Technical Report M7

SEDIMENTATION AND NAVIGATION STUDY OF THE LOWER MISSISSIPPI RIVER AT THE WHITE RIVER CONFLUENCE, MILES 603 TO 596

HYDRAULIC MICRO MODEL INVESTIGATION

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INTRODUCTION

A sedimentation and navigation improvement study of the Lower Mississippi River at the confluence of the White River was initiated by the River Engineering Section of the Memphis District. The purpose of the study was to evaluate a number of design alternatives and/or modifications for channel improvement between Mississippi River Miles 603 and 596.

Personnel from the Memphis District directly in charge of the study and overseeing the project included: Mr. Wayne Max, Acting Chief, River Engineering Section; Mr. James Gutshall, Civil Engineer; Mr. Dewey Jones, Chief, Hydraulics Branch; and Mr. Andy Gaines, Civil Engineer.

Personnel from the Vicksburg Districts who supplied pertinent information, data, and knowledge of the study reach included Mr. Bob Fitzgerald, Chief, River Stabilization Branch, Mr. Jasper Lummus, and Mr. Robert Barnett. Mr. Mitch Eggburn, Little Rock District, provided invaluable information concerning the construction of the lock and dam on the White River. Mississippi Valley Division personnel involved in the study included Mr. Steve Ellis, Mr. Malcolm Dove, Mr. Clarence Thomas, and Mr. John Brooks.

The study was conducted between October 1997 and May 1998, using a physical hydraulic micro model at the St. Louis District Applied River Engineering Center, St. Louis, Missouri. The study was performed by Mr. David Gordon, Hydraulic Engineer, under direct supervision of Mr. Robert Davinroy, District Potamologist for the St. Louis District.

Personnel from other agencies also involved in the study included Mr. Paul Revis, Executive Director of the Arkansas Waterways Commission.

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BACKGROUND

This report details the investigation of a sedimentation and navigation study of the Lower Mississippi River using a physical hydraulic micro model. The micro model methodology was used to evaluate sediment transport and flow conditions in the Mississippi River at the White River confluence. Plate 1 is a vicinity map of the study reach.

Micro modeling methodology was used to evaluate the sediment transport and hydrodynamic response trends that could be expected to occur in the river from various applied channel improvement design alternatives. These alternatives were conceptualized and submitted by members of a study team representing the Memphis and St. Louis Districts, Mississippi Valley Division, and various representatives of the navigation industry. The primary goal was to evaluate the impacts of these measures on the resultant bed configuration (sediment transport response) and hydrodynamic response (flow patterns) within the study reach.

1. Study Reach

Plate 2 is a map depicting the characteristics, configuration and nomenclature of the Lower Mississippi River and White River through the study reach. The confluence of the White River with the Mississippi River occurs downstream of Scrubgrass Bend near Mile 599. The area serves as a boundary between the Memphis and Vicksburg Districts of the Corps of Engineers. The Little Rock District controls the lower ten miles of the navigation channel on the White River. This reach of river serves as the entrance to the McClellan-Kerr Arkansas River navigation system. Plate 3 shows the location of the new Montgomery Point Lock and Dam. This project is currently being constructed on the White River approximately 3000 feet upstream of the confluence. The project completion date depends on a number of factors including funding, and it is estimated to occur sometime between the years 2002 and 2011.

2. History

Until the late 1940's, the Mississippi River displayed active meandering patterns within the study reach. As recent as the early to mid 1930s, the Mississippi River traversed through what is presently known as Smith Point. The right descending bank was located approximately two miles east of its present location. In the 1940s, the Corps began channel improvement measures in this stretch of river as it neared its present day alignment. The current alignment has remained relatively stable and unchanged since the early 1970s. Plate 2 shows alignments from 1933 and 1953 as compared with the present day alignment.

In the late 1930s, a study of the mouth of the White River was undertaken by the Channel Regulation Section of the Memphis District. The study predicted that the Mississippi River would migrate toward the White River in the area of Scrubgrass Bend and that the White River would eventually "break out" or enter into the Mississippi River somewhere near Montgomery Point. This event actually took place in 1953. Additional channel improvement initiatives have enabled the confluence of the two rivers to remain in their present planform configuration. The Mississippi River main channel, between Miles 599 and 597.7, now occupies what was once formally a portion of the White River channel. The White River historic remnant channel was located just downstream of the confluence at Mile 597.7. The historic confluence of the two rivers occurred approximately 8 miles downstream of the current confluence near Mile 591.

3. Navigation Problems

There have been several navigation problems associated with the confluence of the two rivers. The present day alignment has been generally responsible for problems with tows entering or exiting the White River. Interviews were conducted (Max, 1996) with several operators and owners of towing companies who regularly use the White River. Those discussions revealed that navigation problems have occurred frequently, but to varying degrees of severity. All companies interviewed indicated that navigation conditions have consistently deteriorated throughout the years. They also conveyed that a definite safety problem has existed.

Mr. Paul Revis, Executive Director of the Arkansas Waterways Commission, expressed concern about navigation conditions at the mouth of the White River in his testimony before the Mississippi River Commission (MRC) on 18 April 1995 and on subsequent MRC inspection trips. Specifically, Mr. Revis requested that the Corps of Engineers investigate measures to reduce velocities on the Mississippi River at the confluence and to provide safer navigation conditions upon entering and exiting the White River.

Most navigation problems have been encountered during high stages on both the Mississippi and the White Rivers. Problems were reported when the Mississippi River was at +17.5 on the Terrene Landing gage by Augusta Barge, and +25 to +30 on the Arkansas City gage by Jantran. Although the problem has been reported to be more severe at higher stages, August Barge, Augusta Port and Elevator, Jantran, and Pine Bluff Sand and Gravel have reported problems at all stages. Jantran reported that additional maneuverability problems have occurred when the navigation channel of the White River becomes constricted at low stages.

Some of the detailed specifics of the navigation problems associated with the confluence are as follows:

A. Blind Exit Conditions

As tows exit the White River, pilots do not have a visual means to ensure that there are no downbound approaching tows on the Mississippi River. Plate 4 describes this scenario. Downbound tows on the Mississippi River generally hug the right descending bankline due to the high velocities and deep water associated with the outside of the bend. Large trees and thick brush on the upstream point of the confluence obstruct the view of the pilots exiting the White River. Therefore, pilots are forced to "call out" on the radio to ask for responses from any approaching downbound tows on the Mississippi River. If no answers are received, pilots must assume the area is clear and blindly push out into the Mississippi River. This extremely dangerous situation has resulted in several incidents where direct collisions nearly occurred.

B. High Bend Velocities

High velocities on the outside of the Mississippi River bend create detrimental flow conditions for tows entering the White River. The captured planform alignment of the bend has caused the sand bar at Smith Point to encroach into the channel. This has effectively narrowed the navigation channel and increased the depth and the velocities on the outside of the bend at the confluence. The Mississippi River channel width was measured just upstream from the mouth of the White River. In order to have a consistent reference point, measurements were made between the "0" LWRP contour lines on either side of the river. Data was obtained from hydrographic survey sheets between 1973 and 1995. The channel width in this reach has varied over the years. In the early 1970s, the width was between 1000 and 1500 feet. In the late 1970s and 1980s, the trend was toward a wider channel, with widths varying between 1500 and 2250 feet. During the 1990s, except for 1991, the trend has been toward a narrower channel, with a width that has stabilized between approximately 1200 and 1300 feet.

Cross sections taken from hydrographic surveys between 1963 and 1995 did not show any significant change in the depth or width of the channel at Mile 599. In fact, the deep channel on the right descending bank seems to be wider today than it was before the Smith Point Dikes were constructed. The cross-sections showed that Smith Point bar has both aggraded and degraded historically. Aggradation has been the trend over the past few years. Cross sections at Smith Point Dike Number Two near Mile 600 showed that the channel was very shallow at this location prior to construction of the dikes. Since construction, the right descending bank has recessed approximately 600 feet, and the channel has become much deeper.

The sharp contrast or difference in depths between the Mississippi River and the White River was also mentioned by pilots as a perceived navigation problem. Near the mouth of the White River, depths may change up to 80 feet within a distance of 500 feet.

The above conditions have created high velocities on the Mississippi River that may negatively influence a downbound tow trying to enter the White River. This scenario is displayed on Plate 5. A tow pilot has more control over the vessel while heading in the upstream direction. Therefore, most downbound tow pilots prefer to travel downstream on the Mississippi River past the confluence to Victoria Bend near Mile 595.5. In this area, tows turn around and travel back upstream to make an upbound approach into the White River.

Upbound vessels also experience problems when approaching the White River, as displayed on Plate 6. As an upbound tow begins to enter the White River, the pilot must position the tow broadside to the Mississippi River current to make the ensuing sharp turn. During this maneuver, high velocities may push the tow into the downstream bankline or possibly even flood the upstream side of the vessel.

Mr. Joe Janoush of Jantran towing company testified before the MRC on 27 August 1996. Mr. Janoush stated… "When the Mississippi level approaches the 25 to 30 foot level on the Arkansas City gage, we are beginning to experience the high flows and current problems on the Mississippi entering the mouth of the White River. When tows entering the mouth are required to turn at an approximately 90-degree angle, they turn themselves in a broadside condition to get into this entrance channel, which is causing the vessels to be almost swamped at different times when flows are at this level. Last spring we even had a situation where an entire 8-barge loaded tow was swamped down the whole starboard side of the tug."

Exiting the White River also causes a pilot to maneuver his tow broadside to the Mississippi River current. During the winter of 1996 with +17.5 on the Terrene Landing gage and the White River slack, the Vance M. Thompson of Augusta Barge Towing Company was nearly swamped. Captain Tommy Jenkins related that a face-wire had broken as the tow was coming out of the mouth of the White River. The towboat leaned approximately 70 degrees to one side, and water came halfway up onto the first deck. Captain Jenkins stated that he thought the vessel was going to roll over, but fortunately the tow was reassembled without further incident.

C. Size and Horsepower Limitations

The required size and horsepower of vessels navigating this critical area seems to be an unknown factor. Augusta Barge and Augusta Port and Elevator reported having experienced problems with three and four barge tow configurations. Brent Transportation Company has typically pushed four ammonia barges and has reported only minimal difficulty. However, this company has usually entered the White River empty. Pine Bluff Sand and Gravel has typically pushed twelve barges, three wide and four long, while Jantran reports that they have had trouble pushing eight barges.

A wide range of horsepower has been employed between the various towing companies. Jantran has experienced problems with boats up to 3600 horsepower. Some vessels seem to navigate the entrance with less horsepower, but still experience some difficulty. Augusta Port and Elevator have managed to use less than 3600 horsepower, but the company has reported that it must double-trip at times. Brent Transportation has usually averaged 3800 to 4300 horsepower, which seems to have been sufficient to allow them to push into the White River quickly with minimal difficulty. The company has used as small as a 1800 horsepower vessel. Under this power requirement, the company reported that tows had to be dragged along the lower right descending bank of the White River just off the revetment until the tows were “set up” in the White.

D. Maneuvering Methods

Several different navigation maneuvering methods have been employed to counter the problems previously described. Some companies have preferred to break up their tows into smaller configurations and double-trip. This has often been a very time consuming and costly process. Jantran and Pine Bluff Sand and Gravel reported that it normally has taken between 12 to 18 hours to break tow and double-trip. Augusta Port and Elevator stated that it has taken approximately two to three hours to break tow and double-trip. Some companies use a helper boat to assist in navigating into the mouth. Both Augusta Barge and Jantran stated that at certain times another boat is sent along to assist in navigating the mouth of the White. Jantran stated that a helper boat is used approximately 90% of the time.

The strong eddy that occurs off the upstream point of the confluence can sometimes be used as a beneficial guide or aid in navigating the mouth of the White River. Pilots familiar with the conditions produced by the eddy sometimes use the velocities and flow patterns created by the eddy to guide their tow into the mouth. The eddy regularly changes according to conditions associated with both rivers, therefore this can be a very risky maneuver. Mr. Jimmy Hopkins of Augusta Port and Elevator stated that he has used the upstream eddy to help maneuver his tow into the mouth. He must push his tow past the mouth of the White, then has to let the eddy catch the front of the tow to help guide him into the White.

4. Study Purpose and Goals

The purpose of this study was to assess the sediment transport and flow response of the Mississippi River as well as to examine the interaction between the Mississippi River main channel and the White River confluence.

The primary goal was to evaluate design alternatives that would provide improved conditions for navigation. This included examining ways to reduce velocities and redistribute flow patterns in the Mississippi River main channel by the use of bendway weirs. Protection of the confluence with a dike structure, realignment possibilities, and reduction of the eddy were also evaluated. Assessments of these alternatives included examining the ultimate effects to sedimentation, flow patterns, and navigation within the main channel of the Mississippi River as well as interaction with the White River confluence. Design measures that created adverse conditions in the Mississippi River main channel were not considered feasible.

MICRO MODEL DESCRIPTION

1. Scales and Bed Materials

Plate 7 is a photograph of the hydraulic micro model used in this study. The model insert encompassed the Mississippi River channel between Miles 605.0 and 587.0. After entrance and exit conditions in the model were adjusted, the actual study reach was between Miles 602.5 and 596.0. The last 2.5 miles of the White River were also included in the model. The scales of the model were 1 inch = 1000 feet, or 1:12000 horizontal, and 1 inch = 100 feet, or 1:1200 vertical, for a 10 to 1 distortion ratio. This distortion supplied the necessary forces required for the simulation of sediment transport conditions similar to the prototype. The bed material was granular plastic urea, Type II, with a specific gravity of 1.23.

2. Apperturences

Discharge hydrographs were simulated by computer via an electronic control system. The system consisted of computer control interfaced with an electronic control valve and submersible pump. A 3-dimensional digitizer was used to monitor water stages and to measure and record the resultant model bed configurations.

The model was constructed according to recent aerial photography of the study reach. The riverbanks were constructed out of dense polystyrene, while the realignment section at the confluence was constructed out of oil based clay. Rotational jacks located within the hydraulic flume controlled the slope of the model.

Surface current patterns were captured using a flow visualization technique developed at AREC. This technique involved using photographic time exposure prints to examine the general surface velocity patterns of the base test and of all design alternative tests.

MICRO MODEL TESTS

1. Calibration and Verification

The calibration/verification of the micro model involved the adjustment of water discharge, sediment volume, hydrograph time scale, and floodplain slope. These parameters were refined until the measured bed response of the model was similar to that of the prototype.

A. Design Hydrograph

In all model tests, the effective discharge or hydrograph was simulated (1) in the Mississippi River channel only. This hydrograph served as the average design flow response. Because of the constant variation experienced in the prototype, a design hydrograph was used to theoretically analyze the average expected sediment response during any given year. Each hydrograph was run from extreme low flow to near top of bank flow. The time increment or duration of each cycle (peak to peak) was three minutes.

Flow was not simulated in the White River. Historic stage and flow records have indicated that the Mississippi River discharge dominates most of the year. The problems this study addresses have been evident mainly when the Mississippi River is at high stage. The White River then, for purposes of this study, was considered a backwater area with no simulation of flow or sediment transport. The bed of the White River above the confluence was molded according to a 1996 hydrographic survey of the study reach (Plate 8).

B. Prototype Data

Several prototype hydrographic surveys were used to determine the general bed characteristics that have existed in the prototype. High water surveys of the Mississippi River from 1994, 1995, 1996, and 1997 are shown on plates 9, 10, 11 and 12, respectively. Older historical surveys were not used for this study because conditions are substantially different today than in the past. All four modern day surveys show almost identical trends. The general trend has been for the formation of a large, high sand bar, above +20 feet LWRP, to occur at Smith Point. Depths in the adjacent main channel have approached –90 feet LWRP. The thalweg has remained on the outside of the bend and against the right descending bankline throughout most of the study reach. A short, deep crossing has developed at the upper end of the study area, while a long, shallow crossing has occurred at the lower end of the study area. A scour hole in excess of 80 feet has been predominant off the right descending bank at the most downstream point of the White River confluence.

Plate 13 is a 1977 ice photo of the confluence area. Even though the modern day alignment has changed slightly since this time period, the ice in the photo gave a general representation of flow patterns within the study reach. The ice patterns revealed that the flow in the Mississippi River was concentrated tightly along the right descending bankline well past the White River confluence. Flow deflected slightly off the downstream point of the confluence. Further downstream, the flow began to evenly distribute across the channel before approaching the downstream crossing.

Once a favorable comparison of several surveys of both the prototype and model were made, the model was considered calibrated. The resultant survey of this bed response served as both the verification and base test of the micro model (2).

2. Base Test

A. Base Test Survey

Plate 14 shows the resultant bed configuration of the micro model base test. The base test was developed from the simulation of successive design hydrographs until bed stability was reached and a similar bed response was achieved as compared with prototype surveys. This survey then served as the comparison survey for all future design alternative tests. Results of the base test and its comparison to the prototype indicated the following trends:

At the upper end of the study reach in the model, near Mile 602.5, depths in the thalweg along the left descending bankline approached –90 feet LWRP. The prototype surveys showed depths of less than –60 feet LWRP in this area. A crossing developed in the model near Mile 601.5 with depths below –20 feet LWRP. The prototype surveys show a slightly deeper crossing in the same area, with depths approaching –50 feet LWRP. These differences were not significant enough to negatively effect the results of this study.

The section of the model between Miles 601 and 599 responded exceptionally well as compared to the prototype. The thalweg remained on the right descending bankline in the model through this reach of river. Three major points of curvature inflection occurred in this bend in both the model and the prototype at identical locations. The first point of inflection occurred near Mile 601. Depths in the model approached –90 feet LWRP, while depths in the prototype reached –60 feet LWRP. The second inflection point occurred near Mile 600. Depths in the model approached –80 feet LWRP, while depths in the prototype were near –70 feet LWRP. The last inflection point occurred near Mile 599.5, where depths approached –80 feet LWRP in both the model and in the prototype.

On the inside of the bend at Smith Point, between Miles 601 and 598, the formation of a point bar was evident in both the model and prototype. On the downstream point of the confluence, near Mile 598.8, a predominant scour hole in excess of –80 feet LWRP developed in both the model and prototype. Both prototype and base test surveys indicated that the channel in the area of the White River confluence was very deep and narrow.

At Mile 598, a long, shallow crossing with depths of less than –20 feet LWRP developed in the model. In the prototype, the crossing developed at Mile 597.5, where depths were slightly greater. The crossing ended near Mile 596.5 in the model, while prototype surveys showed that the crossing ended near Mile 596.0.

Generally, the bathymetric trends established in the micro model were similar to the trends observed in the prototype surveys. The location of the points of inflection within the bend in the model and the prototype were identical. The only minor difference in trends occurred in the downstream crossing, where the crossing in the model began and ended approximately 0.5 miles further upstream than in the prototype. As discussed previously, depths within the White River were molded to between –10 and –20 feet LWRP according to the prototype survey.

B. Base Test Flow Visualization

In addition to the bathymetry collected from the model, flow visualization information was also recorded. Photographic time exposure was used to examine the general surface velocity patterns of the base test and of each design alternative test.

Plate 14 shows the flow visualization photo of the base test. The trends appeared almost identical to those in the 1977 ice photo. The flow patterns in the model showed a point of inflection at Mile 599.5, followed by an impact point on the downstream point of the White River confluence. These points were evident in almost the same location as in the ice photo. The flow was concentrated on the right descending bankline throughout the confluence area in both the model and the prototype. Flow patterns then widened downstream of the White River within the crossing.

3. Design Alternative Tests

Ten alternative design plans to improve flow and navigation conditions at the confluence of the two rivers were tested in this study. The effectiveness of each plan was evaluated by comparing the resultant bed configuration and flow patterns to that of the base condition. Impacts or changes of each alternative were evaluated by examining both the flow and sediment response of the model. A qualitative evaluation of the ramifications to both upbound and downbound tows was made during team participation meetings at St. Louis, MO. Engineers from the Memphis, St. Louis, Vicksburg, and Little Rock Districts, Mississippi Valley Division, Waterways Experiment Station, and those involved in the navigation industry carefully examined and discussed each alternative.

Alternative A: *6 Bendway Weirs at –15 Feet LWRP Placed Upstream of the Confluence*

Plate 15 is a plan view map of the resultant bed configuration and flow visualization of Alternative A. Test results indicated the thalweg, just upstream of the confluence between Miles 600 and 599, was moved toward the middle of channel. The scour hole at the downstream point of the White River confluence, on the right descending bankline near Mile 599, remained unchanged. The downstream crossing was shorted by 0.8 miles, and the channel deepened approximately 10 feet. The crossing started near Mile 597.2 but ended near the same location as observed in the base test. Flow visualization photos showed minimal changes in the velocity patterns as compared to the base conditions.

<u>Alternative B:</u> *9 Bendway Weirs at –15 Feet LWRP (6 Weirs Upstream, as in Alternative A, and 3 Weirs Downstream of the Confluence)*

Plate 16 is a plan view map of the resultant bed configuration and flow visualization of Alternative B. Between Miles 600.0 and 598, results indicated that the thalweg decreased in depth and moved toward the middle of the channel. The scour hole on the downstream point of the White River confluence near Mile 599 aggraded approximately 50 feet. The bar across the river at Smith Point between Miles 600 and 598.5 degraded 10 to 20 feet. The downstream crossing shortened approximately 0.8 miles and deepened by less than 10 feet. The crossing started near Mile 597.2 but ended near the same location as observed in the base test. Flow visualization showed that the flow patterns were pulled off the right descending bankline. The velocities were completely redistributed across the channel.

<u>Alternative C:</u> *7 Bendway Weirs at –15 Feet LWRP (4 Weirs Upstream and 3 Weirs Downstream of the Confluence)*

Plate 17 is a plan view map of the resultant bed configuration and flow visualization of Alternative C. Between Miles 599.5 and 598.3, the results indicated the thalweg decreased in depth and moved toward the middle of the channel. The scour hole at the downstream point of the White River confluence aggraded to above –10 feet LWRP. The bar at Smith Point and the downstream crossing both degraded slightly. Flow visualization showed minimal changes in the velocity patterns as compared to the base conditions.

<u>Alternative D:</u> *7 Bendway Weirs at –30 Feet LWRP (4 Weirs Upstream and 3 Weirs Downstream of the Confluence)*

Plate 18 is a plan view map of the resultant bed configuration and flow visualization of Alternative D. Results indicated the thalweg between Miles 599.7 and 598.3 remained on the right descending bankline but decreased slightly in depth. The scour hole off the downstream point of the White River confluence aggraded to above –10 feet LWRP. The downstream crossing deepened 10 to

20 feet. Flow visualization showed minimal changes in the velocity patterns as compared to the base conditions.

__Alternative E:__ *7 Bendway Weirs at –15 Feet LWRP (5 Weirs Upstream and 2 Weirs Downstream of the Confluence)*
Plate 19 is a plan view map of the resultant bed configuration and flow visualization of Alternative E. Results indicated the thalweg moved towards the middle of the channel between Miles 599.7 and 598 and the bar at Smith Point degraded. The downstream crossing lengthened slightly and deepened approximately 10 feet. Flow visualization showed that the flow patterns were pulled off the right descending bankline. Velocities were redistributed across the middle of the channel.

__Alternative F:__ *700 Foot Dike at +15 Feet LWRP on the Upstream Point of the White River Confluence*
Plate 20 is a plan view map of the resultant bed configuration and flow visualization of Alternative F. Results indicated a large scour hole approximately 70 feet deep developed off the end of the dike at Mile 599.1. A short crossing formed between Mile 599.1 and Mile 598.3. Near Mile 598.3, the bar at Smith Point laterally eroded back approximately 600 feet as compared to the base condition. Flow visualization showed that the thalweg remained concentrated along the right descending bankline before deflecting off the end of the dike. A boundary shadow of slack water was formed behind the dike and within the mouth of the White River.

__Alternative G:__ *800 Foot Longitudinal Dike at +15 Feet LWRP on the Upstream Point of the White River Confluence*
Plate 21 is a plan view map of the resultant bed configuration and flow visualization of Alternative G. Results indicated that the main channel remained relatively unchanged. The only observed changes were the development of a shallow area off the downstream end of the dike and slight deposition in the

downstream crossing. Flow visualization showed that the flow patterns remained concentrated on the outside of the bend. An area of slack water developed downstream of the dike and within the mouth of the White River.

Alternative H: *Major Realignment of the White River Confluence on the Downstream Point*

Plate 22 is a plan view map of the resultant bed configuration, realignment area and flow visualization of Alternative H. Results indicated that the original 80 foot scour hole at the White River confluence scoured to over 100 feet LWRP. The deepest area of scour occurred within the realigned section. A short, shallow crossing developed between Miles 598.6 and 598.3. A 70-foot LWRP scour hole formed off the left descending bankline near Mile 598.2. Flow visualization showed that the realignment area took the impact from most of the flow in the upstream thalweg. Downstream, the channel crossed over severely to the left descending bank.

Alternative I: *7 Bendway Weirs Built –15 Feet LWRP as in Alternative E (5 Weirs Upstream and 2 Weirs Downstream of the Confluence), an 800 Foot Longitudinal Dike Built at +15 Feet LWRP, and a Minor Realignment of the White River Confluence on the Downstream Point*

Plate 23 is a plan view map of the resultant bed configuration, realignment area, and flow visualization of Alternative I. Results indicated that the thalweg moved toward the middle of the channel between Miles 599.7 and 598.0. The scour hole on the downstream point of the White River confluence aggraded, but adequate depth for navigation was maintained. The bar at Smith Point was eroded, while the downstream crossing deepened. Flow visualization showed that the flow patterns moved off the right descending bankline and the velocities were redistributed across the middle of the channel. An area of slack water formed just downstream of the dike and within the confluence. The minor realignment of the confluence did not seem to influence the bed response or the flow conditions.

<u>Alternative J:</u> *500 Foot Longitudinal Dike Built at +15 Feet LWRP and Minor Realignment of the White River Confluence as in Alternative I*

Plate 24 is a plan view map of the resultant bed configuration, realignment area, and flow visualization of Alternative J. Results indicated that the thalweg remained relatively unchanged. The scour hole on the downstream point of the White River confluence aggraded. The downstream crossing also remained relatively unchanged. Flow visualization showed that the flow patterns remained concentrated on the outside of the bend before spreading out slightly downstream of the dike. An area of slack water formed just downstream of the dike. The minor realignment of the confluence did not seem to influence the bed response or the flow conditions.

CONCLUSIONS

1. Summary of Model Tests

The following is a summary of the findings and recommendations of the model study:

- The bendway weirs used in Alternatives A, B, C, D, E, and I were used to redistribute the flow patterns and reduce velocities at the mouth of the White River. The proper alignment and depth of the bendway weirs were the most important aspects of these alternatives. Bendway weirs at –15 feet LWRP, and the alignments shown in Alternatives B, E, and I proved most effective at moving the thalweg and redistributing the velocities across the middle of the channel.

- Dike structures extending from the mouth of the White River into the Mississippi River navigation channel, such as the one shown in Alternative F, proved effective at improving confluence conditions. However, implementation of these structures would cause an obstruction in the navigation channel of the Mississippi River, which would be a major safety concern.

- The longitudinal dikes shown in Alternatives G, I, and J proved somewhat effective in improving confluence conditions, but again these plans would pose a major safety concern to tows navigating the Mississippi River.

- The major realignment of the mouth of the White River shown in Alternative H proved extremely ineffective. This measure resulted in the development of large scour hole off the tip of the realignment section and the development of scour against the left descending bankline near Mile 598.2. A major realignment of the confluence completely altered the downstream flow conditions and sediment response within the Mississippi River. A minor realignment of the confluence, shown in Alternatives I and J, did not display any negative effects to the sediment response, flow patterns, or navigation conditions of the Mississippi River.

2. Recommended Solutions

- Model tests indicated that the bendway weir configuration in Alternatives E and I proved to be the most effective and economical measure to alleviate the majority of navigation problems at the confluence. The bendway weir configuration in Alternative B proved also to be very effective, but the plan would be more costly to construct.

- The minor realignment of the confluence in Alternative I did not result in any noticeable changes to the flow patterns observed in Alternative E. Therefore, a minor change in the alignment of the confluence, in combination with bendway weirs, should improve flow conditions. A minor realignment of the mouth of the White River on the downstream point would provide tows with an improved, safer approach to the new lock chamber. A small longitudinal dike extending from the upstream point of the confluence, as in Alternative I, may also be beneficial to further protect tows from high velocities and the strong eddy formation within the confluence. However, any new structure of this type must be constructed small enough so as not to obstruct the flow of traffic in the navigation channel on the Mississippi River.

- Any minor realignment or construction of a longitudinal dike should be built in conjunction with the bendway weir alignment shown in Alternatives E and I to effectively reduce and redistribute velocities at the confluence. Model tests clearly indicated that these measures would improve the flow conditions experienced on the Mississippi River and within the White River confluence.

- In the interpretation and evaluation of the results of the tests conducted, it should be remembered that the results of these model tests were qualitative in nature. Any hydraulic model, whether physical or numerical, is subject to biases introduced as a result of the inherent complexities that exist in the prototype. Anomalies in actual hydrographic events, such as prolonged periods of high or low flows are not reflected in these results, nor are complex physical phenomena, such as the existence of underlying rock formations or other non-erodable variables. Flood flows were not simulated in this study.

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3. Max, Wayne, Records and Notes of the Mouth of White River Assessment, Memphis District Corps of Engineers, Unpublished Report, River Engineering Section, 1998.

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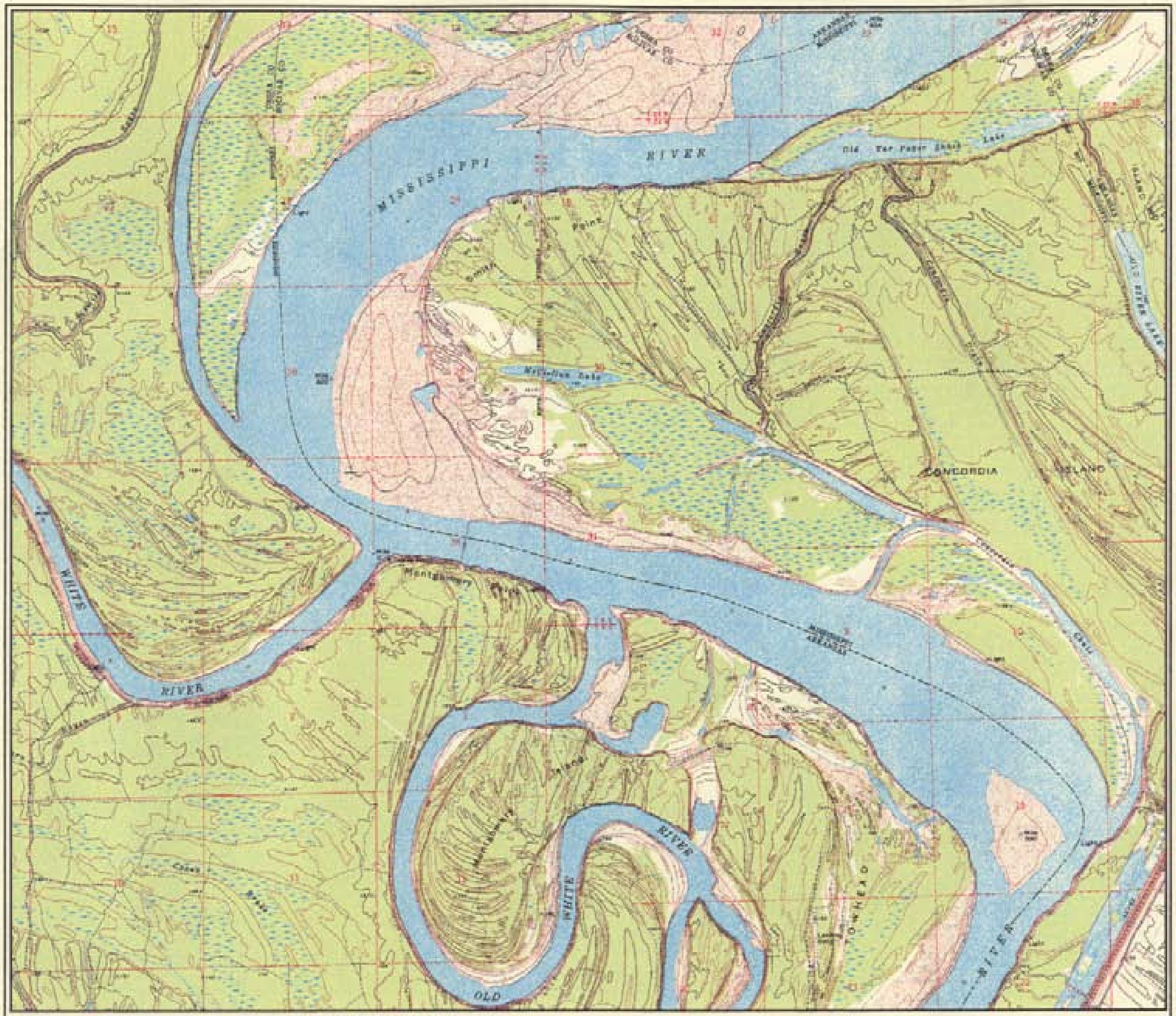
APPENDIX

Plate #'s 1 through 24 follow:

1. Vicinity Map and USGS Quad Sheet of the Study Area
2. Nomenclature & Approximate Historical River Alignments
3. Location of the New Montgomery Point Lock & Dam
4. Navigation Problem # 1
5. Navigation Problem # 2
6. Navigation Problem # 3
7. White River Micro Model
8. 1996 White River Prototype Survey
9. 1994 Prototype Survey
10. 1995 Prototype Survey
11. 1996 Prototype Survey
12. 1997 Prototype Survey
13. 21 Jan 1977 Ice Photo
14. Base Test
15. Alternative A
16. Alternative B
17. Alternative C
18. Alternative D
19. Alternative E
20. Alternative F
21. Alternative G
22. Alternative H
23. Alternative I
24. Alternative J



STUDY REACH

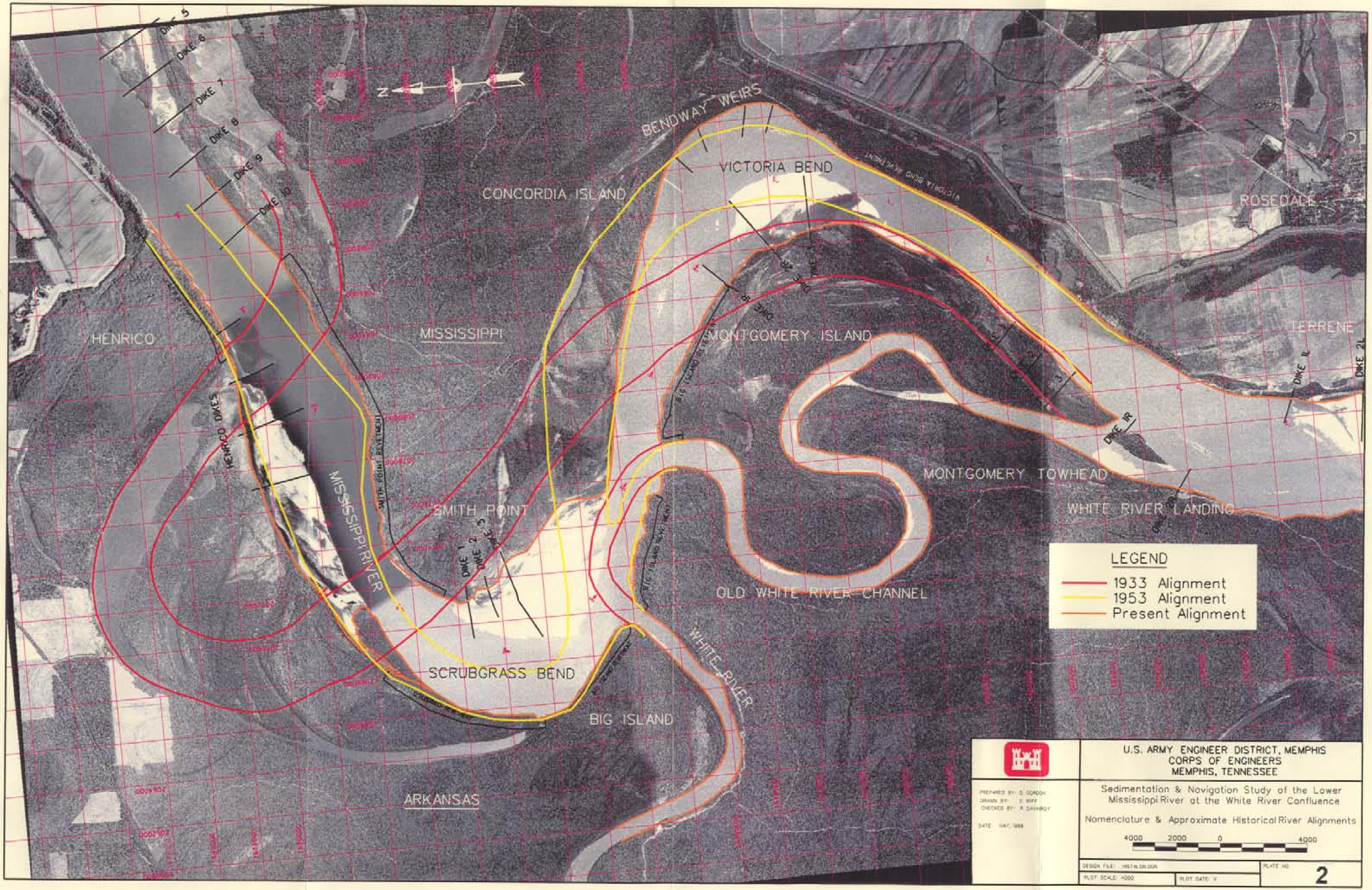
U.S ARMY ENGINEER DISTRICT, MEMPHIS
CORPS OF ENGINEERS
MEMPHIS, TENNESSEE

PREPARED BY: D. Gordon
CHECKED BY: R. Davinroy

Sedimentation & Navigation Study of the Lower Mississippi River at the White River Confluence

Vicinity Map and USGS Quad Sheet of the Study Area

PLATE NO. 1



DIKE 5
DIKE 6
DIKE 7
DIKE 8
DIKE 9
DIKE 10
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BENDWAY WEIRS
VICTORIA BEND
CONCORDIA ISLAND
ROSEDALE
HENRICO
MISSISSIPPI
MONTGOMERY ISLAND
TERRENE
HENRICO DIKES
MISSISSIPPI RIVER
SMITH POINT
DIKE 1
DIKE 2
DIKE 3
MONTGOMERY TOWHEAD
WHITE RIVER LANDING
OLD WHITE RIVER CHANNEL
WHITE RIVER
SCRUBGRASS BEND
BIG ISLAND
ARKANSAS
LEGEND
1933 Alignment
1953 Alignment
Present Alignment
U.S. ARMY ENGINEER DISTRICT, MEMPHIS
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Sedimentation & Navigation Study of the Lower Mississippi River at the White River Confluence
Nomenclature & Approximate Historical River Alignments
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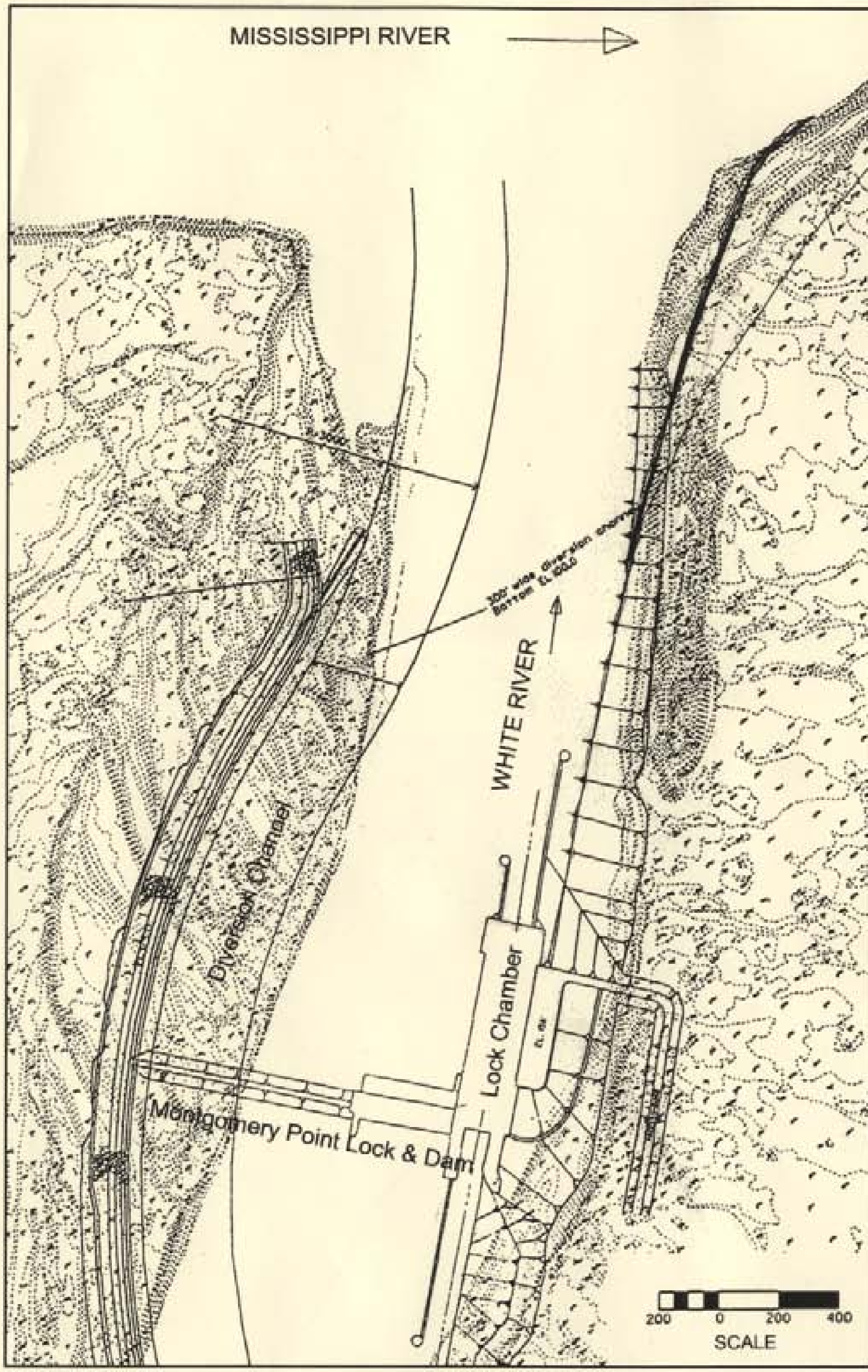
PLATE NO.
2



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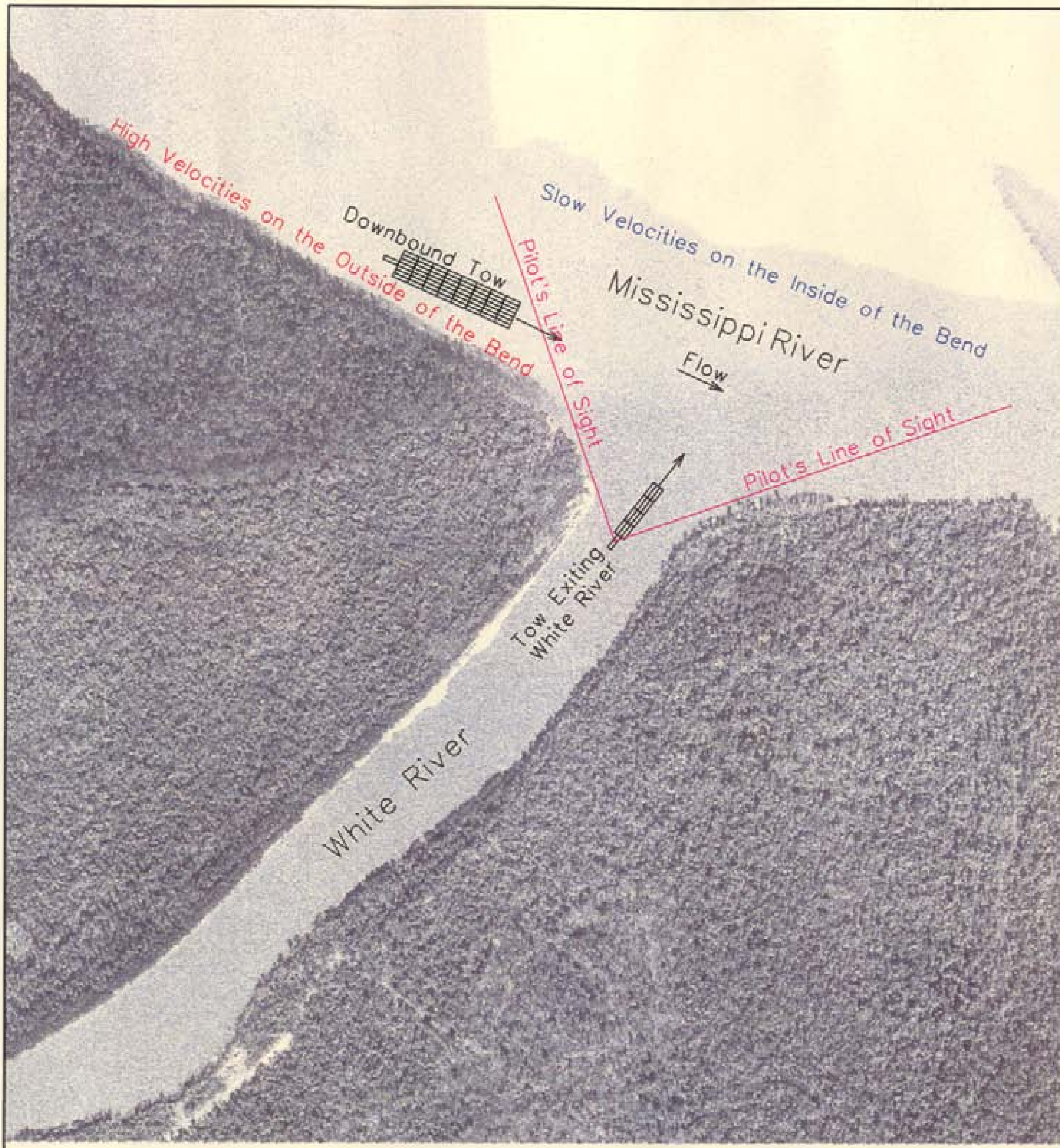
MEMPHIS, TENNESSEE

PREPARED BY: D. Gordon
CHECKED BY: R. Davinroy

Sedimentation & Navigation Study of the Lower Mississippi River at the White River Confluence

Location of the New Montgomery Point Lock & Dam

PLATE NO. **3**



	U.S. ARMY ENGINEER DISTRICT, MEMPHIS CORPS OF ENGINEERS MEMPHIS, TENNESSEE
PREPARED BY: D. GORDON DRAWN BY: E. RIFT CHECKED BY: R. DAVINROY DATE: MAY, 1998	Sedimentation & Navigation Study of the Lower Mississippi River at the White River Confluence Navigation Problem #1 1000 500 0 1000
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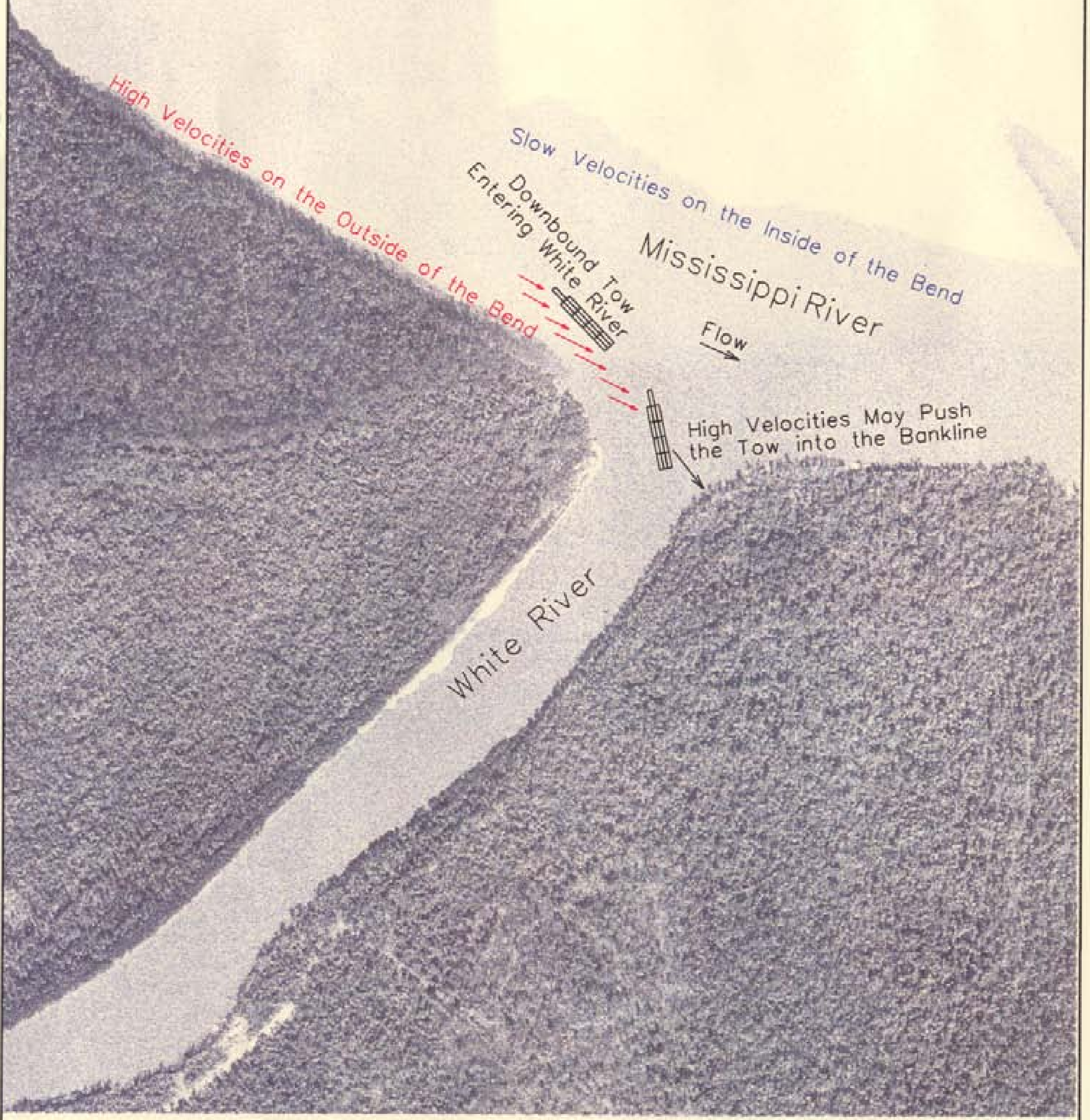

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MEMPHIS, TENNESSEE

PREPARED BY: D. GORDON
DRAWN BY: E. RIFF
CHECKED BY: R. DAVINROY

DATE: MAY, 1998

Sedimentation & Navigation Study of the Lower Mississippi River at the White River Confluence

Navigation Problem #2

1000 500 0 1000

DESIGN FILE: navdiag2.dgn	PLATE NO. 5
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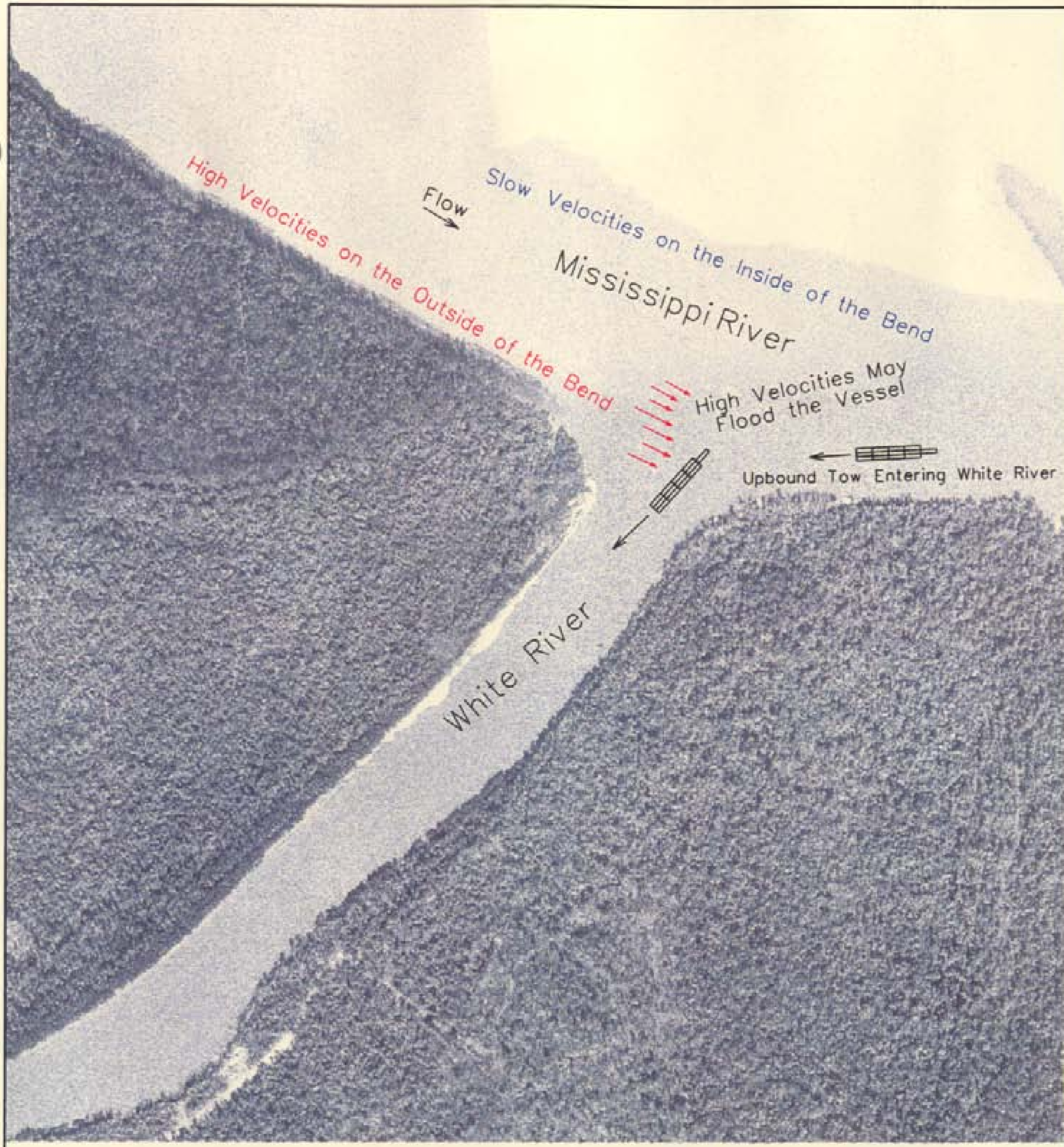

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PREPARED BY: D. GORDON
DRAWN BY: E. RIFF
CHECKED BY: R. DAVINROY

DATE: MAY, 1998

Sedimentation & Navigation Study of the Lower Mississippi River at the White River Confluence

Navigation Problem •3

1000 500 0 1000

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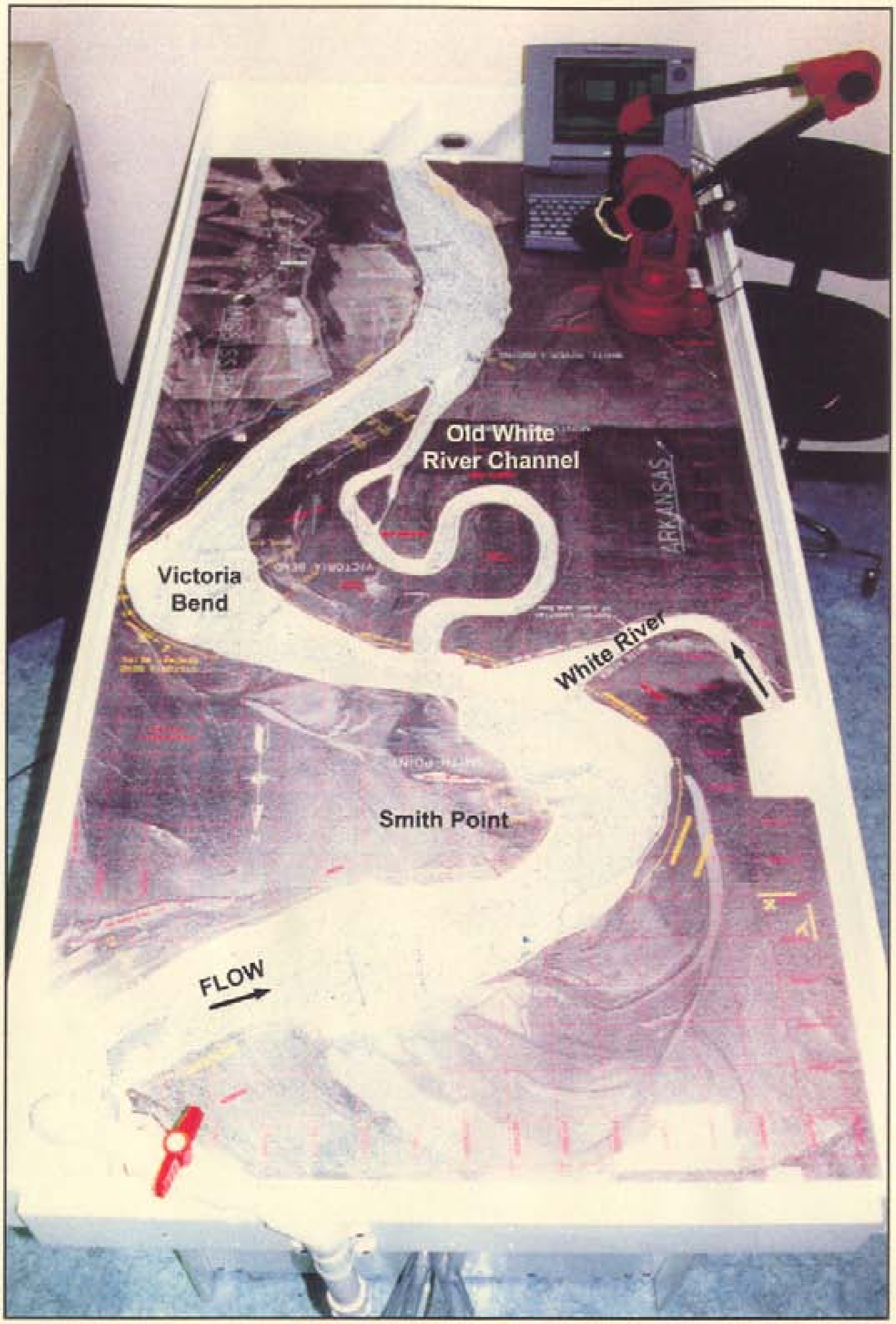
PLOT SCALE: 2000

PLOT DATE: X

PLATE NO. 6



U.S ARMY ENGINEER DISTRICT, MEMPHIS
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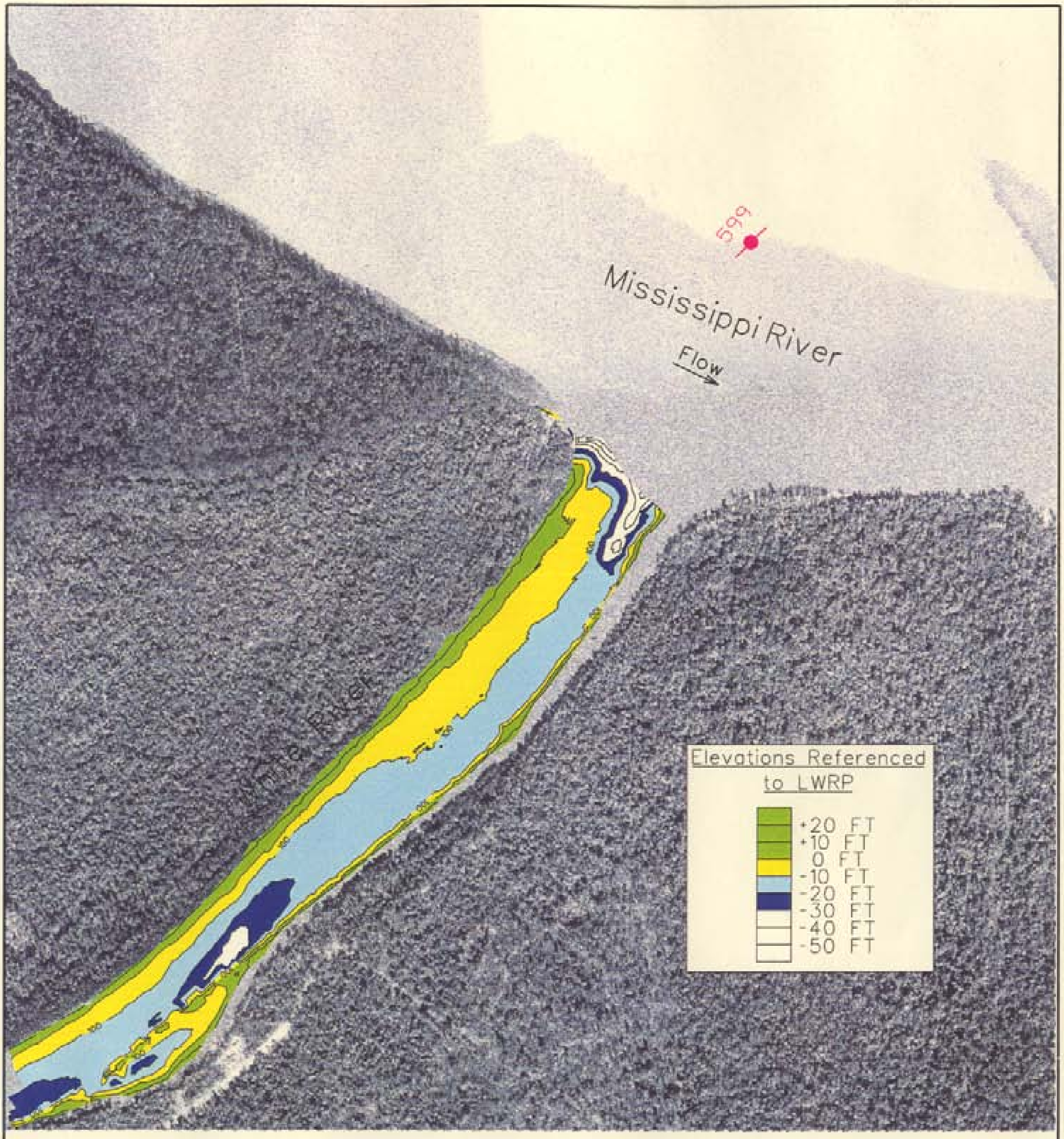
PREPARED BY: D. Gordon
CHECKED BY: R. Davinroy

Sedimentation & Navigation Study of the Lower Mississippi River at the White River Confluence

White River Micro Model

PLATE NO. **7**



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CORPS OF ENGINEERS
MEMPHIS, TENNESSEE

PREPARED BY: D. GORDON
DRAWN BY: L. RIFF
CHECKED BY: R. DAVINROY

DATE: MAY, 1998

Sedimentation & Navigation Study of the Lower Mississippi River at the White River Confluence

1996 White River Prototype Survey

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DESIGN FILE: whitrvr.dgn

PLOT SCALE: 1000

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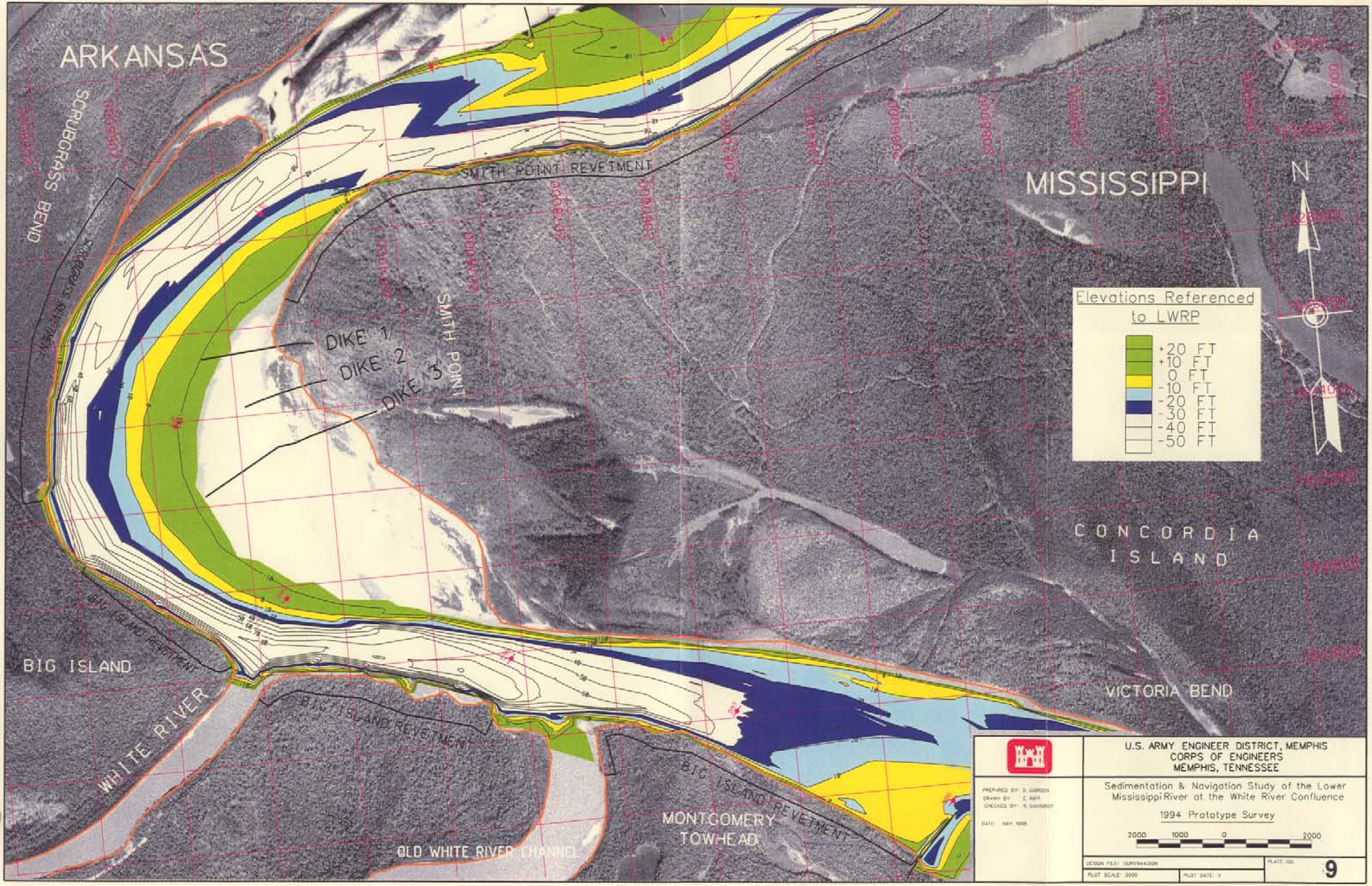
PLATE NO. 8



ARKANSAS
MISSISSIPPI
SCRUBGRASS BEND
SCRUBGRASS REVETMENT
SMITH POINT REVETMENT
SMITH POINT
DIKE 1
DIKE 2
DIKE 3
CONCORDIA ISLAND
BIG ISLAND
BIG ISLAND REVETMENT
WHITE RIVER
OLD WHITE RIVER CHANNEL
MONTGOMERY TOWHEAD
VICTORIA BEND
N
Elevations Referenced to LWRP
+20 FT
+10 FT
0 FT
-10 FT
-20 FT
-30 FT
-40 FT
-50 FT
U.S. ARMY ENGINEER DISTRICT, MEMPHIS
CORPS OF ENGINEERS
MEMPHIS, TENNESSEE
Sedimentation & Navigation Study of the Lower Mississippi River at the White River Confluence
1994 Prototype Survey
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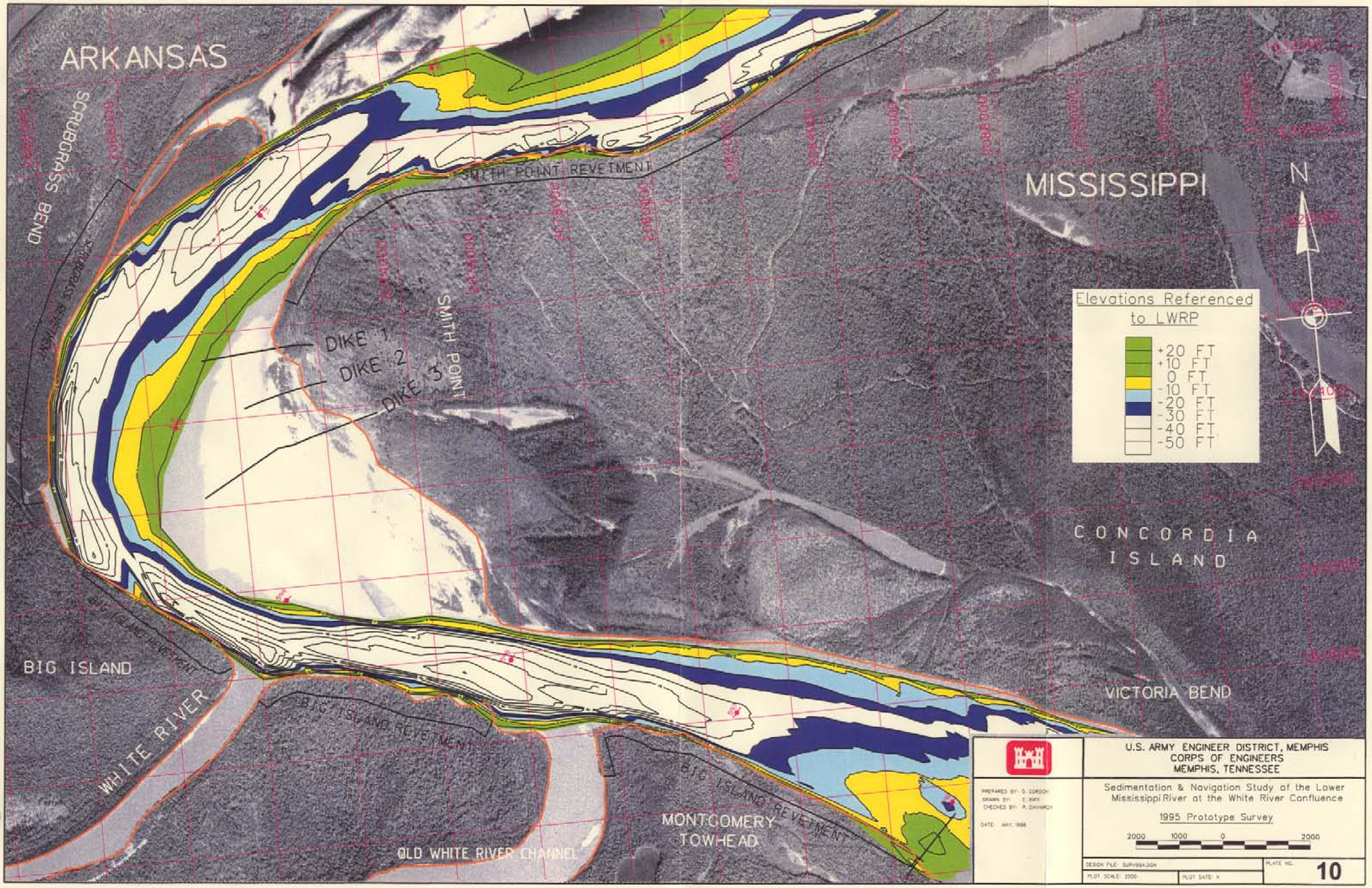
PLATE NO.
9



U.S. ARMY ENGINEER DISTRICT, MEMPHIS
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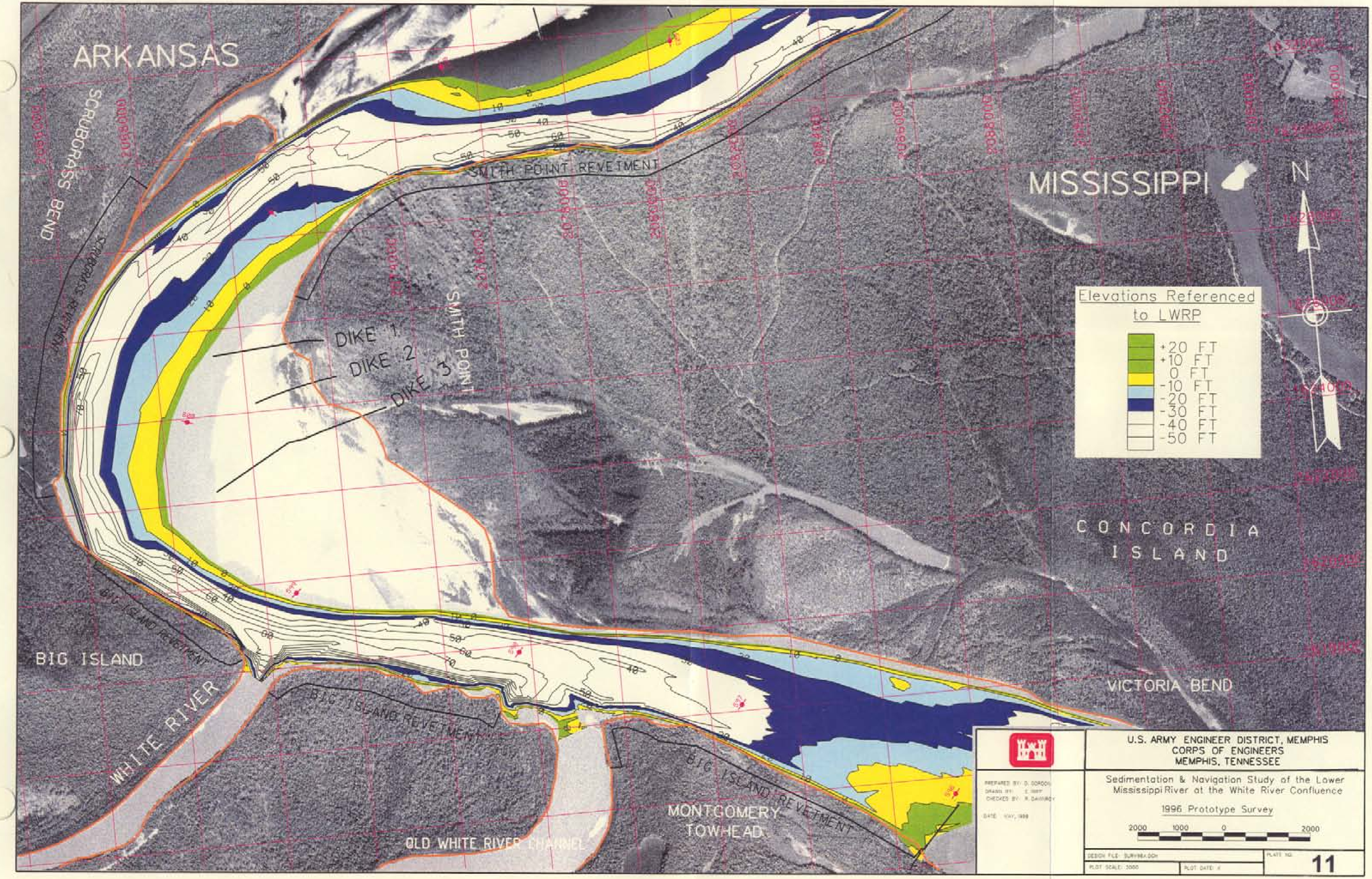
MEMPHIS, TENNESSEE

Sedimentation & Navigation Study of the Lower Mississippi River at the White River Confluence

1995 Prototype Survey

2000 1000 0 2000

PLATE NO. 10



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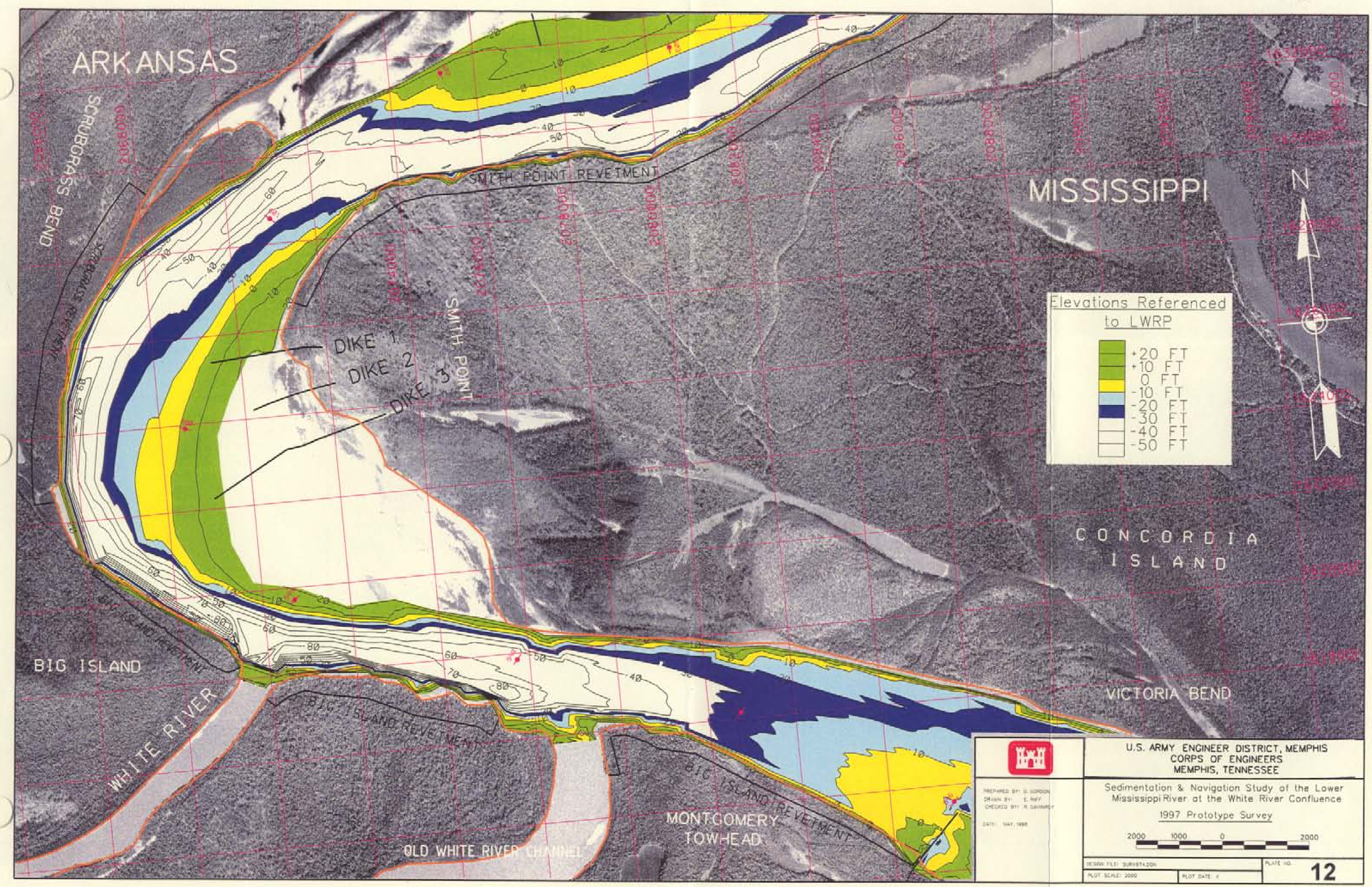
SCRUBGRASS BEND
SCRUBGRASS REVETMENT
SMITH POINT REVETMENT
SMITH POINT
DIKE 1
DIKE 2
DIKE 3
Elevations Referenced to LWRP
+20 FT
+10 FT
0 FT
-10 FT
-20 FT
-30 FT
-40 FT
-50 FT
CONCORDIA ISLAND
BIG ISLAND
BIG ISLAND REVETMENT
WHITE RIVER
VICTORIA BEND
MONTGOMERY TOWHEAD
OLD WHITE RIVER CHANNEL
U.S. ARMY ENGINEER DISTRICT, MEMPHIS
CORPS OF ENGINEERS
MEMPHIS, TENNESSEE
Sedimentation & Navigation Study of the Lower Mississippi River at the White River Confluence
1996 Prototype Survey
2000 1000 0 2000
PLATE NO. 11



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SMITH POINT
DIKE 1
DIKE 2
DIKE 3
Elevations Referenced to LWRP
+20 FT
+10 FT
0 FT
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-50 FT
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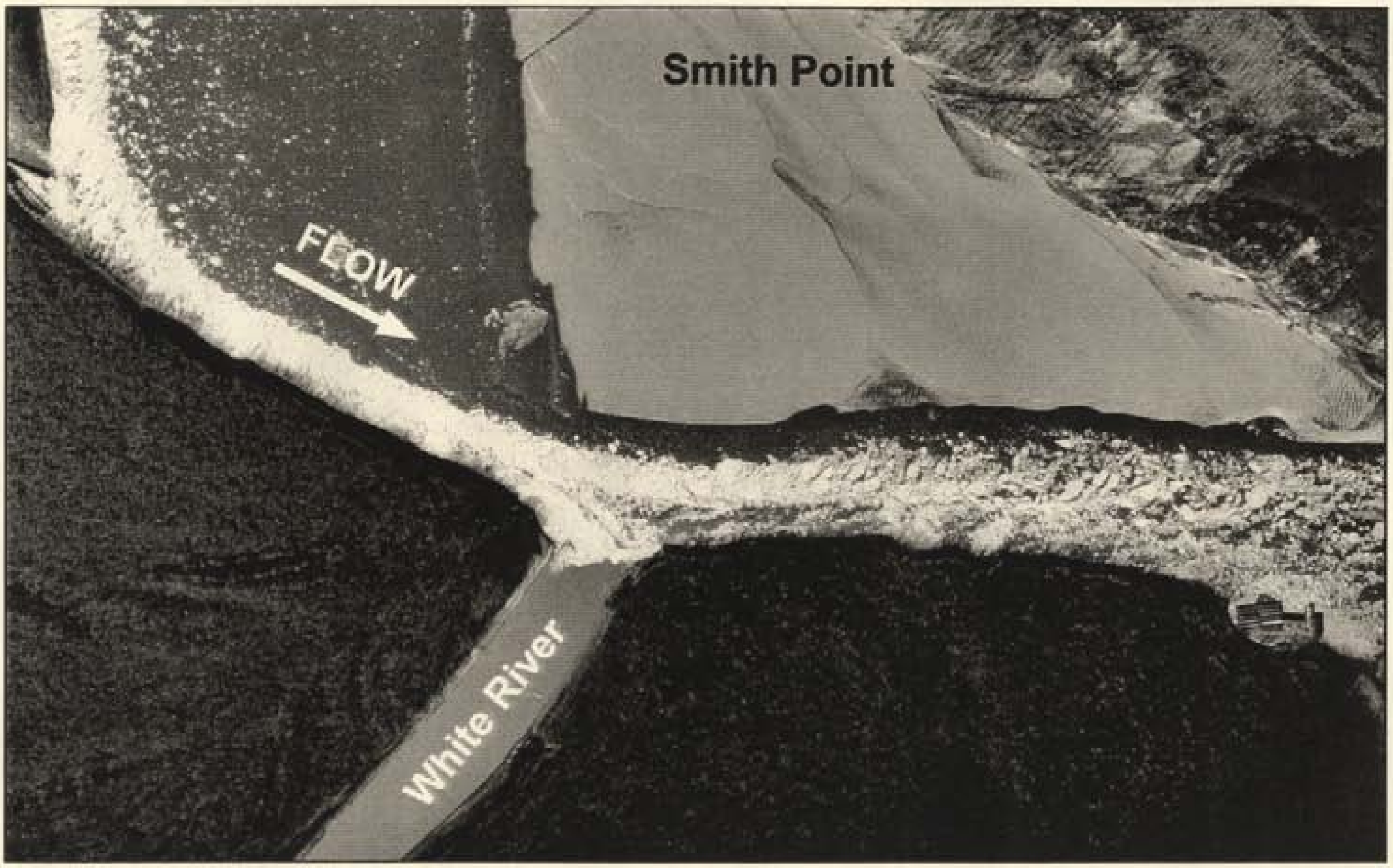
BIG ISLAND
BIG ISLAND REVETMENT
WHITE RIVER
OLD WHITE RIVER CHANNEL
MONTGOMERY TOWHEAD
VICTORIA BEND
U.S. ARMY ENGINEER DISTRICT, MEMPHIS
CORPS OF ENGINEERS
MEMPHIS, TENNESSEE
Sedimentation & Navigation Study of the Lower Mississippi River at the White River Confluence
1997 Prototype Survey
2000 1000 0 2000
PLATE NO.
12



U.S ARMY ENGINEER DISTRICT, MEMPHIS
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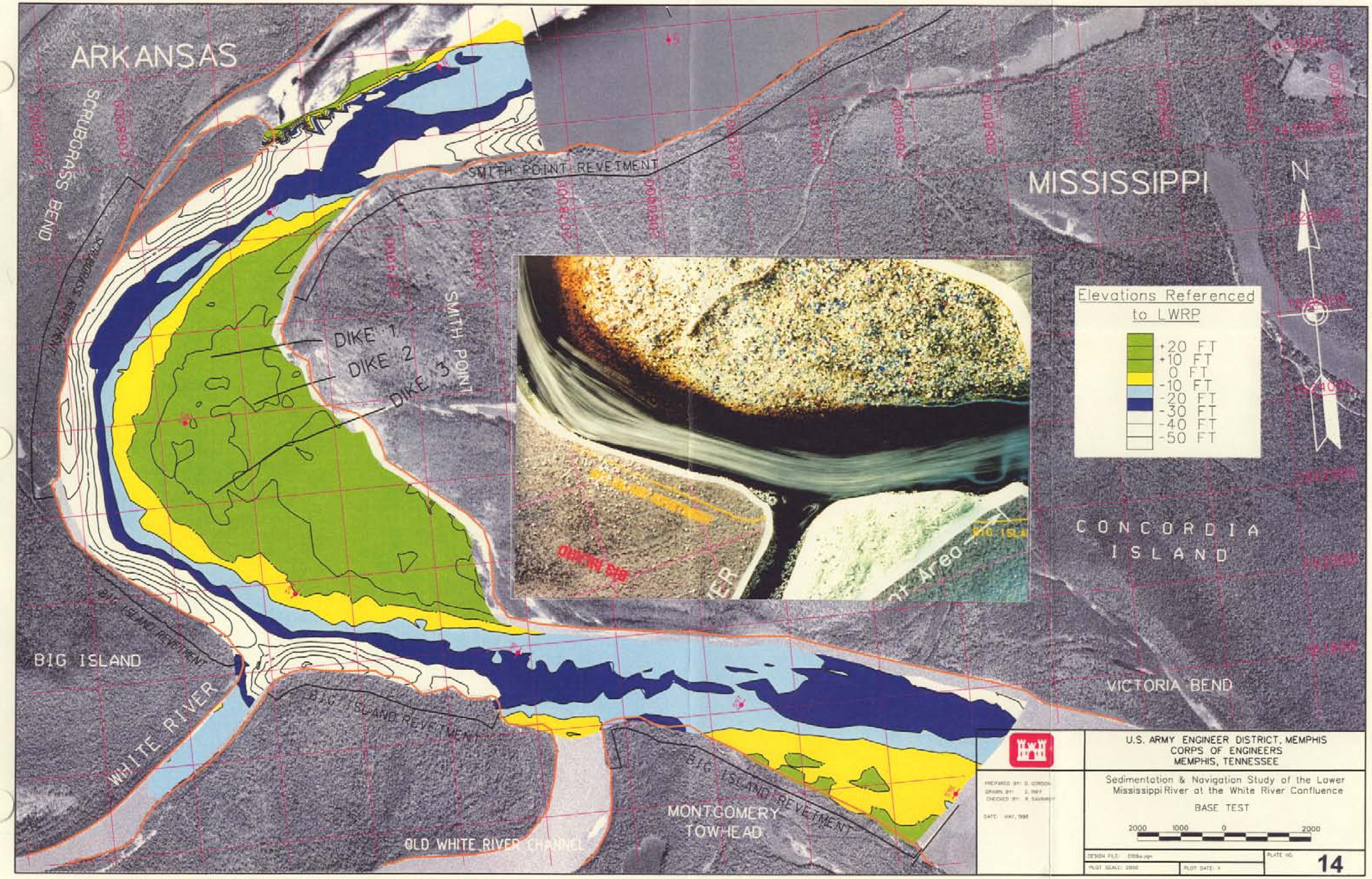
MEMPHIS, TENNESSEE

PREPARED BY: D. Gordon
CHECKED BY: R. Dawkins

Sedimentation & Navigation Study of the Lower Mississippi River at the White River Confluence

21 Jan 1977 Ice Photo

PLATE NO. **13**



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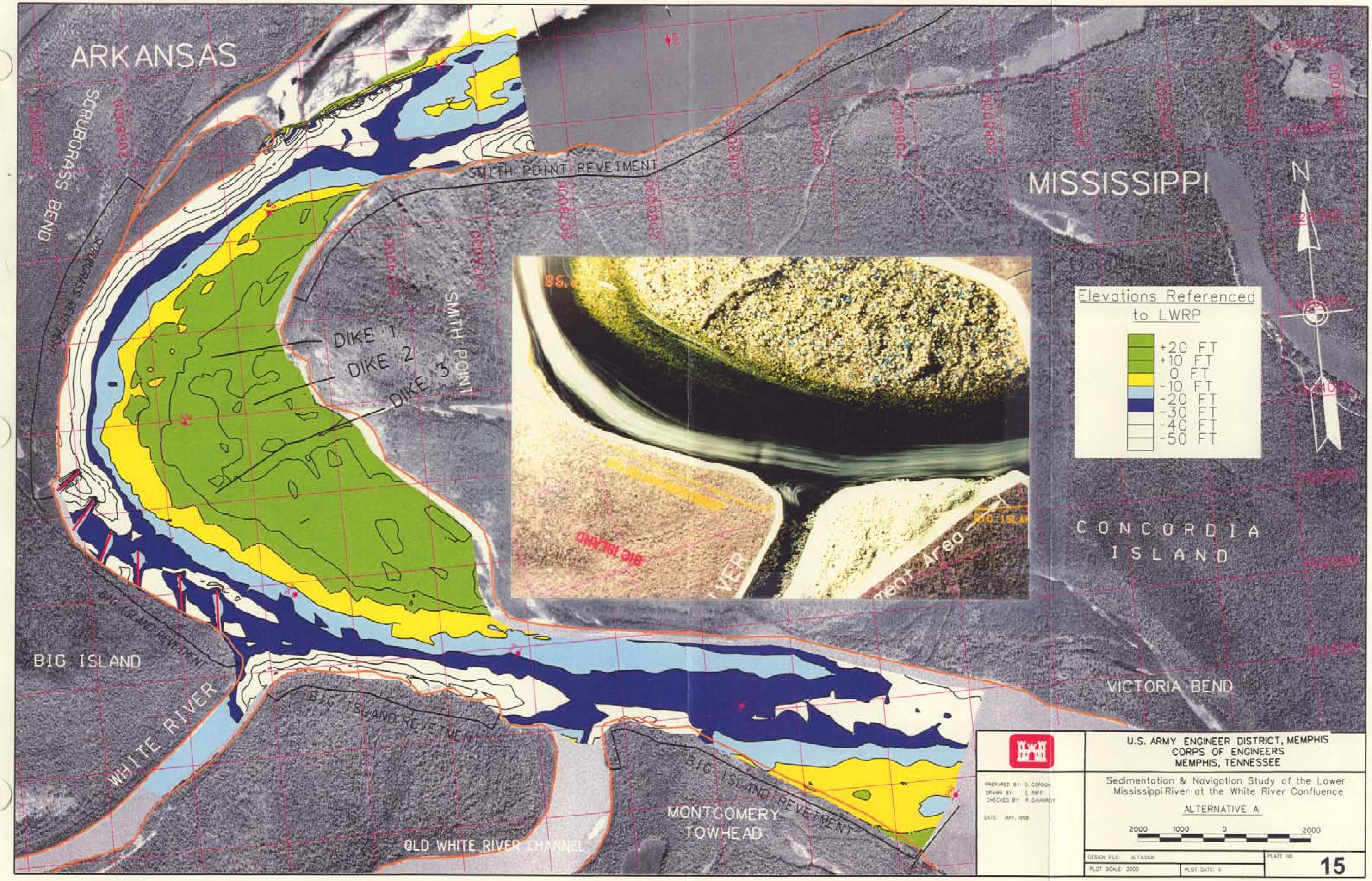
SMITH POINT
DIKE 1
DIKE 2
DIKE 3
Elevations Referenced to LWRP
+20 FT
+10 FT
0 FT
-10 FT
-20 FT
-30 FT
-40 FT
-50 FT
N
CONCORDIA ISLAND
BIG ISLAND
BIG ISLAND REVETMENT
WHITE RIVER
VICTORIA BEND
MONTGOMERY TOWHEAD
OLD WHITE RIVER CHANNEL
U.S. ARMY ENGINEER DISTRICT, MEMPHIS
CORPS OF ENGINEERS
MEMPHIS, TENNESSEE
Sedimentation & Navigation Study of the Lower Mississippi River at the White River Confluence
BASE TEST
2000 1000 0 2000
PLATE NO.
14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SCRUBGRASS BEND
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DIKE 1
DIKE 2
DIKE 3
N
Elevations Referenced to LWRP
+20 FT
+10 FT
0 FT
-10 FT
-20 FT
-30 FT
-40 FT
-50 FT
CONCORDIA ISLAND
BIG ISLAND
BIG ISLAND REVETMENT
WHITE RIVER
VICTORIA BEND
MONTGOMERY TOWHEAD
OLD WHITE RIVER CHANNEL
U.S. ARMY ENGINEER DISTRICT, MEMPHIS
CORPS OF ENGINEERS
MEMPHIS, TENNESSEE
Sedimentation & Navigation Study of the Lower Mississippi River at the White River Confluence
ALTERNATIVE A
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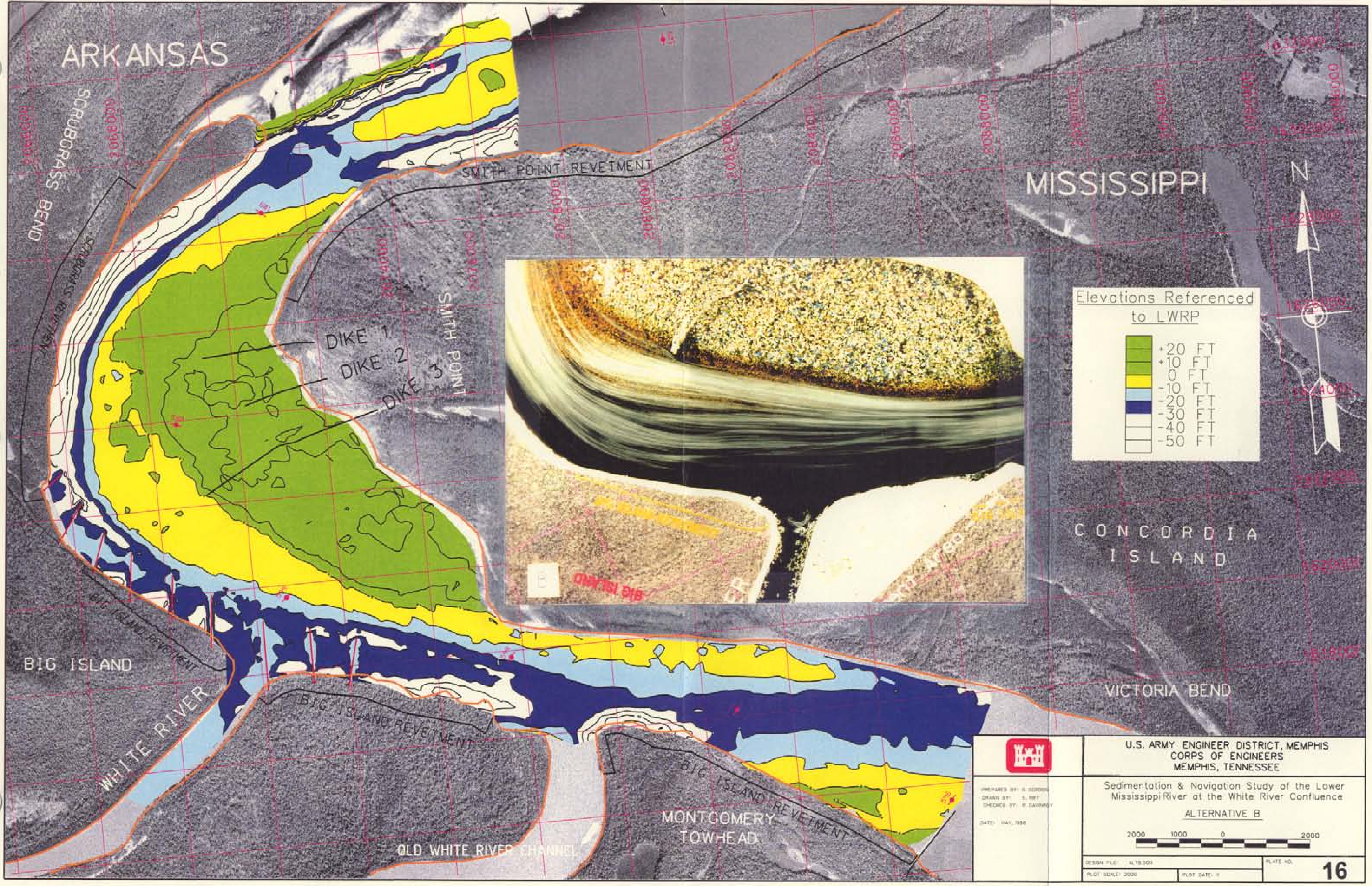
15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MISSISSIPPI
SCRUBGRASS BEND
SMITH POINT REVETMENT
SMITH POINT
DIKE 1
DIKE 2
DIKE 3
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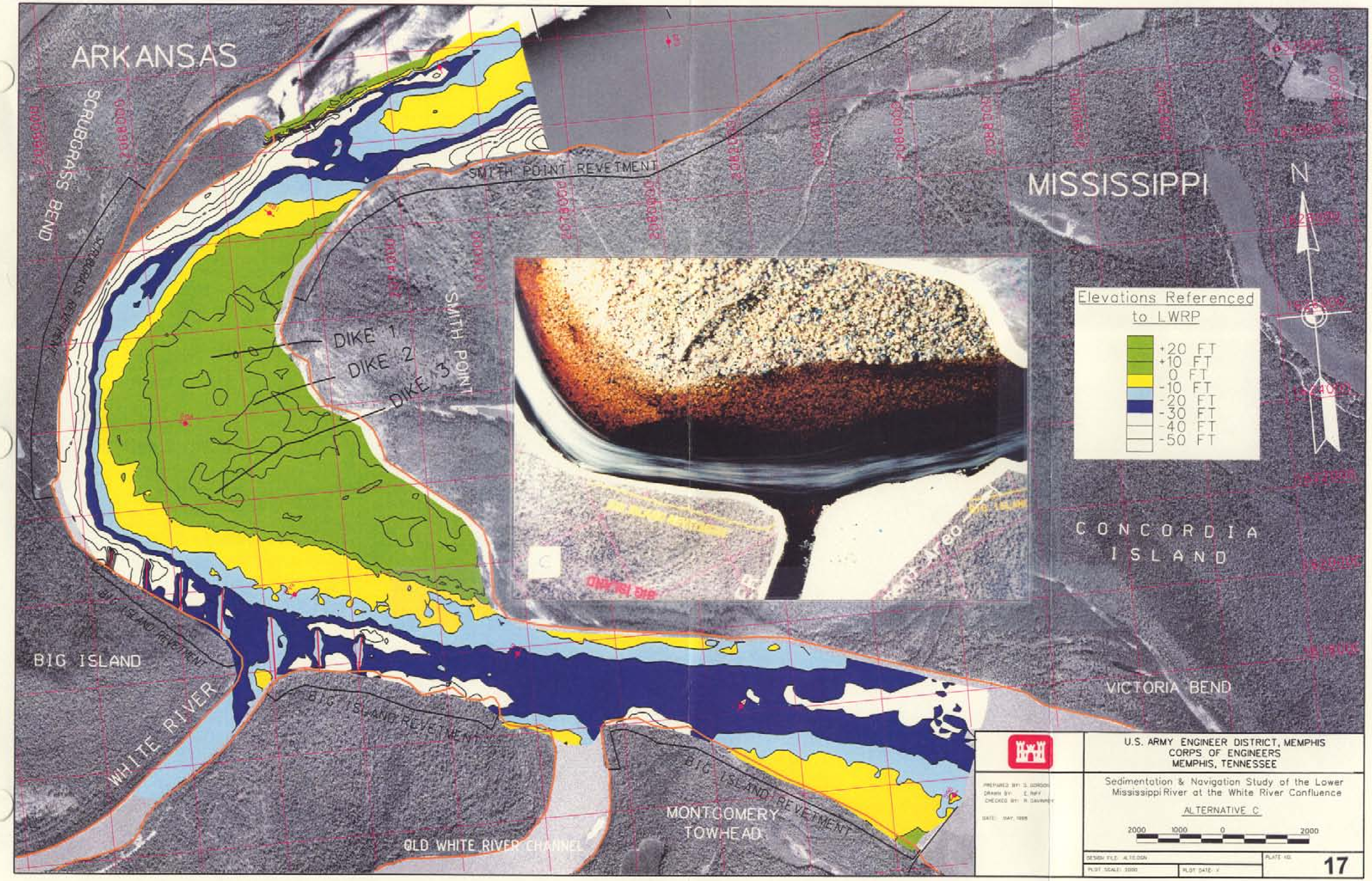
Elevations Referenced to LWRP
+20 FT
+10 FT
0 FT
-10 FT
-20 FT
-30 FT
-40 FT
-50 FT
CONCORDIA ISLAND
VICTORIA BEND
BIG ISLAND
BIG ISLAND REVETMENT
WHITE RIVER
OLD WHITE RIVER CHANNEL
MONTGOMERY TOWHEAD
BIG ISLAND
U.S. ARMY ENGINEER DISTRICT, MEMPHIS
CORPS OF ENGINEERS
MEMPHIS, TENNESSEE
Sedimentation & Navigation Study of the Lower Mississippi River at the White River Confluence
ALTERNATIVE B
2000 1000 0 2000
PLATE NO.
16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MISSISSIPPI
SCRUBGRASS BEND
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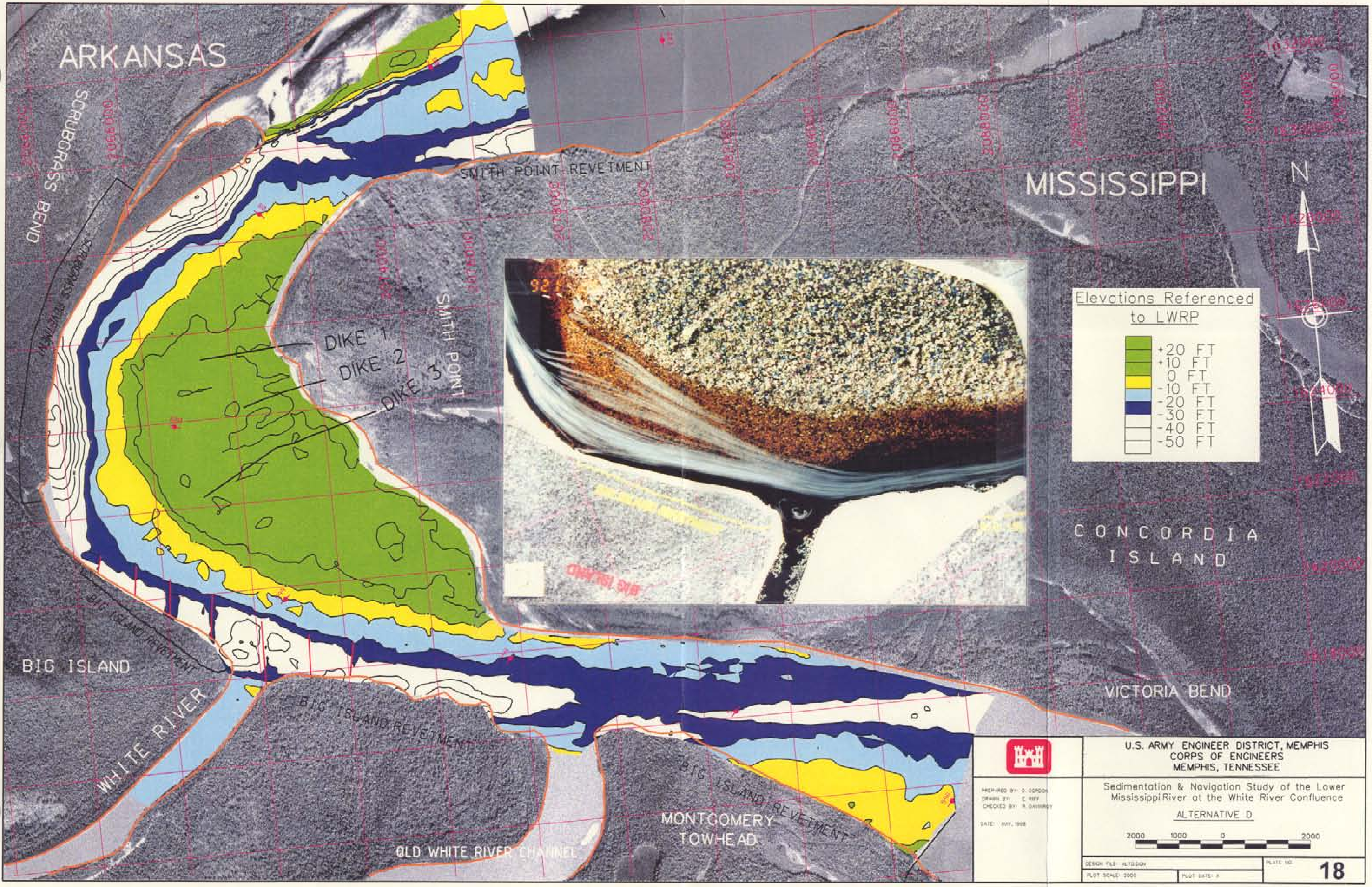
SMITH POINT REVETMENT
SMITH POINT
DIKE 1
DIKE 2
DIKE 3
Elevations Referenced to LWRP
+20 FT
+10 FT
0 FT
-10 FT
-20 FT
-30 FT
-40 FT
-50 FT
N
CONCORDIA ISLAND
BIG ISLAND
BIG ISLAND REVETMENT
WHITE RIVER
VICTORIA BEND
MONTGOMERY TOWHEAD
OLD WHITE RIVER CHANNEL
U.S. ARMY ENGINEER DISTRICT, MEMPHIS
CORPS OF ENGINEERS
MEMPHIS, TENNESSEE
Sedimentation & Navigation Study of the Lower Mississippi River at the White River Confluence
ALTERNATIVE C
2000 1000 0 2000
17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MISSISSIPPI
SCRUBGRASS BEND
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DIKE 1
DIKE 2
DIKE 3
Elevations Referenced to LWRP
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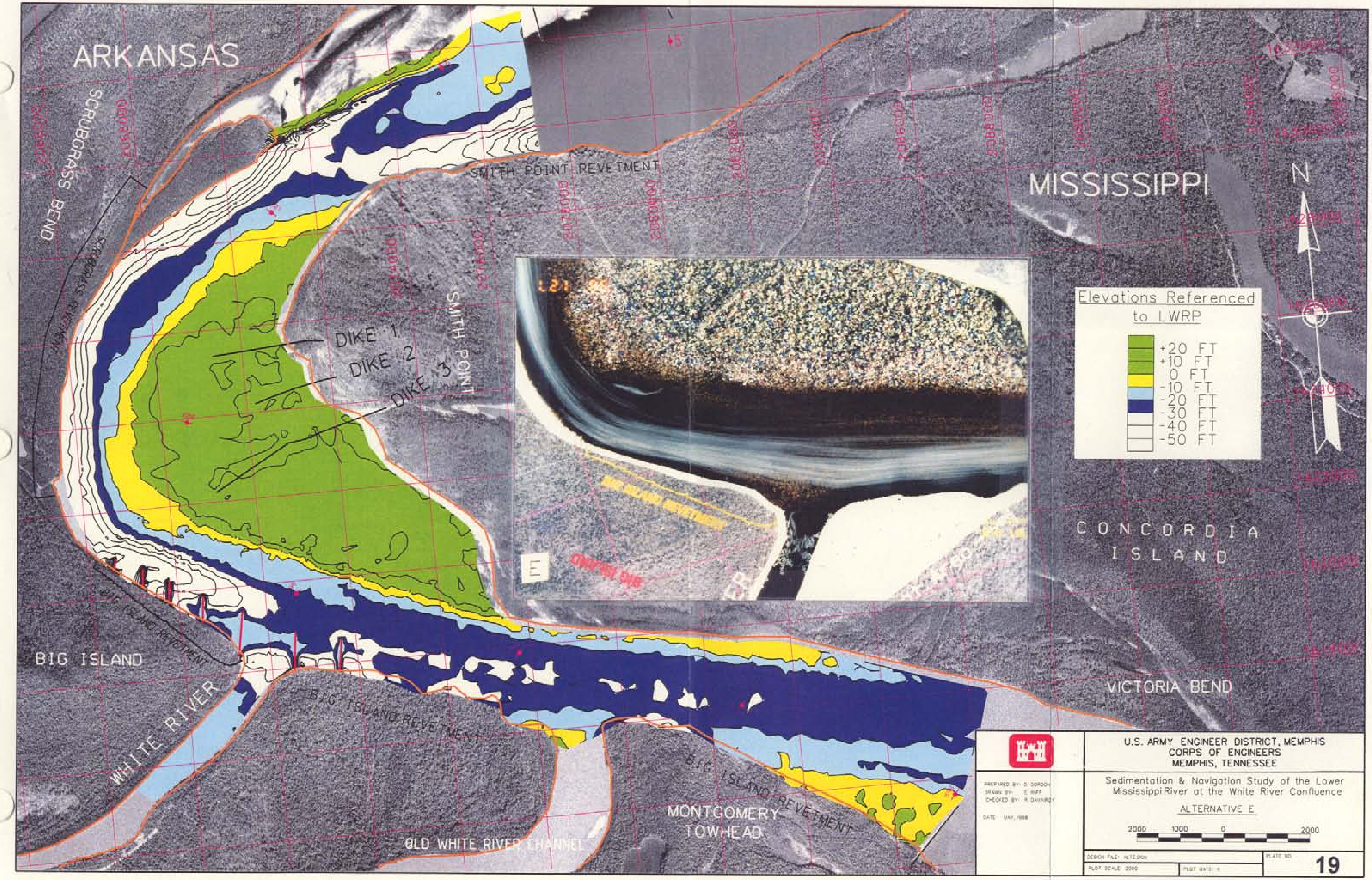
+10 FT
0 FT
-10 FT
-20 FT
-30 FT
-40 FT
-50 FT
N
CONCORDIA ISLAND
BIG ISLAND
WHITE RIVER
BIG ISLAND REVETMENT
VICTORIA BEND
MONTGOMERY TOWHEAD
OLD WHITE RIVER CHANNEL
U.S. ARMY ENGINEER DISTRICT, MEMPHIS
CORPS OF ENGINEERS
MEMPHIS, TENNESSEE
Sedimentation & Navigation Study of the Lower Mississippi River at the White River Confluence
ALTERNATIVE D
2000 1000 0 2000
PLATE NO. 18


ARKANSAS
MISSISSIPPI
SCRUBGRASS BEND
SMITH POINT REVETMENT
SMITH POINT
DIKE 1
DIKE 2
DIKE 3
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Elevations Referenced to LWRP
+20 FT
+10 FT
0 FT
-10 FT
-20 FT
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-40 FT
-50 FT
E
CONCORDIA ISLAND
VICTORIA BEND
BIG ISLAND
BIG ISLAND REVETMENT
WHITE RIVER
OLD WHITE RIVER CHANNEL
MONTGOMERY TOWHEAD
U.S. ARMY ENGINEER DISTRICT, MEMPHIS
CORPS OF ENGINEERS
MEMPHIS, TENNESSEE
Sedimentation & Navigation Study of the Lower Mississippi River at the White River Confluence
ALTERNATIVE E
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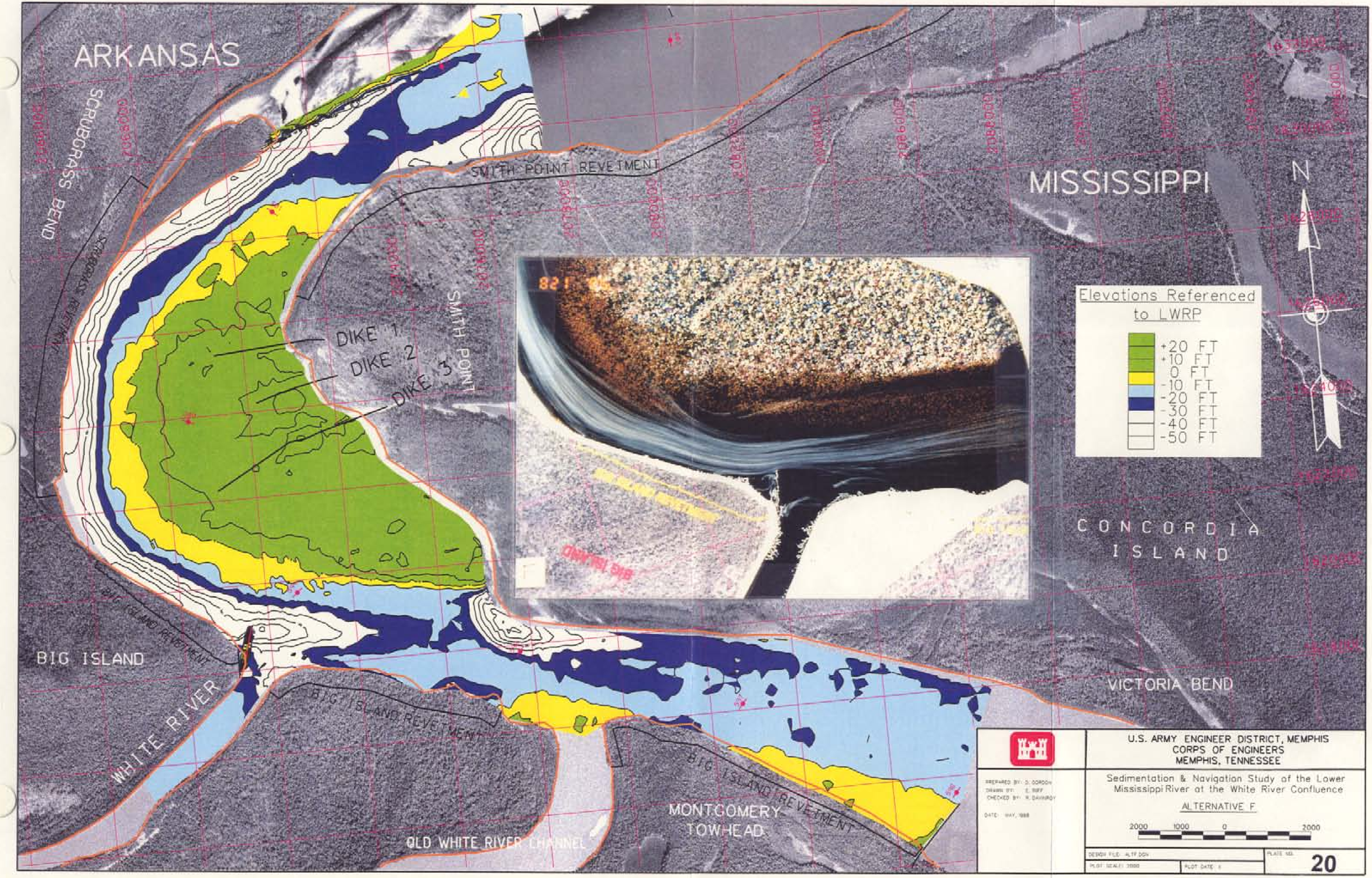
19



ARKANSAS
MISSISSIPPI
SCRUBGRASS BEND
SCRUBGRASS REVETMENT
SMITH POINT REVETMENT
SMITH POINT
DIKE 1
DIKE 2
DIKE 3
Elevations Referenced to LWRP
+20 FT
+10 FT
0 FT
-10 FT
-20 FT
-30 FT
-40 FT
-50 FT
N
CONCORDIA ISLAND
BIG ISLAND
BIG ISLAND REVETMENT
WHITE RIVER
VICTORIA BEND
MONTGOMERY TOWHEAD
OLD WHITE RIVER CHANNEL
U.S. ARMY ENGINEER DISTRICT, MEMPHIS
CORPS OF ENGINEERS
MEMPHIS, TENNESSEE
Sedimentation & Navigation Study of the Lower Mississippi River at the White River Confluence
ALTERNATIVE F
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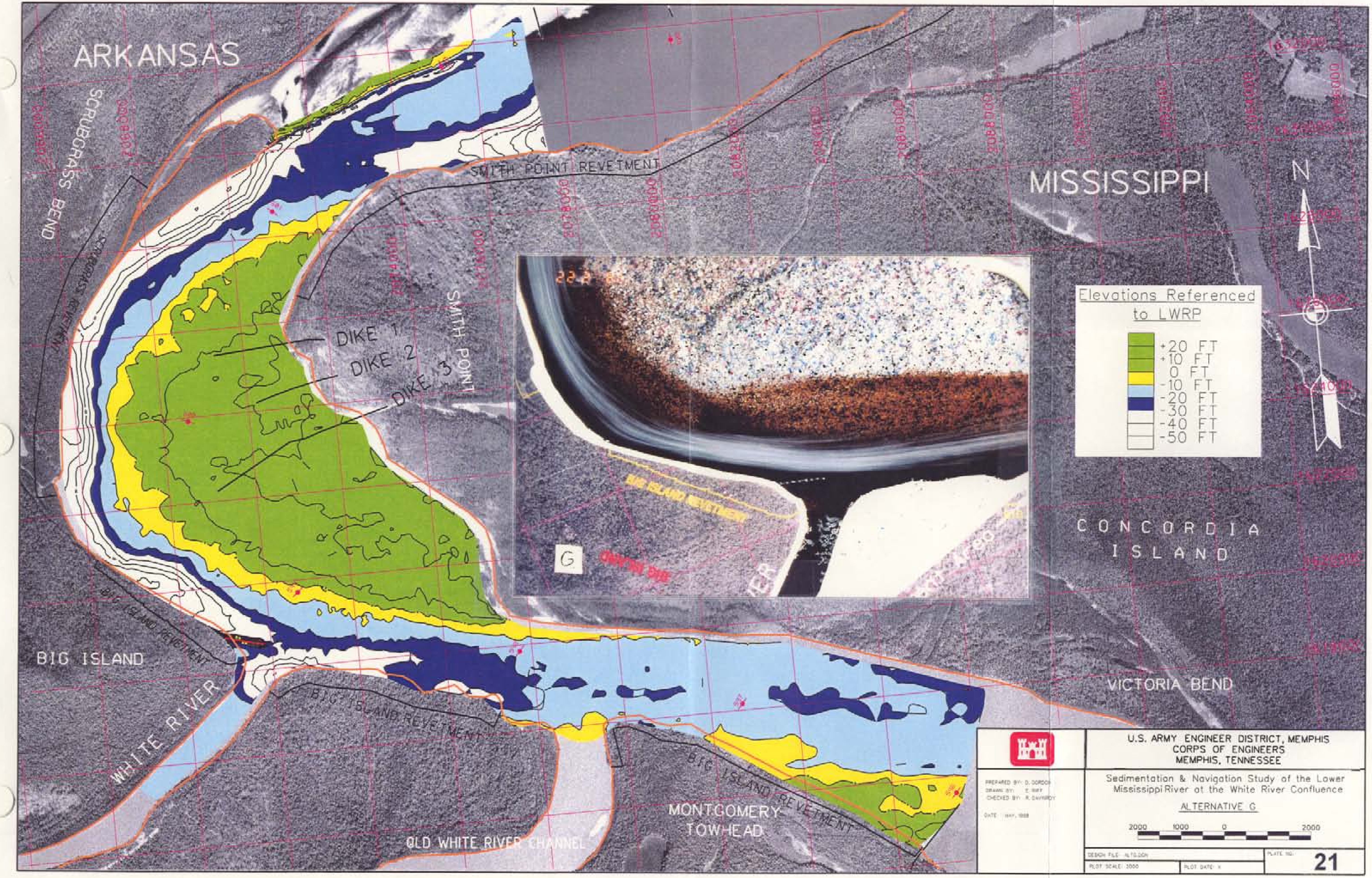
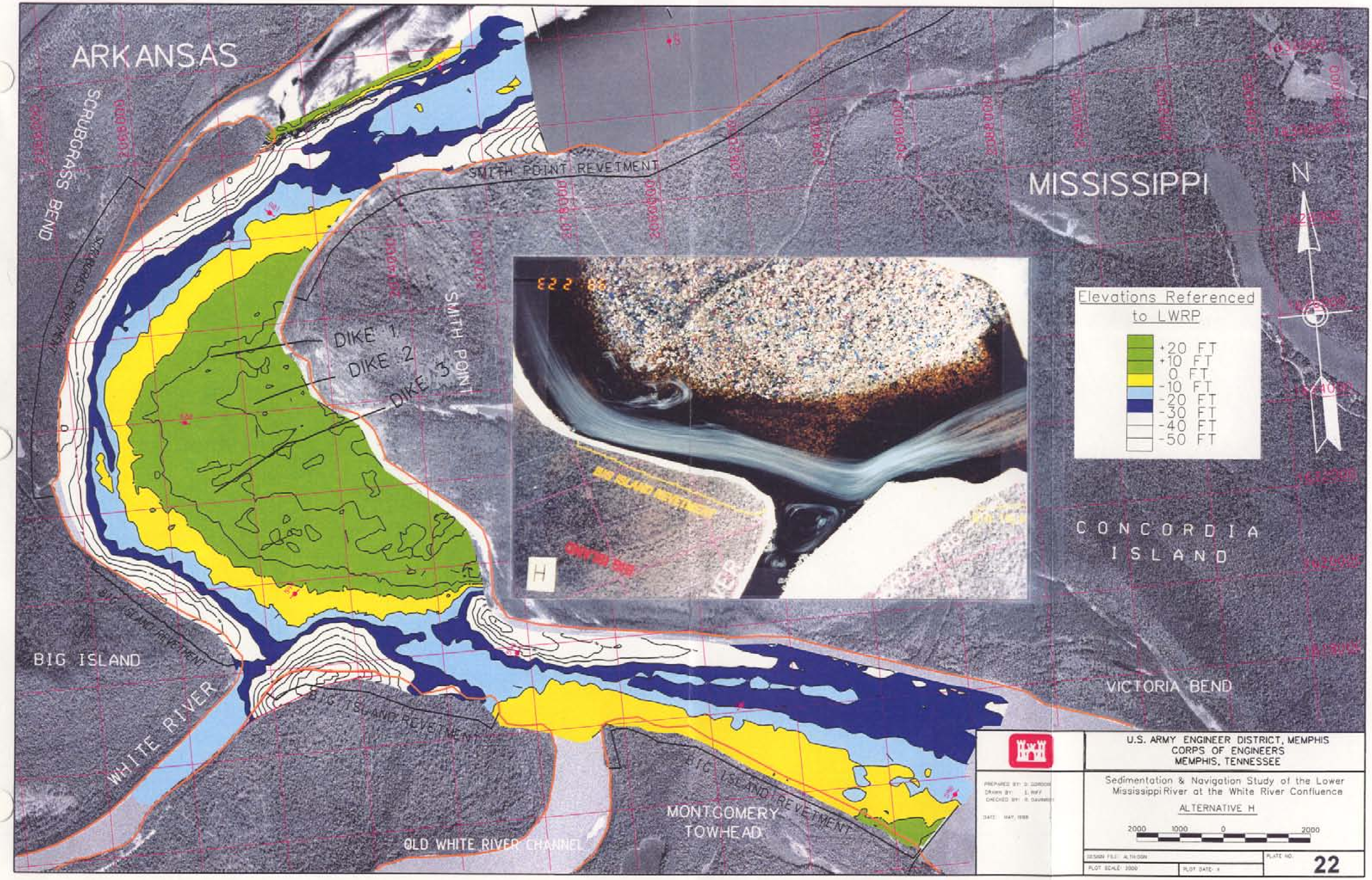
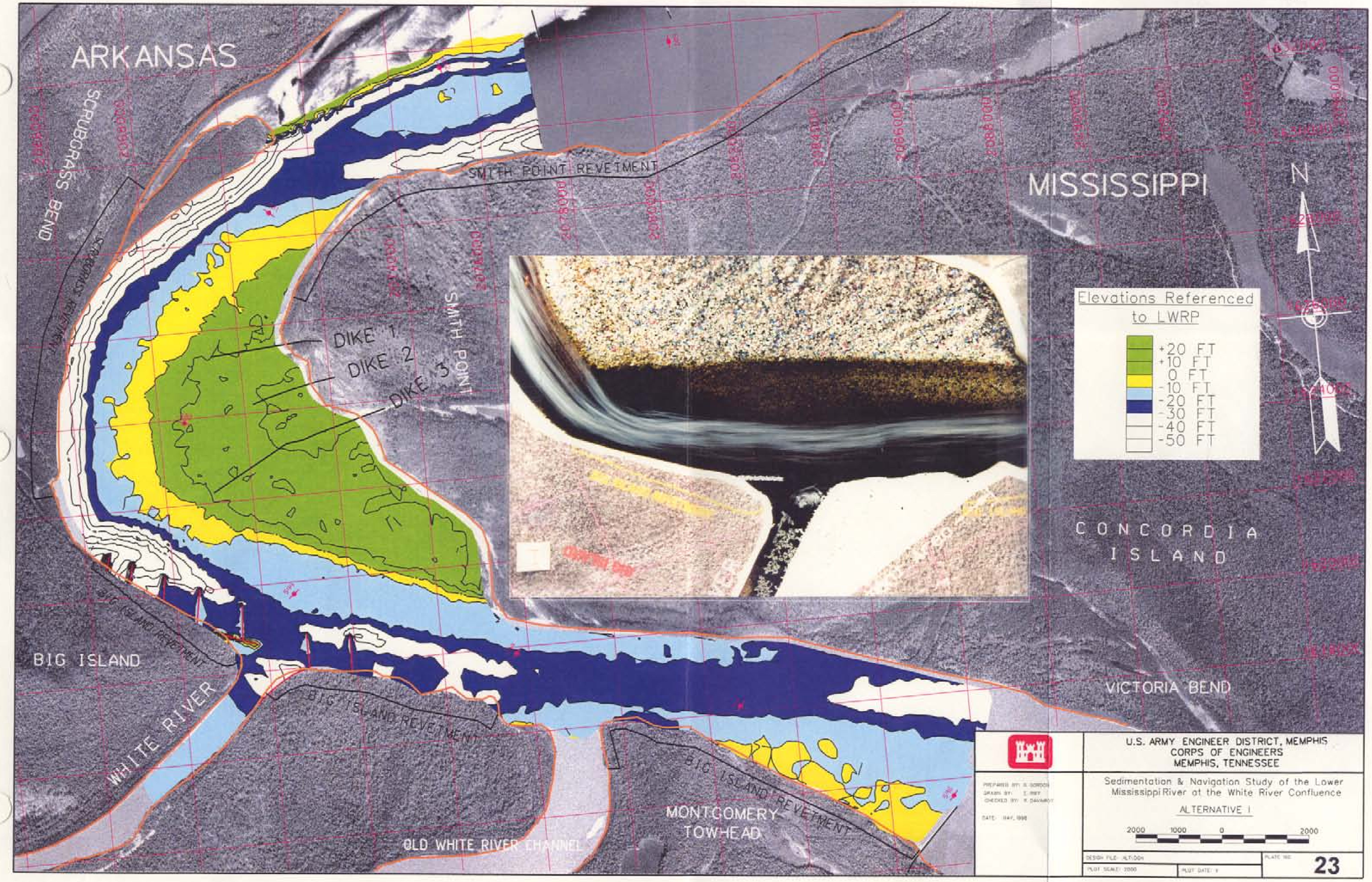

ARKANSAS
MISSISSIPPI
SCRUBGRASS BEND
SCRUBGRASS REVETMENT
SMITH POINT REVETMENT
SMITH POINT
DIKE 1
DIKE 2
DIKE 3
BIG ISLAND REVETMENT
G
CONCORDIA ISLAND
BIG ISLAND
WHITE RIVER
BIG ISLAND REVETMENT
VICTORIA BEND
MONTGOMERY TOWHEAD
OLD WHITE RIVER CHANNEL
N
Elevations Referenced to LWRP
+20 FT
+10 FT
0 FT
-10 FT
-20 FT
-30 FT
-40 FT
-50 FT
U.S. ARMY ENGINEER DISTRICT, MEMPHIS
CORPS OF ENGINEERS
MEMPHIS, TENNESSEE
Sedimentation & Navigation Study of the Lower Mississippi River at the White River Confluence
ALTERNATIVE G
2000 1000 0 2000
PLATE NO. 21


ARKANSAS
MISSISSIPPI
SCRUBGRASS BEND
SCRUBGRASS REVETMENT
SMITH POINT REVETMENT
SMITH POINT
DIKE 1
DIKE 2
DIKE 3
N
Elevations Referenced to LWRP
+20 FT
+10 FT
0 FT
-10 FT
-20 FT
-30 FT
-40 FT
-50 FT
H
CONCORDIA ISLAND
BIG ISLAND
BIG ISLAND REVETMENT
WHITE RIVER
VICTORIA BEND
MONTGOMERY TOWHEAD
OLD WHITE RIVER CHANNEL
U.S. ARMY ENGINEER DISTRICT, MEMPHIS
CORPS OF ENGINEERS
MEMPHIS, TENNESSEE
Sedimentation & Navigation Study of the Lower Mississippi River at the White River Confluence
ALTERNATIVE H
2000 1000 0 2000
PLATE NO. 22



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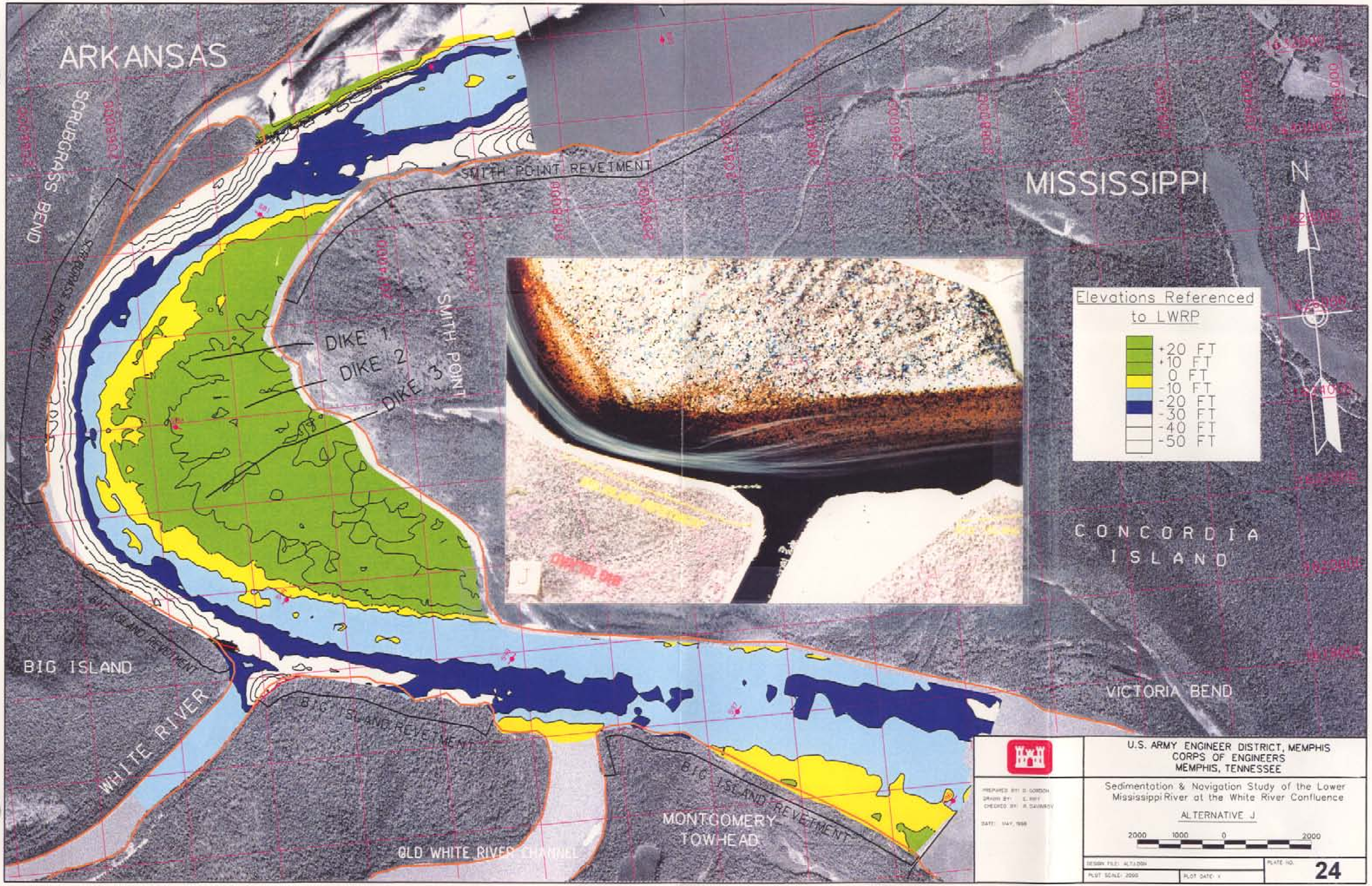
CORPS OF ENGINEERS
MEMPHIS, TENNESSEE

Sedimentation & Navigation Study of the Lower Mississippi River at the White River Confluence

ALTERNATIVE I

DATE: MAY, 1998

PLATE NO. 23



ARKANSAS
MISSISSIPPI
SCRUBGRASS BEND
SCRUBGRASS REVETMENT
SMITH POINT REVETMENT
SMITH POINT
DIKE 1
DIKE 2
DIKE 3
Elevations Referenced to LWRP
+20 FT
+10 FT
0 FT
-10 FT
-20 FT
-30 FT
-40 FT
-50 FT
N
CONCORDIA ISLAND
VICTORIA BEND
BIG ISLAND
BIG ISLAND REVETMENT
WHITE RIVER
OLD WHITE RIVER CHANNEL
MONTGOMERY TOWHEAD
U.S. ARMY ENGINEER DISTRICT, MEMPHIS
CORPS OF ENGINEERS
MEMPHIS, TENNESSEE
Sedimentation & Navigation Study of the Lower Mississippi River at the White River Confluence
ALTERNATIVE J
2000 1000 0 2000
PLATE NO.
24