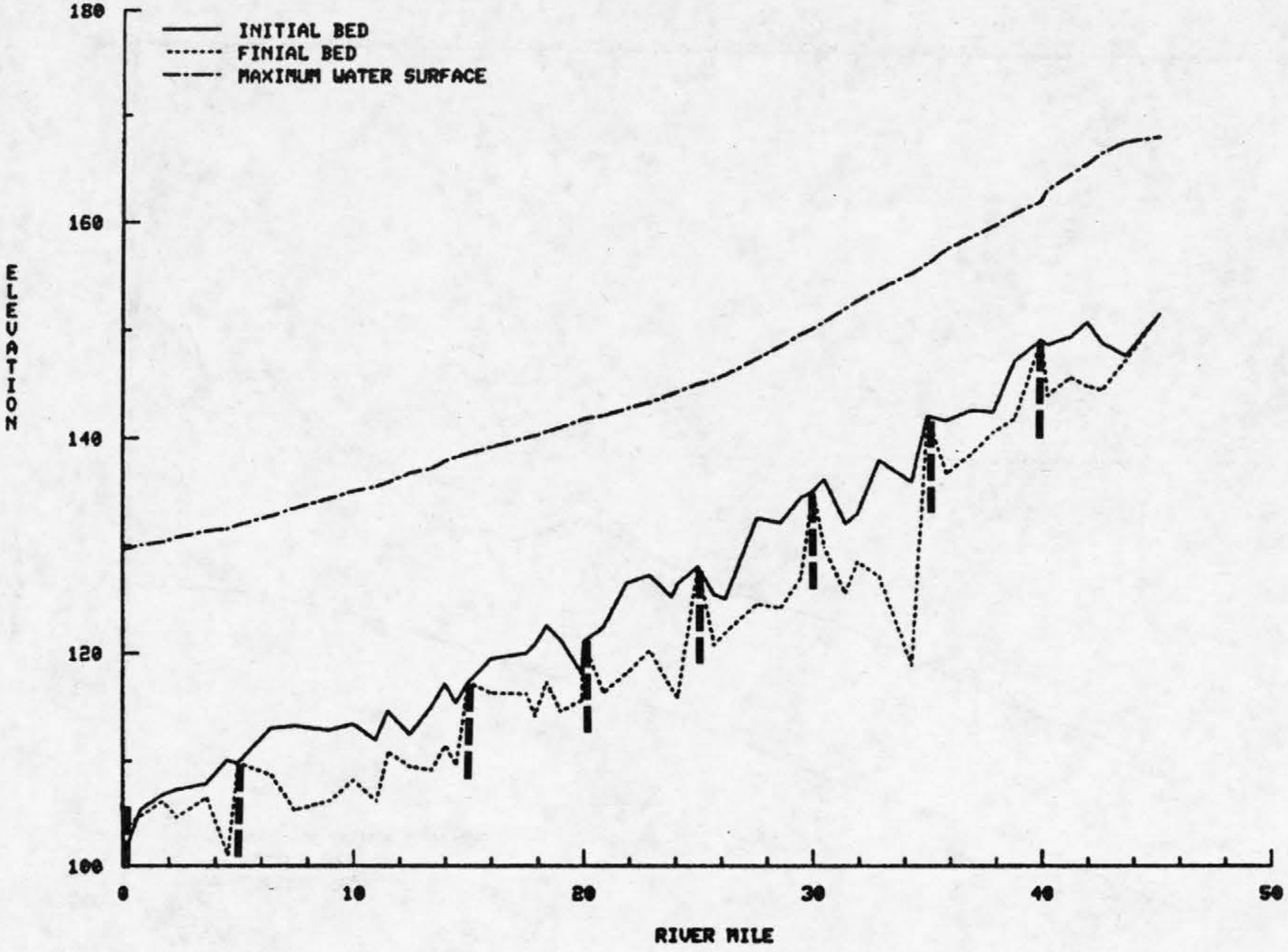


Figure 6.58. Profiles on Yalobusha River for maximum sediment control conditions (Run 6).

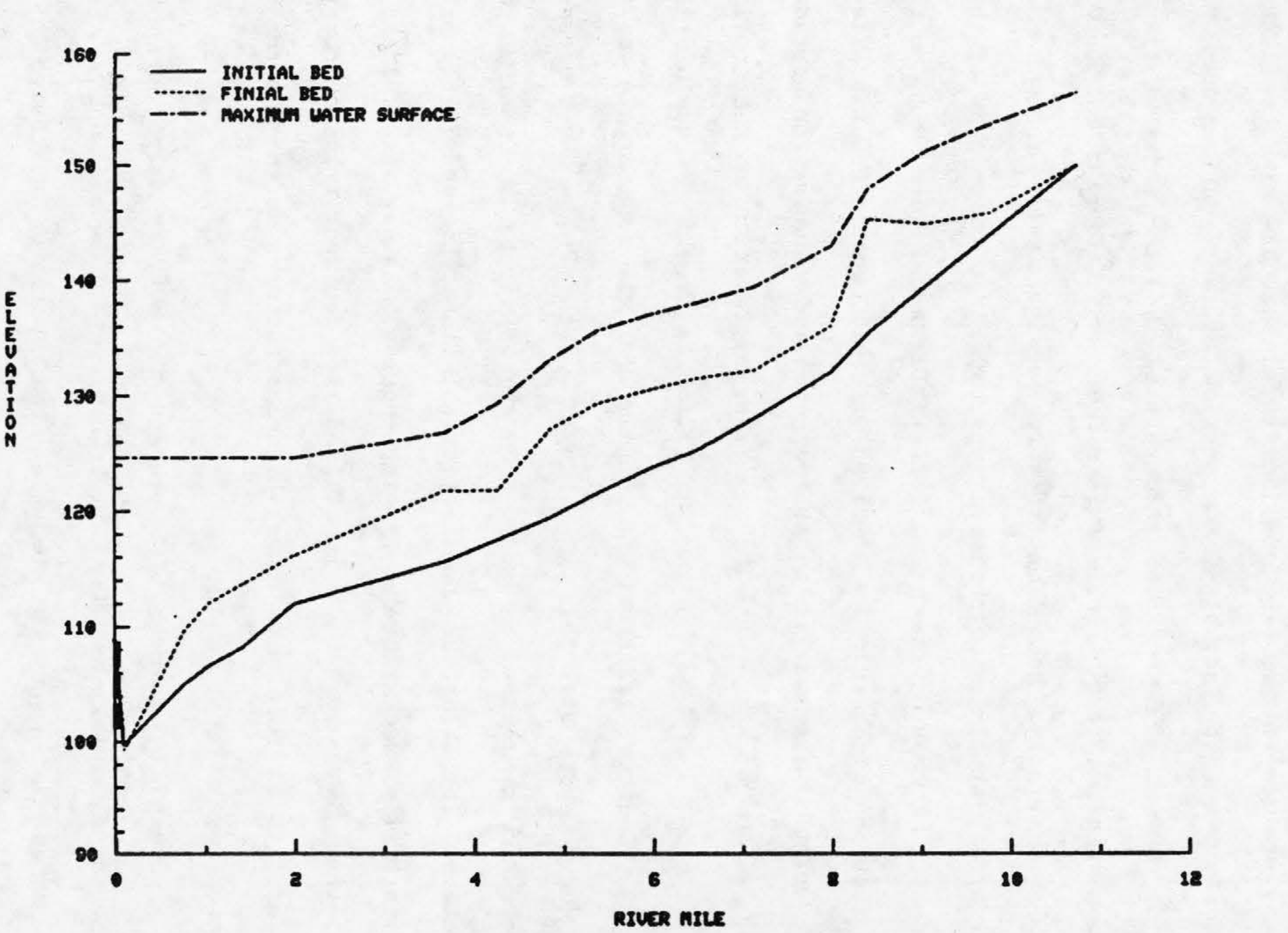


Figure 6.59. Profiles on Pelucia Creek for maximum sediment control conditions (Run 6).

bed profiles and the maximum sedimentation control. While the final thalweg profile on the P-Q, and Little Tallahatchie may show lowering, in most cases the actual cross section aggraded and a deep narrow section formed. Figures 6.60 through 6.62 show the sediment transport on the mainstem, P-Q, Little Tallahatchie and Yalobusha for Runs 2, 5 and 6. Generally, not all structures designed were effective. The structures with the most positive impact were at the mouths of the P-Q Floodway, Tillatoba Creek, and Pelucia Creek. Figures 6.54 and 6.56 show that the high structure at river mile 1.00 on the P-Q was effective in reducing sediment input to the mainstem and reducing the aggradation at the mouth of the P-Q. The remaining aggradation at the confluence (Figure 6.54, R.M. 232) is due to Tillatoba Creek. Figure 6.61 shows that the sediment transport out of the P-Q was reduced almost 10 MCY from Run 5. The structure at R.M. 8.0 on the P-Q was not necessary. Figure 6.55 shows that it would have to be increased in height to be effective. The structures on the Little Tallahatchie and Yalobusha were only partially successful in stopping erosion. As Figures 6.61 and 6.62 show, the structures only slightly modified sediment transport on these streams. It is felt that fewer, higher structures on these streams may be necessary.

Figures 6.63 through 6.66 present the 50-year stage duration at Greenwood, Swan Lake, Whaley and Batesville for Runs 5 and 6. Figure 6.63 shows the impact of reducing the operation discharge of the Ft. Pemberton cut-off from 25,000 to 15,000 cfs and the other features changed in Run 6. The frequency of stages less than approximately 116 ft NGVD was increased. The frequency of stages above 116 ft NGVD were reduced by the reduced aggradation downstream. Stages at Swan Lake

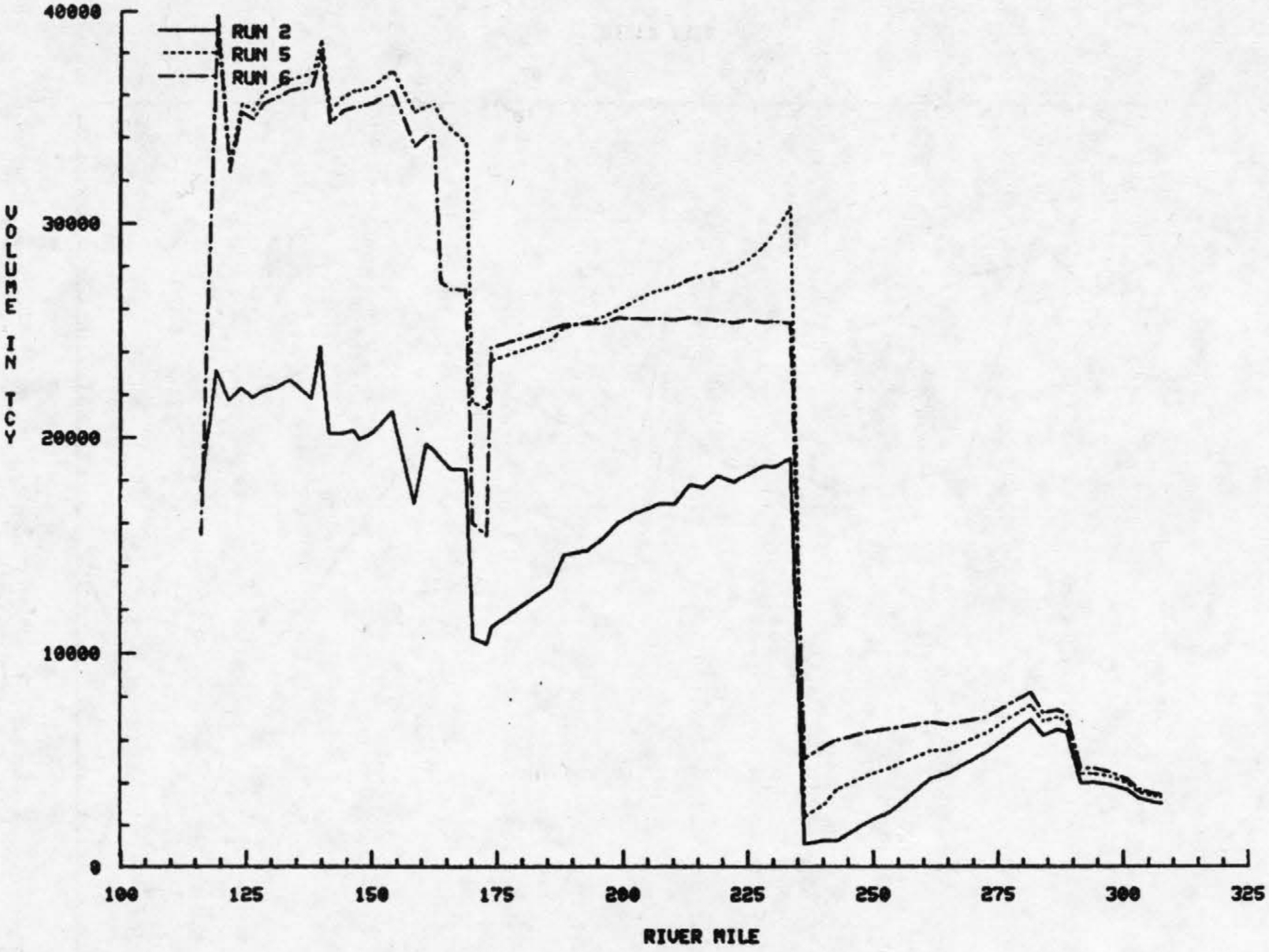


Figure 6.60. Volume of sediment transport on mainstem for Runs 2, 5 and 6.

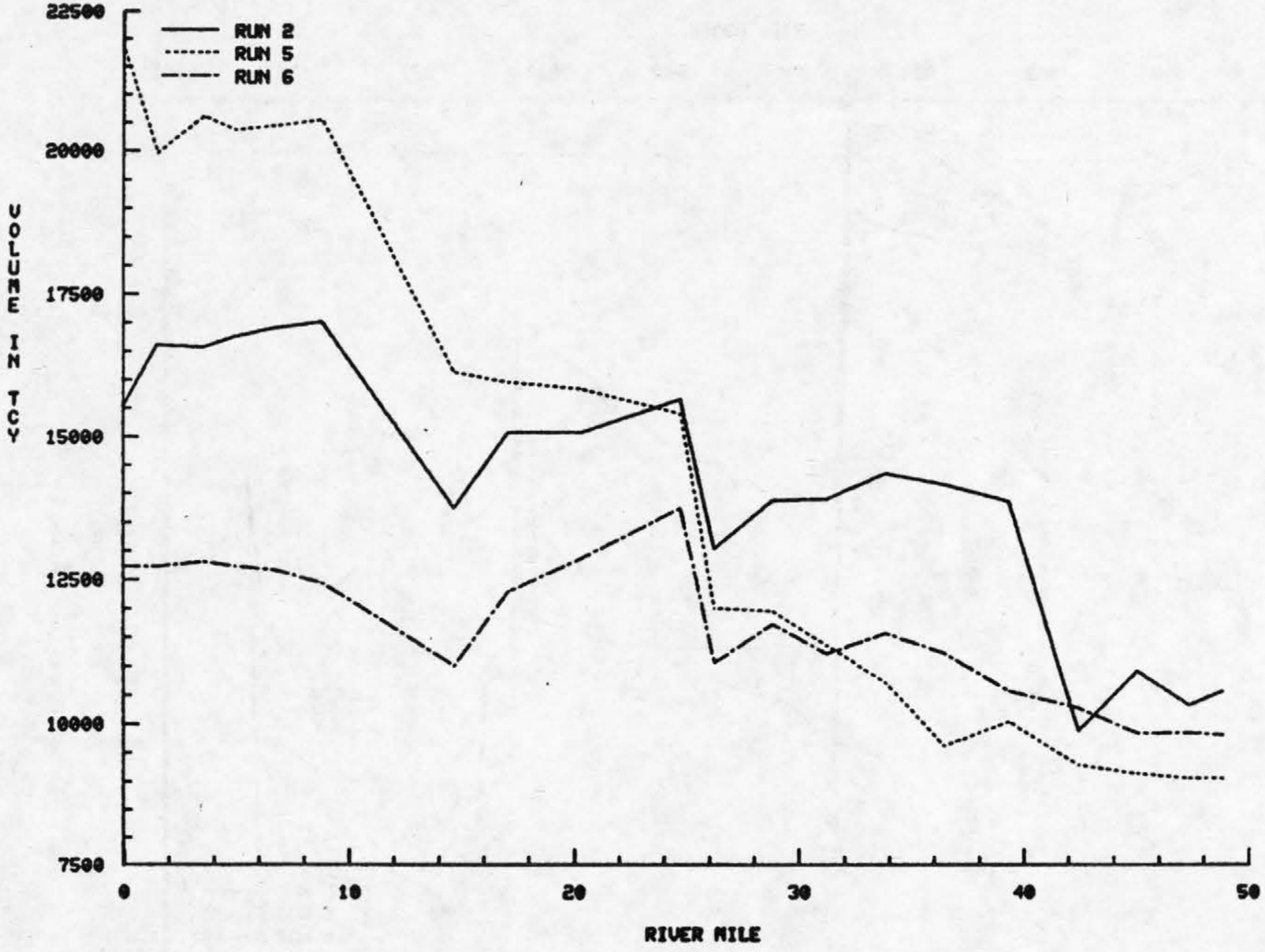


Figure 6.61. Volume of sediment transport on P-Q, Little Tallahatchie for Runs 2, 5 and 6.

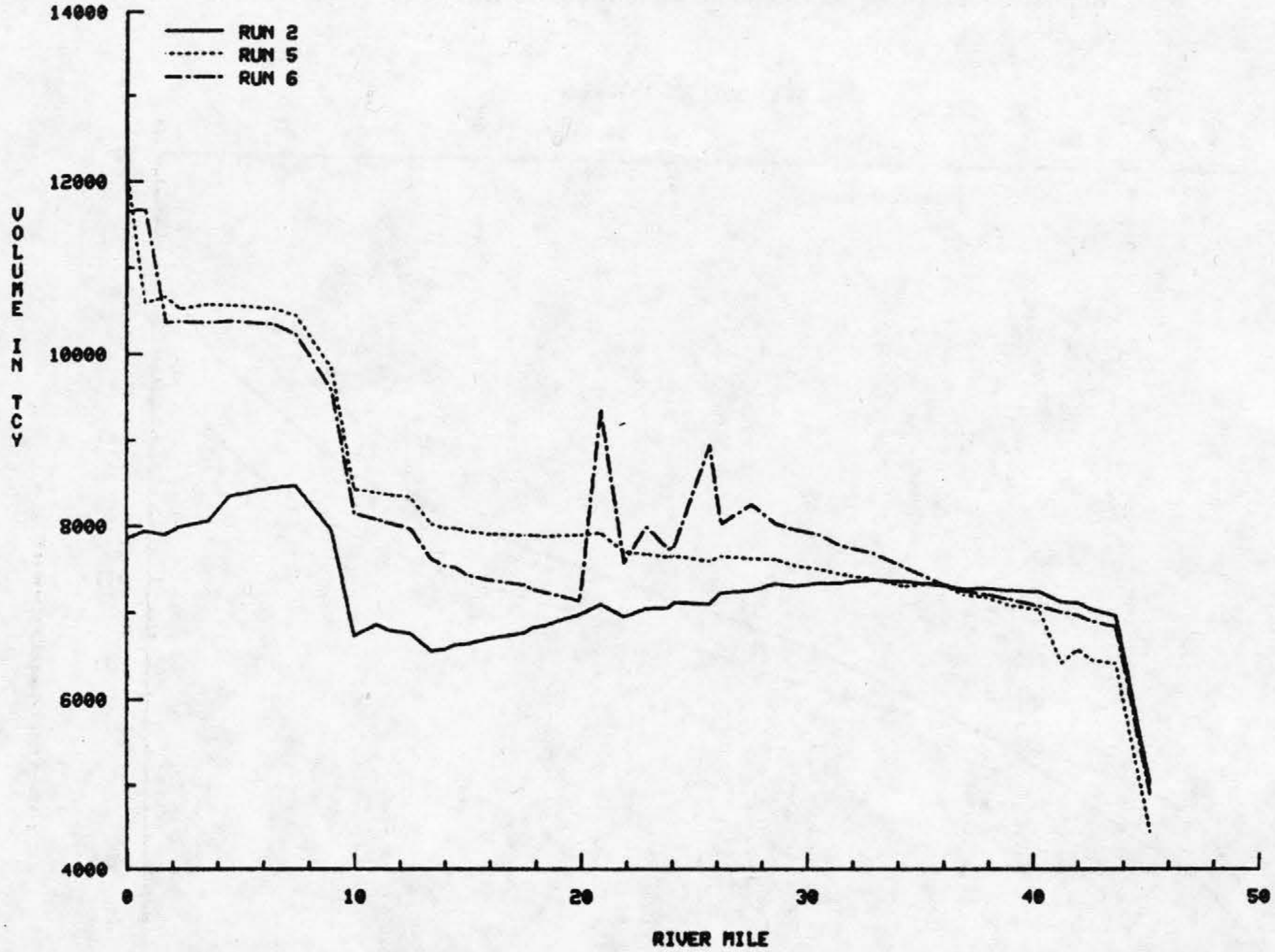


Figure 6.62. Volume of sediment transport on Yalobusha River for Runs 2, 5 and 6.

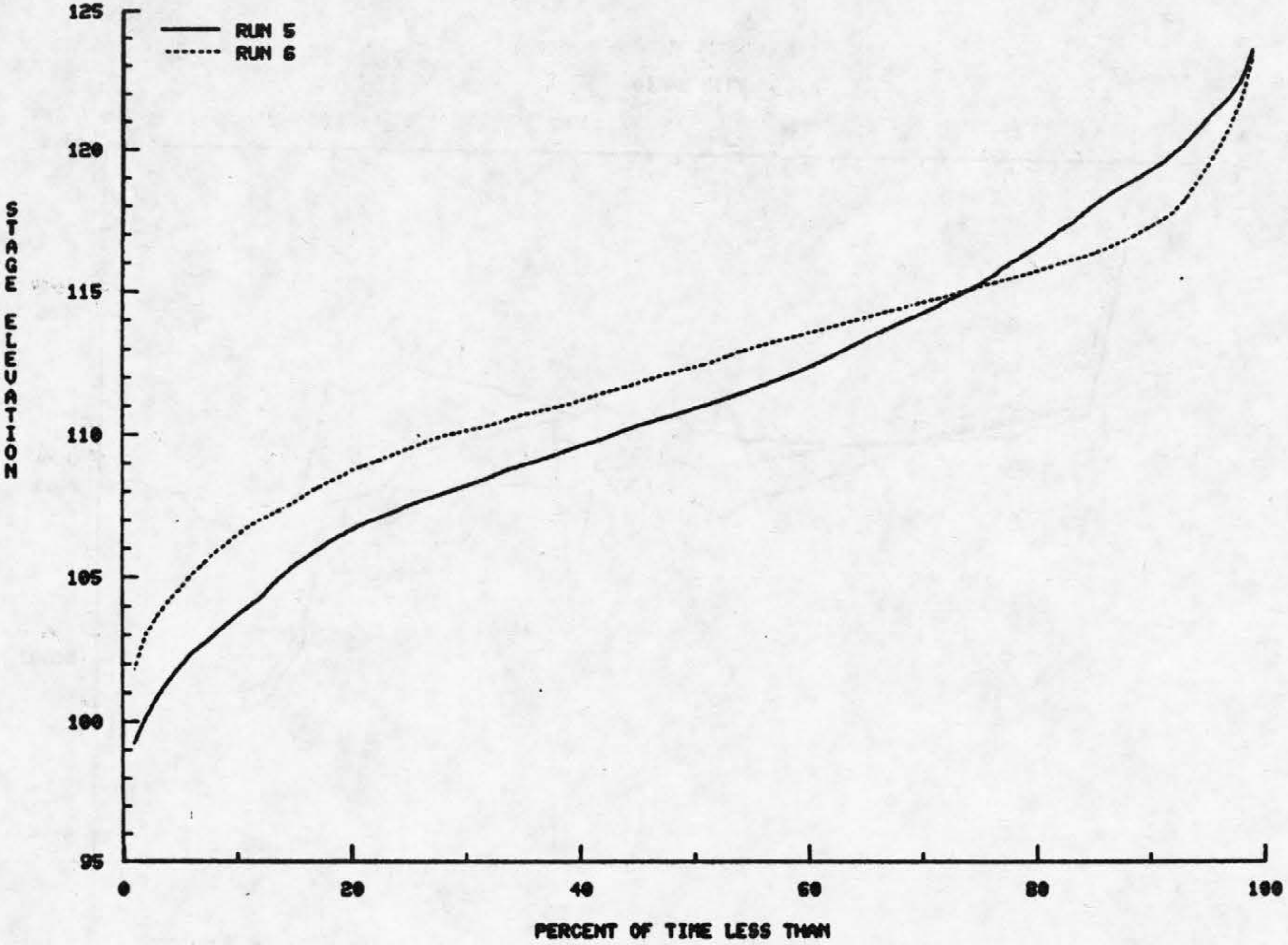


Figure 6.63. Stage duration at Greenwood for Runs 5 and 6.

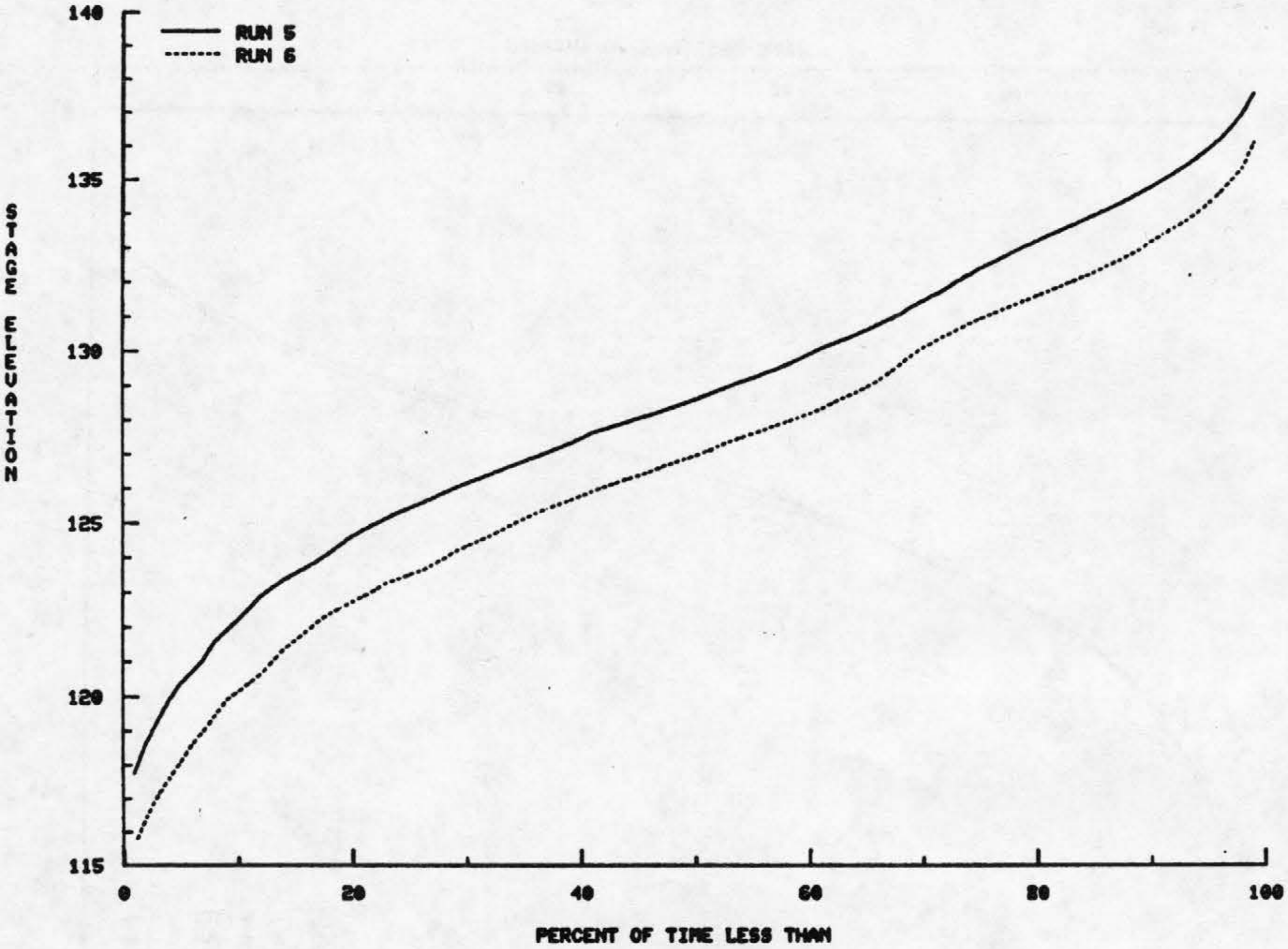


Figure 6.64. Stage duration at Swan Lake for Runs 5 and 6.

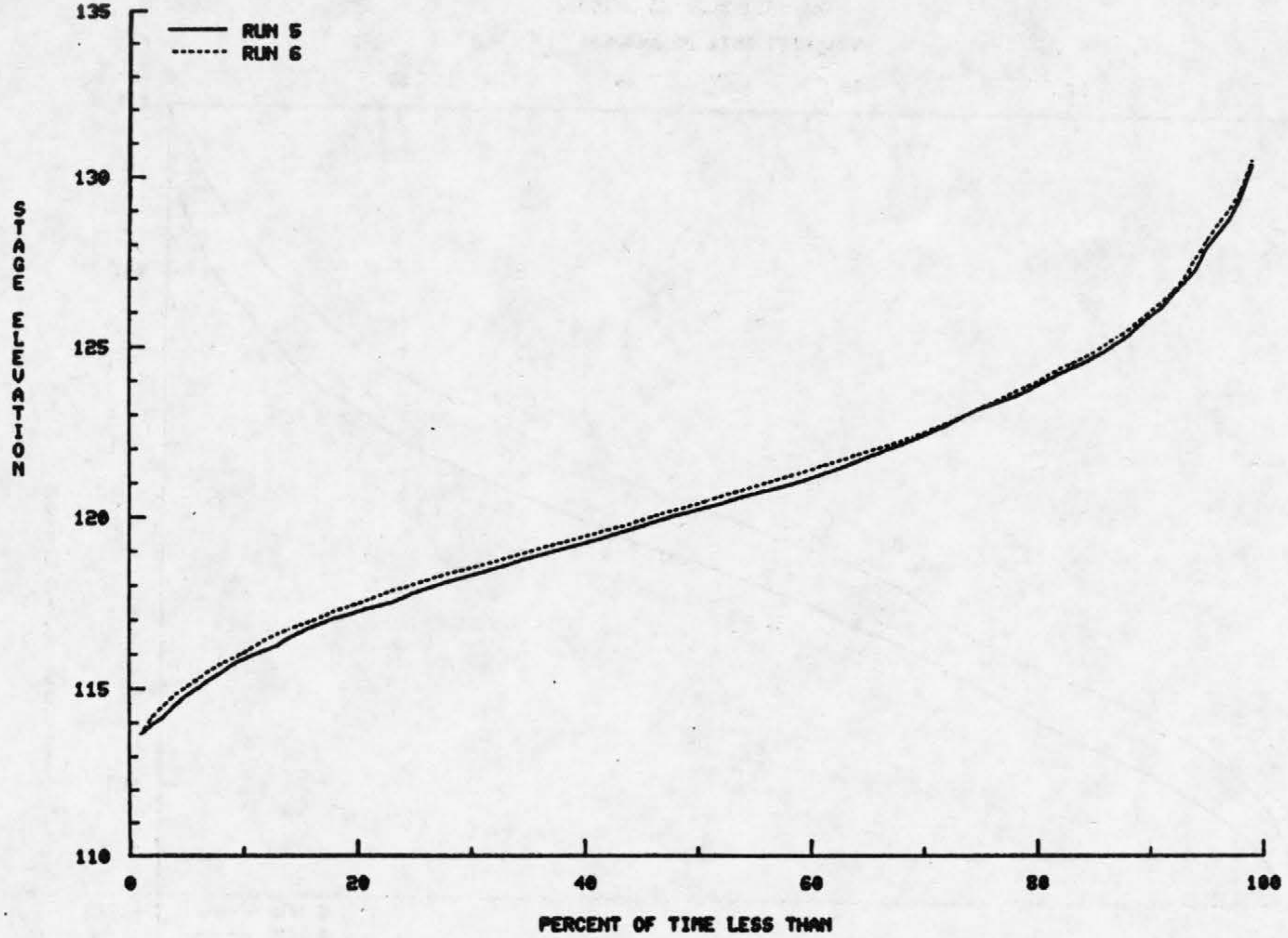


Figure 6.65. Stage duration at Whaley for Runs 5 and 6.

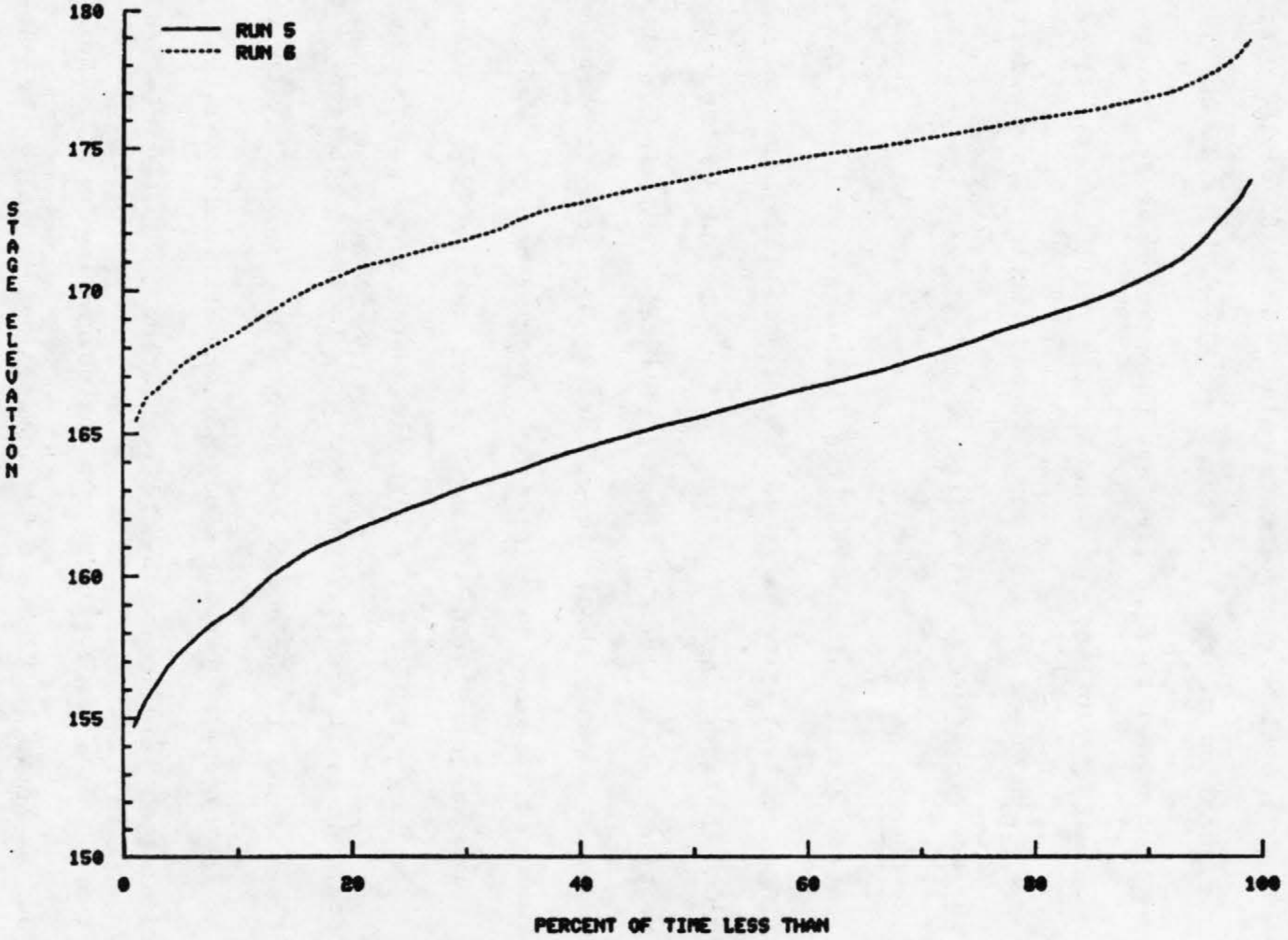


Figure 6.66. Stage duration at Batesville for Runs 5 and 6.

were uniformly reduced by 2 ft from Run 5, while at Whaley there was little change. At Batesville, stages were increased by about 8 ft due to the high weirs and the change from degradation to aggradation on the P-Q and Little Tallahatchie. It is recognized that this may not be acceptable from a flood control standpoint. Revision of the crest grade or the elimination of the structures at River Miles 14.00, 19.00 and 24.00 may be needed to alleviate any potential adverse impacts on the flood control capability of the Little Tallahatchie River. The structures at River Miles 1.00 and 8.00 had little if any effect on the water surface elevation at Batesville.

6.8 Conclusions

From the results of the runs the following conclusions can be made concerning the best alternatives. First and foremost the runs have shown that the step channel design is far superior to the trapezoidal cross section. While the step channel will require a wider right-of-way the additional expense should be off set by the long term stage reductions provided assuming no maintenance dredging occurs. While the step channel does aggrade with similar volumes as the Plan E channel the aggradation does not effect the high flow water surface as much.

The river basin was fairly insensitive to the regulation of the Ft. Pemberton cut-off of Greenwood Bendway. This insensitivity was also found in the Greenwood Bendway study (Simons, Li, and Brown, 1979). The only significant difference due to regulation at 25,000 cfs and 15,000 cfs (Runs 5 and 6 respectively) was the change in the stage duration at Greenwood as shown in Figure 6.63. Surpisingly opening the cut-off at lower discharges raised low flow stages and lowered the high flow stages, both beneficial effects. This was probably caused by having a more uniform flow hydrograph allowing it to maintain a smaller but more stable and uniform channel.

The results obtained here are not adequate to determine the best operation of the cut-off, but they do indicate that the existing earthen plug is beneficial and that it should be operated to moderate the flows in the Bendway. If a structure replaces the plug, experience once it is built should indicate the best operation method but until that time the plug with a 15,000 cfs rule should be adequate.

The study results indicate that the best and most effective grade control features were those structures located at the confluence of tributaries and the mainstem. Specifically the confluence structures on the Yalobusha, P-Q, Pelucia and Tillatoba are the most important. The higher these structures are the more sediment they stop from moving into the mainstem. Their height should only be limited by upstream backwater considerations. Because they are located at confluences which are currently deposition zones, these structures do not cause downstream channel degradation. The high structure on the P-Q at RM 1.0 (Run 6) was very effective. It is strongly recommended that this structure be given more consideration. Less successful were the midstream structures on the Yalobusha and Little Tallahatchie. These low structures were ineffective in dissapating energy and thus stopping erosion.

VII. RECOMMENDATIONS FOR FUTURE STUDIES

7.1 General

With the completion of Phase II, the Sedimentation Study of the Yazoo River Basin has reached a logical ending point. While the future actions of man or nature may invalidate some of the assumptions made here, the general conclusions and recommendations regarding sediment problems addressed here should remain valid barring the most severe of environmental changes. Site specific studies may be needed if major features of the design are changed. The only specific recommendation made is that "trouble spots" be monitored on a continuing basis to ensure maintenance of current conditions and the success of Plan E once completed. The following sections outline the specific monitoring suggested and the conditions under which additional site specific studies would be needed.

7.2 Monitoring

This analysis has established the location of seven existing or possible problem areas. It is recommended that these areas be monitored on a continuing basis. In order of relative importance the areas are: 1) Tallahatchie River at confluence of P-Q Floodway, 2) the Yazoo River at the confluence of Pelucia Creek, 3) the Upper Little Tallahatchie River, 4) the Upper Yalobusha River, 5) Teoc Creek, 6) Potacocowa Creek, and 7) Ascalmore Creek. Table 7.1 lists each area, the recommended monitoring method and frequency and corrective actions. The Corps of Engineers is currently formally or informally carrying out some of this monitoring so that this program will not be entirely new. Two mainstem locations, the confluences of Pelucia Creek and the P-Q Floodway have the potential for severe aggradation. Both of these locations can

Table 7.1. Monitoring Program

Stream	Location	Problem	Problem Condition	Monitoring Method	Frequency	Corrective Actions
Tallahatchie	Confluence of P-Q	Aggradation	3,000 sq. ft. at elevation 140.0	Cross sectioning	Quarterly	Degredging or grade control on P-Q
Yazoo	Confluence of Pelucia	Aggradation	5,000 sq. ft. at elevation 116	Cross sectioning	Semi-annual	Dredging or borrow excavation of Pelucia Creek
Little Tallahatchie	R.M. 30 to Dam	Stream Bank Erosion	Two years continuous erosion	Cross sectioning and erosion pins	Annual	Bank erosion and grade control
Yalobusha	R.M. 30 to Dam	Stream Erosion	Two year continuous erosion	Cross sectioning and erosion pins	Annual	Bank erosion and grade control
Teoc	Basin	Increased Sediment Yield	1 ft. bed change	Land use survey and cross sectioning	Annual	Grade control or borrow areas
Potacocowa	Basin	Increased Sediment Yield	1 ft. bed change	Land use survey and cross sectioning	Annual	Grade control or borrow areas
Ascalmore	Basin	Increased Sediment Yield	1 ft. bed change	Land use survey and cross sectioning	Annual	Grade control or borrow areas

experience rapid loss of channel capacity, resulting in flooding and overbank deposition. It is recommended that a minimum of three cross sections at each location be monitored quarterly at the P-Q and semi-annually at Pelucia. Minimum average bankfull channel area at the P-Q should be 3400 sq. ft. (elevation 140) and 5,000 sq. ft. (elevation 116) at Pelucia to maintain existing flood flow lines. If the high sediment control sturctures are constructed, this monitoring should be discontinued.

Three tributaries to the Yalobusha have potential to cause severe aggradation in the Yalobusha and Greenwood Bendway. These tributaries Teoc, Potacocowa and Ascalmore Creeks, should be monitored on an annual basis. Of concern on these creeks is an increase in sediment load over present values. Possible causes of increased sediment load would be base level lowering which could induce head cutting and land use changes. It is proposed that a minimum of three cross sections be established on each creek and surveyed once a year. A bed elevation change of one foot would indicate potential problems. In addition, land use in the watersheds should be monitored with potential problems occurring when forested land changes to row crop.

The upper reaches of the Yalobusha and Little Tallahatchie Rivers have a large potential for bed and bank erosion. It is proposed that approximately ten cross sections with active erosion be identified on each river. Cross sections and erosion pins should be placed at these spots. Of particular concern should be the reported outcrop of "ironstone" in the Little Tallahatchie one-half mile upstream of the Belmont Bridge. The exact nature and extent of this hard point should be determined. If erosion continues for more than two years the degradation may be more than normal for the stream and corrective action taken if justified.

7.3 Site Specific Studies

No additional system analysis runs are required. The runs provided here present a wide range of alternatives and conditions. Experience has shown (Brown, 1982) that it is not necessary to run the model for slight changes in conditions. In the long term the river system behaves rationally, once properly understood. Therefore, proper engineering judgement can predict the river response to small changes from the design alternatives. Site specific studies may be needed for four conditions. These conditions are:

1. channel enlargement
2. channel realignment
3. tributary modifications
4. grade control systems

The first three conditions are self-explanatory. The fourth condition refers to situations where one or more grade control structures are planned for a stream. In this study it has been found that effects of structures can be passed far downstream in the form of degradation and bank erosion, therefore, analysis should be carried out before hand. The analysis required may be simple equilibrium slope calculations (Mussetter, 1982) or sediment routing.

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