United States
Environmental Protection
Agency

Environmental Monitoring
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EPA-600/4-79-036
May 1979

Research and Development

Hydraulics of the Atchafalaya Basin Main Channel System:

Considerations from a Multiuse Management Standpoint

EPA/600/4-79/036

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May 1979

HYDRAULICS OF THE ATCHAFALAYA BASIN MAIN CHANNEL SYSTEM
Considerations from a Multiuse Management Standpoint

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FOREWORD

Protection of the environment requires effective regulatory actions that are based on sound technical and scientific information. This information must include the quantitative description and linking of pollutant sources, transport mechanisms, interactions, and resulting effects on man and his environment. Because of the complexities involved, assessment of specific pollutants in the enviornment requires a total systems approach that transcends the media of air, water, and land. The Environmental Monitoring and Support Laboratory-Las Vegas contributes to the formation and enhancement of a sound integrated monitoring data base for exposure assessment through programs designed to:

- develop and optimize systems and strategies for monitoring pollutants and their impact on the environment

- demonstrate new monitoring systems and technologies by applying them to fulfill special monitoring needs of the Agency's operating programs

This report presents hydraulics of the Atchafalaya Basin main channel systems. The U.S. Environemental Protection Agency, the U.S. Army Corps of Engineers, the U.S. Department of the Interior, the State of Louisiana, special interest groups, and other interested individuals will use this information to assess the potential impact of proposed hydrological modifications and to develop alternative land and management plans, which will accommodate flood-flows and maintain an acceptable level of environmental quality. For further information contact the Water and Land Quality Branch, Monitoring Operations Division.

George B. Morgan
Director
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Las Vegas

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INTRODUCTION

The Atchafalaya Basin in south-central Louisiana is a large alluvial basin that has national significance as a multiple resource. It derives this significance principally from possessing high quality habitats for fish and wildlife, being a semiwilderness area of high recreational value, and functioning as a floodway for the lower Mississippi River. To meet the need for flood control, the U.S. Army Corps of Engineers is considering hydrological modifications (channel training or channelization) for the Basin. The Basin's present hydrological cycle and complex water circulation pattern supports one of the world's most highly productive natural areas.

In response to a request by the Governor of Louisiana and a joint U.S. congressional resolution, the U.S. Environmental Protection Agency (USEPA), U.S. Army Corps of Engineers (USCE), and U.S. Department of the Interior (USDI) are conducting a water and land quality study in the Atchafalaya River Basin. The study is assessing the potential impact of proposed hydrological modifications and developing alternative land and water management plans to accommodate floodflows and maintain an acceptable level of environmental quality for the Atchafalya Basin. The purpose of this report is to consider the hydraulics of the Atchafalaya Basin main channel system from a multiuse management standpoint.

CONCLUSIONS

1. The use of the Atchafalaya Basin for flood control must be within the constraints imposed by the presence of the Atchafalaya River.

2. Ultimately, the excess capacity of the area within the guide levees for flood control use will be only the cross-sectional area above the stable, active channel cross section and that above the overbank area.

3. Any additional capacity can only be acquired by raising the guide levees.

4. The inherent limitations of raising the guide levees must be resolved through the diversion of floodwaters outside the Basin above or at the latitude at which the project flow line exceeds the grade of the guide levees.

5. The most effective alternative for achieving maximum long-term use for flood control at a minimum cost to the environment is to enhance the development of the channel in the direction of its ultimate stable conditions while simultaneously minimizing sedimentation in the backwater areas.

6. There should be confinement of flows to the Atchafalaya Basin main channel and the channel leading to Wax Lake outlet for discharges of up to but no more than 400,000 cfs[1] at Simmesport. This should be accomplished without reducing peak flows through the Old River control structure.

7. The decrease in discharge in a downstream direction should be minimized by limiting diversion through the east and west freshwater distribution channels, the east and west access channels, and any other minor channels to only the volume necessary to enhance surface water quality and environmental integrity. Provided that internal circulation is improved through the measures indicated above, the limitation of diversion to 15 percent of the Simmesport discharge appears justified.

8. Confinement of flows below the diversion points should thus be for 340,000 cfs to 382,000 cfs until bifurcation occurs toward the Wax Lake outlet and lower Atchafalaya River. From there flow should be confined in each of the two branch channels up to the proportion of the 340,000 cfs to 382,000 cfs received at the bifurcation point.

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[1] Because all available data used in preparing this report were in English units, metric units are not used. Conversion factors are given in the Appendix.

9. Confinement of flows should be achieved through the use of training levees. Levee material may be dredged from the main channel and should be deposited in a natural configuration on the channel banks with severe constraints on width and height of the deposits and on distance from the present channel.

10. Prior to such dredging, it must be determined what the water surface profile will be for the confined, delineated discharges under present channel conditions.

11. Height of the training levees should not exceed the elevation of the water surface profile so as to maintain the overbank flow for greater discharges, thereby ensuring environmental integrity.

12. Width of the levees should be no more than is necessary to support the needed height and to prevent frequent crevassing. Distance of levees from the center line of the channel should be in accord with the width of the channel expected to develop under the present discharge regime.

13. The above specifications for flow confinmement establish a maximum limit that should not necessarily be interpreted as the recommended height of training embankments. The dredging of material from the Atchafalaya Basin main channel for the purpose of flow confinement should not result in channel enlargement to the extent that modification of the water surface profile adversely affects duration, depth, and extent of annual flooding.

14. Flow confinement should proceed only to the extent allowed by annual flooding regime requirements, with further confinement to take place through the natural process of overbank flow and associated greatest deposition of sediment on the channel banks.

BACKGROUND

The Atchafalaya River Basin, Louisiana, coincides with the natural basin formed by alluvial ridges that relate to present and former Mississippi River courses (Figure 1). The Basin extends inland from the Gulf of Mexico for a distance of 125 miles to the former confluence of the Mississippi River and Red River. Continuity of the Basin is only interrupted by an alluvial ridge, the Teche Ridge, that crosses the Basin at the latitude of Morgan City, Louisiana. Central to the Basin is the Atchafalaya River, which connects the Mississippi River and Red River to the Gulf of Mexico and flows through the Teche Ridge at Morgan City where it becomes the Lower Atchafalaya River.

Until 1928 the entire Basin functioned as the Atchafalaya River flood plain and afforded a natural outlet for Mississippi and Red River floodwaters to the Gulf of Mexico. Since then major changes have evolved. In 1928 and 1956, respectively, Congress authorized the construction of a floodway through the Basin and the construction of a control structure at Old River to regulate the diversion of Mississippi River flow into the Atchafalaya River (Figure 2). To provide a defined floodway, guide levees were constructed east and west of and parallel to the Atchafalaya River and at an average distance of 15 miles apart. Floodflows as well as the annual overflow of the Atchafalaya River thus became confined to the central part of the natural basin as far south as the Teche Ridge. Through the ridge, flows are temporarily further confined to only the channels of the Lower Atchafalaya River and the constructed Wax Lake outlet until the guide levees terminate and water escapes the channels into adjacent wetlands and the Gulf of Mexico.

Despite the many adverse changes that have taken place as a result of indiscriminate use of the Atchafalaya Basin's water- and land-related resources, the Basin still constitutes a resource complex of exceptional recreational, ecological, and commercial significance. The floodway system above the Teche Ridge is one of the largest remaining alluvial flood plain hardwood swamps in the United States. It contains more than 700,000 acres of hardwoods, nearly one-third of which are cypress-tupelo swamps, and 53,000 acres of water bodies (Figure 3). To this must be added the hardwood swamps of the Basin outside the floodway. Below the Teche Ridge the Basin environment becomes one of fresh and brackish water marshes and bays, with the development of the Atchafalaya River delta the most important process. This delta offers the potential development of a 300 to 350 mi^2 area of new wetlands in a state where the loss of wetlands amounts to a staggering 16 mi^2 per year.

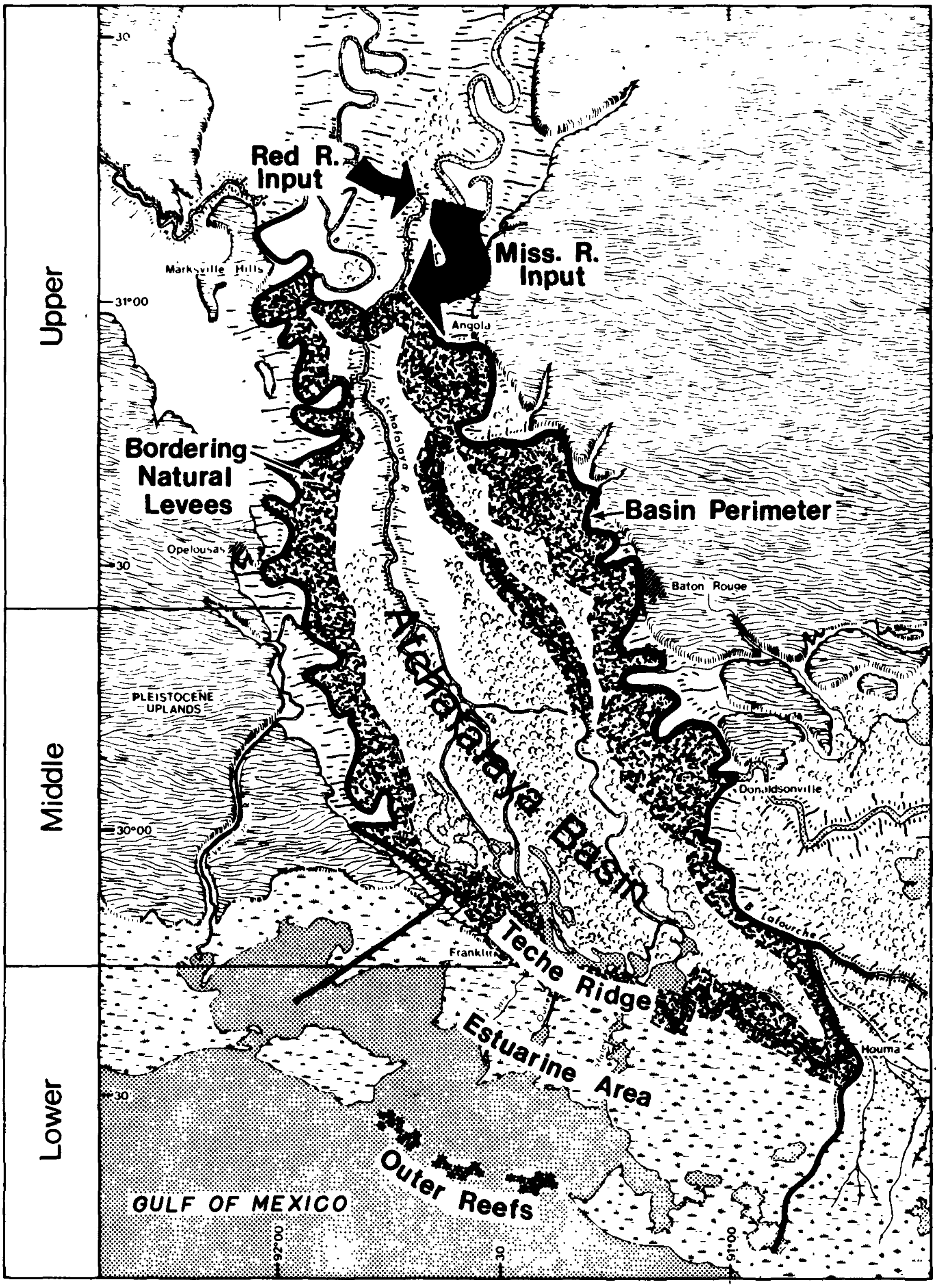

Figure 1. Physiographic setting of the Atchafalaya Basin, Louisiana.

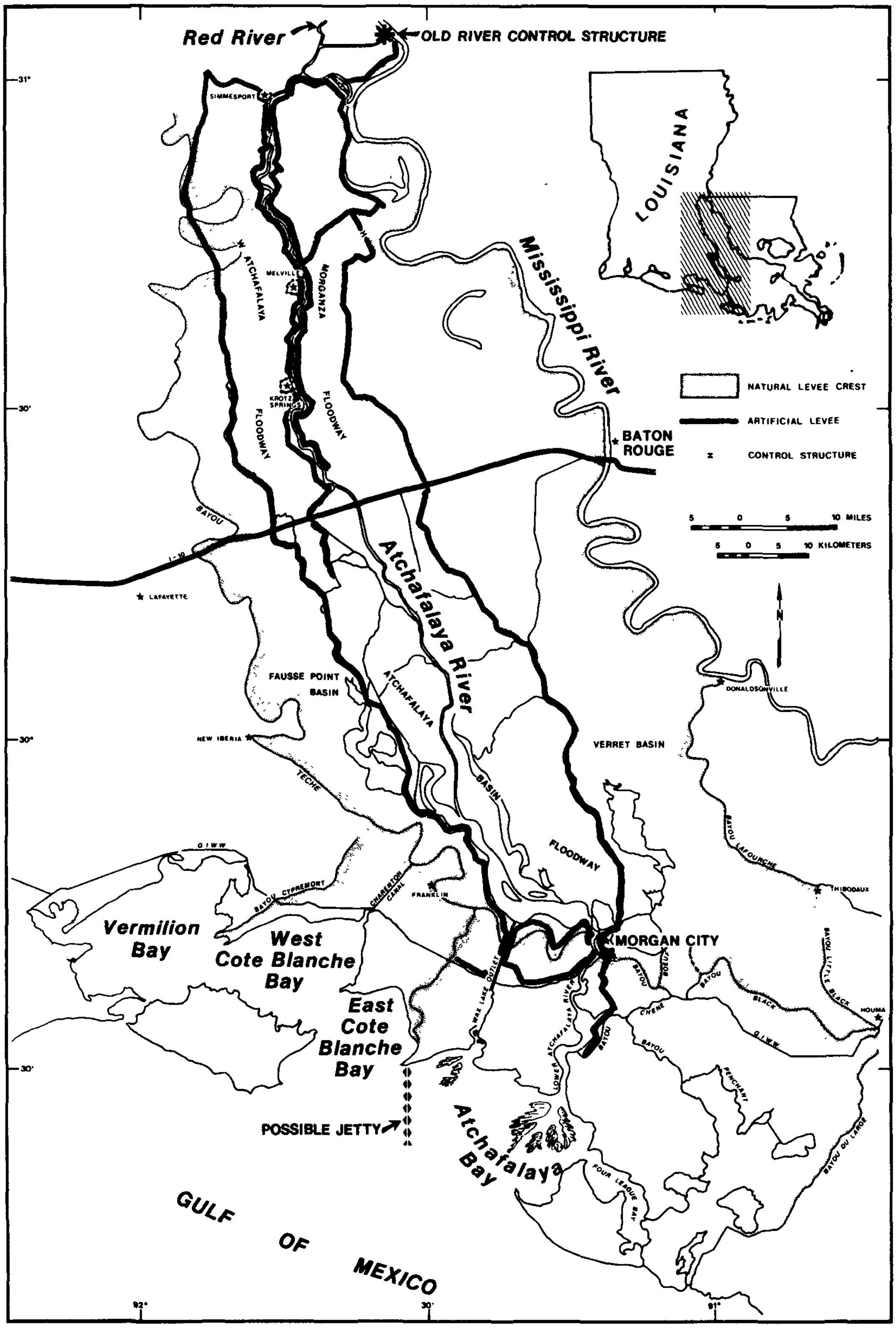

Figure 2. Levees of floodway system within the Atchafalaya Basin.

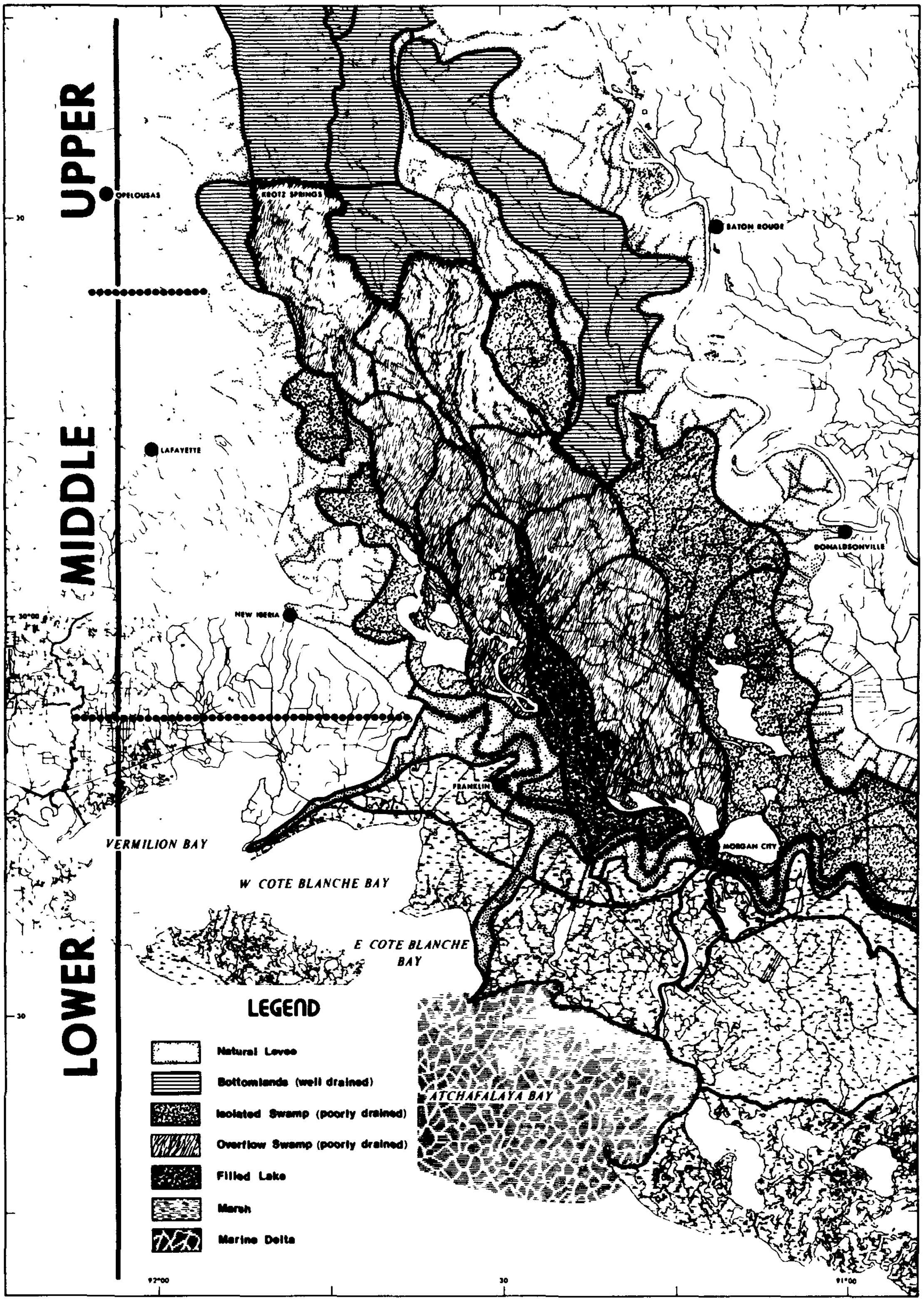

Figure 3. Natural environments and management unit boundaries of the Atchafalaya Basin.

Uniqueness and quality of its environment and associated biological productivity give the Basin an exceptional recreational and commercial value.

Use of the Atchafalaya Basin for flood control has significantly affected the integrity of the Basin's waters physically, biologically, and chemically. Most drastic has been the segmentation of the natural basin and associated modification of the overflow regime. Floodway guide levees have divided the Basin into the central floodway and two subbasins, the Verret subbasin on the east side and Fausse Point subbasin on the west side (Figure 2). The resultant restriction of the active flood plain has intensified riverine processes within the floodway area while it has eliminated annual overflow in the marginal areas. Within the floodway, the overflow regime was further modified as a result of partial channelization of the Atchafalaya River and associated spoil disposal along its lower course from Interstate Highway 10 to Morgan City. In combination with other actions related to navigation and oil and gas extraction, the modification of the hydrologic regime has had a major adverse impact.

Adverse impacts on the Basin's wetland system and related biological and recreational value could be further increased as a result of future actions for the purpose of improved flood control. Achieving the authorized and needed floodway capacity of 1,500,000 cfs requires further development of the Atchafalaya River channel from I-10 to the Teche Ridge and the restriction of sedimentation in the overbank area. Depending on the alternative selected to meet the requirements for flood control use, the hydrologic regime may be modified to the point that the viability of the present wetland system is severely threatened. Adverse effects of improper management on the duration and extent of flooding, and on circulation and water quality, could destroy the viability of the system. Indirect support provided for expansion of agricultural development adjacent and into present wetlands could destroy the wetlands directly and indirectly.

After flood control, maintenance dredging mainly for navigation is the most detrimental to the Basin's ecology. Annual maintenance above the Teche Ridge requires dredging of approximately 2,000,000 yds^3 (USCE, 1973). One-half of this dredging is done in waterways in the backwater areas and waterways connecting the former to the Atchafalaya River. These include the east and west access channels, which account for 600,000 yds^3, the freshwater distribution channels, and the alternate route of the Gulf Intracoastal Waterway. As indicated to some extent by the volume of maintenance dredging required, these channels are also the main route for the diversion of excessively larger volumes of sediment into the backwater area of the floodway below I-10. Not only does this result in a decrease in floodway capacity, it also results in several ways in the degradation of environmental integrity of the floodway's wetlands. Introduction of sediments through these channels into the flood plain swamps greatly contributes to the present reduction of the total water area and the degradation of the quality of forested wetlands.

Equally detrimental has been the disposal of spoil on stream banks. This has been a major cause of reduced circulation and resultant water quality problems, in particular the depression of dissolved oxygen values. While annual reduction of dissolved oxygen values is in part a natural phenomenon resulting from large organic litter input and the organic nature of swamp sediments, at present the oxygen values in large swamp areas as well as streams are depressed for periods in excess of one month to levels where water can no longer support fishes and other aquatic life.

In the Lower Atchafalaya River connecting Morgan City and the surrounding industrial development to the Gulf of Mexico, provisions for navigation are creating a serious degradation of the environment. Because this navigation route traverses the area of the most rapid growth of the Atchafalaya delta, maintenance of the authorized navigation channel requires annual dredging. This action channelizes water and sediment through the active delta to deeper water, thus reducing the potential for valuable development of new wetlands.

The direct and indirect support for agricultural development in the Basin, inside and outside the floodway, is creating destructive pressure on the systems in the Basin. Expansion of agricultural development is facilitated by a number of processes and actions. Within the floodway, enlargement of the Atchafalaya River channel has resulted in a lowering of annual flood stages above I-10 thus reducing backwater flooding in the upper floodway. Since that area is already protected from direct river overflow by levees within the floodway along the Atchafalaya River, the reduced backwater flooding has allowed the expansion of agricultural development through the clearing of flood plain forests. Application has been received by the United States Soil Conservation Service (USSCS) for planning of a small watershed project involving 165,000 acres. Similarly, agricultural expansion takes place along and into the swamp forests of the Basin outside the floodway with support of a number of USSCS watershed projects.

The potential for further expansion of agricultural development and habitation of the floodway is increased by the consideration of reducing diversion of waters from the Mississippi River into the Atchafalaya River during annual flood stages. This plan is considered for the purpose of enhancing agricultural development in the flood plain of the Red River immediately north of the floodway. Such reduction in flows would equally affect the backwater stages in the northern part of the floodway, thus providing for increased flood plain development, and would reduce annual overflow in the lower floodway affecting the hydrologic regime of the wetlands there.

Concern for the protection of the environment has been growing, as has concern that the flood control value of the floodway is becoming increasingly less than it should be. On June 11, 1968, and March 23, 1972, the United States Senate Committee on Public Works, and on June 14, 1972, the United States House of Representatives Committee on Public Works, adopted resolutions concerning management and use of the water and related land resources of the Atchafalaya River Basin. These resolutions directed the USCE to determine whether, in light of changed conditions, modifications to the operation of the Old River control system are warranted and to review in cooperation with other agencies, including the USEPA, the report on the Mississippi and Tributaries Project, House Document 308, 88th Congress, and other pertinent reports with a view to developing a comprehensive plan for the management and preservation of the water and related land resources of the Atchafalaya River Basin, Louisiana. As directed, this would include provisions for reduction of siltation, improvement of water quality, and possible improvement of the area for commercial and sport fishing.

In response to the Senate and House resolutions, the Atchafalaya Basin Land and Water Resources Interagency Study was initiated in 1972. Participants are the USCE, USEPA, USDI, and State of Louisiana. The USEPA is in a position to make recommendations, enforceable through its responsibilities, to insure that Federal environmental requirements and objectives are sufficiently considered in the selection of a resource management plan. Objectives of the USEPA in the Atchafalaya Basin include: 1) land use requirements to control agriculturally related nonpoint sources of pollution (Federal Water Pollution Control Act Amendment (FWPCAA), 1972, Sec. 208); 2) the 1983 goal of water quality, which provides for the protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water, and the restoration and maintenance of the chemical, physical, and biological integrity of the nation's water (FWPCAA, 1972, Sec. 101); 3) avoidance of degradation in any way of waters that in their existing condition could be used for sport fishing with degradation reducing their value for that use; 4) reduction of the adverse impact of spoil disposal on fishery, wildlife, or recreational areas (FWPCAA, 1972, Sec. 404); 5) monitoring of the discharge of dredged material in wetlands; 6) the avoidance of long- and short-term adverse impacts associated with destruction and modification of wetlands (Exec. Order 11990); 8) the avoidance of direct or indirect support of new construction in wetlands (Exec. Order 11990); 9) the avoidance, to the extent possible, of long- and short-term adverse impacts associated with the occupancy and modification of flood plains (Exec. Order 11988); 10) the avoidance of direct or indirect support of flood plain development whenever there is a practicable alternative (Exec. Order 11988); and 11) the avoidance of discharge of material that would have an unacceptable adverse effect on municipal water supplies, shellfish beds, and fishery, wildlife, or recreational areas (Public Law 92-500, Sec. 404, C).

MAIN CHANNEL SYSTEM

In a natural system, the river channel is not a static shape but is constantly changing size, cross-sectional shape, and alignment. In the alluvium of a coastal zone, these processes are more obvious. A river enlarges its bed by scouring when the water velocity is high and fills in its bed with sediment deposition when water velocity is low. It builds natural levees when overbank flooding takes place; this process leaves sediment on the banks of the river channel and permits the flood plain to receive water that does not bring with it enormous amounts of sediment. These natural levees in turn affect the channel, tending to increasingly confine the river between the banks of the natural levee before overbank flooding takes place. This changes every part of the river through time in a seaward direction. Also, the river and its channel change through time as the entrained sediment continuously builds a delta. This changes the gradient of the channel and the slope of the water surface. There are diurnal changes. The discharge will be higher during some parts of the year than others, and a larger part of the flood plain must be used to carry this water.

Furthermore, the plant and animal communities in the water and in the flood plain are delicately tuned to all of this fluctuation. Any change in course, any change in seasonal variation or overbank flooding, any change in sediment deposition must cause an equal adjustment in the ecological balance of the entire flood plain.

However, no matter how complicated a system has developed, flood control is an essential use of the Atchafalaya Basin. Channel conditions in the Basin must meet flood control needs and provide for long-term use of the flood plain for that purpose. Unfortunately, this is not a simple requirement, even if ecological considerations are ignored. The hydraulics of maintaining a channel of sufficient size, and of obtaining a channel that will remain at a sufficient size, must include a calculation of all of the factors that make the river and its channel a constantly fluctuating system.

Adding to this the requirement that flood control must be made available within some kind of multiuse management of the Atchafalaya Basin makes it mandatory that every possibility for obtaining the required flood control be evaluated and, furthermore, that each possibility be evaluated in the light of the interrelation of the river channel and the other natural systems.

Since these natural systems are adapted to and based upon the hydrologic regime as controlled primarily by stages and discharges of the Atchafalaya

River and since, within the present floodway system, the needed increase in capacity of flood control can only be obtained by increased efficiency and related necessary change of the Atchafalaya River main channel, the channel system is the most important element in the consideration of alternatives.

The alternatives available within the Atchafalaya Basin for the combined increase in flood control capacity and maximum retention of future floodway capacity fall basically into four categories. The first category is the dredging of the Atchafalaya Basin main channel to a larger size from river mile 50 to 120 (Figure 4) in order to obtain a reduction in the flow line for all discharges. The lowered annual river stages would reduce the extent and depth of annual overflow and result in lesser sedimentation in the overbank area. Likewise the flow line for the project flood discharge would be lowered, thus increasing capacity below a given grade of the guide levee or, alternatively said, decreasing the elevation to which the levees need to be raised to provide for the required 1,500,000 cfs capacity.

The second category of alternatives is to increase, where necessary below mile 55, channel efficiency and size through intensification of natural channel development by confinement of flows up to a given discharge and to obtain reduction of overbank sedimentation through management of water and sediment diversion. This would involve some dredging for construction of channel embankments, providing for overbank flow only where possible and taking structural measures where channelized diversion is necessary or unavoidable.

A third group of alternatives combines dredging, as in the first type of alternative, or channel training, as in the second type, with modification of the outlets, including the construction of an additional outlet. Since the present river regime cannot maintain additional outlet capacity, such additional capacity must be separate from the present channel system and only function when needed for flood control. The outlet element of this third group of alternatives only concerns floodway capacity. The latter is increased by lowering the project flood flow line through either diversion of floodwater from the present floodway above the Teche Ridge or by increasing the outlet capacity through the Teche Ridge parallel to the Wax Lake outlet and Lower Atchafalaya River.

The fourth group of alternatives combines elements of each of the above groups.

These categories of alternatives must be evaluated as to their efficacy in providing flood control and also their appropriateness to a multiuse management scheme for the Basin. In order that the categories can be evaluated, the relationship among the hydraulic elements in the Atchafalaya Basin floodway system and the present conditions and trends of the Atchafalaya Basin main channel must be understood.

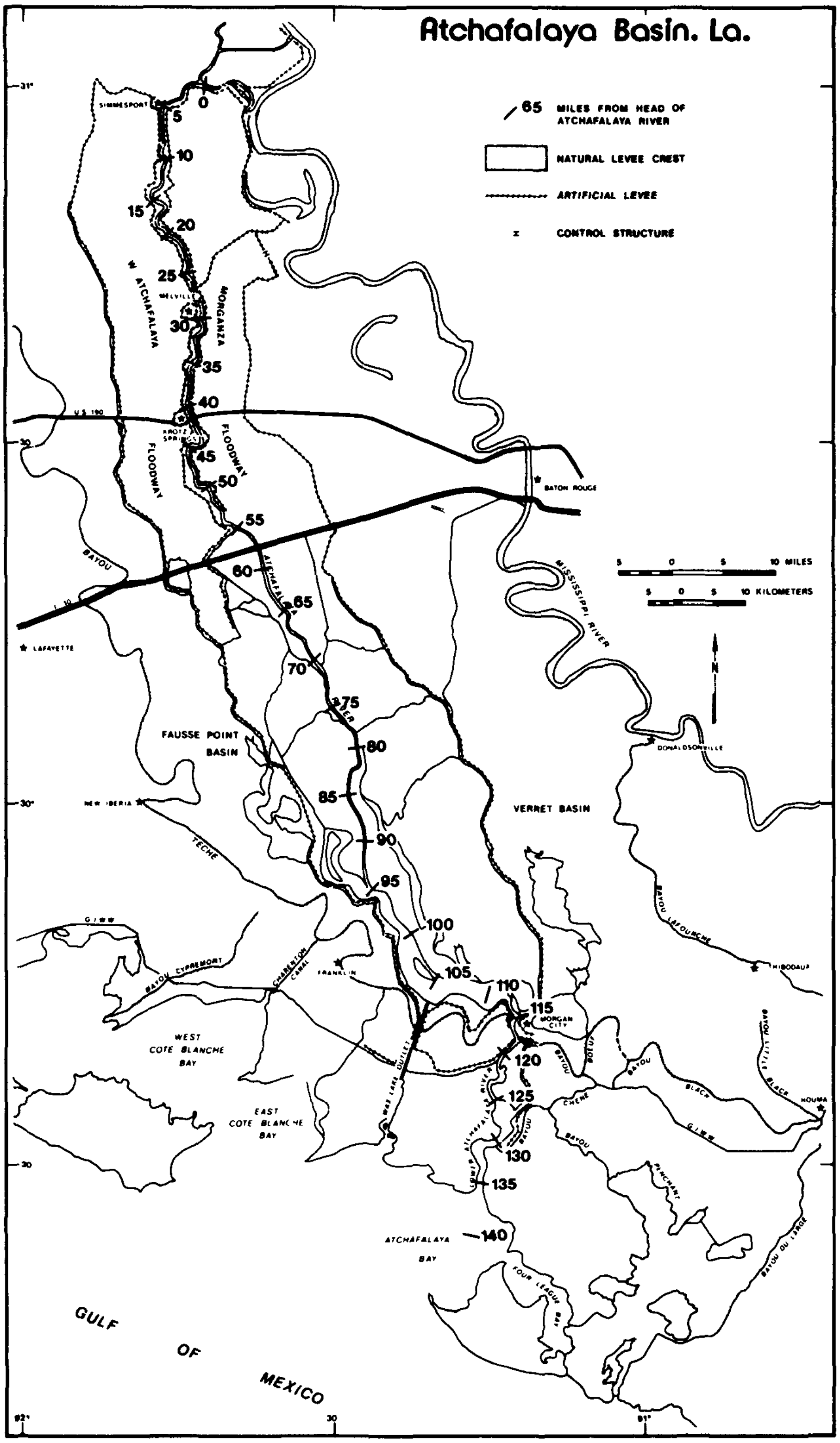

Figure 4. River miles along Atchafalaya Basin main channel.

RELATIONSHIPS AMONG HYDRAULIC ELEMENTS

Relationships among hydraulic elements are summarized in Figure 5. The most important elements are the annual discharge regime as governed by the Old River control structure, the distance between the Old River structure and the Gulf of Mexico, which is identified as the river length, and the division of flow between Wax Lake outlet and the Lower Atchafalaya River. With the ability of the river to modify its channel through scour and deposition, discharge regime and river length will ultimately determine the river slope and channel form of the future stable channel in which width, depth, and slope are related to discharge in such a manner that velocity is just sufficient to transport the sediment load.

Along the stream course, a number of other variables affect development and ultimate size, form, and water surface slope of the channel. The most important among these is the diversion of water from the stream into the backwater area. The magnitude of discharge diversion along the Atchafalaya Basin main channel is illustrated in Figure 6. Below river mile 55, diversion reduces main channel discharges from 10 percent to 25 percent at flows of approximately 425,000 cfs, depending on return flows. The largest reduction follows with diversion of 30 percent of the initial discharge into Wax Lake outlet so that only 60 percent remains after about mile 100 flowing toward Morgan City and the Lower Atchafalaya River.

Since river channels are continuously adjusting to seasonal and annual variation in discharge, the future stable channel must be viewed as an average future condition. At present, a reasonable working hypothesis for the Atchafalaya River is to consider this average condition associated with discharges within the range of 400,000 to 450,000 cfs, as measured at Simmesport, and having a frequency of occurrence between 1.5 and 2.5 years. This discharge will be referred to hereafter as the "channel determinant discharge."

It is evident that any changes in operation of the Old River control structure will affect the discharge regime and therefore the size, form, velocity, and water surface profile characteristics of the future stable channel. More specifically, the reduction that is being considered (of annual flood stage in the Red River backwater area) by reduction of annual peak flows would diminish the discharges for given frequencies; this would affect the channel determinant discharge and size of the channel that is stable and self-maintaining.

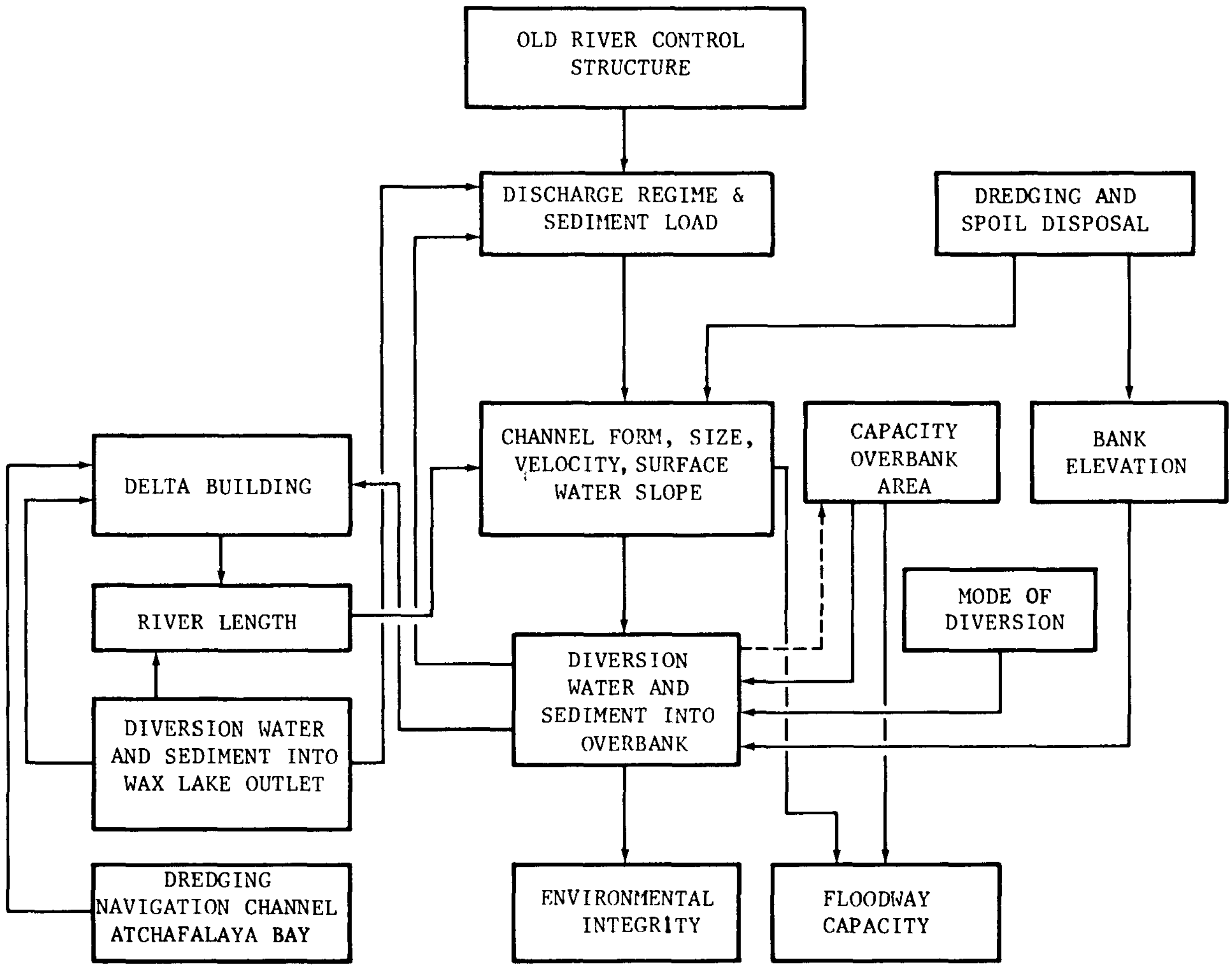

Figure 5. Relationships among hydraulic elements in the Atchafalaya Basin floodway system.

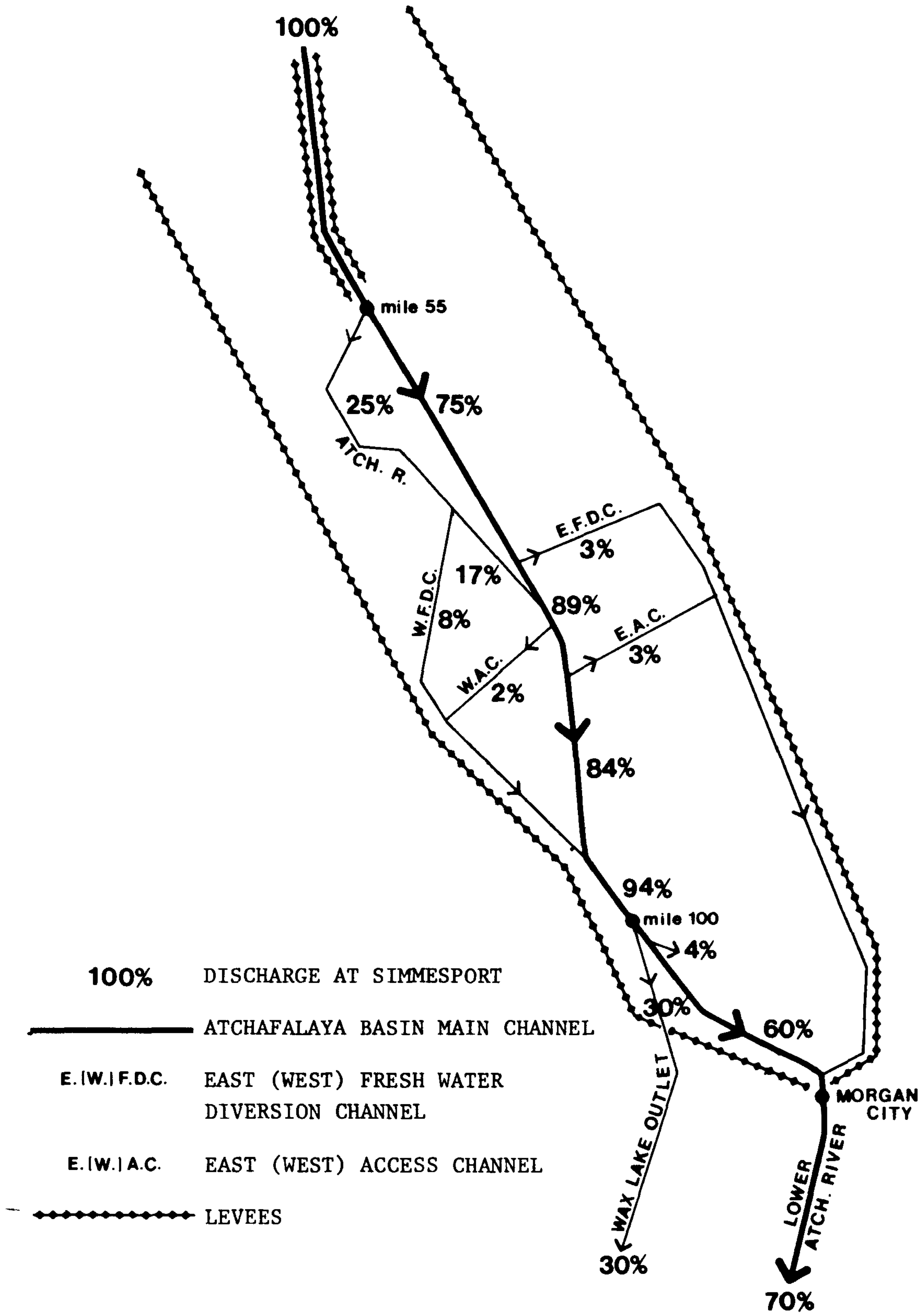

Figure 6. Diversion from the Atchafalaya Basin main channel during average annual flood.

River length must presently also be considered a variable parameter because of division of flows between the Lower Atchafalaya River and Wax Lake outlets and because of delta building in Atchafalaya Bay. Since the progradation of the delta in the 1950's, river length has increased from 135 to 145 miles at present. By the year 2020, length can be expected to have increased to 160 miles, or an increase of almost 20 percent. As a result, the water surface profile must be expected to continue to move upward in the lower part of the Atchafalaya River.

Diversion is mostly controlled by flood plain topography and by the natural or man-made changes (Figure 5) affecting bank elevation, storage capacity of the overbank area, and the mode of diversion--that is, whether diversion occurs through overflowing of the stream banks or through diversion channels.

Where diversion of water in the flood plain is prevented by artificial levees such as along the upper part of the Atchafalaya River, discharges of a given frequency are larger, and consequently the future stable channel will be larger, than along the lower reaches.

When diversion of water and sediment occurs from the channel into the flood plain mainly by overflow of the channel banks, most sediment is deposited on the stream bank as natural levee ridges (Figure 7A). The resultant increase in bank elevation confines larger discharges for a given frequency, thus allowing the river to maintain a larger channel. The process of enlargement will continue until the grade of the natural levee ridges follows the water surface profile for the discharge of the channel determinant frequency. This type of adjustment reduces adverse deposition of sediments in the backwater area to only flood occurrences greater than the determinant discharge.

When most of the diversion of water into the flood plain takes place through diversion channels, however, a quite different condition develops (Figure 7B), in particular where banks have been elevated by spoil until overflow no longer occurs on a regular basis. Under those circumstances, diversion of water takes place at high velocity into the flood plain, enabling the water to carry large quantities of sediment. Most of the sediment is deposited in the backwater area, gradually reducing overbank capacity. Any resultant increase in channel discharges as a result of loss in overbank capacity will perpetuate the process of backwater sedimentation as long as the greater channel discharges or overall adjustment of the river gradient elevate the water surface profile and thereby maintain the gradient into the backwater area. Channel enlargement will take place at much less than the potential rate since the increase in elevation of the water surface profile minimizes the losses of overbank storage relative to the river so that channel discharges increase only slowly. Loss of overbank storage relative to a fixed datum plain, however, is considerable and represents a major loss of floodway capacity.

Enlargement of the Atchafalaya Basin main channel through dredging must be viewed also in terms of the above discussed hydraulic relationships.

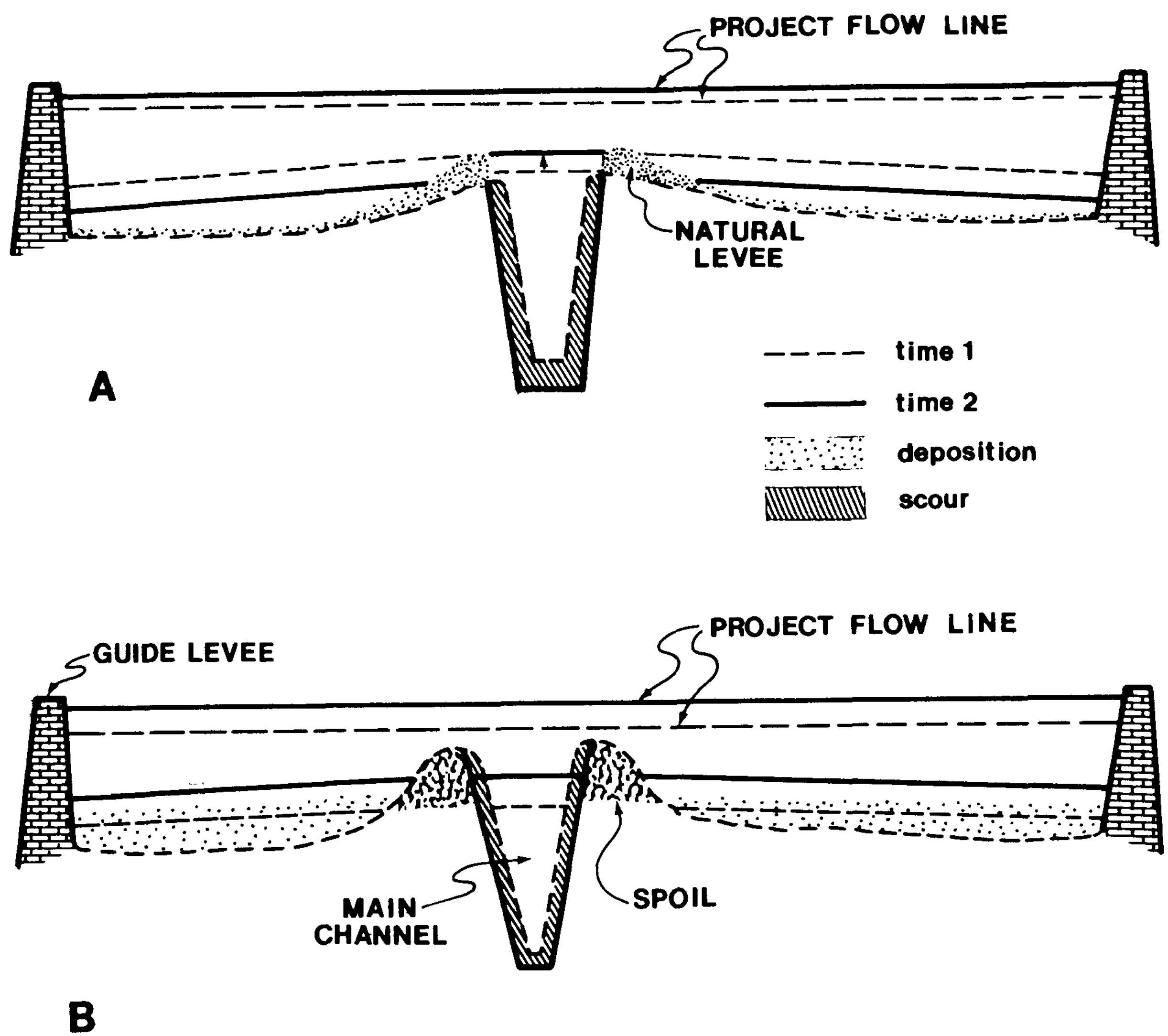

Figure 7. Annual flooding of backwater area and associated topographic and water level changes. (A) Overflow across stream banks. (B) Overflow through channelized diversion.

Dredging will change the form, size, velocity, and water surface slope characteristics of the main channel, as shown in Figure 5. This in turn will affect the diversion of water and sediments into the overbank area and therefore the discharge regime of the main channel. Whether the acquired channel will be stable depends then on whether the new channel characteristics are in equilibrium with the then occurring discharge regime including the sediment load. Any major deviation from the required velocity and gradient for the channel determinant discharge and sediment loads will otherwise result in deposition within the channel. This would negate the channel enlargement accomplished by dredging, while any adverse impacts resulting from spoil disposal and from the decrease in annual duration and extent of flooding of the wetlands would remain.

The second effect of channel dredging stems from the associated spoil disposal if no measures are taken to control inflow through diversion channels. The spoil deposition would add to the relative change in bank elevation resulting from a lowering of the water surface profile. This is true in particular since dredging would take place along the lower course of the main channel where overbank flow at present is still significant. The elimination of the overbank flow process during average annual floods would change the mode of water diversion into the overbank area to channel flow at higher velocities. This would adversely affect the desired reduction of sediment diversion into the overbank area obtained through lowering of the flow line.

Along the lower course of the Atchafalaya River, the most important factor becomes the division of main channel flows between Wax Lake outlet and the Lower Atchafalaya River and the processes influenced by this division as shown in Figure 6. First, the division controls the channel determinant discharge for the remainder of the main channel and the Lower Atchafalaya River. Because of gradient advantage (the Wax Lake outlet route being some 15 miles shorter), discharges through Wax Lake outlet and, consequently, channel size have increased since construction. Conversely, the channel determinant discharge along the Lower Atchafalaya River route continues to decrease.

Present processes of deltaic growth reinforce this trend. With 70 percent of the total discharge still passing through the Lower Atchafalaya River, delta progradation is much more rapid on the east side of the Atchafalaya Bay causing a more rapid increase in length of the lower Atchafalaya River than of Wax Lake outlet. That process is further augmented by maintenance of a navigation channel through the Atchafalaya River delta.

PRESENT CONDITIONS AND TRENDS

With the above-described process relationships in mind, we may now focus on present conditions and trends of the Atchafalaya Basin main channel. At present, neither the flow line nor the cross-sectional area of the Atchafalaya Basin main channel is stable. Figure 8 illustrates the trend in flow line change for a discharge of 450,000 cfs at Simmesport. Since 1969 the flow line has decreased in elevation upstream from the Whiskey Bay Pilot Channel (WBPC) while below the Pilot Channel the flow line has increased in elevation.

Also shown in Figure 8 are the project flow lines as determined in 1963 and in 1973 during floodflows. The difference comprises a 4 ft upward revision as a result of sedimentation in the overbank areas and delta development. Since 1973, as a result of the flood and associated sedimentation, the project flow line is being revised upward again, but the new flow line has not been made available at present.

The change in flow line for the 450,000 cfs discharge has been associated with a change in cross-sectional area of the channel. This trend is best illustrated by the bank-full datum plane in Figure 8, which at one time followed natural stream bank elevation. The present flow line for 450,000 cfs is seen to lie well below this datum plane above mile 70 and far above this plane below mile 70. The change has been associated with strong scouring of the channel above mile 70 and with channel, levee, and flood plain development below mile 70. These two processes are schematically shown in Figure 9A and Figure 9B, respectively.

Figure 9A shows the scouring of the channel and the associated lowering of the water level for a given discharge. Since water levels in the channel become lower relative to the overbank area, less water will be diverted, and stages in the overbank area will decrease resulting in a loss of aquatic habitat and reduction of the area periodically flooded. Below mile 55 such loss is further augmented because sediment introduction into the overbank area occurs increasingly through diversion channels rather than through overbank flow, and therefore most sediment is deposited in the aquatic habitats rather than on the channel bank. The process illustrated in Figure 9A will continue until the flow line has stabilized, and future loss of aquatic habitat and wetlands to mixed forest hardwoods must thus be expected. Likewise, a shift to drier hardwoods must be expected, and therefore an increasing encouragement for agricultural development will follow forest clearing.

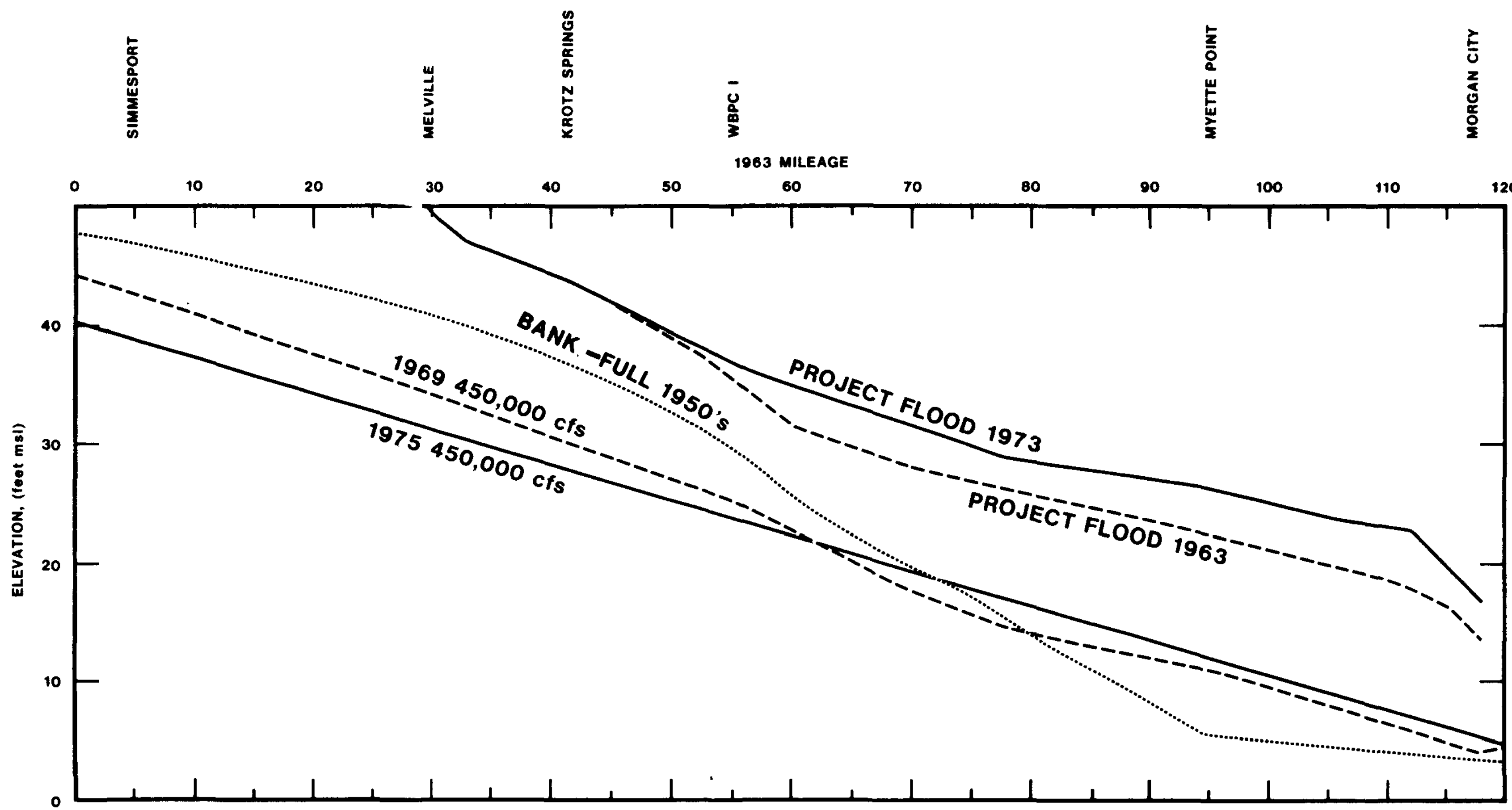

Figure 8. Changes in flow line along the Atchafalaya Basin main channel for the 450,000 cfs and project flood discharges. (The 1950's bank-full datum plane provides an additional references.)

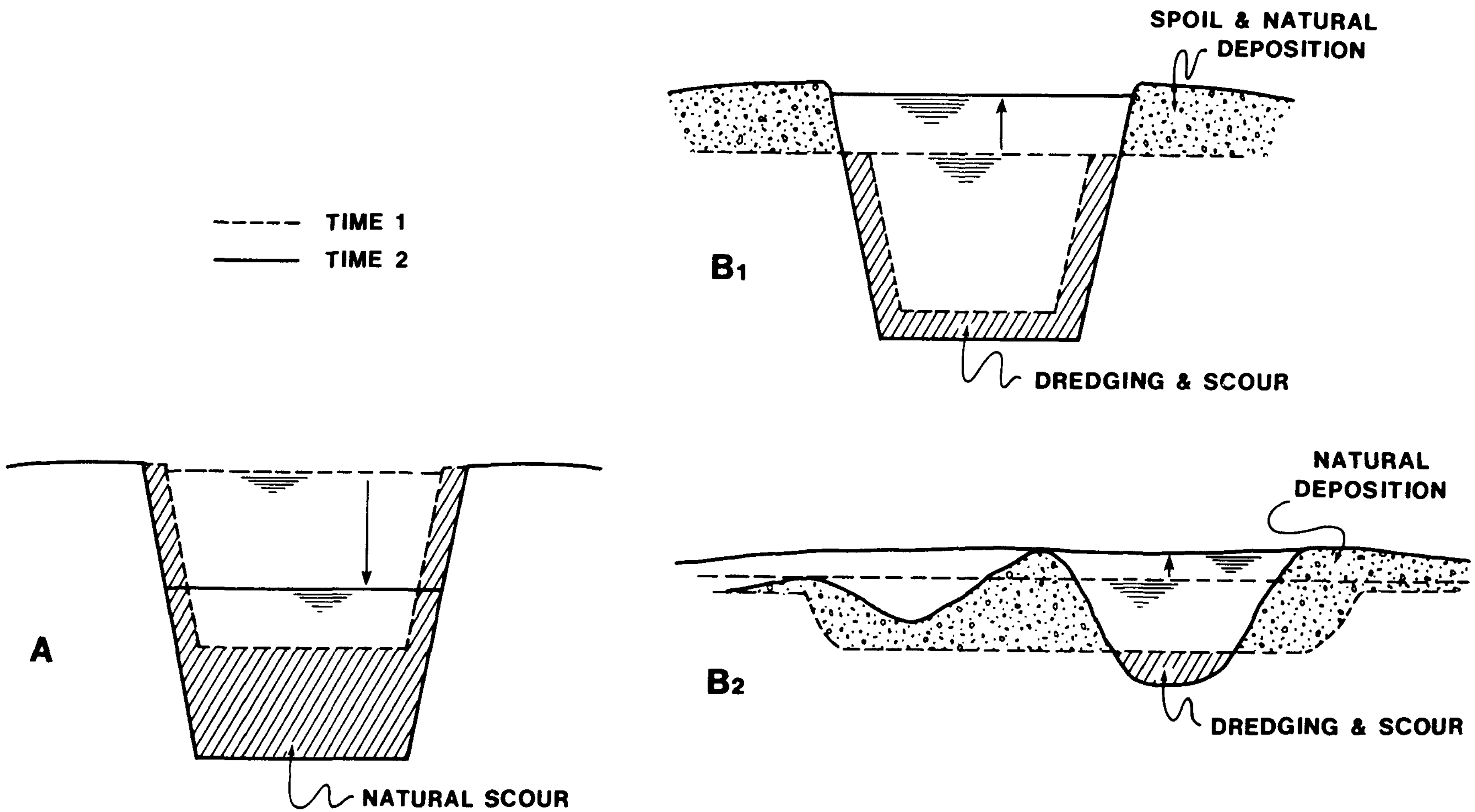

Figure 9. Schematic representation of channel and flow line changes along the Atchafalaya Basin main channel. (A) Channel scouring and associated lowering of flow line (above mile 70). (B_1) Scouring of channel and rise in flow line (mile 70-85). (B_2) Flow confinement through deposition, scouring of channel, and rise in flow line (mile 95-115).

Also illustrated in Figure 9A is the increase in channel area below a fixed reference level such as the project flood flow line. Consequently, the frequency at which use of the overbank area for flood control is necessitated diminishes and increases the likelihood of agricultural development and settlement. At present, the channel area below the 1963 and 1973 project flood flow lines exceeds 100,000 ft^2 as far downstream as mile 55, the 100,000 ft^2 dimension being the stated need for flood control by the USCE.

Figure $9B_1$ and $9B_2$ illustrates the two major processes occurring below mile 70. The two are successive in time, with the processes illustrated in Figure $9B_1$ preceding those in Figure $9B_2$. For mile 70 to mile 95, approximately Myette Point, channel development has long since progressed beyond the filling stage to the stage depicted in Figure $9B_1$. Although channel enlargement takes place, processes differ from those illustrated in Figure 9A. While overbank deposition and past spoiling tend to confine increasingly greater discharges to the channel thus resulting in channel enlargement, the flow line moves upward at the same time. This tends to partially offset the loss in overbank storage as well as to negate the need for the river to enlarge its channel through scour so as to maintain a cross-sectional area in equilibrium with the discharge regime. Consequently, the rate of channel enlargement is low.

Continuation of upward movement of the flow line is expected as a result of delta building, which lengthens the channel as a result of continuing sedimentation, which decreases storage in the overbank area, and as a result of overall adjustment of the stream gradient. Associated with this will be natural building of the channel banks in the form of natural levees where banks have not yet been elevated to greater elevation as a result of previous spoil deposition.

It is evident that elevating the stream banks beyond the natural levee height by spoil deposition makes flow into backwater areas increasingly dependent on diversion channels, thus enhancing sediment introduction into these areas with resultant loss of aquatic habitat, loss of periodically flooded areas, and loss of floodway capacity. Preservation of wetlands is much better served by natural building of stream banks so that overbank flow is maintained and sedimentation concentrated along the channel. It is furthermore apparent that the limitation of flow diversion into backwater areas to only the volume necesary to maintain water quality and high productivity increases the rate of channel development.

Channel development from mile 70 to mile 95, the reach represented by Figure $9B_1$, has progressed to where the present channel size is approximately 70,000 ft^2 as measured below the 1963 project flow line and approximately 58,000 ft^2 as measured below the channel bank.

Between the time dredging was stopped in 1968 and early 1973, the channel increased in size from mile 70 to mile 83 and remained stable from mile 83 to mile 95. However, the 1973 flood produced a reduction as a result of sedimentation throughout the 25-mile reach. Table 1 summarizes the changes.

TABLE 1. RATES OF CHANNEL DEVELOPMENT ALONG THE ATCHAFALAYA BASIN MAIN CHANNEL

Period	Years	Channel Segment (mi)	Total Average Change (ft^2)	Average Annual Rate of Change (ft^2)
1969-1973	4	55 - 70	+ 5,746	+ 1,436
1973	1	55 - 70	+10,702	+10,702
1969-1973	4	70 - 83	+ 2,840	+ 710
1973	1	70 - 83	- 4,603	- 4,603
1969-1973	4	83 - 95	+ 48	+ 12
1973	1	83 - 95	- 3,343	- 3,343
1971-1973	2	95 - 103	+ 2,097	+ 1,048
1971-1973	2	103 - 112	+ 348	+ 174
1972-1973	1	112-120	- 17	- 17
1973	1	95 - 112	- 967	- 967
1973	1	112 - 120	+19,191	+19,191

Below Myette Point (mile 95), where the main channel follows Six Mile Lake, the flow conditions are rapidly changing as a result of the processes shown in Figure $9B_2$. Through deposition in the lake, on either side of the main current thread, the channel increasingly gains definition and the flows become more confined. This contributes further to the rise in flow line. With additional confinement of flows and an increase in velocities, the river will increase its depth by scour insofar as sufficient depth is not provided by the rise in flow line.

The above picture is complicated, however, by the partial diversion of discharge to Wax Lake outlet at approximately mile 103 and by the fact that the diversion ratio has been increasing because of gradient advantage. Related to this, the channel size from mile 95 to mile 103 averages 50,000

ft^2 below the 1963 flow line but decreases to about 30,000 ft^2 into the confined reach of the Lower Atchafalaya River. The rate of channel development follows the same trend, being much greater above the diversion point than below that point as shown in Table 1 (mile 95 to 103 and 103 to 112). Deposition and decrease in channel size associated with the 1973 flood was about equal in both reaches.

At this point it must be emphasized again that a distinction must be made between active channel cross section and channel cross section as expressed by the USCE. The active channel cross section is the cross-sectional area of the channel occupied by the river during flood discharges representative for the river's regime. The cross-sectional area as expressed by the USCE is the area below a fixed datum plane in which channel flow conditions occur when water level in the river equals the level of the datum plane. This can be extremely misleading to those not familiar with the meaning of "channel cross section" as used by the USCE when considering changes in cross-sectional area of the channel. True changes can only be observed by considering both the change in water surface profile and cross-sectional area below a fixed datum plane. This is illustrated by Table 2.

We may now proceed with the assessment of dredging needs. Simultaneous consideration will be given to riverine processes and the trends of the water surface profile and channel cross section below a fixed datum plane indicate the following. Through a complex system of interacting processes (Figure 5) involving the river channel, overbank area, and delta, the Atchafalaya River attempts to achieve stability for the present discharge regime. This stability requires a change in water surface slope, active channel cross section, and velocity. Above approximately mile 70 the change involves a downward adjustment of the water surface profile associated with channel enlargement through scour (Condition 7, Table 2). Because the rate of scour greatly exceeds the rate of profile adjustment, the active channel is enlarging through scour.

Below mile 70 the gradient adjustment results in an upward movement of the water surface profile that is associated with a decreasing rate of scour from mile 70 to mile 95 (Condition 1, Table 2) and with essentially no change from mile 95 to Morgan City (Condition 2, Table 2) except between mile 95 and 103. Scouring between mile 95 and 103 is, however, a superimposed condition related to rapid scouring in the branch channel leading to Wax Lake outlet, which scoured at an average annual rate of 2,000 ft^2. Active channel cross sections are thus enlarging along both of the above reaches at greater rates than indicated by physical channel changes because of water surface profile adjustments. From mile 70 to 95, active channel enlargement amounts to approximately 1,200 ft^2 per year, which includes 700 ft^2 as a result of scour and 500 ft^2 as a result of increased water levels for the representative discharge. Below mile 95 the active channel enlargement represents primarily an increase in water levels and associated increase in elevation of the banks through deposition and amounts to about 250 ft^2 per year. The absence of scour suggests that, presently, changes in the discharge-channel relationships are still accommodated by a change in slope

TABLE 2. POSSIBLE NET CHANGE IN CHANNEL CROSS SECTION FROM COMBINED CHANGES IN THE BED AND FLOW LINE

Condition	Water Surface Profile		Channel Cross-sectional Area Below Fixed Datum		
	Direction of Change	Change In Cross. Area (A_1)	Process of Change	Change In Cross. Area (A_2)	Net Change in Cross Section for Discharge Representative of Discharge Regime ($A_1 + A_2$)
1	Up	$\Delta A_1 > 0$	Scour	$\Delta A_2 > 0$	$\Delta A_1 + \Delta A_2 > 0$
2	Up	$\Delta A_1 > 0$	Same	$\Delta A_2 = 0$	$\Delta A_1 + \Delta A_2 > 0$
3	Up	$\Delta A_1 > 0$	Deposition	$\Delta A_2 < 0$	$\Delta A_1 + \Delta A_2$ >, =, or < 0
4	Same	$\Delta A_1 = 0$	Scour	$\Delta A_2 < 0$	$\Delta A_1 + \Delta A_2 > 0$
5	Same	$\Delta A_1 = 0$	Same	$\Delta A_2 = 0$	$\Delta A_1 + \Delta A_2 = 0$
6	Same	$\Delta A_1 = 0$	Deposition	$\Delta A_2 < 0$	$\Delta A_1 + \Delta A_2 < 0$
7	Down	$\Delta A_1 < 0$	Scour	$\Delta A_2 > 0$	$\Delta A_1 + \Delta A_2$ >, =, or < 0
8	Down	$\Delta A_1 < 0$	Same	$\Delta A_2 = 0$	$\Delta A_1 + \Delta A_2 < 0$
9	Down	$\Delta A_1 < 0$	Deposition	$\Delta A_2 < 0$	$\Delta A_1 + \Delta A_2 < 0$

and/or depths without necessitating scouring to satisfy hydraulic requirements. In other words, the channel appears stable for the given conditions of slope, water depth, and velocity. This is further indicated by a decrease in cross-sectional area through deposition following the termination of channel enlargement through dredging in 1963.

An important aspect brought out by the foregoing information is that the potential rate of channel enlargement through scour for average discharge conditions is on the order of at least 1,500 ft^2 per year when adjustment of surface slope insufficiently increases or diminishes water depth and forces a greater water depth through scour. This means that channel dimensions below the 1963 datum plane as considered for flood control could be attained according to the time frame given in Table 3 if the projected channels would be in accord with the stable conditions the river attempts to establish under present regime conditions. Clearly, the indicated duration required for natural channel enlargement eliminates the need and justification for dredging to an 80,000 ft^2 dimension above mile 95 (Myette Point). Since the 100,000 ft^2 dimension was eliminated as a viable alternative at the Agency Management Group* meeting of September 1977,** this leaves only enlargement of the channel segment to 80,000 ft^2 from Myette Point to Morgan City (mile 95 to 112). Considering that the main purpose is to lower the project flow line, channel enlargement through dredging along the latter channel segment appears equally unwarranted because of very limited long-term beneficial, and severe long-term adverse, effects as suggested by the results of the U.S. Geological Survey (USGS) simulation study (USGS 1977).

The most important results of the simulation study of flow and sediment transport in the Atchafalaya River Basin are summarized in Figure 10. Through use of a mathematical simulation model, channel and water surface profile changes for 50-year period are predicted under the present discharge regime. While the model admittedly has a number of major limitations, it represents the best available state-of-the-art and "has demonstrated the ability to reproduce, with reasonable accuracy, the historical changes in water surface elevation and bed profile" (USGS 1977). The model was calibrated and supplied by the Hydrologic Engineering Center and the New Orleans District, U.S. Army Corps of Engineers.

Figure 10 shows the water surface profiles for present and future (50 years) conditions for a discharge of 450,000 cfs and for the project flood (1,500,000 cfs) when, alternately, the channel is allowed to develop

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*Coordinating Committee for the Interagency Atchafalaya Basin Land and Resource Study.

**Since this report was prepared, the 100,000 ft^2 channel is again being considered as an alternative.

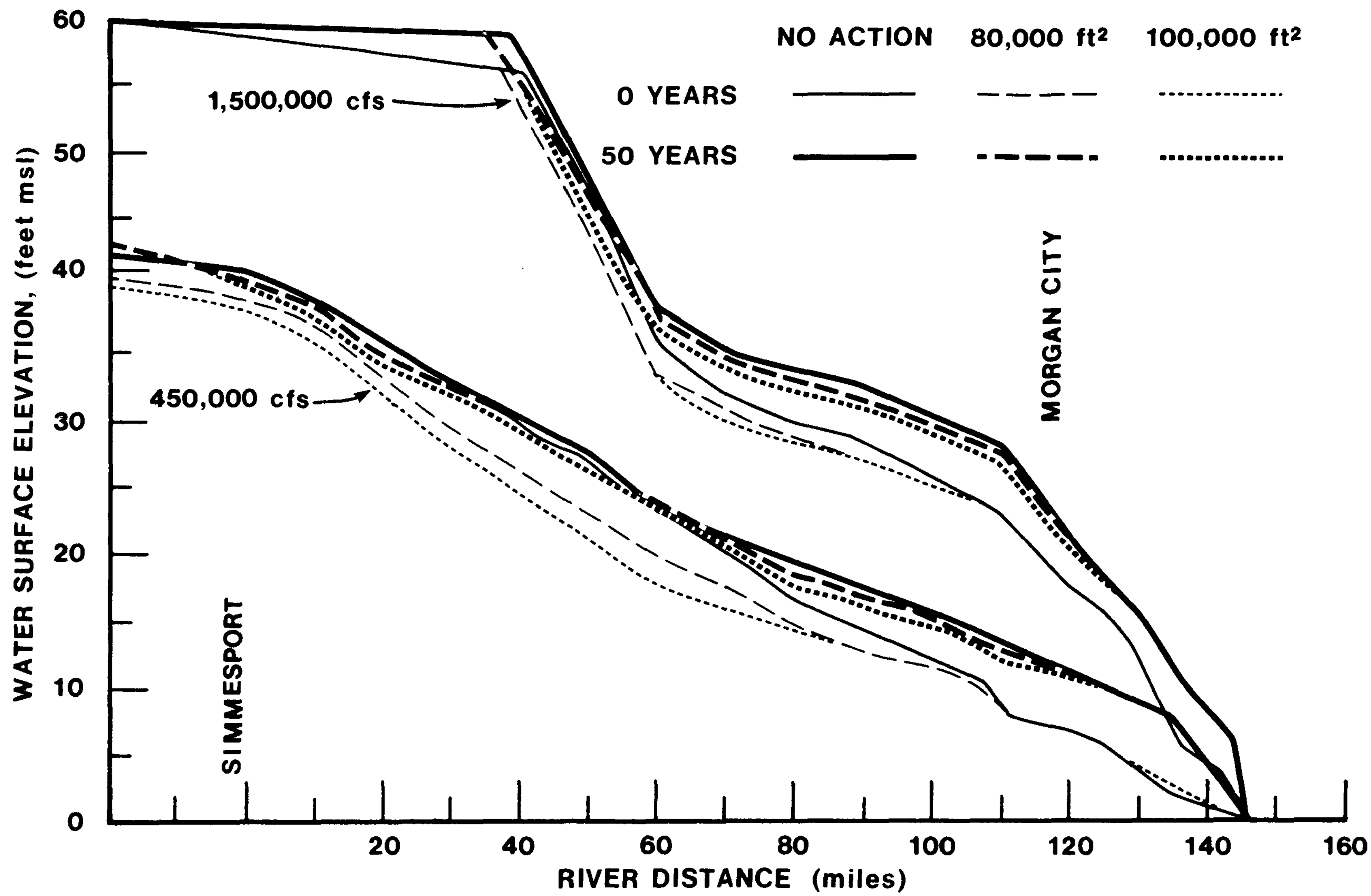

Figure 10. Immediate and future main channel flow lines for three alternatives derived through mathematical modeling (USGS, 1977).

TABLE 3. ESTIMATED TIME REQUIREMENTS FOR NATURAL CHANNEL ENLARGEMENT TO ALTERNATIVE DIMENSIONS OF 100,000 ft^2 AND 80,000 ft^2

Channel Area below 1963 Datum Plane ft^2	Main Channel Segment River Miles	Estimate of Years Required this Report (Base Year 1973)	Estimate of Years Required USCE* (Base Year 1973)
100,000	0 - 55	0	0
80,000	0 - 55	0	0
100,000	55 - 95	20	32
80,000	55 - 95	7	3
100,000	95 - 105	33	60+
80,000	95 - 105	20	21
80,000	95 - 112	35	42

*Source: New Orleans District, U.S. Army Corps of Engineers, Letter of March 24, 1978 to Victor W. Lambou, Project Officer for this study, from Early J. Rush III, District Engineer.

naturally or is dredged to dimensions of 80,000 ft^2 and 100,000 ft^2, respectively, below the 1963 datum plane. Channel enlargement through dredging is seen to produce an immediate lowering of the water surface profile for the 450,000 cfs discharge (approximately the average annual high water profile). The main effect is in the middle part of the floodway with lowering of stages decreasing below mile 70. The obtained reduction in stages is approximately equivalent to a reduction in mean annual peak discharge from 430,000 cfs to 330,000 cfs, or nearly 25 percent. After a period of 50 years, however, this profile is seen to have almost returned to conditions associated with natural development of the channel--that is, a continuation of the upward movement of the water surface profile below mile 70 with an increase to about 5 ft near Morgan City.

Concomitant with the dredged channel enlargement is a lowering of the project flood water surface profile on the order of 1 to 2 ft, of which approximately 1 ft is retained after 50 years. Since channel conditions at that time were nearly the same, the reduction must be considered to have been achieved through lesser overbank sedimentation as a result of lower stages during the initial part of the 50-year period. The achieved reduction in water surface profile elevation represents an increased floodway capacity of approximately 40,000 cfs or 2.5 percent of the required capacity.

The two major points that are apparent are the following. First the channel enlargement through dredging produces only a very limited benefit with regard to flood control. Second, the lowering of the water surface profile constitutes a major perturbation of the environment. Below mile 70 the lowered annual flood stages aggravate the loss of aquatic habitat occurring as a result of present gradient adjustment and increase the feasibility of development in the upper part of the floodway system. A further consideration of importance is that a lowering of water levels in the Atchafalaya Basin channel system includes the alternate route of Intracoastal Waterway and other navigation channels, thus requiring additional dredging and spoil disposal to maintain authorized depths.

CONSIDERATION OF ALTERNATIVES

After consideration of riverine processes and present trends of the Atchafalaya River channel, one cannot escape the conclusion that use of the Atchafalaya Basin for flood control must be within the constraints imposed by the presence of the Atchafalaya River. Ultimately, the excess capacity of the area within the guide levees for flood control use will be only the cross-sectional area above the stable active channel cross section and that above the overbank area (Figure 11). Any additional capacity can only be acquired by raising the guide levees. The inherent limitations of raising the guide levees must be resolved through the diversion of flood waters outside the basin above or at the latitude at which the project flow line exceeds the grade of the guide levees. The most effective alternative for achieving maximum long-term use for flood control at a minimum cost to the environment is to enhance the development of the channel in the direction of its ultimate stable conditions as determined by stream distance and flow-sediment regime while simultaneously minimizing sedimentation in the backwater areas.

The above alternative requires two separate but related actions that concern both the channel and overbank area and that must be executed simultaneously. Actions with regard to the limitation of sedimentation in the overbank area are the same as those desirable from an environmental point of view. Actions with regard to the Atchafalaya Basin main channel will be outlined below and include consideration of the delta system below Morgan City.

First there should be confinement of flows to the Atchafalaya Basin main channel and the channel leading to Wax Lake outlet for discharges of up to but no more than approximately 400,000 cfs at Simmesport. This should be accomplished without reducing peak flows through the Old River control structure. The decrease in discharge in a downstream direction should be minimized by limiting diversion through the east and west freshwater distribution channels, the east and west access channels, and any other minor channels, to only the volume necessary to enhance surface water quality and environmental integrity. Provided that internal circulation is improved through the measures indicated above, the limitation of diversion to 15 percent of the Simmesport discharge appears justified. This includes 3 to 5 percent for diversion into areas affected by the lowering of the water surface profile such as the Bayou des Glaises management unit. Confinement of flows below the diversion points should thus be for 340,000 cfs to 382,000 cfs until bifurcation occurs toward the Wax Lake outlet and Lower Atchafalaya

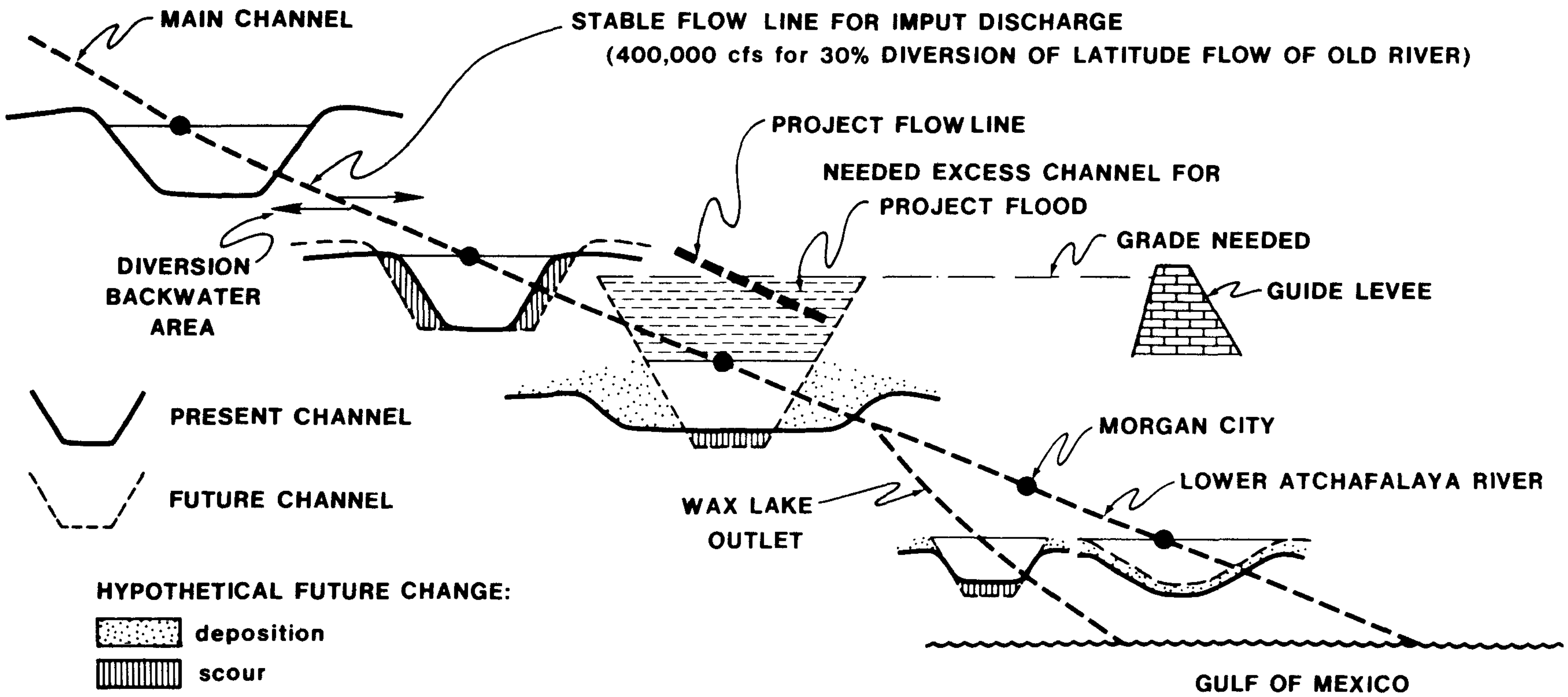

Figure 11. Representation of hypothetical channel changes resulting in stable flow line and the relationship between the future channel and floodway capacity.

River. From there flow should be confined in each of the two branch channels up to the proportion of the 340,000 cfs to 382,000 cfs received at the bifurcation point.

Confinement of flows should be achieved through the use of training levees. Levee material may be dredged from the main channel and should be deposited in a natural configuration on the channel banks with severe constraints on width and height of the deposits and on distance from the present channel. Prior to such dredging, it must be determined what the water surface profile will be for the confined, delineated discharges under present channel conditions. Height of the training levees should not exceed the elevation of the water surface profile so as to maintain the overbank flow process for greater discharges to maintain environmental integrity. It cannot be overemphaiszed that diversion into the overbank area for the greater discharges must be exclusively through overbank flow (except where structural control is exerted) so that sedimentation contributes primarily to natural increase in elevation of the channel banks and does not diminish the depth of the overbank area. Width of the levees should be no more than is necessary to support the needed height and to prevent frequent crevassing. Distance of levees from the center line of the channel should be in accord with the width of the channel expected to develop under the present discharge regime.

The above specifications for flow confinement establish a maximum limit that should not necessarily be interpreted as the recommended height of training embankments. The dredging of material from the Atchafalaya Basin main channel for the purpose of flow confinement should not result in channel enlargement to the extent that modification of the water surface profile adversely affects duration, depth, and extent of annual flooding. Flow confinement should proceed only to the extent allowed by annual flooding regime requirements, with further confinement to take place through the natural process of overbank flow and associated greatest deposition of sediment on the channel banks.

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APPENDIX

CONVERSION FACTORS

In this report, English units are frequently abbreviated using the notations shown below. The English units can be converted to metric units by multiplying by the factors given in the following list:

English Unit to convert	Multiply by	Metric Unit to obtain
acres	4047	square meters
cubic feet per second (cfs)	0.02832	cubic meters per second
cubic yards (yd^3)	0.7646	cubic meters
feet (ft)	0.3048	meters
miles	1.6093	kilometers
square feet (ft^2)	0.09290	square meters
square miles (mi^2)	2.590002	square kilometers

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1. REPORT NO. EPA-600/4-79-036	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE HYDRAULICS OF THE ATCHAFALAYA BASIN MAIN CHANNEL SYSTEM: Considerations from a Multiuse Management Standpoint		5. REPORT DATE May 1979
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Johannes L. van Beek		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Coastal Environments, Inc. 1260 Main Street Baton Rouge, Louisiana 70802		10. PROGRAM ELEMENT NO. 1BD613
		11. CONTRACT/GRANT NO. 68-03-2665
12. SPONSORING AGENCY NAME AND ADDRESS U.S. Environmental Protection Agency-Las Vegas, NV Office of Research and Development Environmental Monitoring and Support Laboratory Las Vegas, Nevada 89114		13. TYPE OF REPORT AND PERIOD COVERED 6/77-1/78
		14. SPONSORING AGENCY CODE EPA/600/07
15. SUPPLEMENTARY NOTES		

16. ABSTRACT

The report examines the relationships among hydraulic elements in the Atchafalaya Basin floodway system in terms of discharge regime, sediment load, channel form and size, flood control, water surface slope, bank elevation, overbank capacity, dredging requirements, and spoil disposal. Hydraulic geometry of the present main channel system is analyzed and the rate of natural channel development along the main channel is presented with the net change in channel cross-sectional area from changes in bed and flow line.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
*Water resources development Flood control Sedimentation Hydrography	Atchafalaya Basin Wetlands Water management Channel stabilization	02 F 08 A, F, H 13 B

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES
RELEASE TO PUBLIC	UNCLASSIFIED	48
	20. SECURITY CLASS *(This page)* UNCLASSIFIED	22. PRICE A03

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