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MISSISSIPPI RIVER AND OLD RIVER CONTROL COMPLEX SEDIMENTATION INVESTIGATION AND HYDRAULIC SEDIMENT RESPONSE MODEL STUDY

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BACKGROUND AND PROBLEM DESCRIPTION

The Old River Control Complex (ORCC), located along the right descending bank (RDB) of the Mississippi River, between River Miles (RM) 319.0 and RM 311.0, was established to provide flow and sediment diversion from the Mississippi River to the Red/Atchafalaya River system. The main control structures include the Low Sill Structure, Auxiliary Structure, and the S.S. Murray Hydroelectric Station Structure (for the rest of this report these are referred to as Low Sill, Auxiliary, and Hydropower). The outflow channels of each structure adjoin into one combined outflow channel. The ORCC system was designed to divert 30% of the Mississippi River flow into the Red/Atchafalaya River system during normal operation conditions. The system was also developed to divert sediment, but the annual amount required to maintain stability on both rivers has been in continual debate. Since implementation of Hydropower, problematic sediment deposition has occurred causing bank erosion in the inflow and outflow channels and endangerment of operational capabilities of the Low Sill and Auxiliary Structures.

In addition, the New Orleans District Corps of Engineers (MVN) has identified a long term upward trend of approximately 2 feet in the Low Water Reference Plane (LWRP) elevations in the Mississippi River. Left unchecked, this upward trend in stages may adversely affect the amount of flood control protection provided by nearby levee systems and also cause increased channel maintenance and associated dredging in the navigation channel.

The U.S. Army Corps of Engineers, St. Louis District, conducted a sedimentation investigation and physical Hydraulic Sediment Response (HSR) Model study of the Mississippi River and the ORCC from RM 325.0 to RM 307.0. Approximately 2 miles of the combined outflow channel that diverts into the Red/Atchafalaya River was also studied. This study was funded by the U.S. Army Corps of Engineers, New Orleans District, Channel Improvement Program.

The study was conducted between February 2010 and March 2011 at the Applied River Engineering Center, U.S. Army Corps of Engineers, St. Louis District. The study was performed by Mr. Ivan Nguyen, Hydraulic Engineer, under direct supervision of Mr. Robert Davinroy, Chief of River Engineering Section for the St. Louis District. Additional personnel from the St. Louis District included: Mr. Leonard Hopkins, Chief of Hydrologic and Hydraulic Branch, Ms. Ashley N. Cox, Hydraulic Engineer, Mr. Jason Floyd, Engineering Technician, Mr. Jasen L. Brown, Hydraulic Engineer, and Ms. Emily Rivera, Student Co-Op.

This study was conducted for the New Orleans District (MVN), Channel Stabilization Branch. Personnel involved in overseeing this study and supplying knowledge and critical river data included: Mr. Donald E. Rawson, Supervisory Civil Engineer, Ms. Erin C. Childers, Civil Engineer, Ms. Tiffany M. Bass, Civil Engineer, Mr. Russell A. Beauvais, Operations Manager of the ORCC, and Mr. Will Veatch, Hydrologist.

TABLE OF CONTENTS

BACKGROUND AND PROBLEM DESCRIPTION 1

TABLE OF CONTENTS 3

SEDIMENTATION INVESTIGATION 5

1. Study Goals 5
2. Study Reach 6
3. Geomorphology and Chronology of Construction Works 6
4. Flow Diversion 8
5. Sediment Diversion and Bedload 8
6. Lower Mississippi River Sediment Study and Conclusions About Bedload Diversion 10
7. Bedload Diversion Calculation, 1964 to 1975, Low Sill Structure Outflow Channel 14
8. Suspended Sediment Trends 17
9. Long Term Erosion in the Low Sill Channel 18
10. Past Study Reach Trends, Main Channel of the Mississippi River 18
11. Past Study Reach Trends, Outflow Channel 20
12. Recent Channel Characteristics and General Trends 20

HSR MODELING 24

1. Model Calibration and Replication 24
2. Scales and Bed Materials 25
3. Appurtenances 25
4. Flow Control 25
5. Replication Test 26

5a. Hydrographic Surveys and Model Comparison 26

5b. Observation of Sediment Transporation in Model 28

6. Model Timing and Low Sill BedLoad Diversion Rate 28
7. Design Alternative Testing 29
7a. Phase 1: Operational Tests 29
7b. Phase 2: Dredging Tests 32
7c. Phase 3: Structural Measures Tests 32
CONCLUSIONS 38
1. Bedload Diversion 38
2. Suspended Sediment Trends 39
3. Mississippi River Trends 40
4. HSR Modeling 40
5. Recommendations 40
6. Interpretation of Model Test Results 42
FOR MORE INFORMATION 43
APPENDIX OF PLATES 44

SEDIMENTATION INVESTIGATION

1. Study Goals.

The goals of the sedimentation investigation were as follows:

a. Summarize the geomorphology and chronology of the various construction works.

b. Evaluate long term sedimentation trends of the Mississippi River and Old River Control complex.

c. Evaluate various operational combinations of the control structures to alleviate the tendency for sediment deposition in the Mississippi River and the ORCC, and improve sediment transport/diversion into the Atchafalaya.

d. Evaluate various design alternatives in the main channel of the Mississippi River to both improve the navigation channel and improve sediment transport/diversion into the Atchafalaya.

e. Evaluate the general effects of dredging the inflow and outflow channels. This would involve the examination of both the bathymetric trends as well as the time associated with the return of dredged sediment associated with each design alternative. Determine long term trends of Low Sill operation by itself with no other structures in place.

f. Approximate the time it takes for sediment to fill back in the Low Sill and Auxiliary Structure inflow and outflow channels dredged to -10 feet elevation ("as built" condition).

g. Evaluate the feasibility of operation to maintain the required flow and sediment split (Flow: 70% through the Mississippi River and 30% to the Atchafalaya River; Sediment: 35% through the Mississippi River and 65% through the ORCC; as called for in the Old River Complex Authorization (Flood Control Act of 1945)).

2. Study Reach.

The study comprised an 18 mile stretch of the Mississippi River between RM 325.0 – RM 307.0, and also included the inflow and combined outflow channels of the ORCC. The ORCC is located on the west bank between RM 317 and RM 311.0 and is comprised of 3 inflow channels, 3 outflow channels, and one combined outflow channel that connects the Mississippi River with the Red/Atchafalaya River system. Approximately 2 miles of the combined outflow channel that diverts into the Red River was studied. Plate 1 is a location and vicinity map of the study reach.

Plate 2 shows the present-day planform and nomenclature of the Mississippi River and ORCC within the study reach. Plates 3 and 4 document field photos of the structures.

3. Geomorphology and Chronology of Construction Works.

Plates 5 and 6 summarize a brief illustration of the geomorphology of the Red, Mississippi, and Atchafalaya Rivers, along with the development of the Old River Control Complex. At one time, the Red River and the Mississippi River were separate rivers and flowed parallel to each other in a north to south direction to the Gulf of Mexico. Sometime during the 15th century, a westwardly migrating meander belt of the Mississippi, later called Turnbull's bend, developed and eventually intercepted the path of the Red River, splitting that river into a tributary and distributary of the Mississippi. The distributary was named the Atchafalaya River.

In 1831, Captain Henry M. Shreve, distinguished steamboat man and a founder of Shreveport dug a canal through the neck of Turnbull's Bend. Over time the north section of Turnbull's Bend filled in with sediment. The lower half remained open and became known as Old River and linked the Mississippi, Red, and Atchafalaya Rivers.

For years, the entrance to the Atchafalaya was blocked by a log jam. In 1939, the State of Louisiana began dislodging the raft and opened up the river as a free flowing

navigable channel. Removal of the log jam caused the Atchafalaya to become deeper and wider, and it began to capture more and more of the Mississippi River flow.

In 1953, the U.S. Army Corps of Engineers concluded that the Mississippi River could change course and take over the Atchafalaya River. Historical flows were increasing down the Atchafalaya. This observation, combined with the fact that the Atchafalaya course to the Gulf was much shorter than the Mississippi (142 miles versus 335 miles), caused engineers great concern for the very real possibility of a future major planform change. They surmised that measures had to be taken to control the flow and sediment interaction between the two rivers. If no actions were taken, they felt that eventual catastrophic flooding and destruction on the Atchafalaya and loss of navigation on the Mississippi would eventually occur. This would have tremendous social and economic impacts to Louisiana and the Federal Government.

Therefore, the Old River Control Structures (Low Sill and Overbank Structures) were constructed by the New Orleans District and came into operation in 1964 (Beauvais 2010). The structures were designed to help maintain the flow distribution between the two rivers at 70% Mississippi and 30% Atchafalaya. This flow distribution was to be maintained in relation to the latitude flow, defined as the total flow of the Mississippi and Atchafalaya Rivers at the latitude locations of Red River Landing on the Mississippi and Simmesport on the Atchafalaya.

The navigation lock was completed in 1962 to provide navigation access between the two rivers. The Low Sill structure was damaged by the 1973 Flood, which limited the operating head to 13 feet. The Auxiliary Structure was designed and completed in 1986 to supplement water and sediment control and allow the Low Sill Structure to be repaired and the head raised to 22 feet.

In 1990, the Sydney A. Murray Jr. Hydroelectric Station was completed. The three sets of inflow and outflow channels for the hydropower plant, Low Sill, and Auxiliary Structures combined to form the present day planform.

4. Flow Diversion.

Between approximately 1964 and 1985, 30% of the average channel flow in the Mississippi was diverted into the Atchafalaya River through the Low Sill Structure. Since the Auxiliary Structure (1986) and S.S. Murray Hydroelectric Station (1990) have been brought online, this 30% flow diversion has been maintained through the use of all 3 structures. The average annual percentages of flow historically operated at the complex are shown in Table 1.

Table 1: Average Annual Operational Flow Percentages, ORCC

Channel	Percentage of Total Flow
Mississippi River	70%
Hydropower	24%
Low Sill	1 %
Auxiliary	5%

5. Sediment Diversion and Bedload.

The original authorizing document for the ORCC project, House Document 478, did not establish an actual sediment diversion percentage associated with the above flow percentage distribution, but did recognize the following: “It is equally important that the Atchafalaya receive its share of the sediments in order that scouring of its bed in the upper river will not be increased. The distribution of flow and sediment in the Mississippi and Atchafalaya Rivers is now (1950) in desirable proportions and should be maintained.”

The Low Sill Structure came online in 1964 (Broudeax et.al). During its operation, before the Auxiliary and Hydropower structures came online, no records were recorded on the amount of sediment diversion that was passing into the Atchafalaya by this single control structure. This amount was estimated and outlined later in this investigation; see section 7 on page 14.

On 13 December 1989, a Memorandum of Agreement (MOA) was established between the Corps of Engineers, the Town of Vidalia, Louisiana, and the Catalysis Old River Hydroelectric Limited Partnership, to establish an acceptable mode of operation for the S.S. Murray, Jr. Hydroelectric Plant.

Besides the 70% - 30% annual flow distribution between the Mississippi and Atchafalaya Rivers, the New Orleans District established an annual operational target of diverting 65% of total Mississippi River bedload (unmeasured load) through the Corps Old River Control Project. This was based on the results of a movable bed model study performed by the Waterways Experimental Station (now referred as the Engineering Research and Development Center or ERDC) in 1978. The results of this model were conveyed by MVN into Design Memorandum No. 17 (DM17) - Hydraulic Design Auxiliary Structure. In DM 17, the following excerpt was taken "The initial flow diversion ratio between the Low Sill and Auxiliary Structure will be ratio 1. Model studies indicate that ratio 1 increase bedload sediment diversion by approximately 48% as compared to the Low Sill Structure alone. Whereas the Low Sill diverts 44% of the Mississippi River's bedload sediment, the structures operated in concert using ratio 1 would divert approximately 65%. This increase in bedload sediment diverted into the Atchafalaya River would tend to slow the rate of channel degradation in the upper Atchafalaya, thus decreasing the rate of channel degradation in the upper Atchafalaya, thus decreasing the rate of tailwater decline at Old River Control".

It should be noted that only the inflow channels of both the Low Sill and Auxiliary structures were modeled (DM17, Appendix D, Movable Bed Model, text and plates). Neither the outflow channels nor the junction of the combined outflow channels were modeled. This is investigated further in the modeling section of this report and in the conclusions.

As part of the MOA, it was determined that the hydropower licensee perform an extensive program of sediment transport studies in cooperation with MVN. "The study results could be used as a basis for future mutually agreed upon refinement to maintain the authorized purposes of the Old River Control Project."

6. Lower Mississippi River Sediment Study and Conclusions about Bedload Diversion.

In 1999, the "Lower Mississippi River Sediment Study" was completed by the Louisiana Hydroelectric Limited Partnership in association with MVN, the Vicksburg District Corps of Engineers (MVK), ERDC, Colorado State, University of Iowa, and Mobile Boundary Hydraulics.

No information was addressed in the study conclusions about sediment diversion, in particular, the 65% bedload diversion requirement established in the MOA. However, several professional experts on the study review committee were asked to provide executive summaries of their individual reviews of the report. Pertaining to the bedload diversion requirement, the following comments were made:

James Tuttle: "Several study members questioned the 65% Mississippi River bed load determined from the moveable bed model. The study data needs to be analyzed in terms of the percent magnitude that the 65% represent in annual sediment loads diverted. If, as some believe, the magnitude is one or two million cubic yards of material annually, it then is not significant and annual flushing could account for such a magnitude. Bed load diversion may be small and cannot be equated to 65% of an indefinable entity and probably is not significant. If it is on the order of 1.0 million cubic yards per year, it can be accounted for in the flushing operation."

Max Lamb: "Model studies should be continued in an attempt to develop a better operation procedure (if possible) for insuring a 70-30 split between both water and sediment to comply with the authorizing document. I see no evidence that supports the goal of diverting 65% of the Mississippi River bedload."

David Biedenharn: "In general, I feel that there are two issues with respect to the stated goal to divert 65% of the bed load from the Mississippi River. The first issue is whether the 65% goal as determined by the movable bed model studies is reasonable, and if so, what would be the appropriate amount to divert to meet this goal. As mentioned above,

there is considerable uncertainty in all the analysis methods. Therefore, I believe the 65% goal, which came from the physical movable bed model studies, should not be taken as an absolute value. However, if we assume that is correct, then it can be used to calculate the sediment diversion deficit due to the operation of hydropower. In order to do this, we must first make some assumption as to what percentage the bed load is of the measured sediment load. This is one question that was not answered definitively by this study. Estimates of this value ranged from 1% to 10% of the measured sand load based on 3D and HEC-6 results. It has also been suggested that the bed load is a much greater percentage, ranging from 10% to 15% of the total measured sediment load. While it may be possible that the bed load percentage is as high as 10% to 15% of the total measured sediment load, there is no technical basis to support this. Therefore, for my estimate, I have assumed that the bed load is 10% to 15% of the measured bed material load. I also used the results of the movable bed model study which stated that the bed load diversion deficit with hydropower in place was about 45%. The annual measured bed material load (>0.125mm) at Coochie for the 1976 to 1996 period is about 18.9 million tons. This results is an annual diversion deficit of about 660,000 yd^3 (based on a specific weight of 95 lb/ft^3) attributable to hydropower. If a more conservative approach is taken, and the total annual measured sand load of 36.3 million tons is used, the deficit is about 1.3 million yd^3. If we assume the bed load is 15% of the measured sand load, then the deficit is about 1 million yd^3 based on the measured bed material load and about 1.9 million yd^3 based on the total measured sand load. Therefore it appears that the annual deficit in sediment diversion due to hydropower may be in the range of about 600,000 yd^3 to 2 million yd^3. These results appear to agree with the HEC-6 results."

Forest Holly: " If it is true that bedload motion is limited to bed material larger than about 0.5 mm (as generally accepted in this study), and yet very little material of this size is found in the bed of the Mississippi River, then the movable-bed model's suggestions of diversion ratios may be of little relevance to the actual diversion ratios. My overall conclusion is that I do not see evidence of present or future significant effects of Hydro operation on Mississippi or Atchafalaya River morphology downstream of

ORCC. However it is very important to realize that, given the long time scale of river response compared to the time ORCC began its control of water and sediment diversions, the lack of evidence of long-term effects does not preclude the possible existence of such effects. It is simply impossible to tell at this time. This argues strongly for a moratorium on any major projects to modify the ORCC sediment diversion at this time. For the present, the sediment diversions of 1 to 2 million tons/year associated with normal operation and periodic flushing should be sufficient and should be maintained. "

Pierre Julien. "Regarding the goal of the Corps of Engineers to transfer 65% of the bedload from the Mississippi to the Atchafalaya, my understanding is that this diversion ratio has been the result of laboratory experiments with crushed coal. Physical models continue to provide valuable information on changes in river bed configuration in complex river systems. The difficulty with applying the diversion ratio at 65% of bedload is two-fold: 1) this diversion ratio is very high compared with prototype measurements for all size fractions; 2) the term bedload is subject to disagreement. Strictly speaking, bedload refers to sediment transport in a layer that is a few grain diameters thick near the bed. In that sense, bedload is negligible in the Mississippi. Perhaps the term has been historically used in the broader sense of the bed material load (i.e. 0.125-1 mm) which is about 10% of the total sediment load. Today, the extensive field measurements of the COE and Louisiana Hydroelectric seem more appropriate to measure the sediment load by size fraction that is really passing through each of the three structures."

Dr. Hseih Wen Shen. "DIVERTING 65% of the MISSISSIPPI RIVER BEDLOAD: There is a special assignment to comment on this goal as stated in the "Diversion Study Outline". If I understand it correctly that this goal of diverting 65% of the Mississippi River bed load was derived from the moveable bed model study of using only a bed load with a particular size of coal particles. In that model, 65% of the coal particles were diverted through the diversions from the Mississippi River. According to this results, we can say that 65% of the bed material load were diverted based on a particle size that

was mainly moved as bed load in the model. If other associate sizes of sediment should be present as either bed load or suspended load, they can also be diverted (along with these coal particles) with different percentages. The correct criteria should be to try to find the desirable flow conditions that can divert this 65% of the coal particles in the physical model.

From both the field data and the three dimensional modeling that much less sediment than this 65% ratio was diverted. In order to divert 65% of the bed material load, the sediment concentration in the diversions should be around three times the corresponding sediment concentration in the Mississippi River. Is this possible or is the physical model result correct? The only chance for this to be possible is that a great deal of coarse sediment should be deposited near the entrances of the diversions when the gates are closed. Then when the gates are opened, a great deal of coarse particle, such as the coal particles, can be moved through the diversions. In that case, more coarse sediment can be diverted than the suspended sediment. Thus a more complete hydrological cycle should be conducted by the three dimensional model to investigate the erosion and deposition processes. We should certainly collect simultaneously field data at several lateral locations in the Mississippi River to study the lateral distribution of sediment concentration for different flow conditions. These data would also be valuable for the calibration of the three dimensional model.

Field data and 3-D modeling indicate that much less than 65% of the sediment is diverted. In order to divert 65% of the bed material load, the sediment concentration in the diversions would have to be approximately three times greater than the corresponding concentration of the Mississippi. Approximately 22% of both latitude flow and sediment are diverted through ORCC annually. To match 65% of the bed material load, the sand concentration of bed material load would have to be 65% / 22% or 3 times what it is now.

As a conclusion, I don’t believe that I can state with certainty about the appropriate amounts of diversion of both bed load and suspended load for different flow conditions with the available information.”

D.D. Simons: "Regarding the Corps' goal to divert 65% of the Mississippi River's bed load, my judgment is that this goal may not be possible or even desirable. The diversion of this volume of bed load from the Mississippi River to the Atchafalaya River would result in significant problems of aggradation in the lower reaches of the Atchafalaya River. There may be advantages to keeping the dredging problem in the MR&T system as is instead of transferring a portion of it to the Atchafalaya River. Past experience has identified the scope and the location of existing dredging problems in the Mississippi River and has established a technology for dealing with these historic sites. Adding a new level of dredging in the Atchafalaya River will introduce a 50-year learning curve to develop knowledge of subsequent impacts and the most desirable procedure of dredging the river. New locations requiring dredging, development of new depositional sites and possible extra costs introduced by this untested activity must be evaluated. Also, the long-term response of the Mississippi River to the proposed diversion of bed material could have adverse impacts which are not fully known at this time."

Tom Pokrefke: "The physical models of the Low Sill Structure diverted a significant portion of the model bed material into the Atchafalaya River System. One model suggested 58% and one suggested 44%."

7. Bedload Diversion Calculation, 1964 to 1975, Low Sill Structure Outflow Channel.

During this investigation, MVN was able to produce a key hydrographic survey that could be used to estimate the amount of bedload diversion supplied by the Low Sill Structure over the first 11 years of operation, between start of operations in 1964 to the time of the survey in 1975. Plate 7 shows a 1964 hydrographic survey of the Mississippi River and inflow and outflow channels of the Low Sill Structure. Plate 8 shows historical aerial photos of the Low Sill outflow channel. At the time of this survey, bottom depths in the outflow channel ranged between -20 feet and -5 feet in elevation, and a narrow constricted reach of channel was observed approximately 3 miles downstream from the entrance to the Mississippi. Internal discussions with MVN

personnel concluded that the outflow channel was eventually excavated to its full width and bottom elevation at – 10 feet or slightly deeper.

Plate 9 shows the 1975 hydrographic survey of the inflow and outflow channels. Assuming that the starting outflow channel condition was at the full width and minimum bottom elevation of -10 feet, several important observations could be noted on the 1975 survey:

- A meandering river planform had developed within the outflow channel below the Low Sill Structure, with the formation of alternating point bars and a defined thalweg. This depositional pattern extended 7.5 miles downstream below the Low Sill Structure.
- The first two alternating point bars located 1.6 miles and 3.16 miles downstream of the Low Sill Structure were at or above + 15 feet elevation. .
- The extent of the downstream bed sediment wave-front resulting from annual diversion operations conducted at the Low Sill Structure had migrated about 7.5 miles downstream, or 2 miles upstream of the junction with the Red River. It was quite apparent that the bed sediment wave-front at this point had not yet entered the Red/Atchafalaya River System.

Assuming a flat bottom channel invert of -10 feet, two different methods were used to compute the total bed deposition within the inflow and outflow channels of the Low Sill Structure (Plate 10). The first method used a gridded volumetric surface computation (Fledermaus) and produced approximately 12,900,000 cubic yards of deposited material. The second method used a triangulated volumetric surface computation (Microstation) and produced approximately 16,400,000 cubic yards of deposited material. Considering the 1975 survey was a 500 foot range survey and provided only limited bathymetric resolution, the greater amount of the two methods was conservatively used for a total computed estimated amount of 16,400,000 cubic yards of bed deposition over the 11 year period. The average annual bed sediment diversion was thus computed as approximately 1,500,000 cubic yards per year.

It was assumed that the majority of this deposition was due to bedload, although a small amount along the channel border areas could have been a result of finer material falling out of the suspended load. The deposition in the inflow and outflow channel may have occurred over a short time period, multiple events, or gradually over time during the 11 year period.

In 2010, ERDC computed a bedload rate in the main channel of the Mississippi River adjacent to Old River of approximately 31,000 tons per day at high flow conditions. For the sake of estimating the amount that would be experienced over the course of a year, MVN and MVS river engineers estimated an average daily rate of 50% of the computed high flow rate, or 15,500 tons per day. Using a 1 to 1 weight/volume ratio conversion, the average rate of bedload moving through the Mississippi River channel was estimated to be approximately 5.5 million cubic yards per year.

Therefore, over the 11 year period between 1964 and 1975, using the 2010 estimated average yearly rate of bedload in the Mississippi River, approximately 60,500,000 cubic yards of bedload would have passed through the Mississippi River Channel adjacent to Old River. The amount diverted by the Low Sill Structure over the 11 year period, computed as approximately 16,400,000 cubic yards, was thus approximately 27 % of the total estimated Mississippi River bedload.

This computed percentage was near the same amount as the average annual flow diversion percentage provided by Low Sill Operations. From these estimates, indications were that at least during the first 11 years of operation, the Low Sill Structure had passed a reasonable and proportional amount of bedload percentage (27 %) to the flow diversion percentage (30%) into the combined outflow channel.

8. Suspended Sediment Trends.

Plate 11 shows historical suspended sediment loads at Tarbert on the Mississippi and Simmesport on the Atchafalaya in relation to each location as a combined total load. Linear trends show approximately a 6% change over the period of record. The Mississippi load had increased from about 62% to 68% of the combined total load while the Atchafalaya load had decreased from about 38% to about 32% of the combined total load. Although these rivers are somewhat dependent on each other, they are not totally dependent because both loads rely on changes occurring upstream in each of the rivers' respective main channels, tributaries, and basins.

Further detailing trends in relation to the implementation of the various structures, the following observations can be seen as outlined on Plate 11: Prior to any structure, between 1952 and 1964, the Mississippi load had increased from about 60% to 69% of the total combined load while the Atchafalaya load had decreased from about 40% to about 31% of the combined total load. It is interesting to note that the original authorization document stated 'the distribution of flow and sediment in the Mississippi and Atchafalaya Rivers is now (1950) in desirable proportions and should be maintained." The sediment proportions at least concerning total load between the Mississippi and Atchafalaya in 1952 were 52% and 49%, in 1953 were 45% and 55%, in 1954 were 80% and 20%, and in 1955 were 62% and 48%. The question remains which of these proportions were desirable, if any?

During stand alone Low Sill Structure operation, the trend remained 64% Mississippi and 36% Atchafalaya. After Auxiliary operation, the trends were from 58% to 67% Mississippi River and from 42% to 33% Atchafalaya. After Hydropower operation, the trends were from 62% to 74% Mississippi, and 38% to 26% Atchafalaya.

As stated previously, all of these trends include inputs occurring in the basin, tributaries, and main channel upstream of the two respective rivers. To isolate the contributions of the ORCC to the Atchafalaya, a sediment station was established in the combined outflow channel (Knox Landing) in 1967 (Plate 12). Trends indicate that the percentage

of the total combined load increased in the combined outflow channel from about 35% to 38% while the Atchafalaya decreased from 65% to 62%. This trend would indicate that there has not been a deficiency in at least the suspended sediment contributions of the Mississippi River through Old River.

9. Long Term Erosion in the Low Sill Channel.

Plates 13 and 14 show the 1975 and 2003 planform comparisons of the Low Sill outflow channel. A total of 17 lines were established to compare changes in bankline widths. Results indicated the following:
Approximate 1975 average width: 1300 feet
Approximate 2003 average width: 1600 feet
This was about a 19 % increase in the average width of the channel. The greatest changes in width occurred just downstream of the Low Sill Structure where the channel makes a curve. At this area the channel had widened from about 1250 feet to over 1620 feet, for a 23 % increase in width.

10. Past Study Reach Trends, Main Channel of the Mississippi River.

A historical look at the Old River reach of the Mississippi River revealed that the river channel within the study reach had changed over time. More specifically, the thalweg location had changed numerous times. In the 1948 hydrographic survey (Plate 15), the thalweg was along the RDB between RM 319.0 – 316.0 and had depths of approximately -30 feet in elevation. From analyzing the hydrographic survey, there appears to have been a small island-like feature along the RDB between RM 315.0 – 314.0 with elevations greater than +15 feet. Because of this feature, the thalweg location transitioned to the LDB between RM 316.0 – 314.0, where it remained through the following bend. Through the thalweg crossing depths ranged between -15 feet and +5 feet in elevation.

In 1964, the Old River Control Structures (Low Sill and Overbank Structures) came into operation, and a hydrographic survey (Plate 16) was conducted the same year. Similar

to the 1948 survey, the thalweg entered the study reach along the RDB between RM 319.0– 316.0 with depths of approximately -30 feet in elevation. The island-like feature described from the 1948 survey appeared to have lost some of its elevation and was no longer limited to the RDB. Between RM 314.0 – 312.5 there were elevations of +5 feet across the entire channel. The thalweg still transitioned to the LDB in this location but was not as clearly defined.

A 1975 hydrographic survey (Plate 17) revealed some major changes in bathymetry. At this point in time, the Low Sill and overbank structures as well as the navigation lock were in place and operational. The thalweg was along the RDB starting at RM 319.0, but instead of transitioning to the LDB around RM 315.0 like previous years, the thalweg remained along the RDB until RM 312.0. The thalweg transitioned to the LDB between RM 312.5 – 311.5. In a little over 10 years, the thalweg had shifted approximately 4,000 feet, and there was now a large bar along the RDB between RM 314.0 – 312.0 that had elevations up to +40 feet. After analyzing the 1975 survey, there were signs that this transition was happening in the 1964 survey by noting the changes in the sedimentation that was taking place across the channel.

A hydrographic survey from 1983 (Plate 18) showed the thalweg entering the study reach along the RDB between RM 319.0 – 316.5 and had depths of approximately -30 feet in elevation. At RM 315.5, the thalweg location shifted to the middle of the channel, but then shifted back to the RDB at RM 314. The thalweg remained along the RDB with depths ranging between -15 feet to +5 feet in elevation until RM 312 where it transitioned back to the LDB. This was similar to what was observed in 1975.

By 1990, all of the present day structures and platform were in place (including the low sill and overbank structures, navigation lock, auxiliary structure, and hydropower station). The 1992 hydrographic survey (Plate 19) showed similar trends to the 1983 survey. The thalweg entered the study reach along the RDB between RM 319.0 – 316.0, and transitioned to the LDB between RM 316.0 – 315.0, where it remained until RM 314.5. At this point, the thalweg shifted back to the RDB. In the location of this shift

(RM 314.0 – 313.5), elevations between +15 feet and +10 feet were observed. Between RM 313.5 – 312.0 the thalweg remained along the RDB and had depths ranging between +15 feet and -15 feet in elevation. Between RM 314.5 – 312.0, a large majority of the channel had depths ranging between +5 feet and +30 feet in elevation. A thalweg transition back to the LDB occurred between RM 312.0 – 311.0.

11. Past Study Reach Trends, Outflow Channels.

Hydrographic surveys from 1962 to 2010 showed significant sediment accumulation within the ORCC inflow and outflow channels. This aggradation has limited the sediment supply to the Red/Atchafalaya River system. Plates 20 through 26 show hydrographic surveys taken in 1999, 2001, 2003, 2006, 2008, and 2010. Conditions of these inflow and outflow channels at the time of this study were as follows:

At Hydropower, the inflow channel had depths between -5 feet to -20 feet in elevation, while the outflow channel had depths between -45 feet in elevation and deeper. It should be noted that the bed of the Hydropower outflow channel was armored. At the inflow channel of Low Sill, depths of +15 feet in elevation and above were observed while the outflow channel had depths ranging between 0 feet to +25 feet in elevation. The Auxiliary inflow channel had depths that were between +25 feet in elevation and above while the outflow channel was lower, with average depths of approximately +10 feet in elevation.

12. Recent Channel Characteristics and General Trends.

A comparison of the above mentioned hydrographic surveys showed that the following bathymetric trends in the main channel of the Mississippi River have remained relatively constant since 2000.

Within the main channel, the thalweg entered the study reach along the LDB between RM 319.0 – 316.0 and had depths of -45 feet in elevation and below. The thalweg shifted back to the RDB between RM 314.5 – 313.5. In the location of this shift (RM 314.5 – 313.5), elevations between +30 feet and +10 feet were observed. Between RM

313.5 – 312.0 the thalweg remained along the RDB and had depths ranging between +15 feet and -15 feet in elevation. Between RM 314.5 – 312.0, a large majority of the channel had depths ranging between +5 feet and +30 feet in elevation. A thalweg transition back to the LDB occurred between RM 312.0 – 311.0. The only general trend difference started becoming visible in the 2006 survey. At approximately RM 312.5 a split flow started to develop. Elevations between +5 feet and -5 feet appeared on the LDB and RDB simultaneously, and this split flow trend continued in the 2008 and 2010 surveys.

Furthermore, an ISOPACH analysis was conducted to compare the area within the main channel between RM 315.0 – 311.0. The ISOPACH compared the 1999 hydrographic survey to the 2001, 2003, 2004, 2006, 2008, 2009, and 2010 hydrographic surveys (Plates 27 through 32 respectively). The ISOPACH analysis allowed for a more comprehensive and detailed view of what had changed within the reach, and should not be confused with the general trends described above.

When analyzing the 2001 vs 1999 ISOPACH, there was little change overall throughout the reach. One notable difference was in the center of the channel between RM 315 – 314, which had a change in elevation between +10 feet and +20 feet. Another area that showed a decent amount of variation from the 1999 hydrographic survey was between RM 312 and 311, which is the where the outflow of the auxiliary structure enters the main channel. Between the RDB and the center of the channel within this area, a change in elevation between -10 feet and -25 feet occurred. Along the RDB within this same area, a change in elevation between +10 feet and +20 feet was observed. Almost all other changes were between -10 feet and +10 feet in elevation, which can be considered within natural variation in the river.

The 2003 vs 1999 and 2004 vs 1999 ISOPACHs were very similar and therefore, can be described together. In the center of the channel between RM 315 – 314 a change in elevation between +10 feet and +20 feet was observed. Along the RDB between RM 314 and 312.5, a +10 feet to +20 feet change in elevation was observed. Between the RDB and the center of the channel within the area where the outflow of the auxiliary

structure enters the main channel, a change in elevation between -10 feet and -25 feet occurred.

The 2006 vs 1999 and 2008 vs 1999 ISOPACHs were very similar and are described together. Similar to the ISOPACHs described before, the center of the channel between RM 315 – 314 a change in elevation between +10 feet and +20 feet was observed. Similar changes in elevation were observed between the RDB and the center of the channel between RM 314 - 312.5. A large change in elevation occurred between the center of the channel and the LDB between RM 312.5 and 311.5. Closer to the center of the channel, a change in elevation between +10 feet and +20 feet occurred with a small area reaching a change in elevation of up to +30 feet. A narrow area along the LDB between RM 313.5 – 311.5 had changes in elevation between -10 feet and below -40 feet. This narrow area along the LDB is the location described as split flow in the first paragraph of this section.

When analyzing the 2009 vs 1999 ISOPACH, a consistent difference in elevation between +10 feet and +20 feet was observed in the center of the channel between RM 314 – 311.5. Similar to the 2006 and 2008 comparisons with the 1999 survey, a narrow area along the LDB between RM 313.5 – 311.5 had changes in elevation between -10 feet and below -40 feet.

The 2010 vs 1999 ISOPACH showed a significant amount of change within the center of the channel between RM 314 – 311.5 when compared with the 2009 vs 1999 ISOPACH. Where the 2009 vs 1999 comparison showed changes in elevation of +10 feet to +20 feet, the 2010 vs 1999 comparison showed changes in elevation between 0 feet and +10 feet. Along the RDB between RM 314 – 312.5, elevation changes ranged between +5 feet and +25 feet, and even had a few spot locations showing +30 feet and above elevation change. The narrow area along the LDB between RM 313.5 – 311.5, which had been observed in the previous three ISOPACHs, remained and had changes in elevation between -10 feet and below -40 feet. In addition, where the outflow of the auxiliary structure enters the main channel, elevation changes of -10 feet to -15 feet were observed. Finally, on the LDB of the main channel where the auxiliary outflow

enters, areas with changes in elevation ranging between -25 feet and +30 feet occurred. Plate 33 shows the 2010 hydrographic survey referenced to the Low Water Reference Plan (LWRP). The LWRP survey shows that navigation depths would be inadequate during low water between RM 314 and RM 311.5. Plate 34 shows historical thalweg locations between 1964 and 2010. Plate 35 shows historical banklines between 1962 and 1966.

HSR MODELING

An HSR model study was conducted to gain insight on the sediment response occurring both in the main channel of the Mississippi River and through the ORCC, and investigate possible remedial measures to increase sediment diversion though the complex and improve navigation depths in the main channel of the river.

1. Model Calibration and Replication.

The HSR modeling methodology employed a calibration process designed to replicate the conditions in the river at the time of the model study. Replication of the model was achieved during calibration and involved a three step process.

First, planform "fixed" boundary conditions of the study reach, i.e. banklines, islands, side channels, tributaries and other features were established according to the 2004 high resolution aerial photography. Various other fixed boundaries were also introduced into the model including any channel improvement structures, underwater rock, clay and other non-mobile boundaries.

Second, "loose" boundary conditions of the model were developed. Bed material was introduced into the channel throughout the model to an approximate level plane. The combination of the fixed and loose boundaries served as the starting condition of the model.

Third, steady state discharge simulation tests were run through the model. Adjustment of the discharge, sediment volume, model slope, fixed boundaries, and entrance conditions were refined during these tests as part of calibration. The mobile bed developed from a static, flat, arbitrary bed into a fully-formed, dynamic, three dimensional bed response. The resulting bed configuration was surveyed numerous times during the calibration tests and compared to recent river bathymetry. Repeated tests were simulated for the assurance of model stability and repeatability. When the general trends of the model bed bathymetry were similar to observed recent river

bathymetry, and the tests were repeatable, the model was considered replicated and alternative testing then began.

2. Scales and Bed Materials.

The HSR model employed a horizontal scale of 1 inch = 1500 feet, or 1:18,000, and a vertical scale of 1 inch = 100 feet, or 1:1200, for a 15 to 1 distortion ratio of linear scales. This distortion supplied the necessary forces required for the simulation of sediment transport conditions similar to those observed in the prototype. The bed material was granular plastic urea, Type II, with a specific gravity of 1.40. Plate 36 is a photograph of the Old River HSR model used in this study.

3. Appurtenances.

The HSR model insert planform was constructed according to the 2004 high-resolution aerial photography of the study reach. The insert was then mounted in a standard HSR model flume. The riverbanks of the model were constructed from dense polystyrene foam, clay, and polymesh to develop proper bendway mechanics. Rotational jacks located within the hydraulic flume controlled the slope of the model. The measured slope of the insert and flume was approximately 0.015 inch/inch. River training structures in the model were constructed of galvanized steel mesh to generate appropriate scaled roughness.

4. Flow Control.

Flow into the model was regulated by customized computer hardware and software interfaced with an electronic control valve and submersible pump. This interface was used to control the flow of water and sediment into the model. For all model tests, flow entering the model was held steady at 1.87 Gallon per Minutes (GPM). This served as the average expected energy response of the river. Because of the constant variation experienced in the actual river, this steady state flow was used to replicate existing

conditions and empirically analyze the ultimate expected sediment response that could occur from future alternative actions.

Two flow meters were setup on the model to control and measure flow diversion into the ORCC. During calibration and replication, a 70 % Mississippi River and 30 % ORCC flow split were maintained. Approximate flow distribution maintained in the model through Hydropower was (24%), Low Sill was (1%), and Auxiliary was (5%). These flow percentages were achieved by having Hydropower fully open and both Low Sill and Auxiliary shut. Because of the small scale of the model the 1% Low Sill and 5% Auxiliary was achieved by seepage flow with the gates fully shut. On all plates the gates were either open or closed and indicated by green (open) and red (shut).

5. Replication Test.

Once model replication was achieved through the calibration process, the resultant bathymetry served as a benchmark for the comparison of all future model alternative tests. In this manner, the actions of any alternative, such as new channel improvement structures, realignments, side channel modifications, etc, were compared directly to the replicated condition. General trends were evaluated for any major differences positive or negative between the alternative and the replication by comparing the surveys of the two and also carefully observing the model while the actual testing was taking place.

5a. Hydrographic Surveys and Model Comparison.

Plate 37 shows the results of the replication test. Plate 38 is a detailed comparison between the combined 2003 survey of the ORCC inflow and outflow channels and the 2010 survey of the Mississippi River and the model replication. The 2008 survey of the Mississippi River was also used when comparing model to prototype. As observed in both these prototype surveys and the model, the thalweg was located along the LDB between RM 324.0 and RM 319.0. At RM 319.0, there was an abrupt crossing from the LDB to the RDB in both the model and the prototype. The bend along the RDB

between 319.0 and 316.0 was very similar, although the channel scour in 2010 extended further downstream in front of Hydropower as compared to the 2008 survey and the model. Trends down the inflow and outflow channel of Hydropower were similar, with depths of -10 feet elevation minimum to -45 feet elevation maximum.

The trends in the crossing between RM 316.0 and 314.0 and the deposition occurring at the inflow channel of Low Sill were very similar. Overall depths developed down the outflow channel of Low Sill in the model were at +15 elevation and similar to the prototype. The trend that could not be replicated was the deep scour hole directly downstream of Low Sill. The model always had the tendency to fill this hole in over time.

A large middle bar was developed in both the model and the prototype between RM 314.0 and 312.0. Scour was developed along this bar along the RDB starting at RM 313.3, but did not extend down as far in the model as compared to the prototype. Trends observed in the adjacent inflow channel of the Auxiliary Structure were very similar to both the model and the prototype, with depths approaching +35 feet and above. Trends in the Auxiliary outflow channel were also similar.

A large scour hole developed at the juncture of the upstream portion of the combined outflow channel in the model, with depths at -45 feet elevation. This hole was also observed in the 2002 survey, but occurred further upstream and depths were less at -30 feet elevation. A depositional area occurred below this scour hole in the model and the prototype with depths both between – 10 feet elevation and 0 feet elevation.

Finally, scour developed along the LDB between Mile 314.0 and 307.0 in both the model and the prototype, although the model scour was exaggerated between RM 312.0 and RM 311.0.

5b. Observations of Sediment Transport in the Model.

During replication, special attention was devoted to where sediment was moving in the model in relation to the channel. Trends indicated that no bed movement was observed down the Hydropower inflow and outflow channels, and the majority of bed movement was observed along the point bar opposite the thalweg of the Mississippi at RM 317. The model showed that the combination of the height and location of the Hydropower intake channel enabled no bed load diversion. In the main channel downstream of Hydropower, the bed movement crossed from the LDB near RM 316.0 to the RDB near RM 315.0 and flowed adjacent to the inflow channel of Low Sill and further down along the RDB where it eventually crossed back over to the LDB at RM 312. Both Low Sill and Auxiliary displayed no sediment movement. The movement of the bed relative to the important areas in the model was captured on video and can be viewed at the following link: http://www.usace.army.mil/arec/models_old.html.

6. Model Timing and Low Sill Bed Load Diversion Rate.

As stated previously, the model employed a steady state flow condition used to represent the average expected energy response of the river. One important question that needed to be addressed in this study was the time response of sediment deposition in the inflow and outflow channels after a dredging scenario and the understanding of how fast sediment would re-deposit back into the channels. To acquire a sense of time, an investigation was conducted examining the observed bedload diversion that occurred down the Low Sill inflow and outflow channels during it's initial operation. Previously discussed in the report was the observation that the main bedload sediment wave had progressed down the Low Sill inflow/outflow channel for a length of approximately 7.5 miles. This occurred sometime during the first 11 year period of operation. To be conservative, it was assumed that the wave progressed gradually over time. Therefore, the bed sediment wave was calculated as moving at a rate of 7.5 miles in 11 years or 0.68 miles/year.

After model replication, the hydropower and auxiliary channels were closed off, and the Low Sill was operated alone to divert 30% of the Mississippi River. The outflow channel was excavated to depths of -10 feet elevation, and timing tests were conducted to determine the rate of bedload down the outflow channel. Plate 39 shows bathymetry of the Low Sill timing test. Results indicated that the sediment wave in the model outflow channel reached a distance of approximately 5.25 miles in 30 minutes in the outflow channel. Since the sediment wave movement in the actual outflow channel was estimated at 0.68 miles/year, the model to prototype time factor was 1 minute (model) = 0.2566 years (prototype).

7. Design Alternative Testing.

Design alternatives testing involved three phases of study. Phase 1 involved the testing of various operational combinations of the control structures and hydropower in the hopes of providing manageable and sustainable bed load diversion. Phase 2 involved testing complete dredging of the inflow and outflow channels and observing the associated filling times of those channels. Phase 3 involved the testing of various structural alternatives placed in both the Mississippi River channel and within the ORCC for purposes of channel improvement and sediment diversion enhancement.

7a. Phase 1: Operational Tests.

As stated previously, in all operational tests, conditions of the three individual control structures were studied as either closed or completely open under dominant, steady state energy conditions. This was accomplished in order to simplify testing and observe major general long term trends of deposition and scour in both the Mississippi River and the inflow and outflow channels. By testing different combinations of flow control in this manner, the model focused on the most operational efficiency schemes as if related to bed load transport through the outflow channels.

Condition 1: (Hydropower Open, Low Sill Closed and Auxiliary Closed)
This is the replication test.

Condition 2: (Hydropower Open, Low Sill Closed and Auxiliary Open)
Plate 40 shows the resultant bathymetry of Condition 2. Test results indicated that similar trends were observed as compared to the replication test. It was evident that the location of the Auxiliary structure inflow channel was problematic as the majority of energy and sediment movement from the main channel was located on the opposite side of the river along the RDB. The mouth of the inflow channel had a tendency to choke off and remained high throughout repeated tests.

Trends indicated that the majority of the 30% flow split flow during this test diverted down Hydropower because of its location. Very minimal bed sediment loads were introduced to the combined outflow channel. Both Low Sill inflow and outflow channels remained high in elevation between +25 feet and +35 feet. Very little flow and bedload at the junction was observed.

Condition 3: (Hydropower Closed, Low Sill Open and Auxiliary Closed)
Plate 41 shows the resultant bathymetry of Condition 3. Test results indicated that the Mississippi River main channel from RM 316.0 to 309.0 increased in depth. Initially during this condition a fair amount of bed load and flow was observed down the Low Sill outflow channel. This flow was able to move away some of the deposition in the combined outflow channel. However, with the passing of time, the inflow and outflow channels experienced higher and higher deposition with depths approaching +45 feet elevation. Eventually both the flow and bedload down Low Sill was minimal.

Condition 4: (Hydropower Closed, Low Sill Open and Auxiliary Open)
Plate 42 shows the resultant bathymetry of Condition 4. Test results indicated that initially during this condition a fair amount of bed load and flow was observed down the Low Sill outflow channel. This flow was able to move away some of the deposition in the combined outflow channel and also develop some scour along the RDB of the

combined outflow channel. However, with the passing of time, the inflow and outflow channels of Low Sill and Auxiliary experienced higher and higher deposition with some depths approaching +45 feet elevation. Eventually no bed movement transport was observed throughout the entire inflow/outflow channel of both Low Sill and Auxiliary.

Condition 5: (Hydropower Open, Low Sill Open, and Auxiliary Closed)
Plate 43 shows the resultant bathymetry of Condition 5. Test results indicated that the Low Sill inflow and outflow channels experienced deposition as a result of the dominant effect of the Hydropower channel. The Hydropower flow provided a backwater effort up the low sill outflow channel. Eventually no sediment transport was observed throughout the entire inflow/outflow channel of Low Sill.

Condition 6 (Hydropower Closed, Low Sill Closed, and Auxiliary Closed)
Plate 44 shows the resultant bathymetry of Condition 6. Test results indicated that the main channel of the Mississippi River increased in depth along the RDB between Hydropower and Low Sill. This increased scour also caused a more continuous channel along the RDB between RM 314 until it crossed over to the LDB at RM 312. Some slight increase in depth was observed at the Low Sill inflow channel.

Condition 7: (Hydropower Closed, Low Sill Closed, and Auxiliary Open)
Plate 45 shows the resultant bathymetry of Condition 7. Test results indicated results similar to condition 6.

Condition 8: (Hydropower Open, Low Sill Open, and Auxiliary Open)
Plate 46 shows the resultant bathymetry of Condition 8. Dominant flow in the hydropower was observed while sediment deposition occurred for both the Low Sill and Auxiliary inflow channels. Eventually no sediment transport was observed throughout the entire inflow/outflow channel of both Low Sill and Auxiliary.

7b. Phase 2: Dredging Test

A test was conducted to examine dredging the inflow and outflow channels and observing the estimated time that these channels would fill back in (Plate 47). All three channels were completely open to observe maximum channel development. The inflow and outflow channels of both Low Sill and Auxiliary were dredged to -10 feet elevation and the model was timed until conditions came back to the replication test. Results indicated that the Low Sill sediment would develop to 1.8 miles down the Low Sill inflow/outflow channels, where it eventually stopped because of the backwater effect of Hydropower. Some sediment actually backed into the Auxiliary channel junction. The sediment wave down the Auxiliary channel moved about .75 miles down before the movement completely stopped. This was due to the deposition occurring in the Low Sill Channel caused by the dominance of Hydropower. With this condition all sediment movement in all inflow and outflow channels stopped in 20 minutes, or approximately 5 years in the prototype.

At the beginning of this test it was observed that the flow distribution to the combined outflow channel was almost doubled from 30% to 50% of the total flow. This distribution was gradually reduced to minimal flow as deposition accumulated in the inflow and outflow channels. Test results indicated that the Mississippi main channel increase in depths between RM 314.5 and 312.0.

7c. Phase 3: Structural Measures Tests

Alternative 1: Chevrons.

Plate 48 shows the resultant bathymetry of Alternative 1. Three chevrons were tested along the LDB between RM 314.0 to 312.5 for the purpose of trying to maintain the thalweg along the RDB.

Table 1: Alternative 1 Summary.

Type of Structure	River Mile	LDB or RDB	Dimension (feet)	Elevation (feet)
Chevron	313.9	LDB	800	0.5
Chevron	313.3	LDB	800	0.5
Chevron	312.5	LDB	800	0.5

Test results indicated that depths generally increased along the RDB between RM 314.0 and through the crossing to RM 312.0. However, a shallow crossing still was observed in the upstream crossing between RM 314.5 and 314.0, with depths as high as -5 feet elevation. Both Low Sill and Auxiliary Structures were opened to see if more sediment could be carried down the inflow and outflow channels with this plan. Results indicated that no sediment could be moved through these channels with Hydropower open or shut.

Alternative 2: Weirs

Plate 49 shows the resultant bathymetry of Alternative 2. Five bendway weirs were placed at the bend upstream of the Hydropower inflow channel. The purpose of these weirs was to try and deflect the thalweg away from the RDB and consequently force more flow into the Low Sill inflow channel. The weirs were 700ft in length and were placed on the RDB between RM 318.0 and RM 316.8.

Note: Both Hydropower and Auxiliary gates had to be closed in order to generate the best result.

Table 2: Alternative 2 Summary

Structure Type	River Mile	Length (ft)	RDB or LDB	Elevation (ft)
Weir 1	317.8	850	RDB	-20
Weir 2	317.5	850	RDB	-20
Weir 3	317.3	850	RDB	-20
Weir 4	317.1	850	RDB	-20
Weir 5	316.9	850	RDB	-20

Similar to the prototype, the bathymetric survey showed the thalweg extended past the Hydropower inflow channel. No sediment movement was observed in front of Hydropower. Test results indicated that the Mississippi River main channel from RM 316.0 to 309.0 increased in depth. Low Sill and Auxiliary inflow and outflow channels remained the same.

This test also simulated when Hydropower was closed and Low Sill open. Theoretically, this condition would produce more flow down Low Sill. After numerous tests, trends indicated that there was some bed movement deposition in the Low Sill outflow channel. However, with the passing of time, the inflow and outflow channels experienced higher and higher deposition with depths approaching +35 feet elevation, and the bed movement was minimal.

Alternative 3: Bankline Excavation and Dikes

Plate 50 shows the resultant bathymetry of Alternative 3. This proposed alternative consisted of a combination of bankline excavation and four dikes located along the LDB. The bankline excavation was located along the RDB between the Hydropower and Low Sill Structures at RM 315.5. A total of approximately 1.5 million cubic yards of bankline material was representatively excavated in the model. Four dikes each approximately 780 feet in length were tested along the LDB between Miles 316.1 and Miles 315.2. The goal of this alternative was to hopefully deflect enough flow toward Low Sill to develop a self maintaining sediment diversion channel.

Table 3: Alternative 3 Summary

Structure Type	River Mile	Length (ft)	RDB or LDB	Elevation (ft)
Bankline Excavation	315.75-314.9	3900Lx325W	RDB	-29.5
Dike 1	316.1	750	LDB	+29.5
Dike 2	315.7	750	LDB	+29.5
Dike 3	315.5	750	LDB	+29.5
Dike 4	315.25	750	LDB	+29.5

Tests were conducted with Low Sill fully open and Hydropower and Auxiliary gates closed. Even though significant flow was diverted into the Low Sill inflow channel, the flow was not enough keep the channel open. The energy coming through the combined outflow was not enough to carry sediment loads to the Red River. Eventually the combined outflow channel would lose energy due to excessive sedimentation, and the inflow and outflow channel of Low Sill would become high enough to eventually stop all bedload movement. The test was conducted several times for repeatability.

Alternative 4: MVN Masterplan Dikes

Plate 51 shows the resultant bathymetry of Alternative 4. This proposed alternative involved 4 dikes along the LDB between RM 315.0 and RM 312.9 that were presented in the MVN Masterplan. Test results indicated that the dikes developed a thalweg along the RDB between RM 314.0 that eventually crossed over to the LDB at RM 312.0. However this channel was relatively shallow with depths as high as -5 feet to 0 feet elevation. Tests were run with Low Sill closed and open and no improvement in sediment transport diversion was observed through either of the inflow and outflow channels.

Table 4: Alternative 4 Summary

Structure Type	River Mile	Length (ft)	RDB or LDB	Elevation (ft)
Dike 1	315.05	500	LDB	+29.5
Dike 2	314.75	675	LDB	+29.5
Dike 3	313.75	925	LDB	+29.5
T-Dike 4	312.9	1200x1000	LDB	+29.5

Alternative 5: Expansion of Outflow Channel

Plate 52 shows the resultant bathymetry of Alternative 5. This proposal alternative involved increasing the Low Sill outflow channel by 500ft in width along the LDB. This would increase the total width to roughly 2000ft. This increase would possibly allow more flow to enter and meander toward the combined outflow channel. Two conditions were tested: 1) Low Sill gate open; 2) Low Sill and Hydropower open at the same time. Note: Auxiliary was closed at all times.

Table 5: Alternative 5 – Low Sill Bankline Excavation

Structure Type	River Mile	Length (mi)	RDB or LDB	Elevation (ft)
Excavation	Low Sill Gate to Combined Outflow Channel	2.5	LDB	-10

For condition 1, where only the Low Sill gate was open, test results indicated that there were meandering paths developed but disappeared soon after energy dissipated. The inflow and outflow channel experienced higher and higher deposition depths approaching +35 feet elevation. For condition 2, where Hydropower and Low Sill were open at the same time, test results indicated that sediment deposition occurred in the Low Sill inflow and outflow channels. Eventually no sediment transport was observed for both the inflow and outflow channels of Low Sill. The widened Low Sill outflow channel was found to be incapable of diverting sediment loads. The main channel bathymetric surveys show similar trends as in Condition 3 and 5 in the Operational Section above.

Alternative 6: Constriction

Plate 53 shows the resultant bathymetry of Alternative 6. The proposed alternative was to constrict the Low Sill outflow channel from 1200 feet to 900 feet in width. The wall structure was estimated to be 2.5 miles in length and would be placed along the RDB from the gate to the combined outflow channel junction. The constricted channel would hopefully increase the energy and bedload transport capability.

Table 6: Alternative 6 – Low Sill Constriction Test

Structure Type	River Mile	Length (mi)	RDB or LDB	Elevation (ft)
Wall Dike 1	Low Sill Gate – Combined Outflow Channel	2.5	RDB	+29.5

Test results indicated that the sediment wave in the Low Sill outflow channel stopped approximately one mile away from the combined outflow channel. Velocities down the Low Sill outflow channel did not increase and the outflow channel became less efficient. Even when only the Low Sill channel was open, the sediment wave would not approach the combined outflow channel.

CONCLUSIONS

1. Bedload Diversion

As outlined in this report, several experts involved in the "Lower Mississippi River Sediment Study" of 1999 stated that the goal of diverting 65 % of the total bed load of the Mississippi through the ORCC was suspect and not achievable. This 65 % diversion was based upon results of a moveable bed model study conducted in 1978. Plate 54 highlights the layout of the model used in the 1978 study. The inflow channels of the Low Sill and Auxiliary were modeled, but the outflow channels were not modeled. Tests conducted in this 2010 model study of Low Sill in single operation and of Low Sill and Auxiliary in combined operation showed that when including the outflow channel, the efficiency of bedload diversion dramatically decreased with time. The natural meandering tendency and buildup of point bars and deposition within the outflow channels occurred. In repeated tests, where the channels were excavated to an "as built" condition, a fair amount of bedload diversion occurred initially at the Low Sill inflow channel and to a lesser degree at the Auxiliary inflow channel, but as deposition accumulated in the outflow channels, the rate of diversion was reduced less and less until eventually little or no bedload diversion occurred down any of the channels. This is the same phenomena that has been observed in the formation of point bars in other models. If a point bar is fully excavated in a channel with fixed banks, the point bar will redevelop, with a large amount of bedload movement first initially observed over the original location. However, as the point bar becomes fully formed, most of the bedload is then transferred along the channel side of the point bar.

Calculations from hydrographic surveys of bedload diversion down the inflow and outflow channel of Low Sill conducted in this study showed that during the first 11 years of operation, approximately 30 % of the total bedload of the Mississippi River was diverted down Low Sill (based upon estimates collected in 2010), although none of this bedload diversion had reached the Red/Atchafalaya, but rather remained contained within the inflow and outflow channel. The 1975 hydrographic survey showed that a

meandering thalweg had developed in the outflow channel, manifesting the buildup of high point bars and scour along the outer banks. Several areas of the outflow channel had eroded and widened as a result. If the outflow channel were allowed to freely meander, then this approximate 27 % bed load diversion may have been able to be sustained. Unfortunately this was not practical from a real estate or operational perspective. The outer banklines were revetted and the outflow channel constrained from meandering. Tests conducted in this model study with Low Sill in single operation and the outflow channel banks constrained showed that initial meandering and the buildup of point bars developed, but because the channel was constrained, the within channel meandering eventually subsided. The channel would shoal with sediment to a point of an entire blockage. It was clear that with time even with Low Sill operating alone and a continuous 30 % flow diversion, the constrained outflow channel would eventually become a sediment trap, supplying little or no bedload diversion into the Red/Atchafalaya River.

Tests conducted with hydropower in operation showed an even greater tendency for no bedload diversion from Low Sill and Auxiliary. No combination of any operational setting eliminated the buildup of deposition in the constrained outflow channels of Low Sill and Auxiliary.

2. <u>Suspended Sediment Trends</u>.

Trend analysis were conducted comparing the percentages of total suspended loads over the years of both the Mississippi and Atchafalaya, but unfortunately these two systems contain other inputs occurring in their basins that make direct correlation to the diversion effects of ORCC problematic. However, isolated suspended sediment contributions of ORCC into the Red/Atchafalaya were analyzed using the Knox Landing Station located in the combined outflow channel. Trends showed that a relatively stable contribution of suspended sediment load from ORCC has occurred since the mid 1960's, between an average of 35% to 38% of the total combined load with the

Atchafalaya. This trend indicates that although hydropower had not diverted significant bedload, the suspended sediment load contribution has apparently been adequate.

3. Mississippi River Trends.

Hydrographic survey analysis and isopacs indicated that since 1999 relatively little major change has occurred in the bathymetry of the main channel between RM 315 and RM 311. The middle bar located between RM 314 and RM 312 has varied in elevation from approximately 0 to +20 feet. At the maximum height in this area the channel shoaled higher than -10 LWRP. Future sustained low water conditions may require maintenance dredging in this location.

4. HSR Modeling.

In all model tests, no operational or structural measures created continuous sustained sediment diversion through the ORCC. In every test, all observed trends indicated that the ORCC did not divert significant bed load into the combined outflow channel. The overall general trends were always consistently the same, bedload would accumulate in the inflow and outflow channels, but eventually with time the deposition would become higher and higher until eventually complete blockage caused no bedload diversion within ORCC. This trend occurred with or without Hydropower operation. The only difference was that without hydropower operation the eventual complete filling of the inflow and outflow channels of Low Sill and Auxiliary occurred over a longer time period.

5. Recommendations.

The ORCC, utilizing Hydropower operation in combination with localized sediment flushing at Low Sill and Auxiliary, has provided reliable flow diversion. In addition, according to the Knox Landing Gage, has provided approximately the same amount of suspended sediment diversion since the mid 1960's. However, it was concluded from

studying hydrographic surveys and all the model tests run that there is a real possibility and threat that both Low Sill and Auxiliary could become totally buried with sediment during an extreme event. This was particularly alarming since most of the flow diversion is dependent upon Hydropower and if ever this structure were inoperable there could be a scenario where minimal flow diversion could take place between the Mississippi and the Red/Atchafalaya River.

The amount of bedload diverted naturally between the Mississippi and Red/Atchafalaya prior to ORCC is unknown. There is high probability that the natural connecting channel between the two rivers diverted a fair amount of bedload because the channel was free to meander as point bars developed. However, modern day hydrographic surveys and the trends observed during all testing in this HSR model study indicated that the ORCC acts as a sediment trap and not as a continuous bedload diversion project.

Engineers should decide how much bedload, if any, needs to be diverted into the Red/Atchafalaya River. A reasonable management number could be in the order of 30% of the Mississippi Load, or approximately 1.5 million cubic yards per year as estimated in this report. All tests indicated that the only reliable way for this to occur, considering real estate is limited and channels must be constrained from meandering, would be to periodically dredge material out of the Low Sill and Auxiliary inflow and outflow channels and place this material in the outflow channel of Hydropower (Plate 55). This dredging would have to be carried out in order to ensure that the material is assimilated gradually into the Red/Atchafalaya River without incurring major sediment blockage. The fact that the flow down the outflow channel of Hydropower is continuous and devoid of bedload should enable a better chance of diversion of the dredge disposal into the Red/Atchafalaya. Channel meandering within the Hydropower outflow channel or the combined outflow channel may result in future bank erosion and should be monitored.

6. Interpretation of Model Testing Results

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

This model study was intended to serve as a tool for the river engineer as a guide in the assessing the general trends that could be expected to occur in the Mississippi River from a variety in imposed design alternatives. Measures for the final design may be modified based upon engineering knowledge and experience, real estate and construction considerations, economic and environmental impacts, or any other special requirement.

FOR MORE INFORMATION

For more information about Hydraulic Sediment Response modeling or the Applied River Engineering Center, please contact Ivan Nguyen or Robert Davinroy at:

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Or you can visit us on the Web at:

http://www.mvs.usace.army.mil/arec/index.html

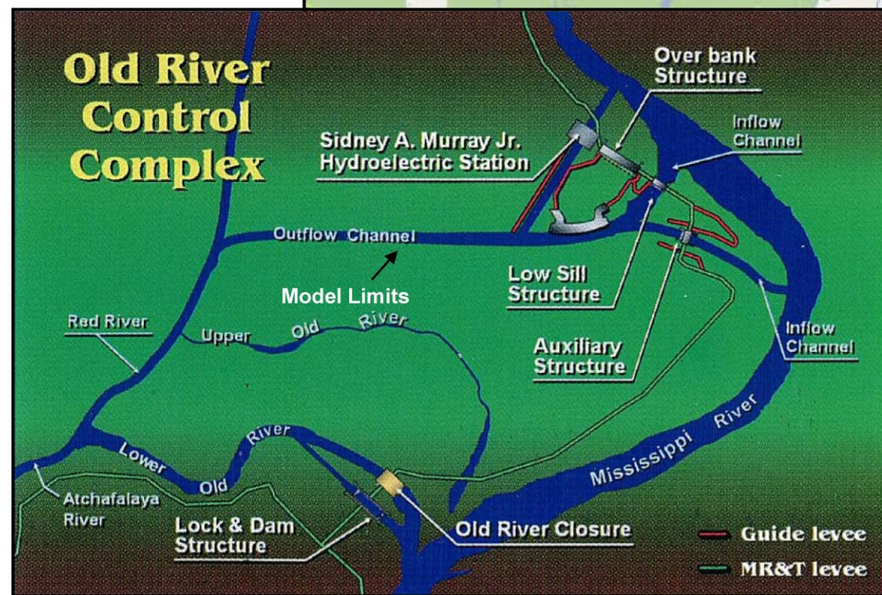
APPENDIX OF PLATES

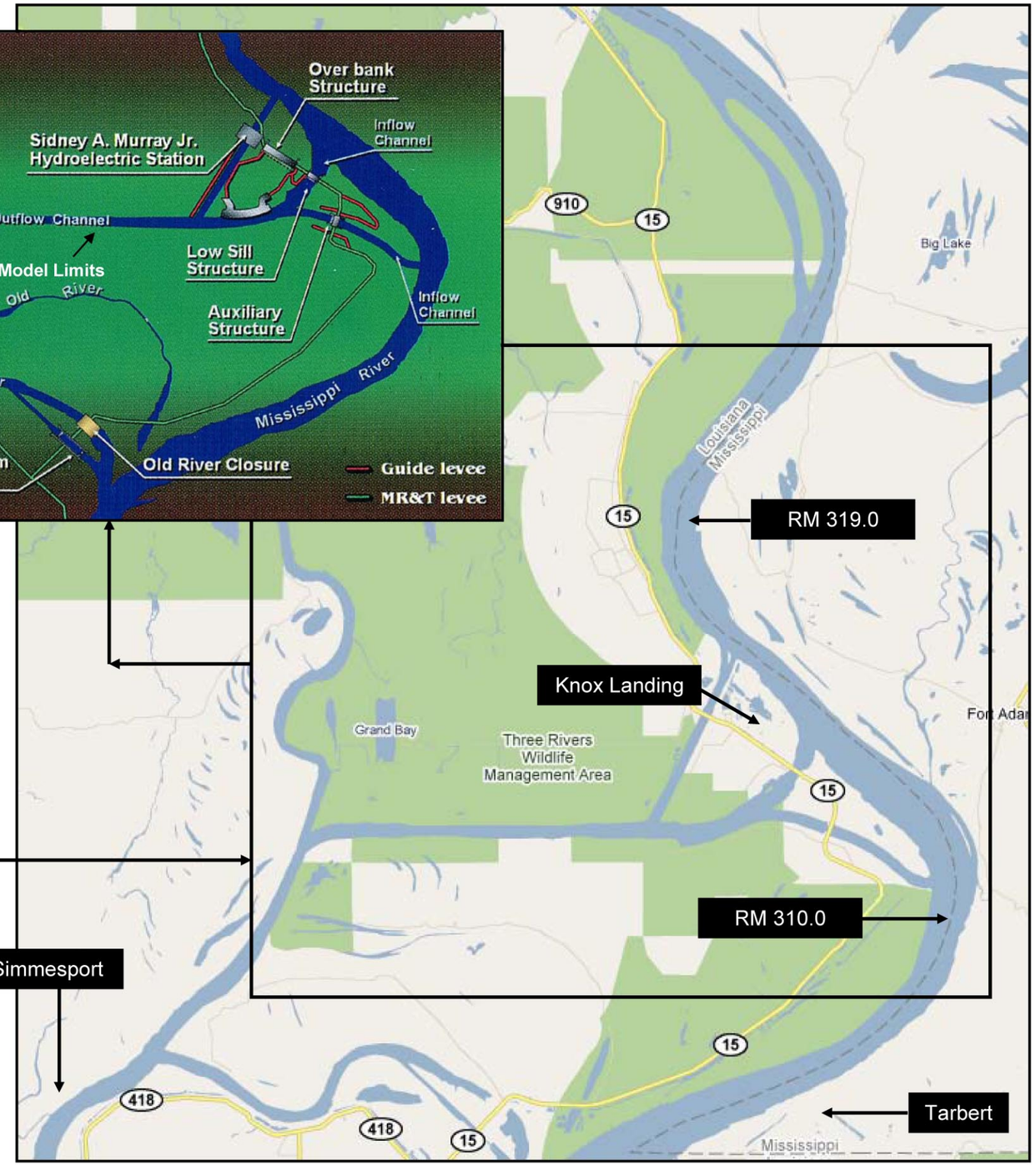
1	Plate:	Location and Vicinity Maps
2	Plate:	Study Reach
3	Plate:	Field Photographs (MVN)
4	Plate:	Field Photographs (February 2010)
5	Plate:	Geomorphology
6	Plate:	Geomorphology
7	Plate:	1964 Hydrographic Survey
8	Plate:	Historic Aerial Photographs
9	Plate:	1975 Hydrographic Survey (Point Bars)
10	Plate:	Inflow and Outflow Volume Calculations of Low Sill
11	Plate:	Suspended Sediment Load Trends
12	Plate:	Suspended Sediment Load Trends-Knox
13	Plate:	1975 Low Sill Channel Width
14	Plate:	2003 Low Sill Channel Width
15	Plate:	1948 Survey
16	Plate:	1964 Survey
17	Plate:	1975 Hydrographic Survey
18	Plate:	1983 Hydrographic Survey
19	Plate:	1992 Hydrographic Survey
20	Plate:	1999 Hydrographic Survey
21	Plate:	2001 Hydrographic Survey
22	Plate:	2003 Hydrographic Survey
23	Plate:	2006 Hydrographic Survey
24	Plate:	2008 Hydrographic Survey – After Dredge
25	Plate:	2008 Hydrographic Survey – Before Dredge
26	Plate:	2010 Hydrographic Survey
27	Plate:	ISOPACH 2001 vs. 1999
28	Plate:	ISOPACH 2003 vs. 1999

29	Plate:	ISOPACH 2004 vs. 1999
30	Plate:	ISOPACH 2006 vs. 1999
31	Plate:	ISOPACH 2008 vs. 1999
32	Plate:	ISOPACH 2010 vs. 1999
33	Plate:	2010 Hydrographic Survey (LWRP)
34	Plate:	Thalwegs
35	Plate:	Historical Banklines
36	Plate:	Model Photograph
37	Plate:	Replication Test
38	Plate:	2003 & 2010 Hydrographic Survey and Replication Test
39	Plate:	Low Sill Sediment Wave Timing Test – 30 Minutes
40	Plate:	Condition 2
41	Plate:	Condition 3
42	Plate:	Condition 4
43	Plate:	Condition 5
44	Plate:	Condition 6
45	Plate:	Condition 7
46	Plate:	Condition 8
47	Plate:	Dredging Test – 20 Minutes
48	Plate:	Alternative 1 – 3 Chevrons
49	Plate:	Alternative 2 – 5 Weirs
50	Plate:	Alternative 3 – Bankline Excavation and Dikes
51	Plate:	Alternative 4 – MVN Master Plan Dikes
52	Plate:	Alternative 5 – Expansion
53	Plate:	Alternative 6 – Constriction
54	Plate:	WES Model Study
55	Plate:	Recommended Plan

To further enhance your understanding, please visit

http://www.usace.army.mil/arec/models_old.html for videos referred in the report





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LOCATION AND VICINITY MAPS

PLATE NUMBER
1

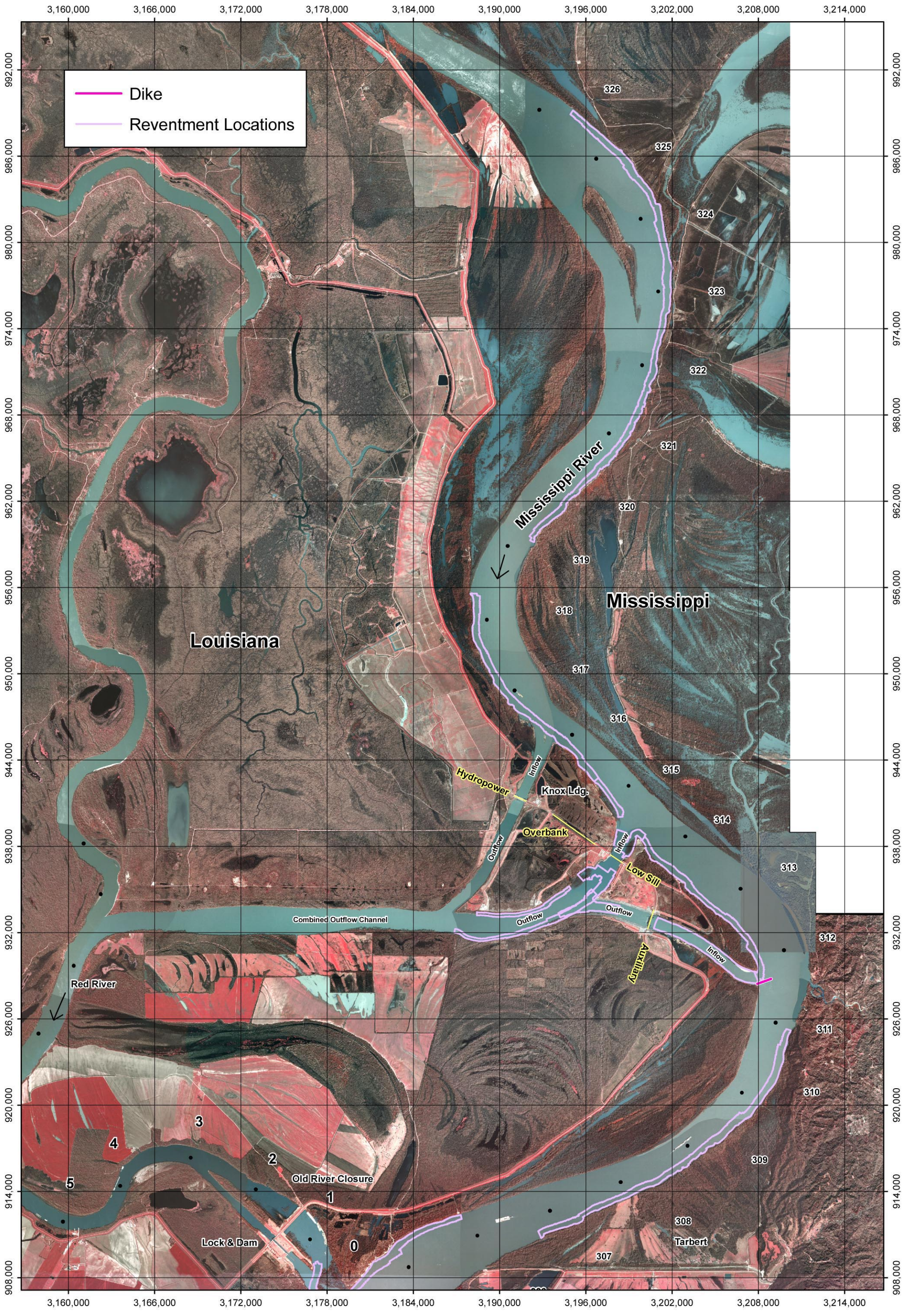

PLATE NUMBER 2

0 3,000 6,000 12,000 Feet

STUDY REACH

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Figure 1: Auxiliary Inflow Channel

Figure 2: Auxiliary Structure

Figure 3: Low Sill Inflow Channel

Figure 4: Low Sill Outflow Channel

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FIELD PHOTOGRAPHS
MVN DISTRICT

PLATE NUMBER
3

Figure 1: Auxiliary Structure

Figure 2: Sidney A. Murray Jr. Hydroelectric Station

Figure 3: Low Sill Wing

Figure 4: Sidney A. Murray Jr. Hydropower Station

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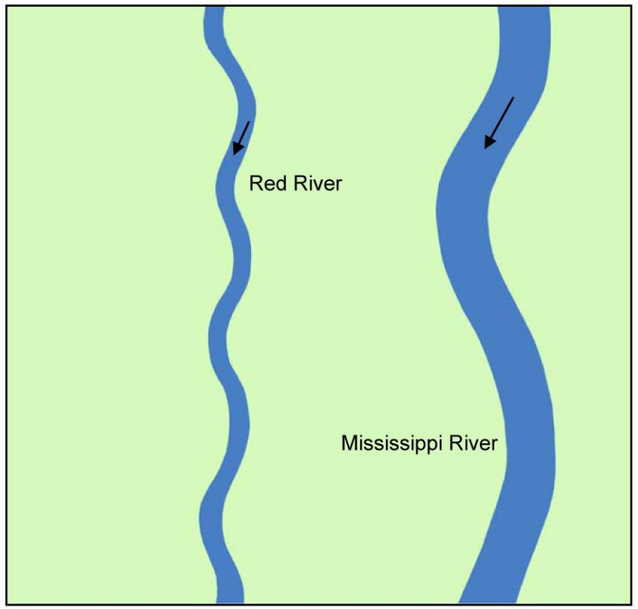
FIELD PHOTOGRAPHS
FEB. 2010

PLATE NUMBER
4

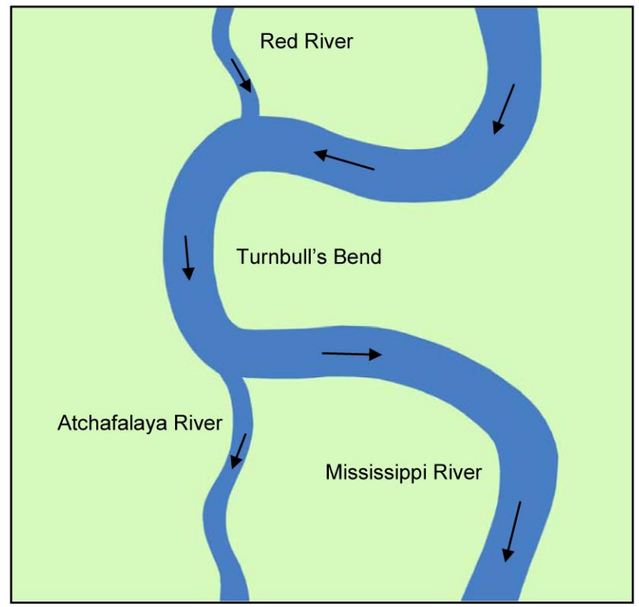
Geomorphology of Old River

Prior Millennium



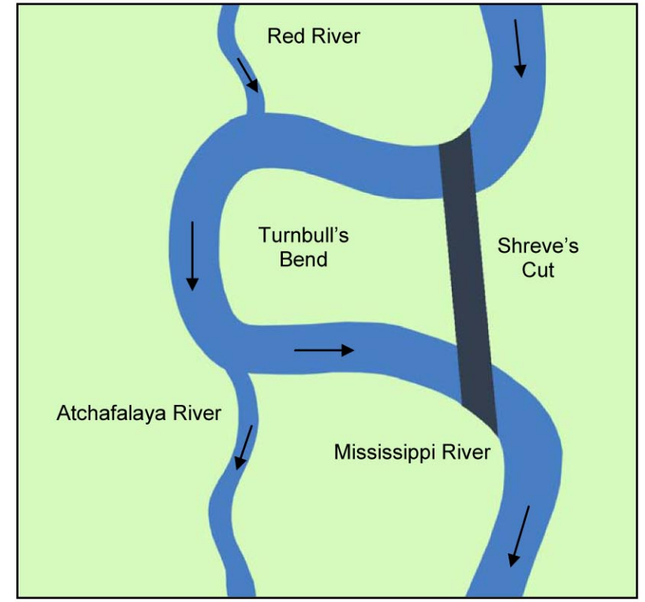
Red River and Mississippi River were parallel rivers each flowing south to the Gulf of Mexico.

15th Century



Westwardly meander belt of the Mississippi intercepts the Red. The upper Red becomes a tributary, the lower Red becomes a distributary, named the Atchafalaya.

1831



Shreve cuts off Turnbull's Bend

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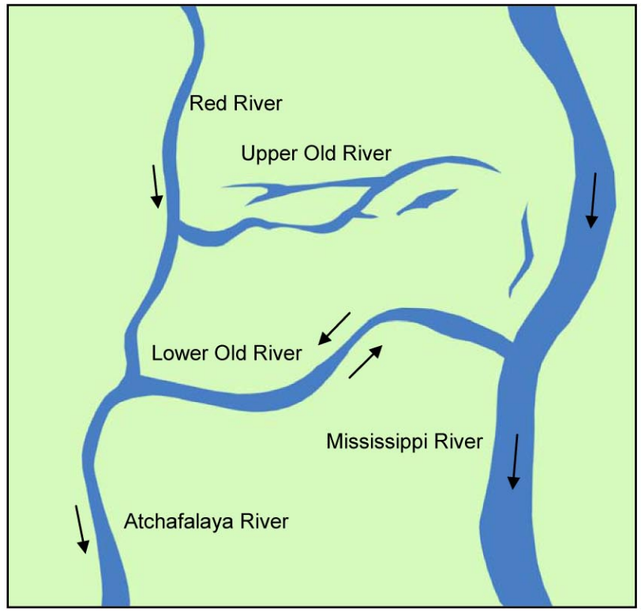
GEOMORPHOLOGY

PLATE NUMBER
5

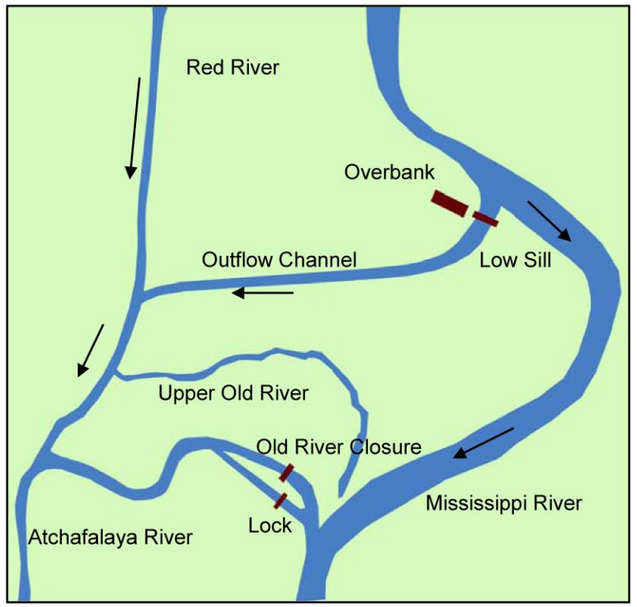
Geomorphology of Old River

1950



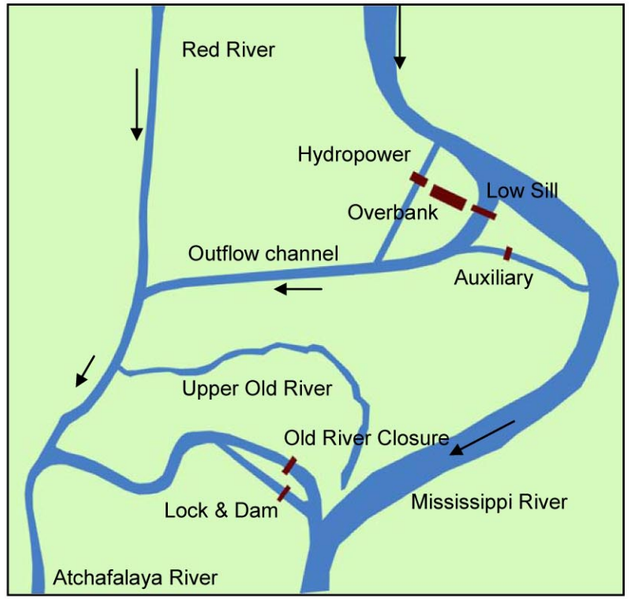
Upper Old River channel abandoned, Lower Old River links the three rivers, log jam in Atchafalaya is removed. Atchafalaya becomes deeper and wider carrying more and more Mississippi flow.

1963



New Orleans District completes construction of Overbank Structure and Low Sill Structure in 1964. Completes Navigation Lock and Old River Closure in 1963.

2010



Auxiliary structure completed in 1986. Hydropower plant completed in 1990.

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NEW ORLEANS DISTRICT
OLD RIVER HSR MODEL

GEOMORPHOLOGY

PLATE NUMBER
6

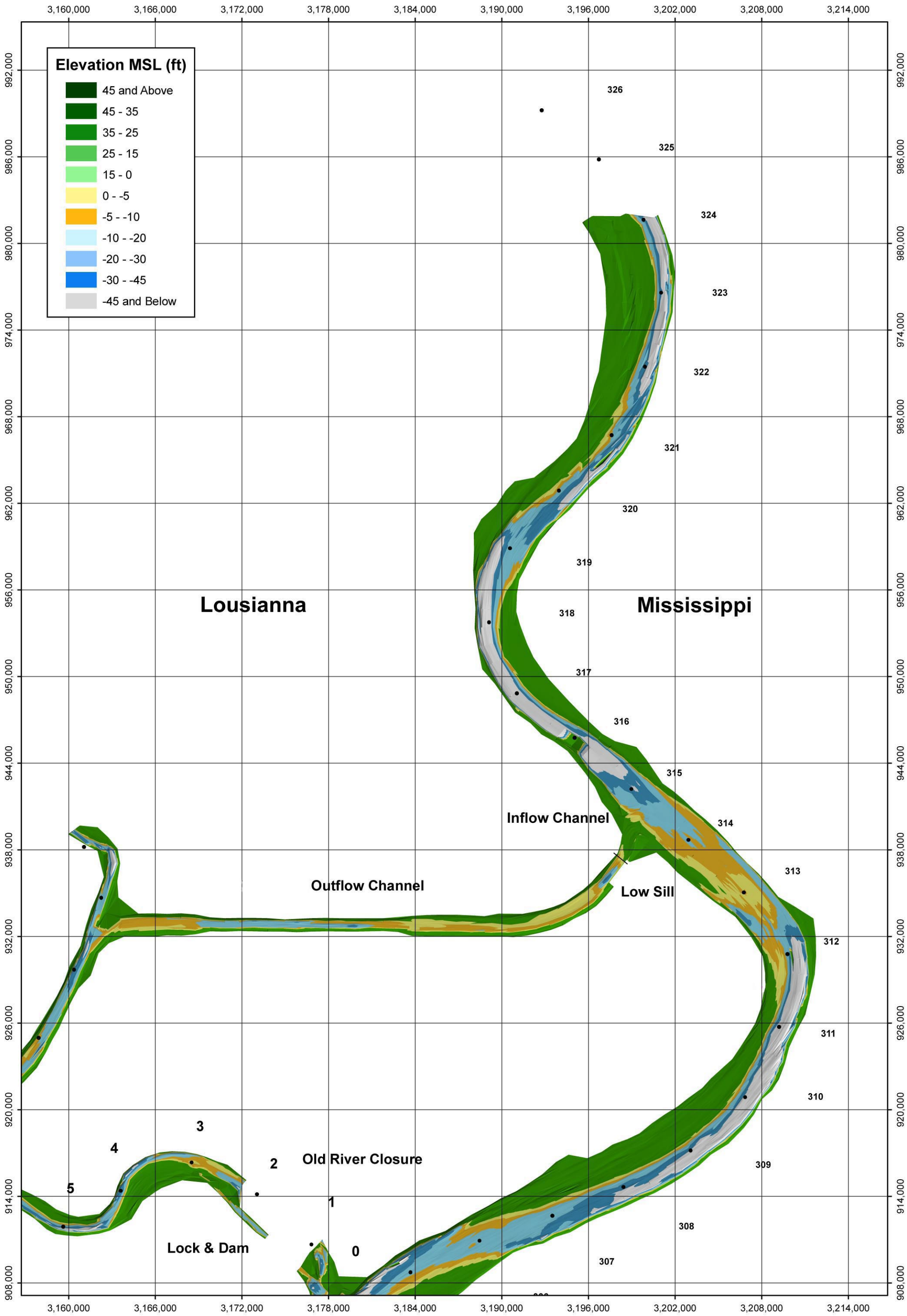

PLATE NUMBER 7

0 3,000 6,000 12,000 Feet

1964 HYDROGRAPHIC SURVEY

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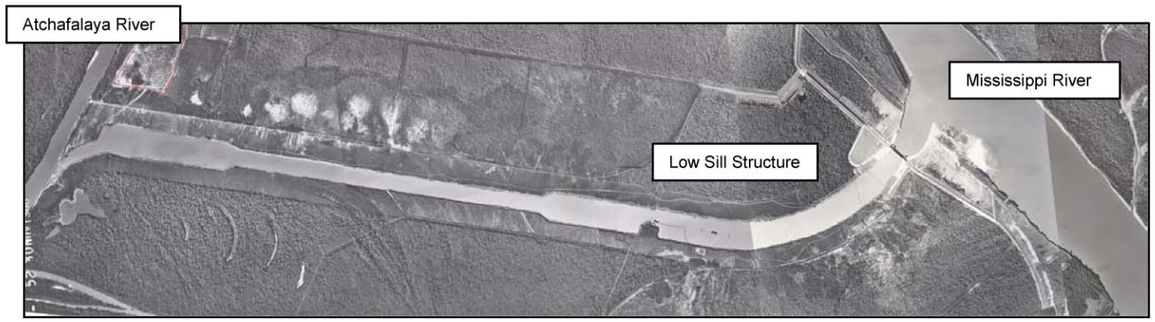
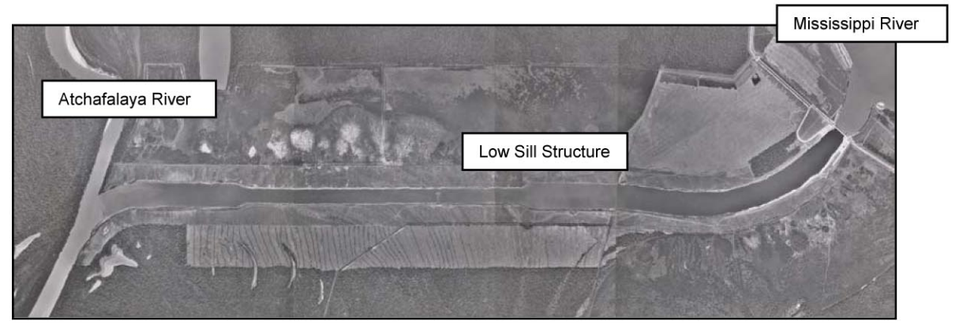
Historic Aerial Photographs

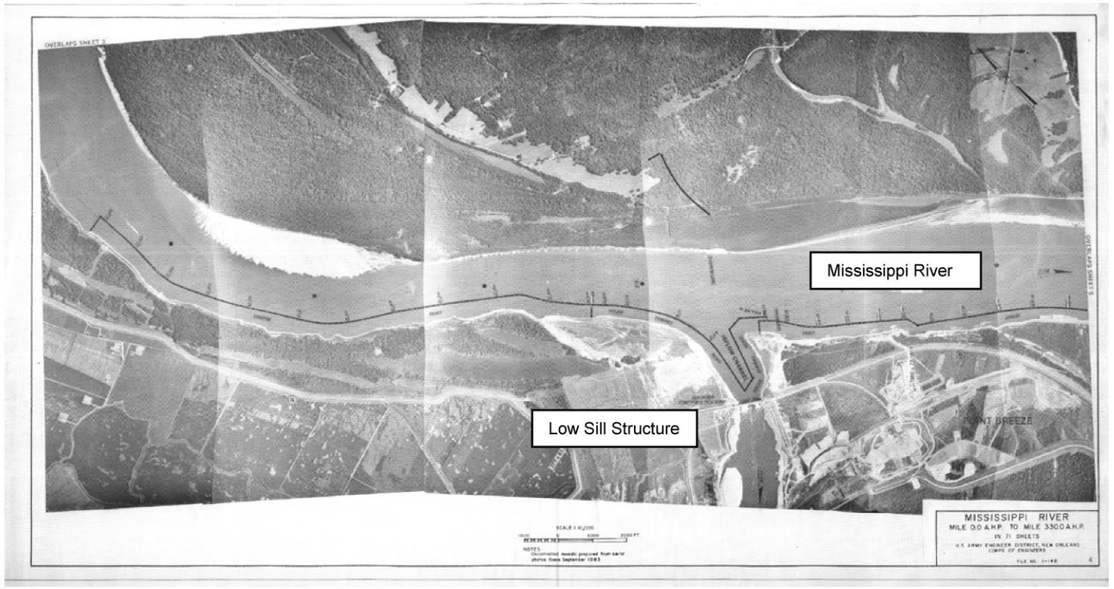
1960



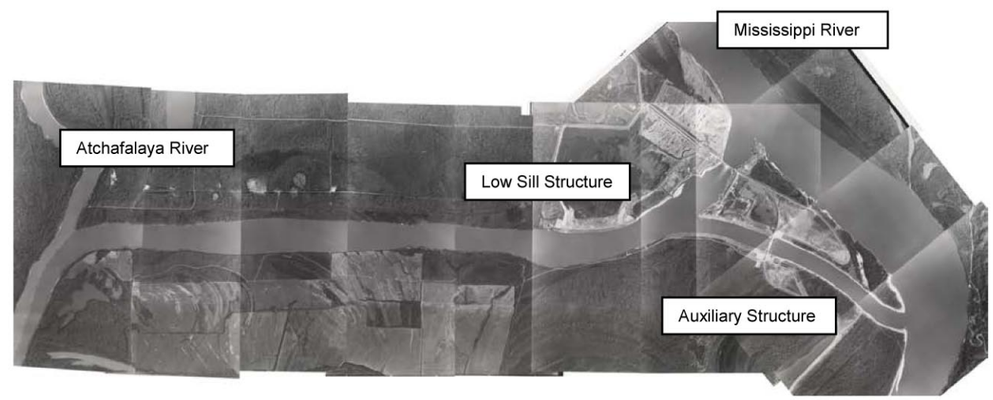
1962



1983



1987



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HISTORIC AERIAL PHOTOGRAPHS

PLATE NUMBER
8

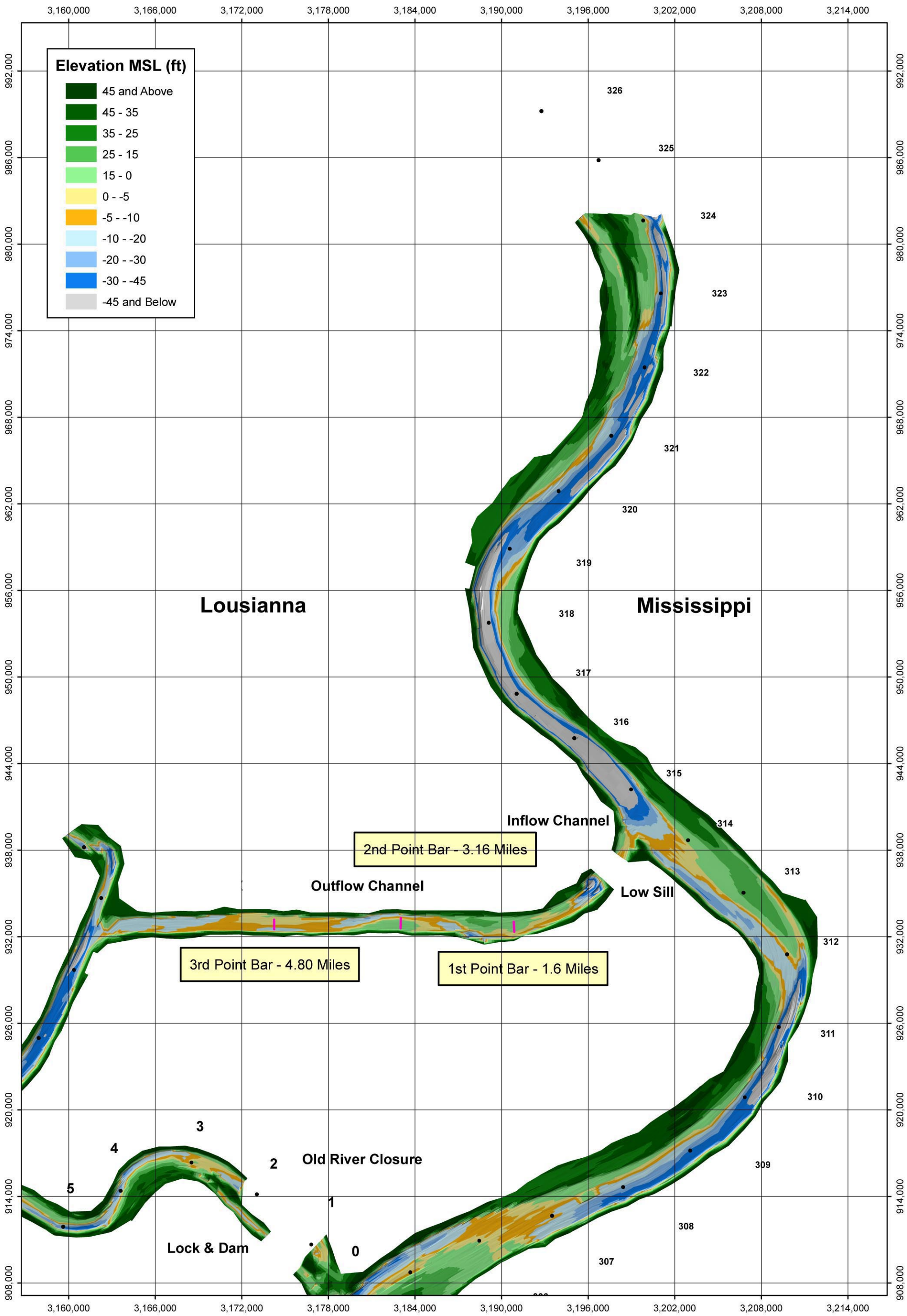

PLATE NUMBER 9

0 3,000 6,000 12,000 Feet

1975 HYDROGRAPHIC SURVEY
POINT BAR

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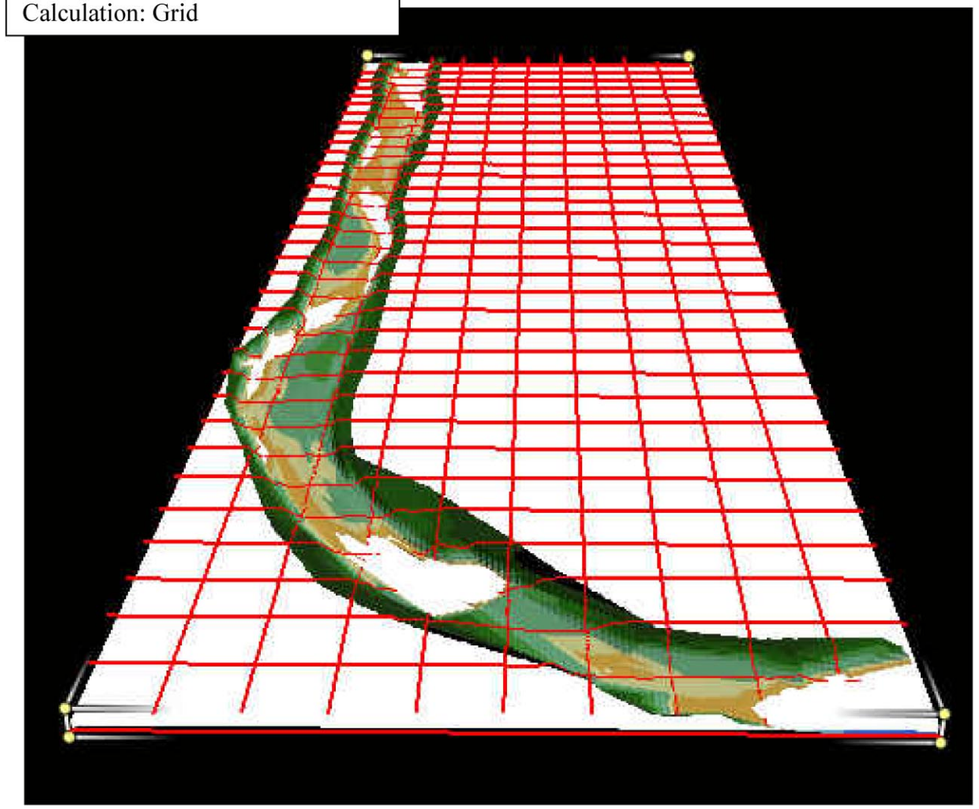
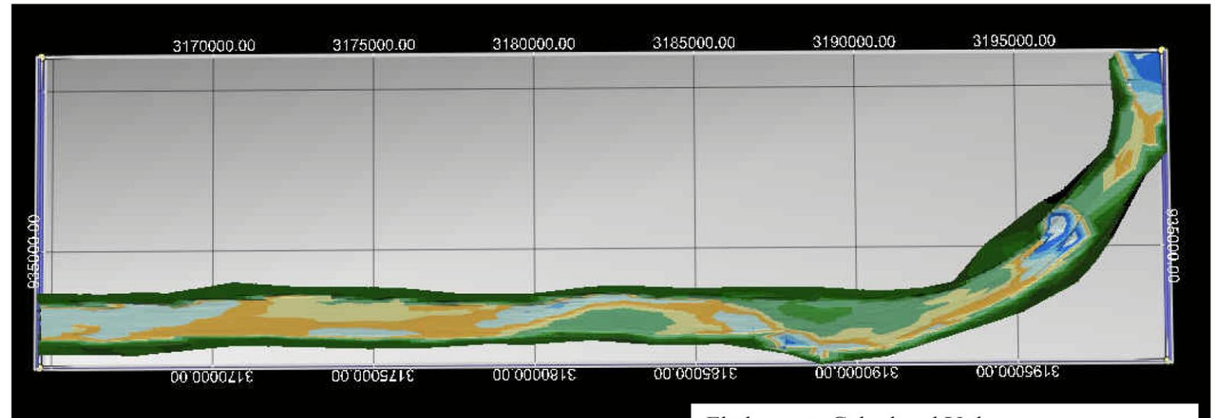
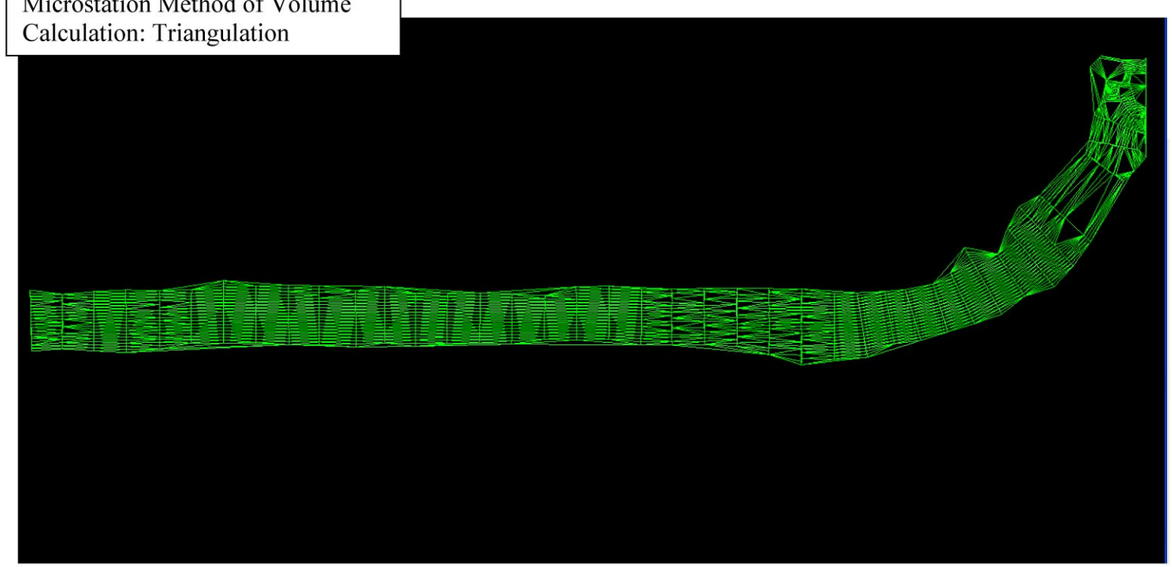
Fledermaus Method of Volume Calculation: Grid



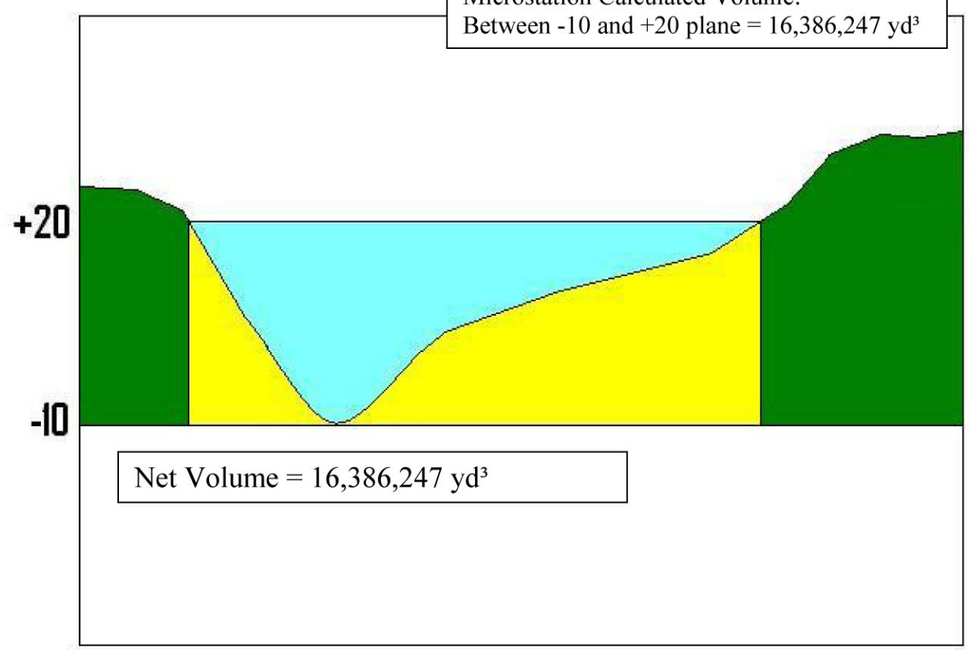


Fledermaus Calculated Volume:
Between -10 and +20 plane = 12,947,640 yd³

Microstation Method of Volume Calculation: Triangulation



Microstation Calculated Volume:
Between -10 and +20 plane = 16,386,247 yd³



Net Volume = 16,386,247 yd³

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SUBMITTED: A Rockwell		APPROVED: R Davinroy, PE.
FILE NAME: ....Old River Side Channel		PLOT DATE: 01/19/2011

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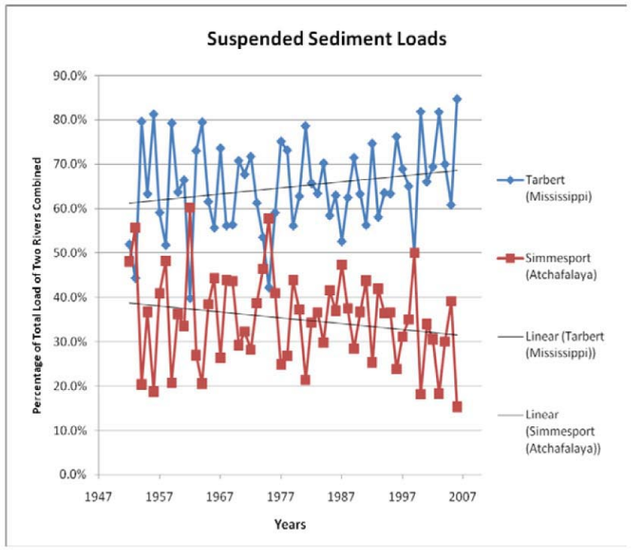
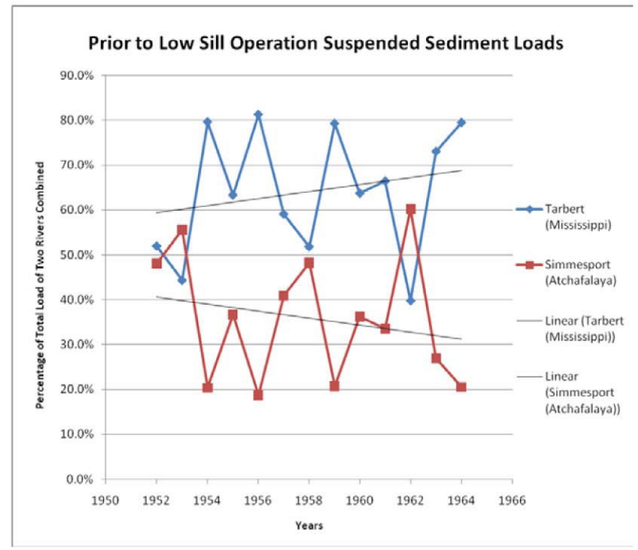
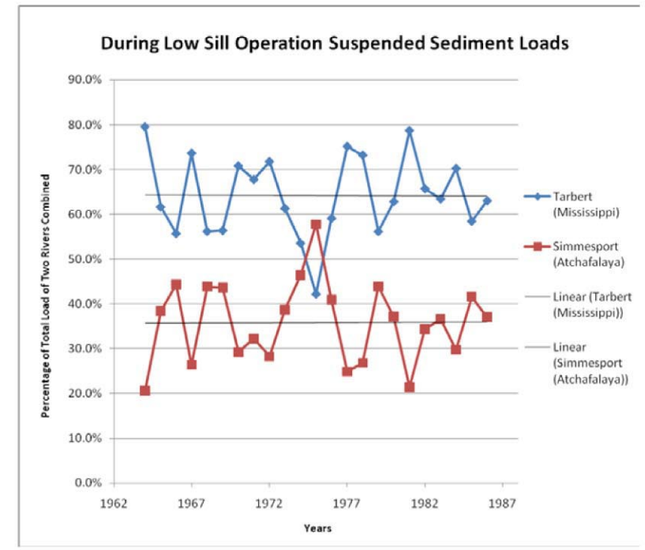
INFLOW AND OUTFLOW VOLUME CALCULATIONS OF LOW SILL

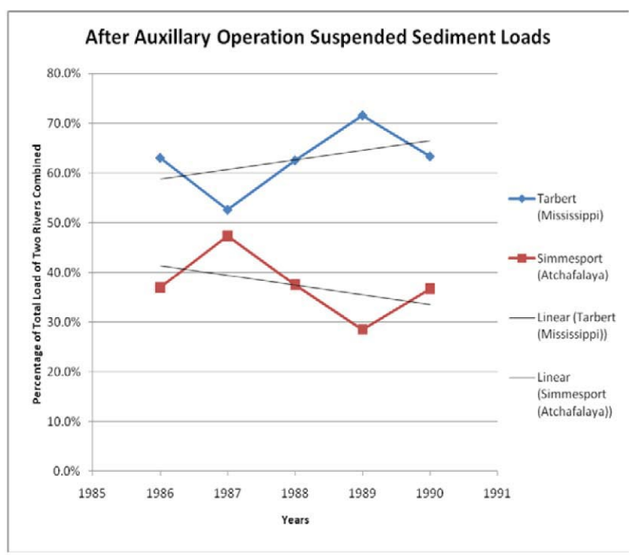
PLATE NUMBER 10

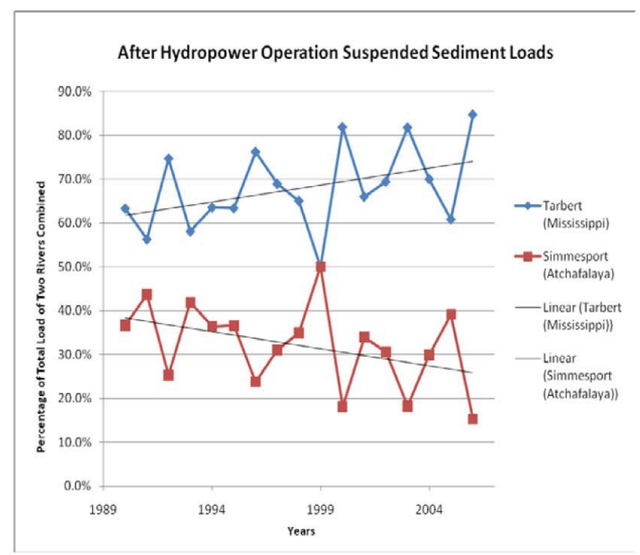
Suspended Sediment, Load Trends, Tarbert (Mississippi), Simmesport (Atchafalaya)











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Lower Mississippi River Basin
New Orleans District
Old River HSR Model

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REVIEWED BY: R DAVINROY
CHECKED BY: R DAVINROY
SUBMITTED: D FISCHER
APPROVED: R DAVINROY
FILE NAME: ...OldRiverMapVicinity.PDF
PLOT DATE: 02/07/2011

Suspended Sediment and Load Trends

PLATE NUMBER

11

Suspended Sediment Load Trends, Combined Outflow Channel/Knox Landing, Simmesport (Atchafalaya)

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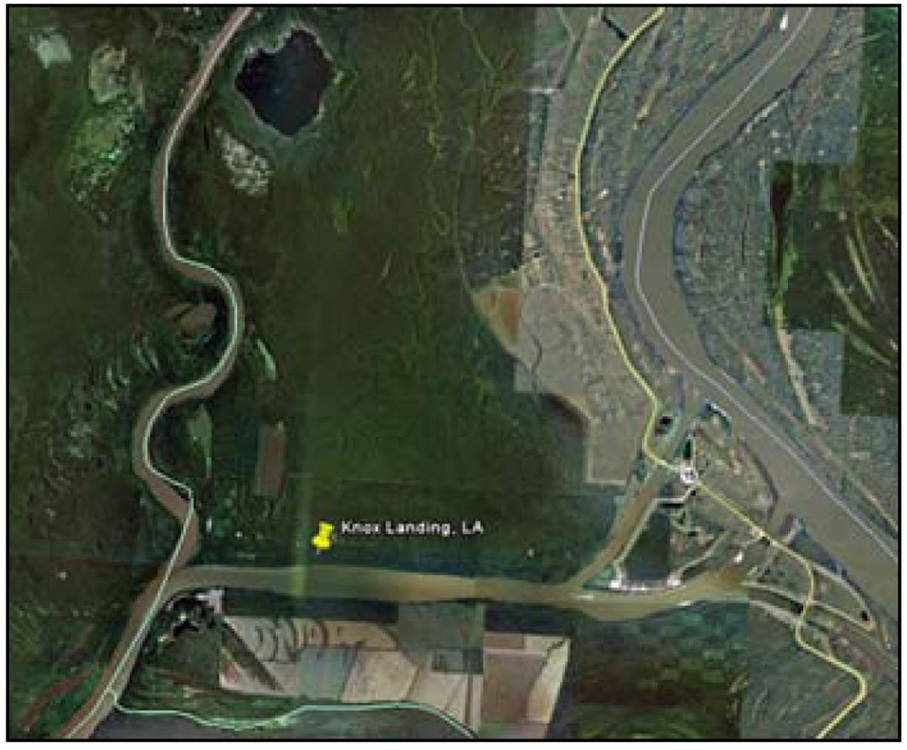

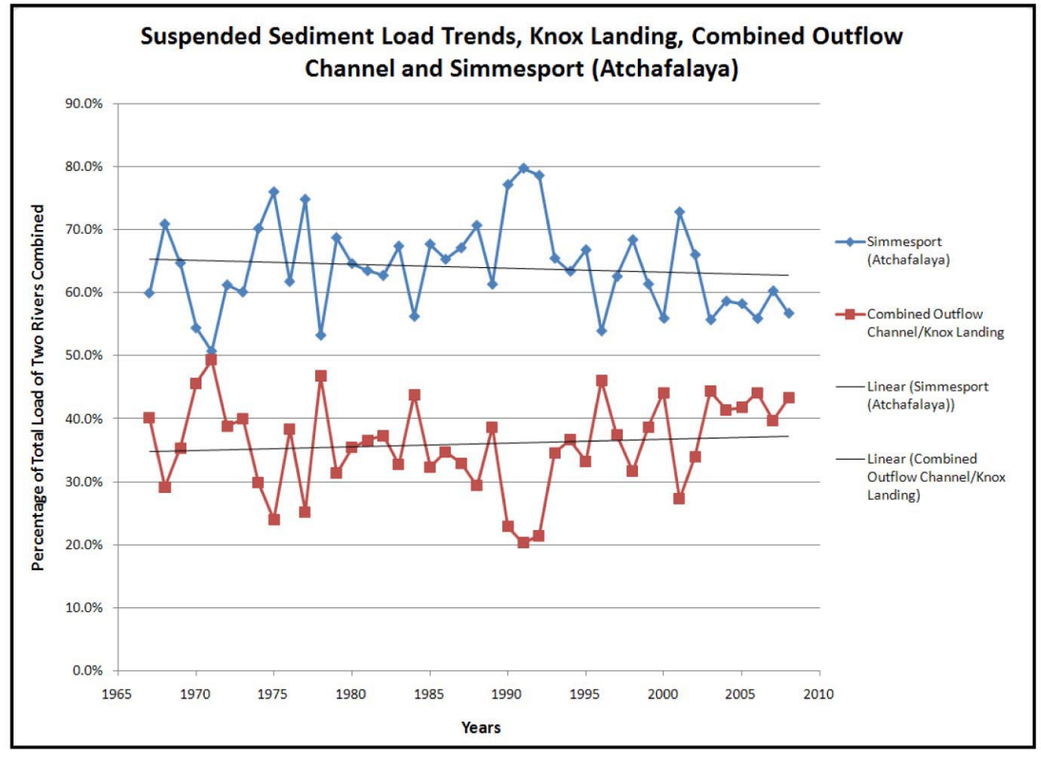

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	SUBMITTED: D FISCHER	APPROVED: R DAVINROY
Lower Mississippi River Basin New Orleans District Old River HSR Model	FILE NAME: ...OldRiver/MapVicinity.PDF	PLOT DATE: 02/07/2011

Suspended Sediment Load Trends

PLATE NUMBER

12

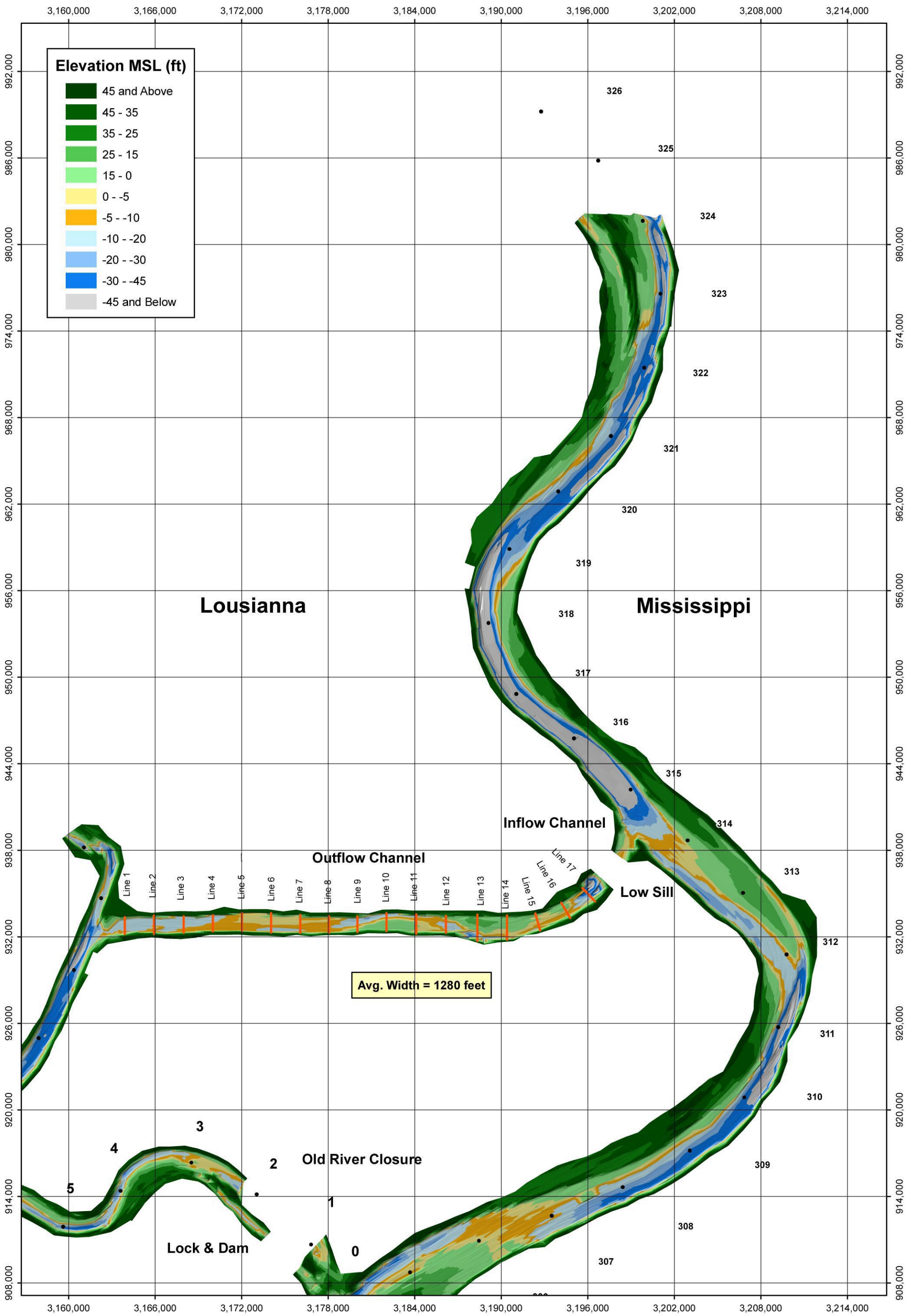

PLATE NUMBER 13

0 3,000 6,000 12,000 Feet

1975 LOW SILL CHANNEL WIDTH

U.S. ARMY ENGINEER DIVISION CORPS OF ENGINEERS ST. LOUIS, MISSOURI	DRAWN BY: I. NGUYEN	REVIEWED BY: J. BROWN, P.E.
	SUBMITTED BY: I. NGUYEN	CHECKED BY: A. COX
LOWER MISSISSIPPI RIVER NEW ORLEANS DISTRICT OLD RIVER HSR MODEL	PLOT DATE: MARCH 2011	APPROVED BY: R. DAVINROY, P.E.
	FILE NAME: ...OLD RIVER HSR MODEL.MXD	

N W E S

APPLIED RIVER ENGINEERING CENTER

US Army Corps of Engineers St. Louis District®

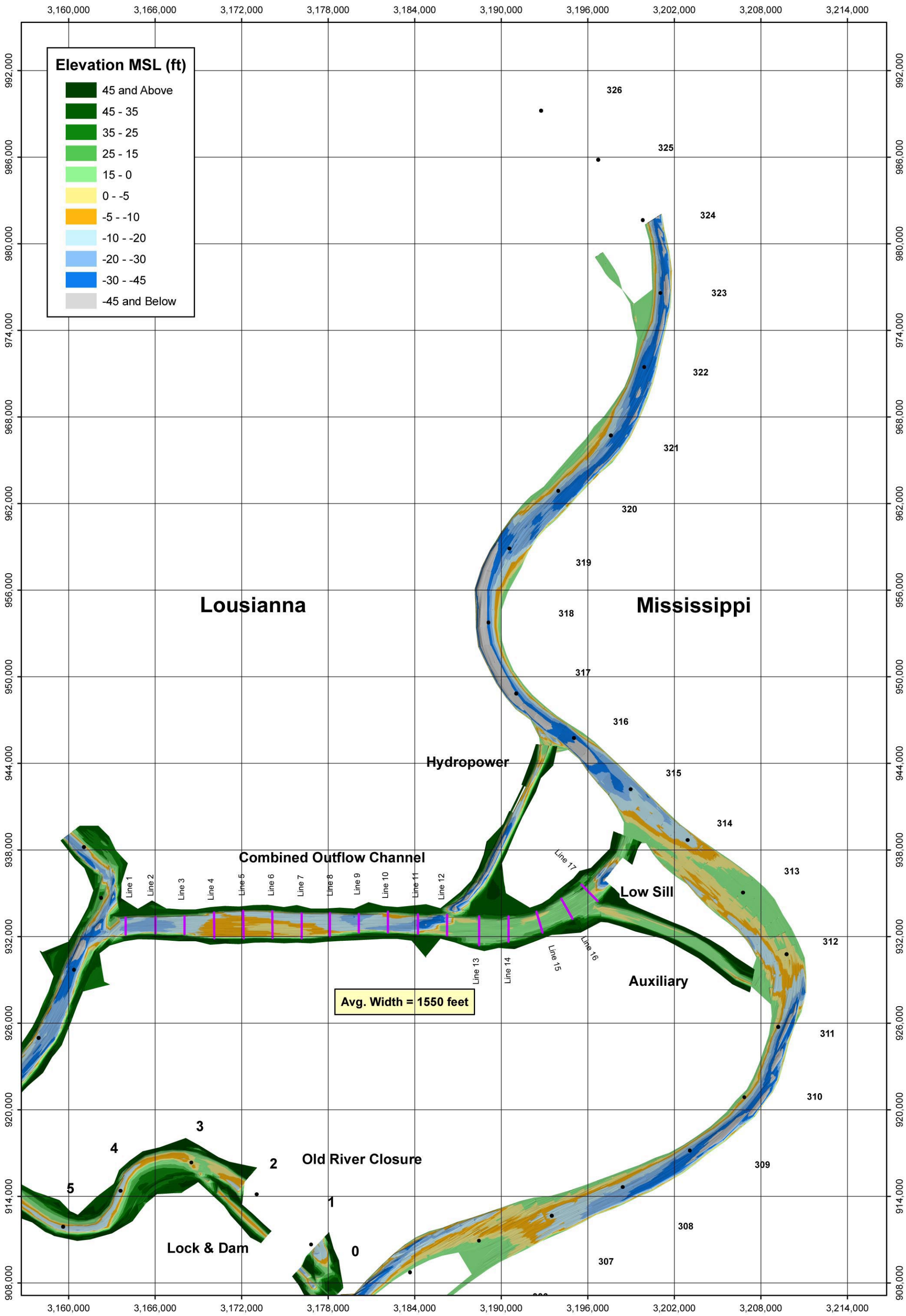

PLATE NUMBER 14

0 3,000 6,000 12,000 Feet

2003 LOW SILL CHANNEL WIDTH

U.S. ARMY ENGINEER DIVISION CORPS OF ENGINEERS ST. LOUIS, MISSOURI	DRAWN BY: I. NGUYEN	REVIEWED BY: J. BROWN, P.E.
	SUBMITTED BY: I. NGUYEN	CHECKED BY: A. COX
LOWER MISSISSIPPI RIVER NEW ORLEANS DISTRICT OLD RIVER HSR MODEL	PLOT DATE: MARCH 2011	APPROVED BY: R. DAVINROY, P.E.
	FILE NAME: ...OLD RIVER HSR MODEL.MXD	

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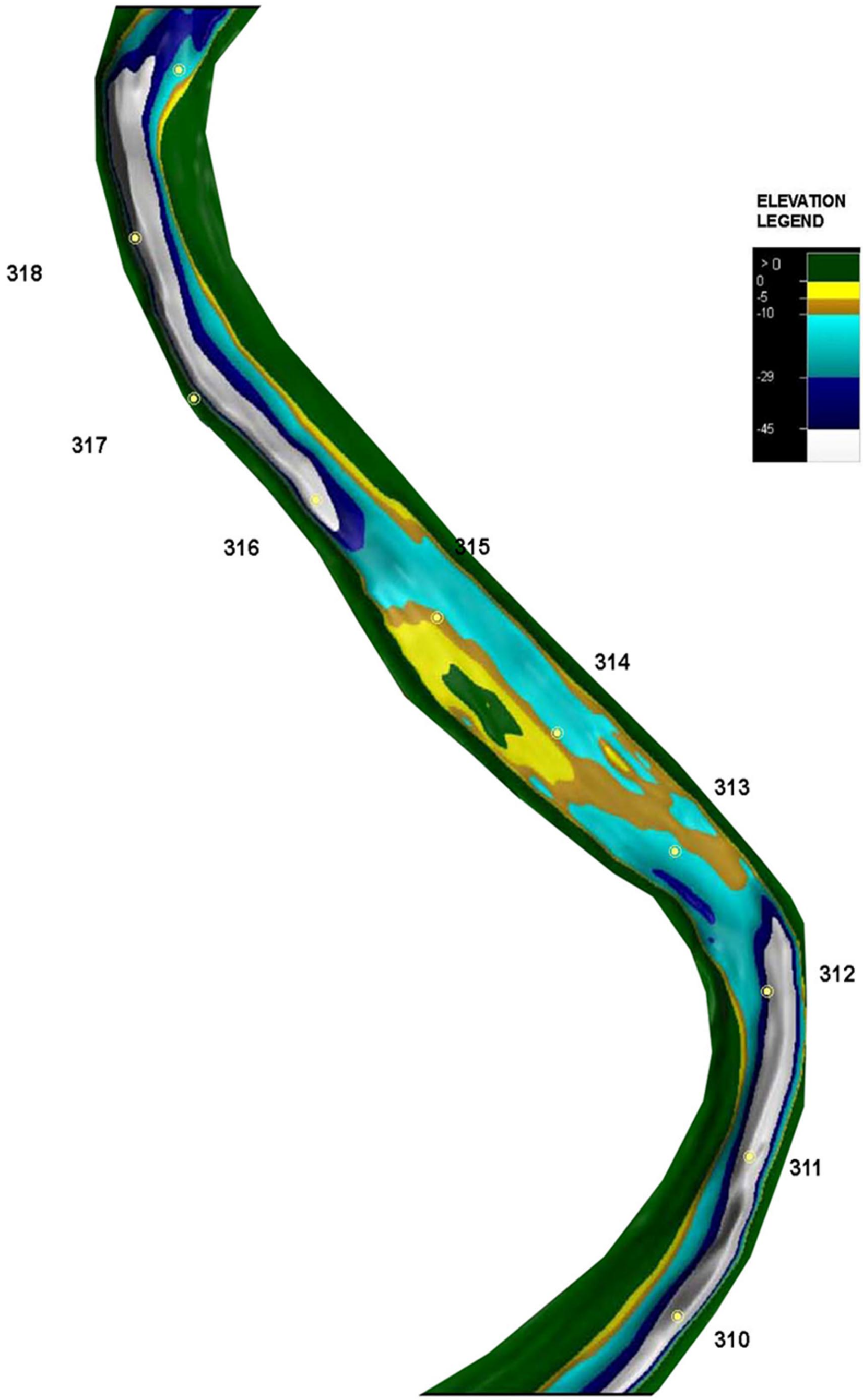

PLATE NUMBER 15

1 mile

1948 HYDROGRAPHIC SURVEY

U.S. ARMY ENGINEER DIVISION CORPS OF ENGINEERS ST. LOUIS, MISSOURI	DRAWN BY: I. NGUYEN	REVIEWED BY: J. BROWN, P.E.
	SUBMITTED BY: I. NGUYEN	CHECKED BY: A. COX
LOWER MISSISSIPPI RIVER NEW ORLEANS DISTRICT OLD RIVER HSR MODEL	PLOT DATE: MARCH 2011	APPROVED BY: R. DAVINROY, P.E.
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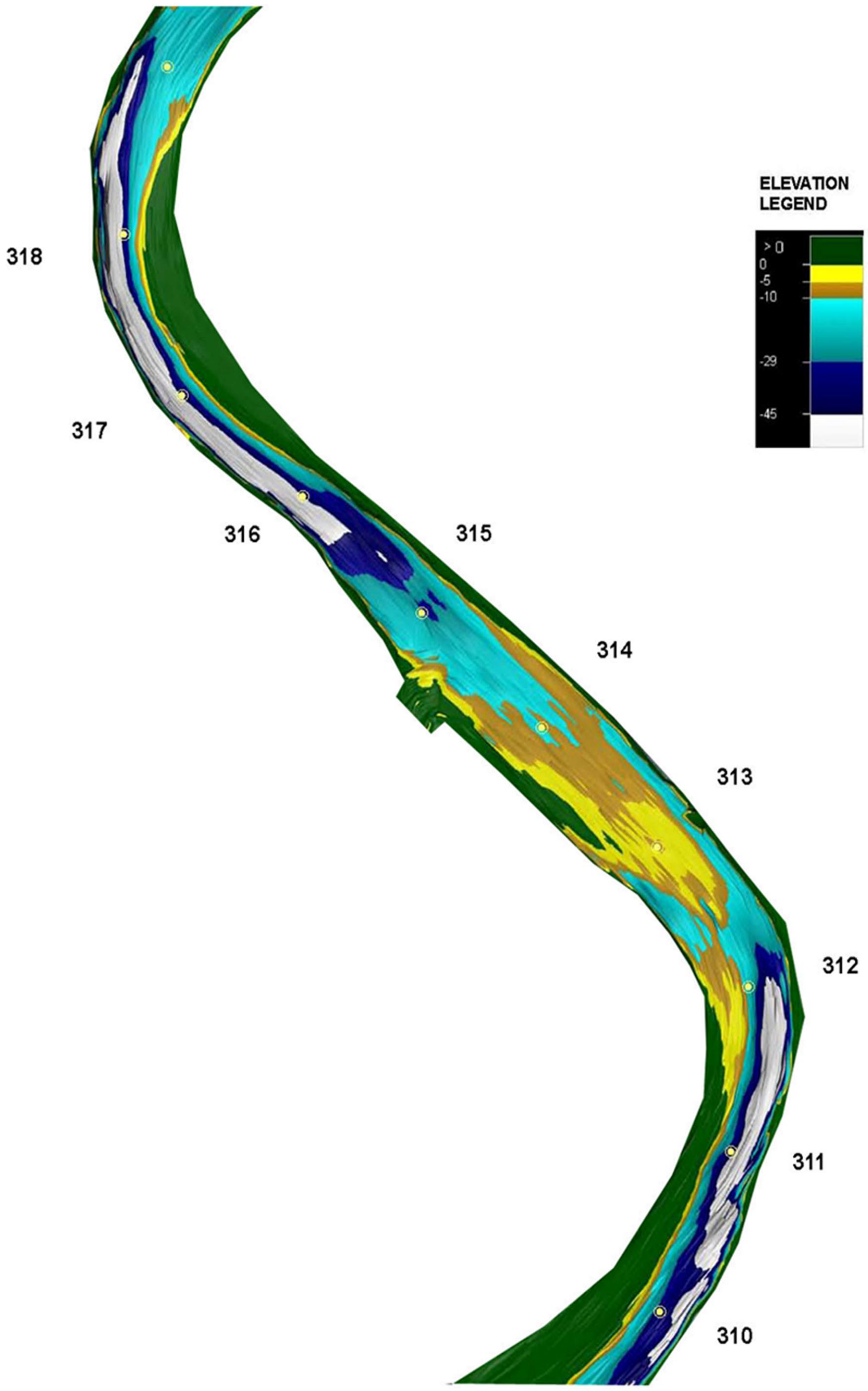

PLATE NUMBER 16

1 mile

1964 HYDROGRAPHIC SURVEY

U.S. ARMY ENGINEER DIVISION CORPS OF ENGINEERS ST. LOUIS, MISSOURI	DRAWN BY: I. NGUYEN	REVIEWED BY: J. BROWN, P.E.
	SUBMITTED BY: I. NGUYEN	CHECKED BY: A. COX
LOWER MISSISSIPPI RIVER NEW ORLEANS DISTRICT OLD RIVER HSR MODEL	PLOT DATE: MARCH 2011	APPROVED BY: R. DAVINROY, P.E.
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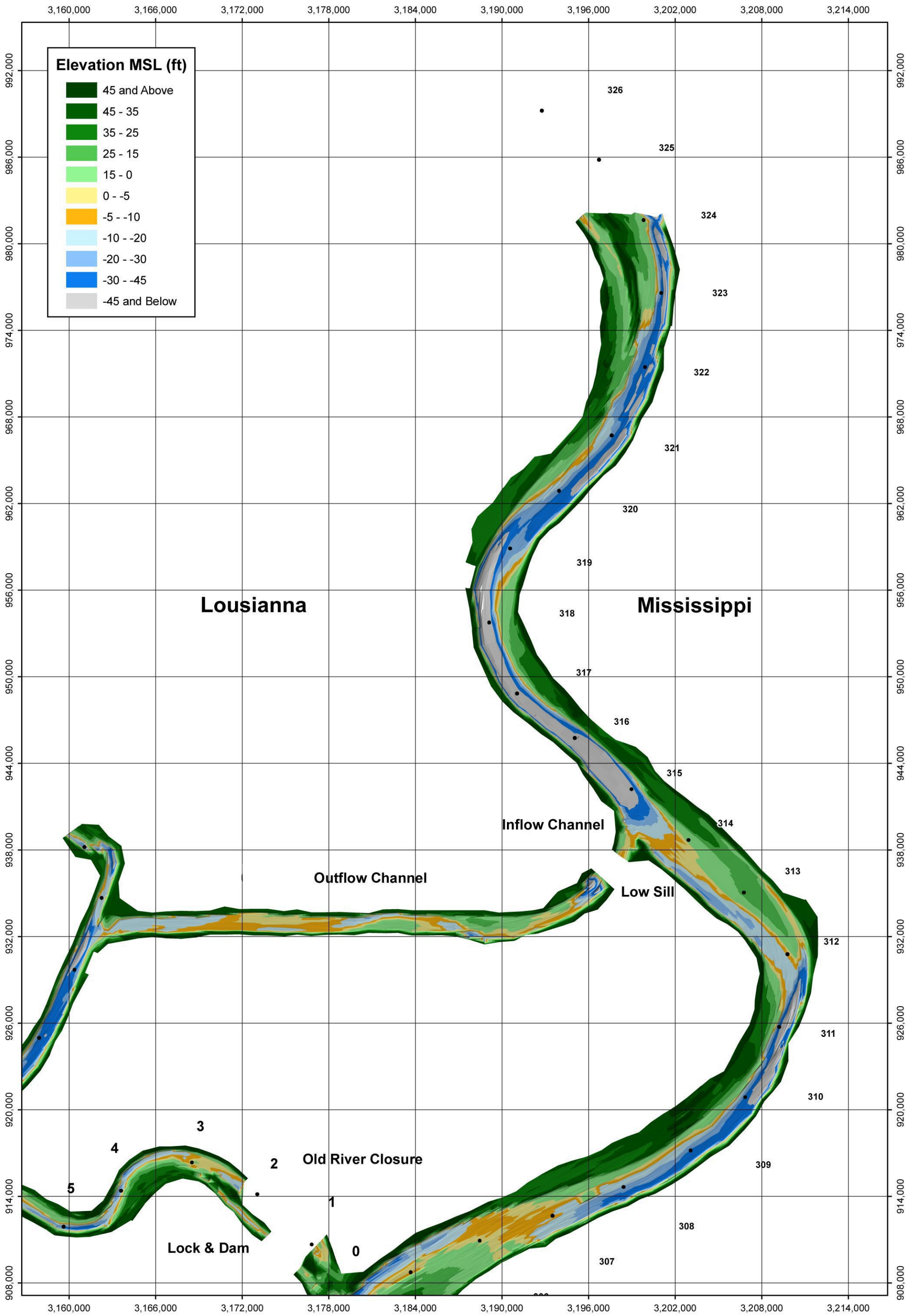

PLATE NUMBER 17

0 3,000 6,000 12,000 Feet

1975 HYDROGRAPHIC SURVEY

U.S. ARMY ENGINEER DIVISION CORPS OF ENGINEERS ST. LOUIS, MISSOURI	DRAWN BY: I. NGUYEN	REVIEWED BY: J. BROWN, P.E.
	SUBMITTED BY: I. NGUYEN	CHECKED BY: A. COX
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	FILE NAME: ...OLD RIVER HSR MODEL.MXD	

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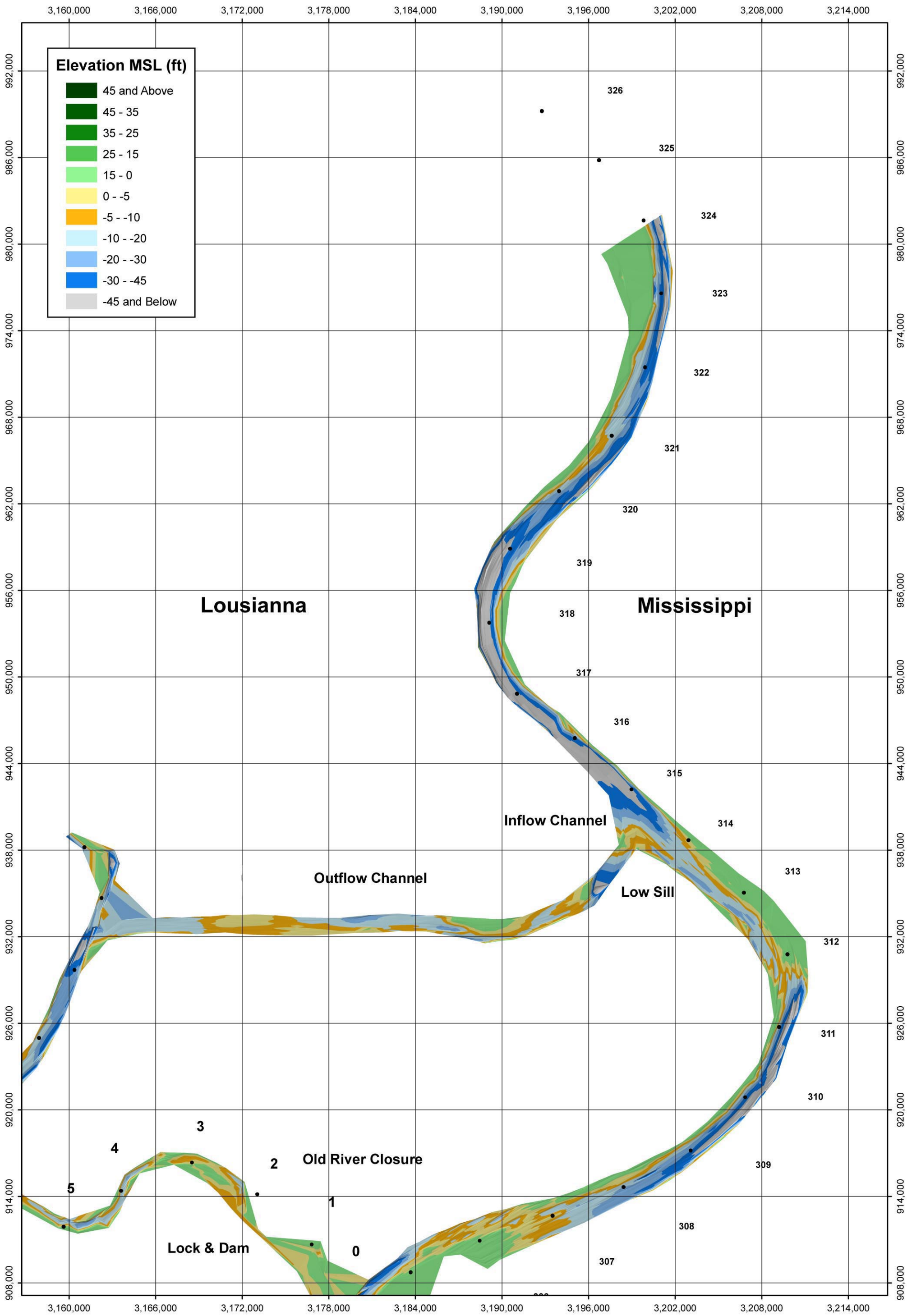

PLATE NUMBER 18

0 3,000 6,000 12,000 Feet

1983 HYDROGRAPHIC SURVEY

U.S. ARMY ENGINEER DIVISION CORPS OF ENGINEERS ST. LOUIS, MISSOURI	DRAWN BY: I. NGUYEN	REVIEWED BY: J. BROWN, P.E.
	SUBMITTED BY: I. NGUYEN	CHECKED BY: A. COX
LOWER MISSISSIPPI RIVER NEW ORLEANS DISTRICT OLD RIVER HSR MODEL	PLOT DATE: MARCH 2011	APPROVED BY: R. DAVINROY, P.E.
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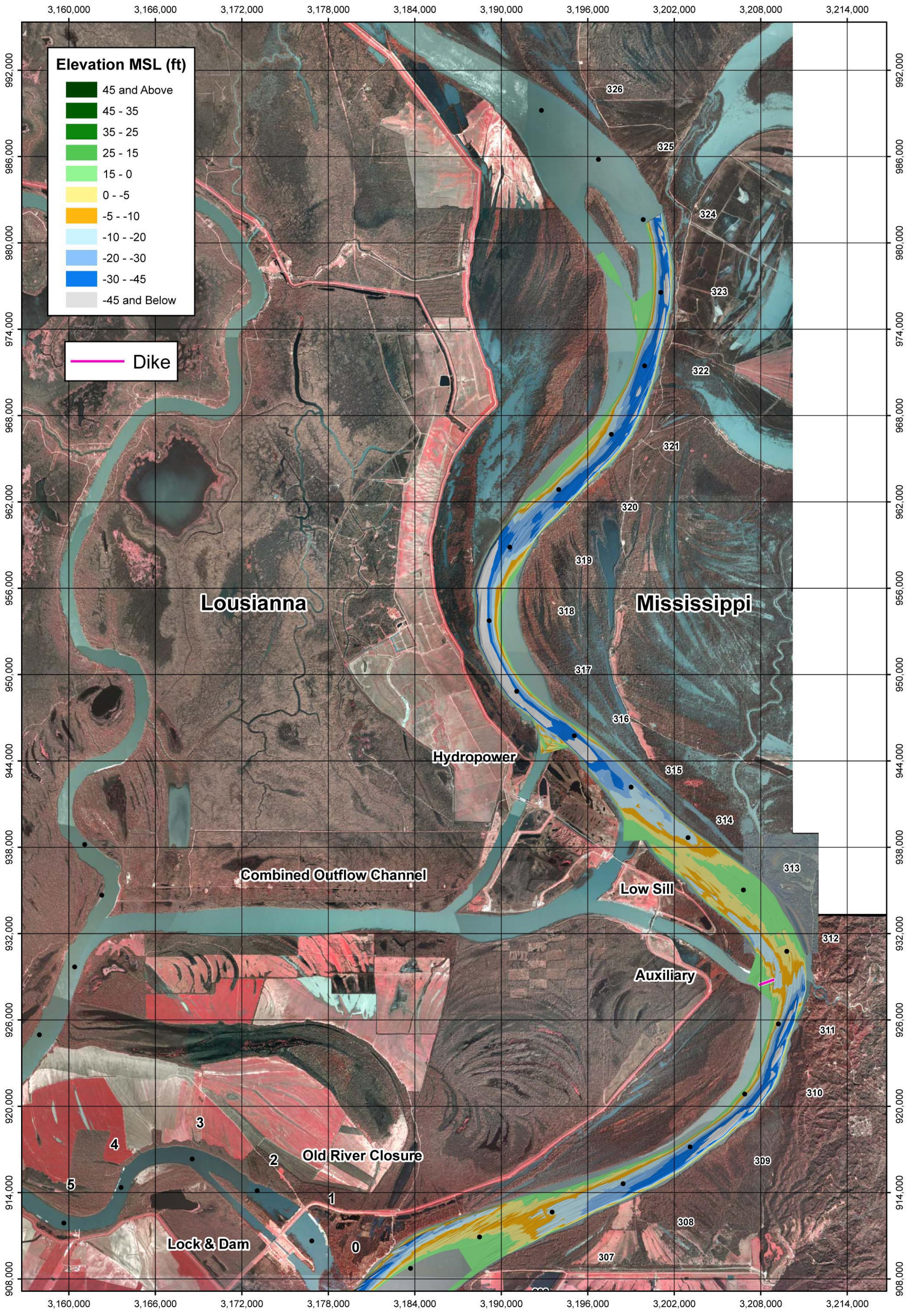

PLATE NUMBER 19

0 3,000 6,000 12,000 Feet

1992 HYDROGRAPHIC SURVEY

U.S. ARMY ENGINEER DIVISION CORPS OF ENGINEERS ST. LOUIS, MISSOURI	DRAWN BY: I. NGUYEN	REVIEWED BY: J. BROWN, P.E.
	SUBMITTED BY: I. NGUYEN	CHECKED BY: A. COX
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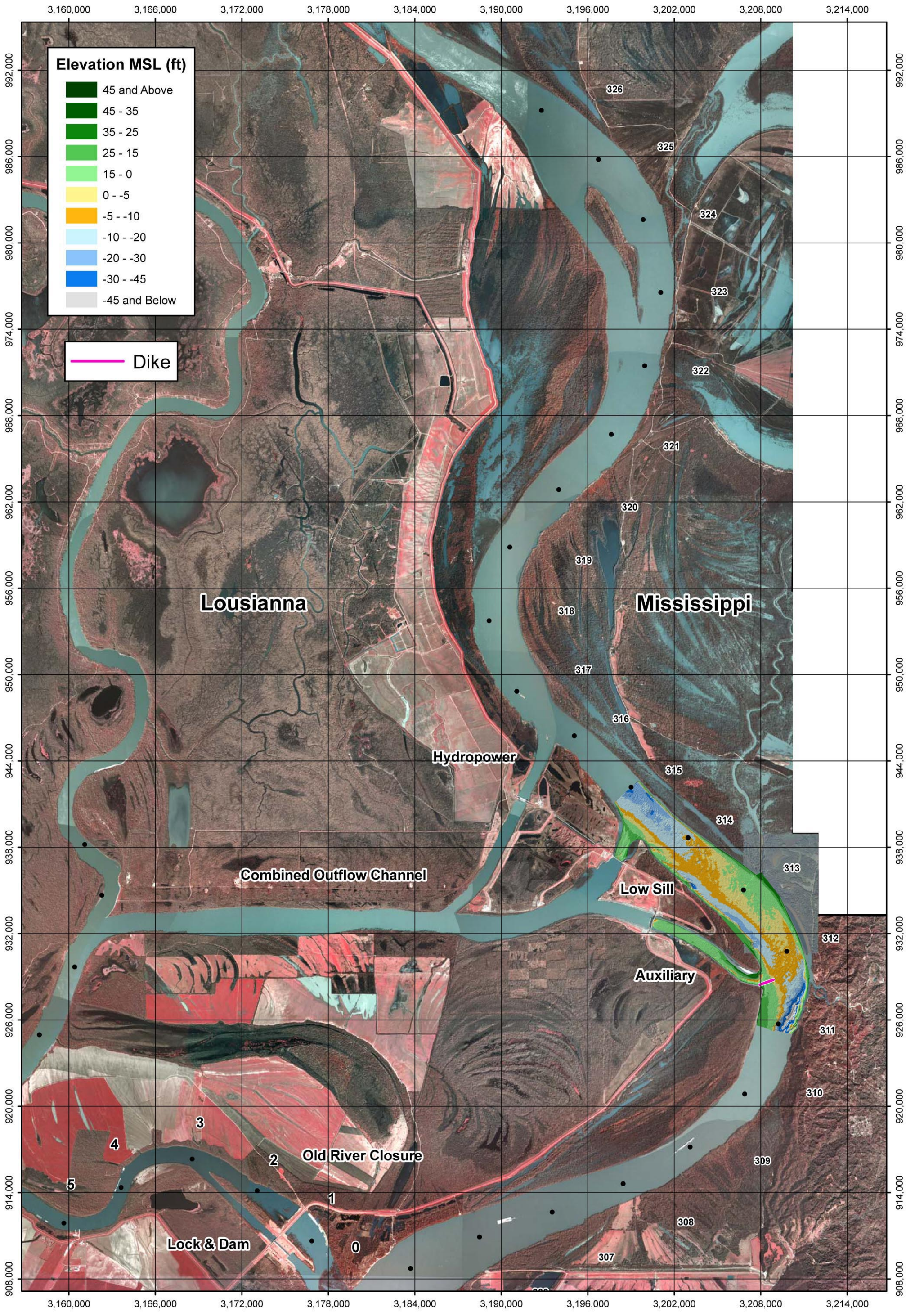

PLATE NUMBER 20

0 3,000 6,000 12,000 Feet

1999 HYDROGRAPHIC SURVEY

U.S. ARMY ENGINEER DIVISION CORPS OF ENGINEERS ST. LOUIS, MISSOURI	DRAWN BY: I. NGUYEN	REVIEWED BY: J. BROWN, P.E.
	SUBMITTED BY: I. NGUYEN	CHECKED BY: A. COX
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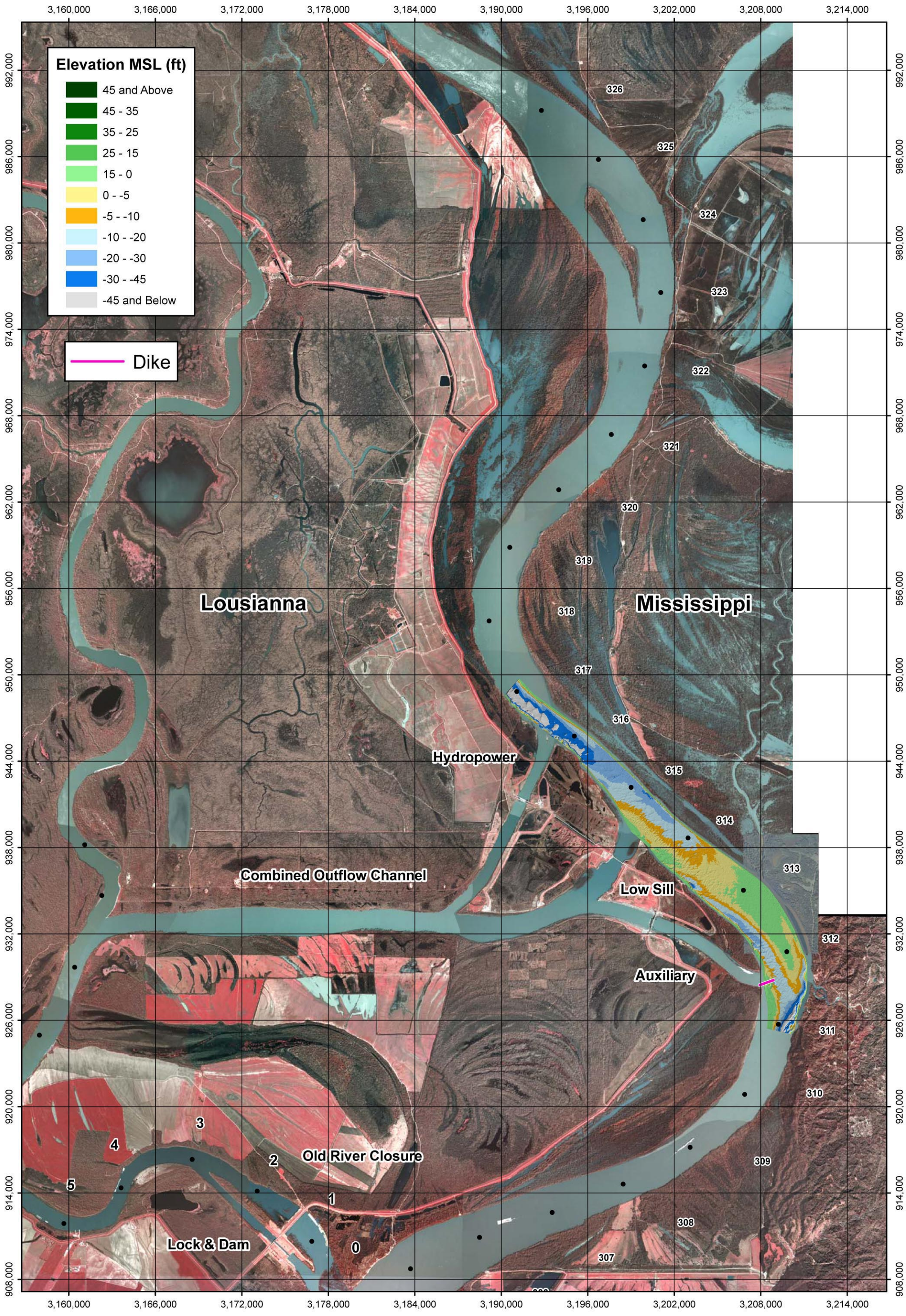

PLATE NUMBER 21

0 3,000 6,000 12,000 Feet

2001 HYDROGRAPHIC SURVEY

U.S. ARMY ENGINEER DIVISION CORPS OF ENGINEERS ST. LOUIS, MISSOURI	DRAWN BY: I. NGUYEN	REVIEWED BY: J. BROWN, P.E.
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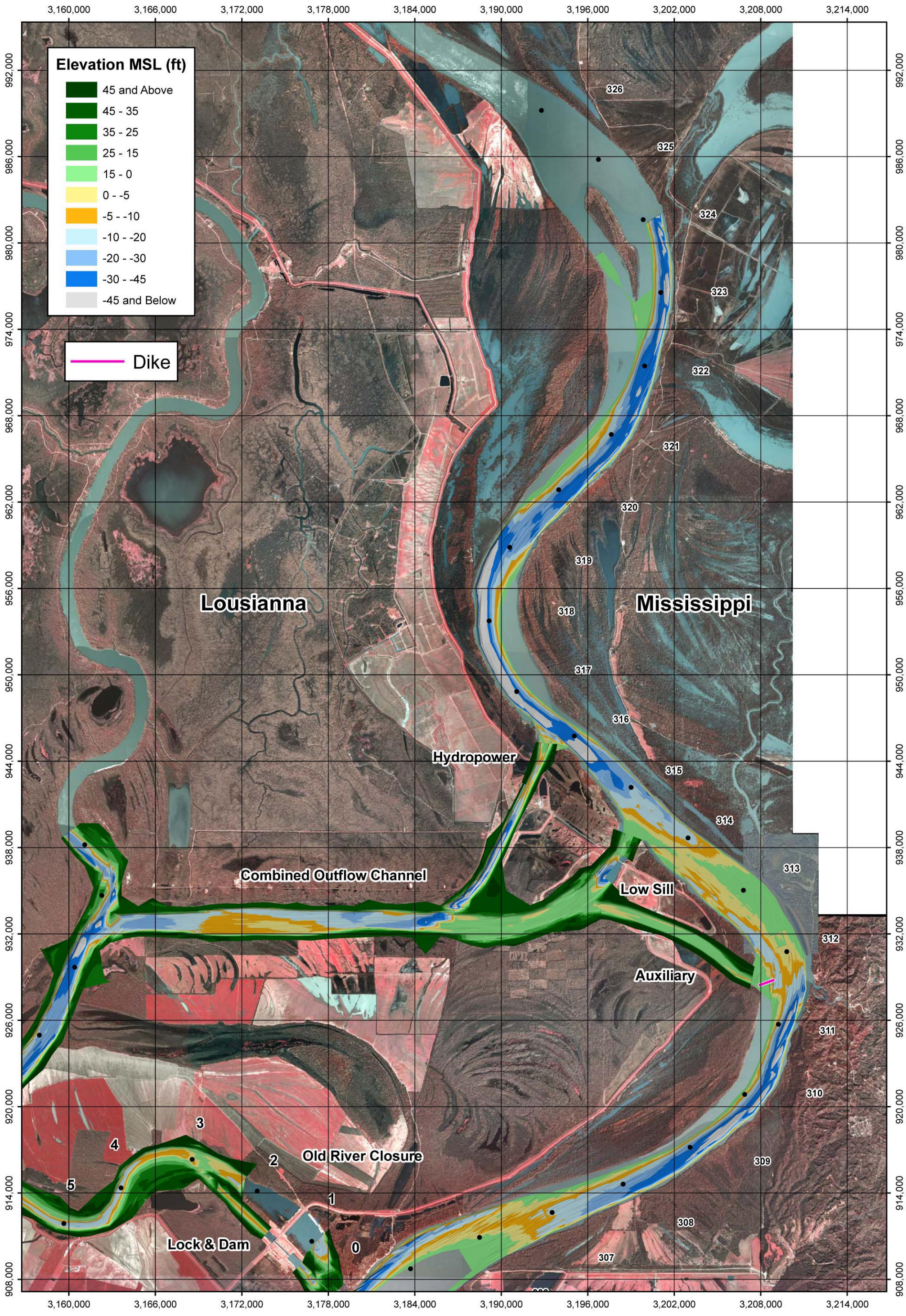

PLATE NUMBER 22

0 3,000 6,000 12,000 Feet

2003 HYDROGRAPHIC SURVEY

U.S. ARMY ENGINEER DIVISION CORPS OF ENGINEERS ST. LOUIS, MISSOURI	DRAWN BY: I. NGUYEN	REVIEWED BY: J. BROWN, P.E.
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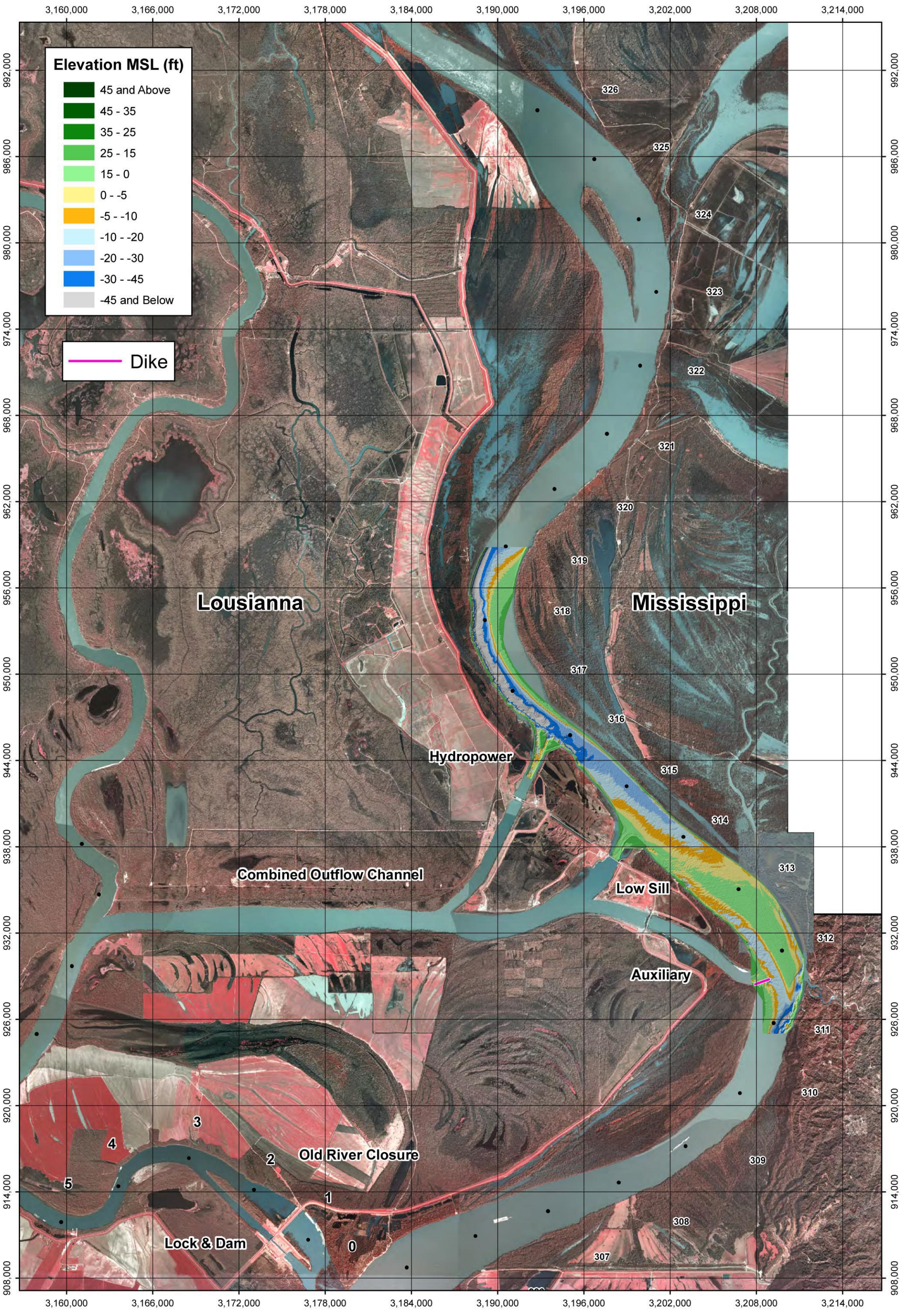

PLATE NUMBER 23

0 3,000 6,000 12,000 Feet

2006 HYDROGRAPHIC SURVEY

U.S. ARMY ENGINEER DIVISION CORPS OF ENGINEERS ST. LOUIS, MISSOURI	DRAWN BY: I. NGUYEN	REVIEWED BY: J. BROWN, P.E.
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LOWER MISSISSIPPI RIVER NEW ORLEANS DISTRICT OLD RIVER HSR MODEL	PLOT DATE: MARCH 2011	APPROVED BY: R. DAVINROY, P.E.
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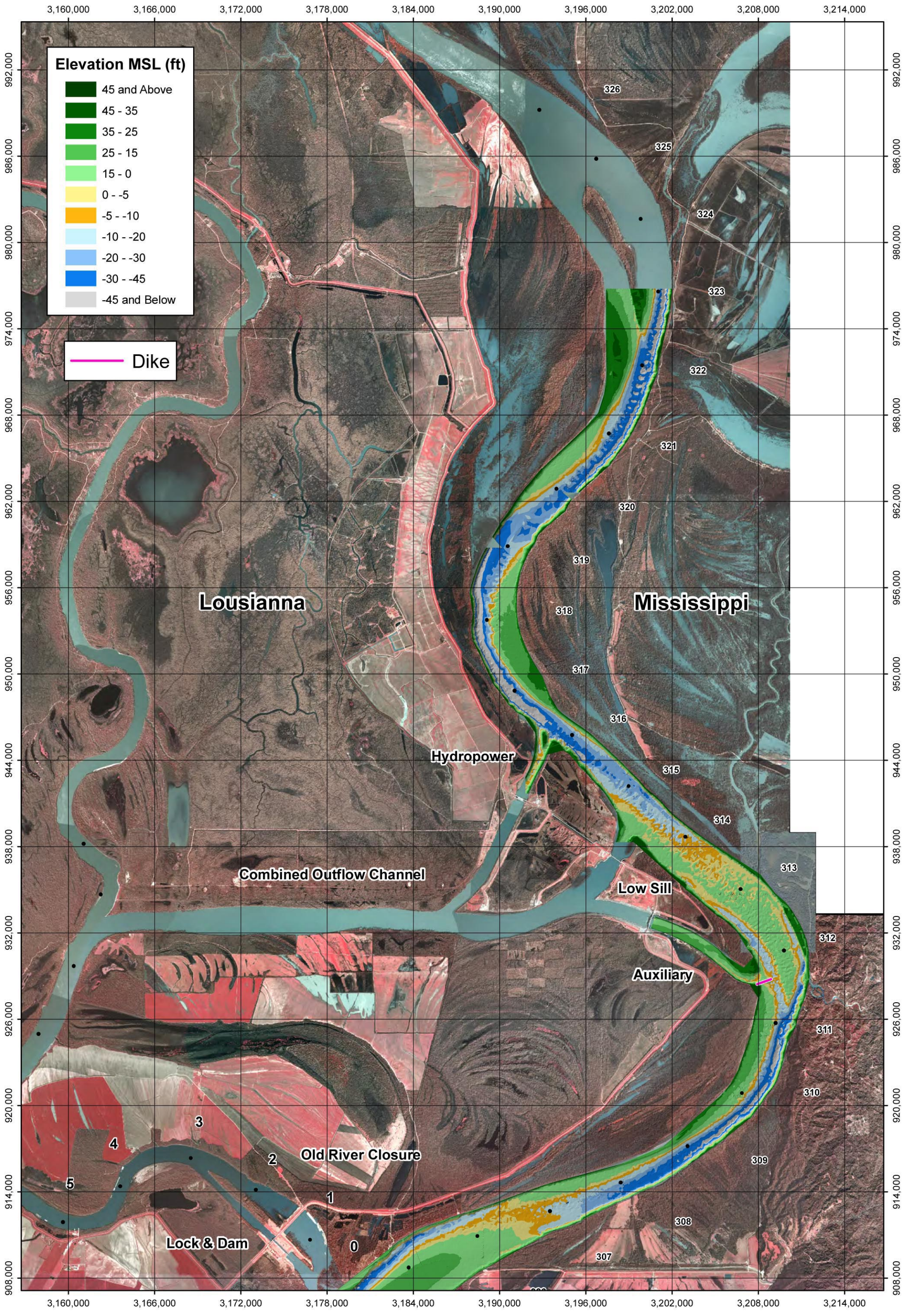

PLATE NUMBER 24

0 3,000 6,000 12,000 Feet

2008 HYDROGRAPHIC SURVEY
AFTER DREDGE

U.S. ARMY ENGINEER DIVISION CORPS OF ENGINEERS ST. LOUIS, MISSOURI	DRAWN BY: I. NGUYEN	REVIEWED BY: J. BROWN, P.E.
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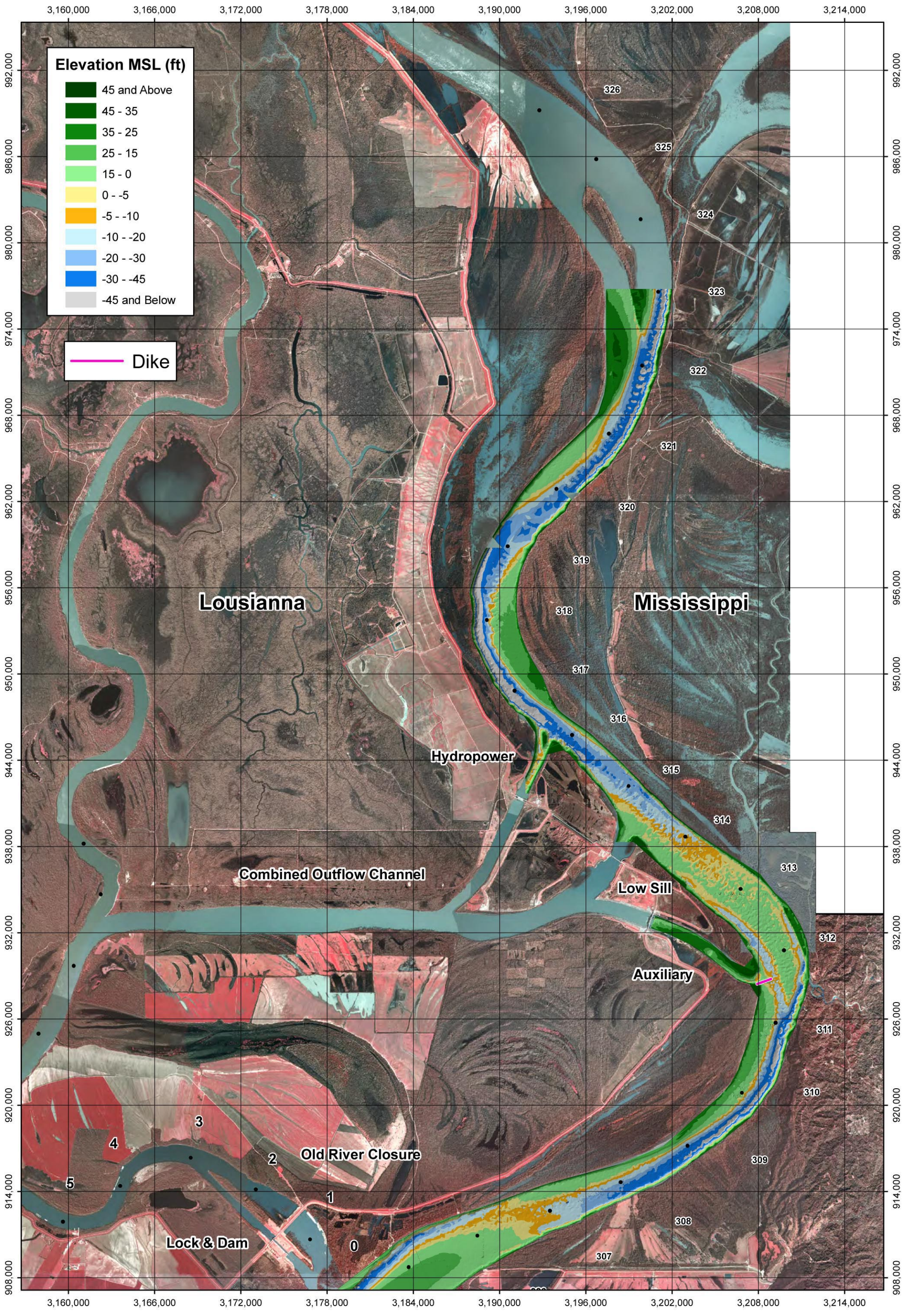

PLATE NUMBER 25

0 3,000 6,000 12,000 Feet

2008 HYDROGRAPHIC SURVEY
BEFORE DREDGE

U.S. ARMY ENGINEER DIVISION CORPS OF ENGINEERS ST. LOUIS, MISSOURI	DRAWN BY: I. NGUYEN	REVIEWED BY: J. BROWN, P.E.
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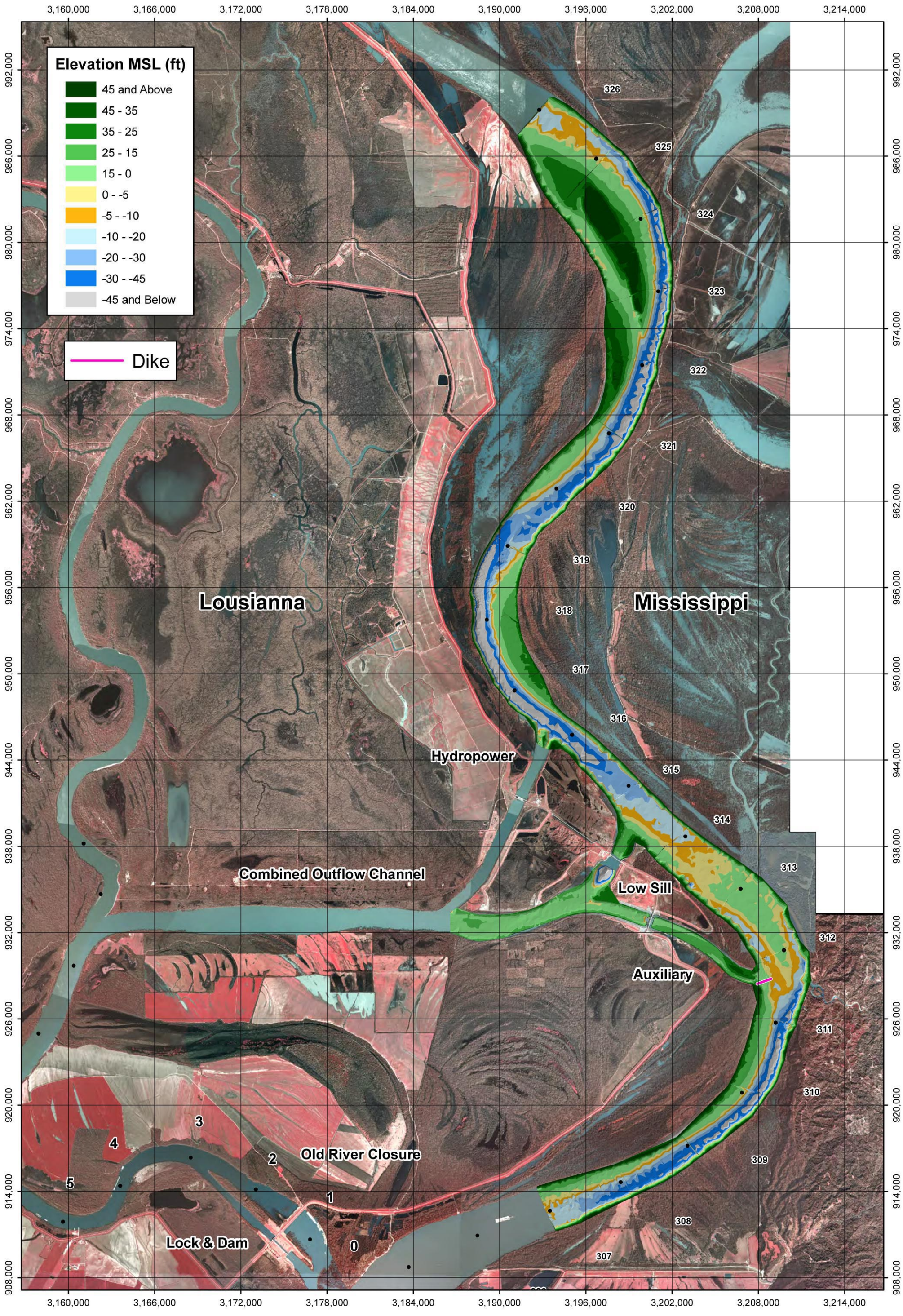

PLATE NUMBER 26

0 3,000 6,000 12,000 Feet

2010 HYDROGRAPHIC SURVEY

U.S. ARMY ENGINEER DIVISION CORPS OF ENGINEERS ST. LOUIS, MISSOURI	DRAWN BY: I. NGUYEN	REVIEWED BY: J. BROWN, P.E.
	SUBMITTED BY: I. NGUYEN	CHECKED BY: A. COX
LOWER MISSISSIPPI RIVER NEW ORLEANS DISTRICT OLD RIVER HSR MODEL	PLOT DATE: MARCH 2011	APPROVED BY: R. DAVINROY, P.E.
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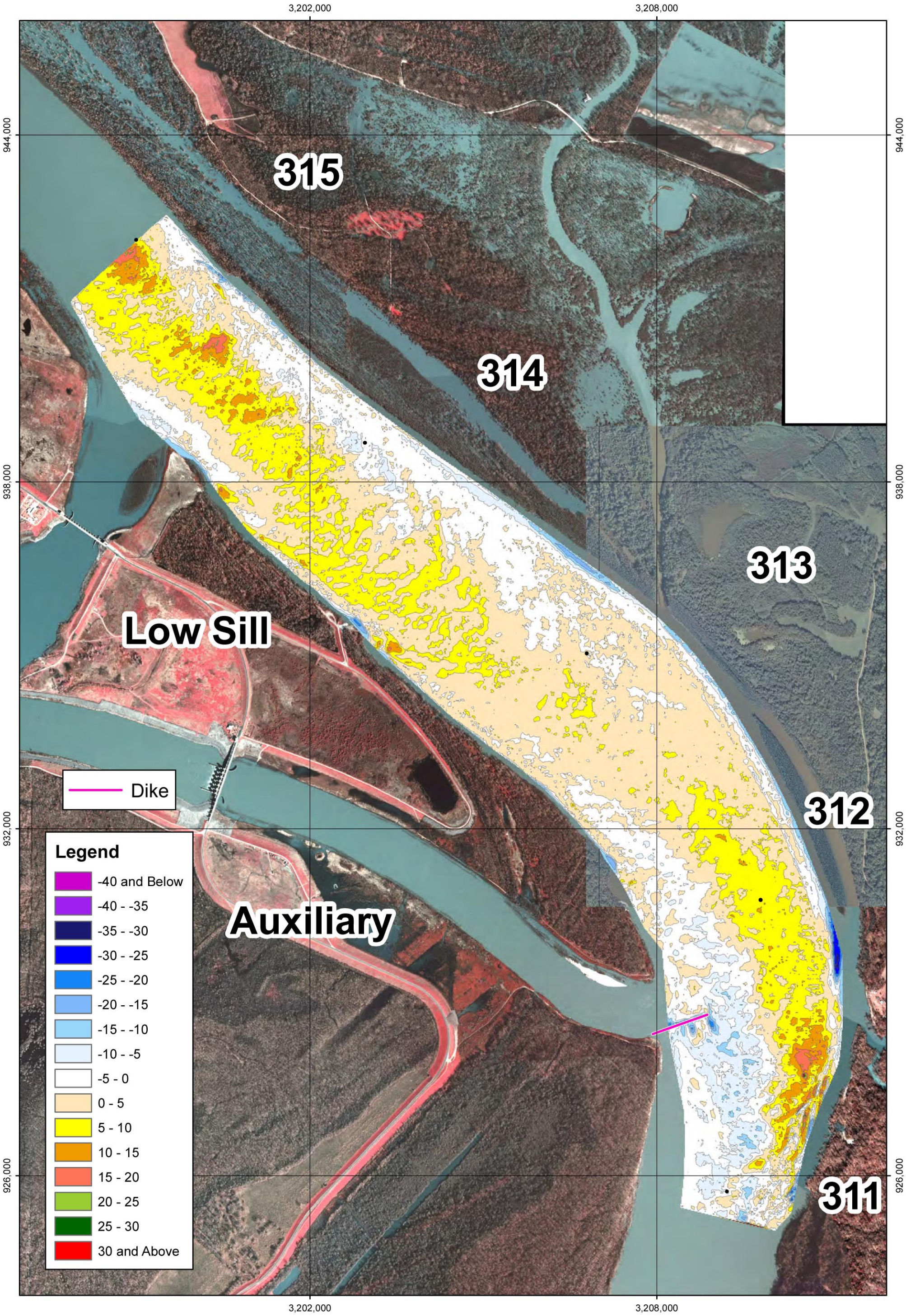

PLATE NUMBER 27

0 750 1,500 3,000 Feet

ISOPACH 2001 vs. 1999

U.S. ARMY ENGINEER DIVISION CORPS OF ENGINEERS ST. LOUIS, MISSOURI	DRAWN BY: I. NGUYEN	REVIEWED BY: J. BROWN, P.E.
	SUBMITTED BY: I. NGUYEN	CHECKED BY: A. COX
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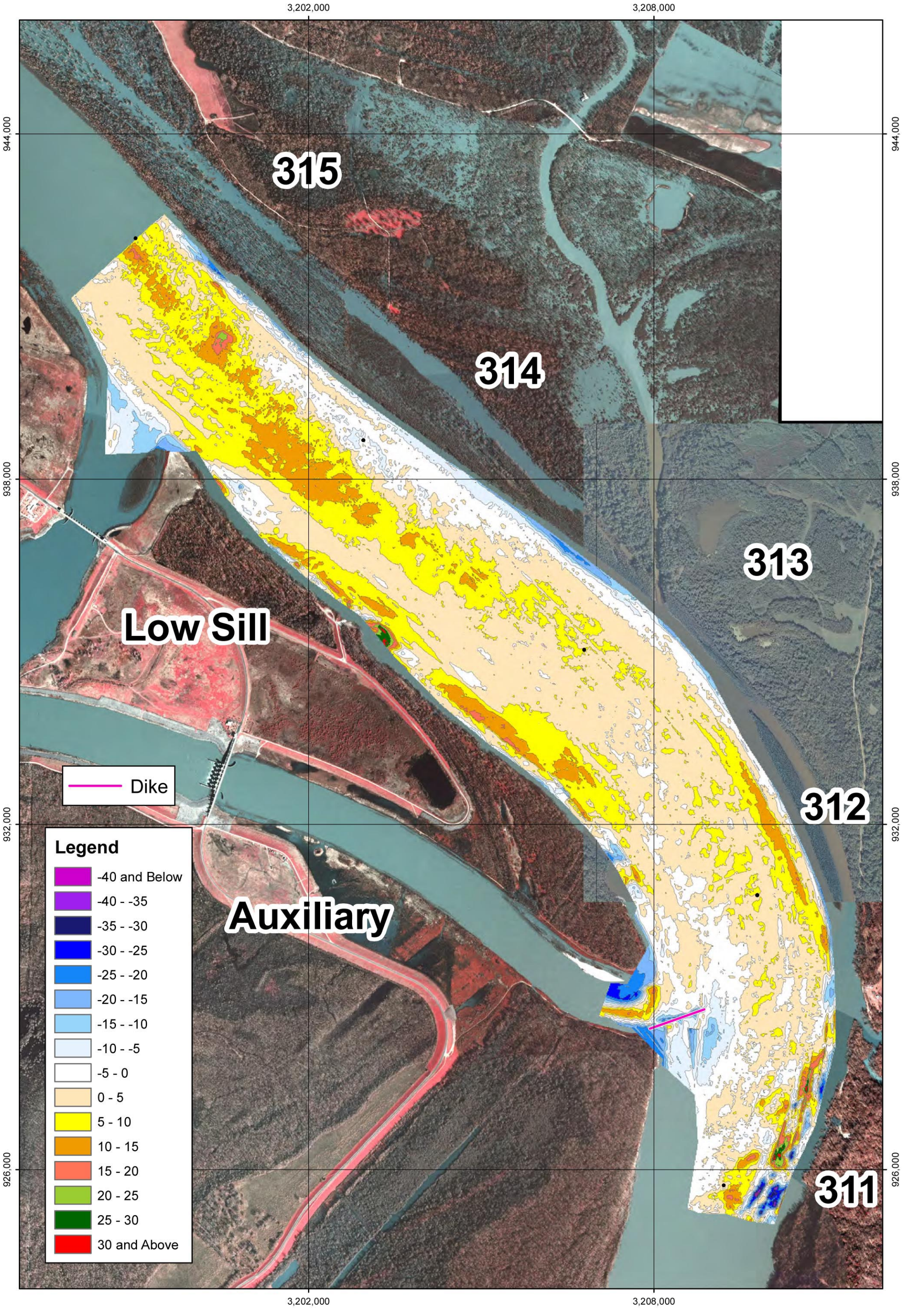

PLATE NUMBER 28

0 750 1,500 3,000 Feet

ISOPACH 2003 vs. 1999

U.S. ARMY ENGINEER DIVISION CORPS OF ENGINEERS ST. LOUIS, MISSOURI	DRAWN BY: I. NGUYEN	REVIEWED BY: J. BROWN, P.E.
	SUBMITTED BY: I. NGUYEN	CHECKED BY: A. COX
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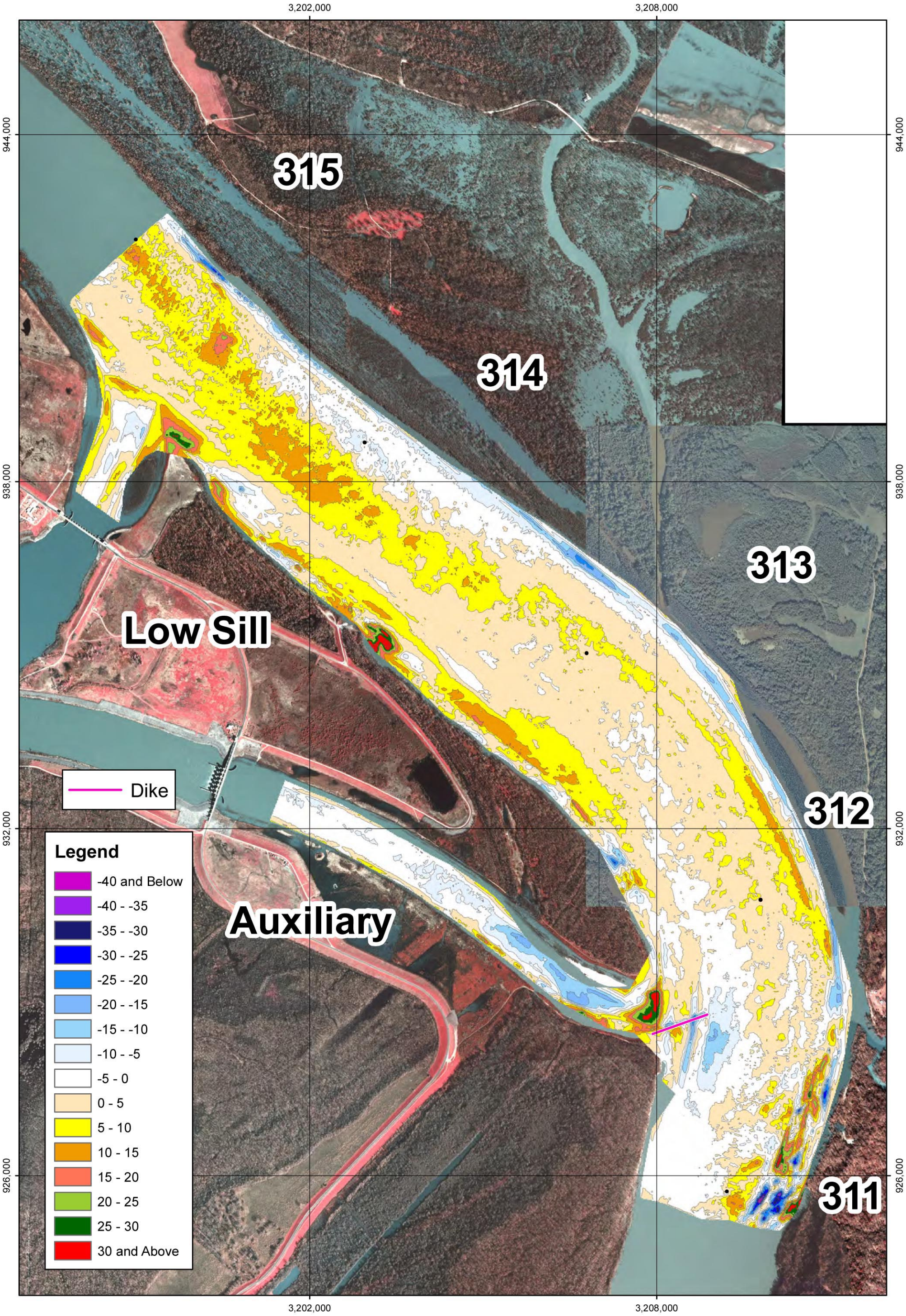

PLATE NUMBER 29

0 750 1,500 3,000 Feet

ISOPACH 2004 vs. 1999

U.S. ARMY ENGINEER DIVISION CORPS OF ENGINEERS ST. LOUIS, MISSOURI	DRAWN BY: I. NGUYEN	REVIEWED BY: J. BROWN, P.E.
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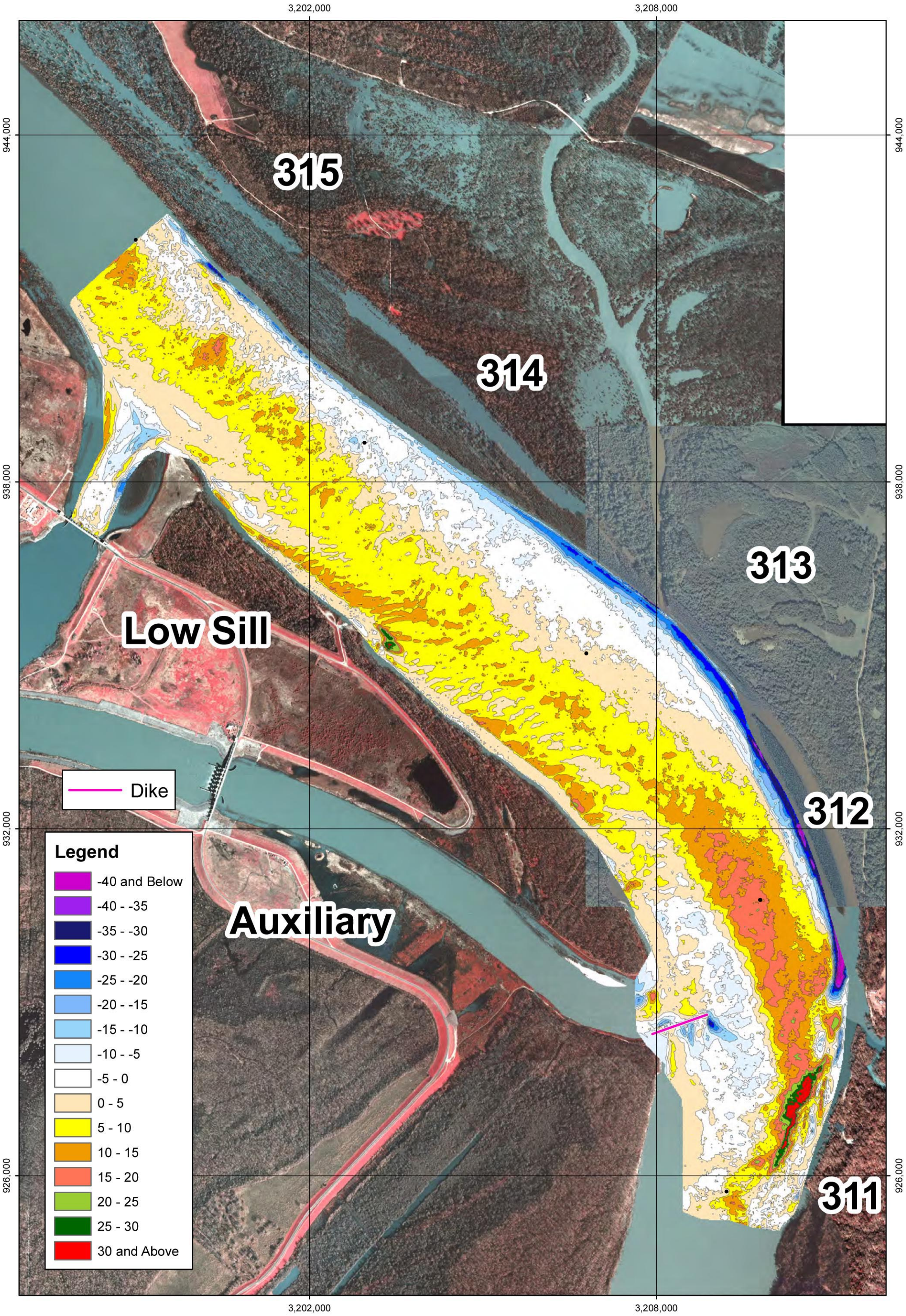

PLATE NUMBER 30

0 750 1,500 3,000 Feet

ISOPACH 2006 vs. 1999

U.S. ARMY ENGINEER DIVISION CORPS OF ENGINEERS ST. LOUIS, MISSOURI	DRAWN BY: I. NGUYEN	REVIEWED BY: J. BROWN, P.E.
	SUBMITTED BY: I. NGUYEN	CHECKED BY: A. COX
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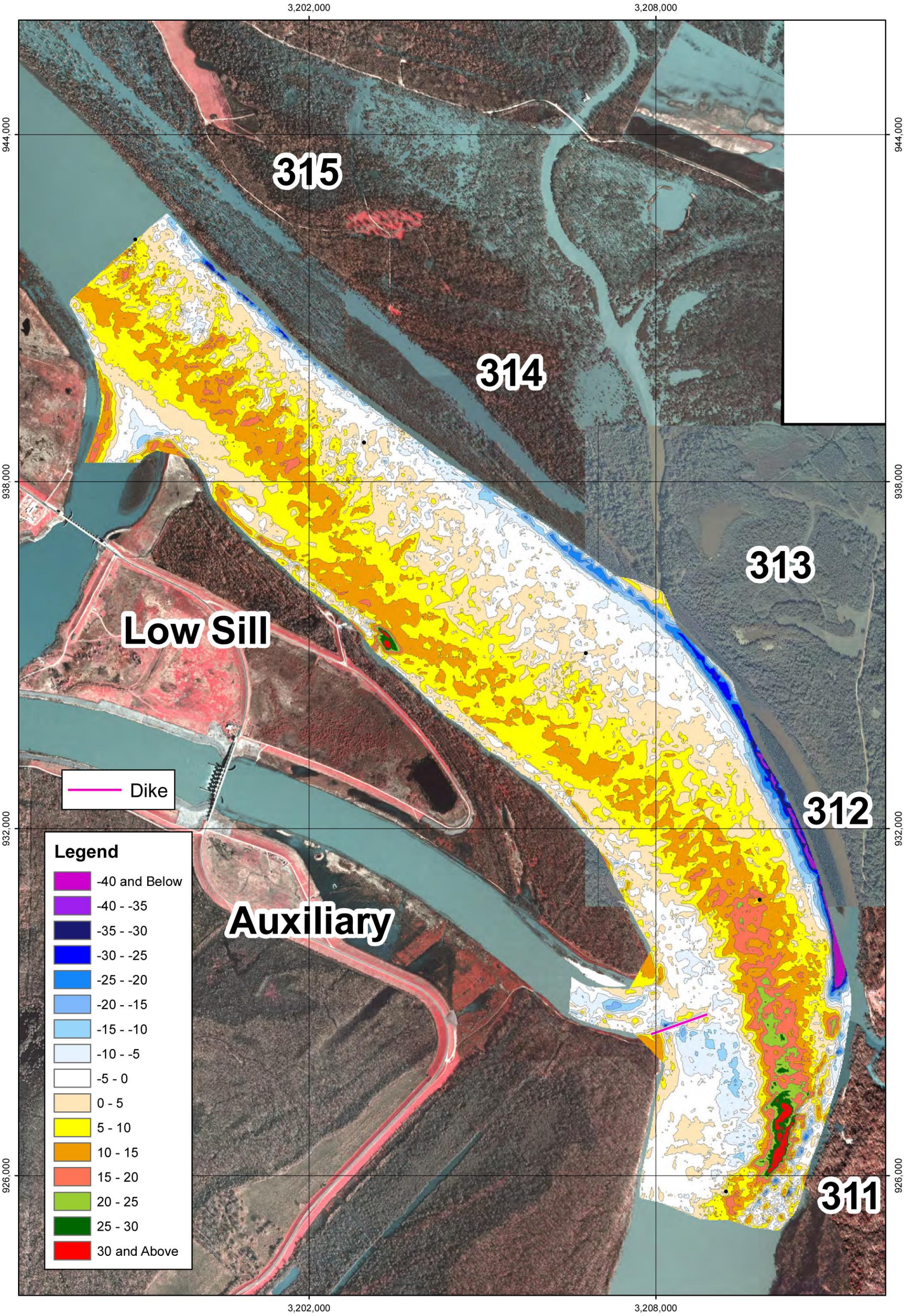

PLATE NUMBER 31

0 750 1,500 3,000 Feet

ISOPACH 2008 vs. 1999

U.S. ARMY ENGINEER DIVISION CORPS OF ENGINEERS ST. LOUIS, MISSOURI	DRAWN BY: I. NGUYEN	REVIEWED BY: J. BROWN, P.E.
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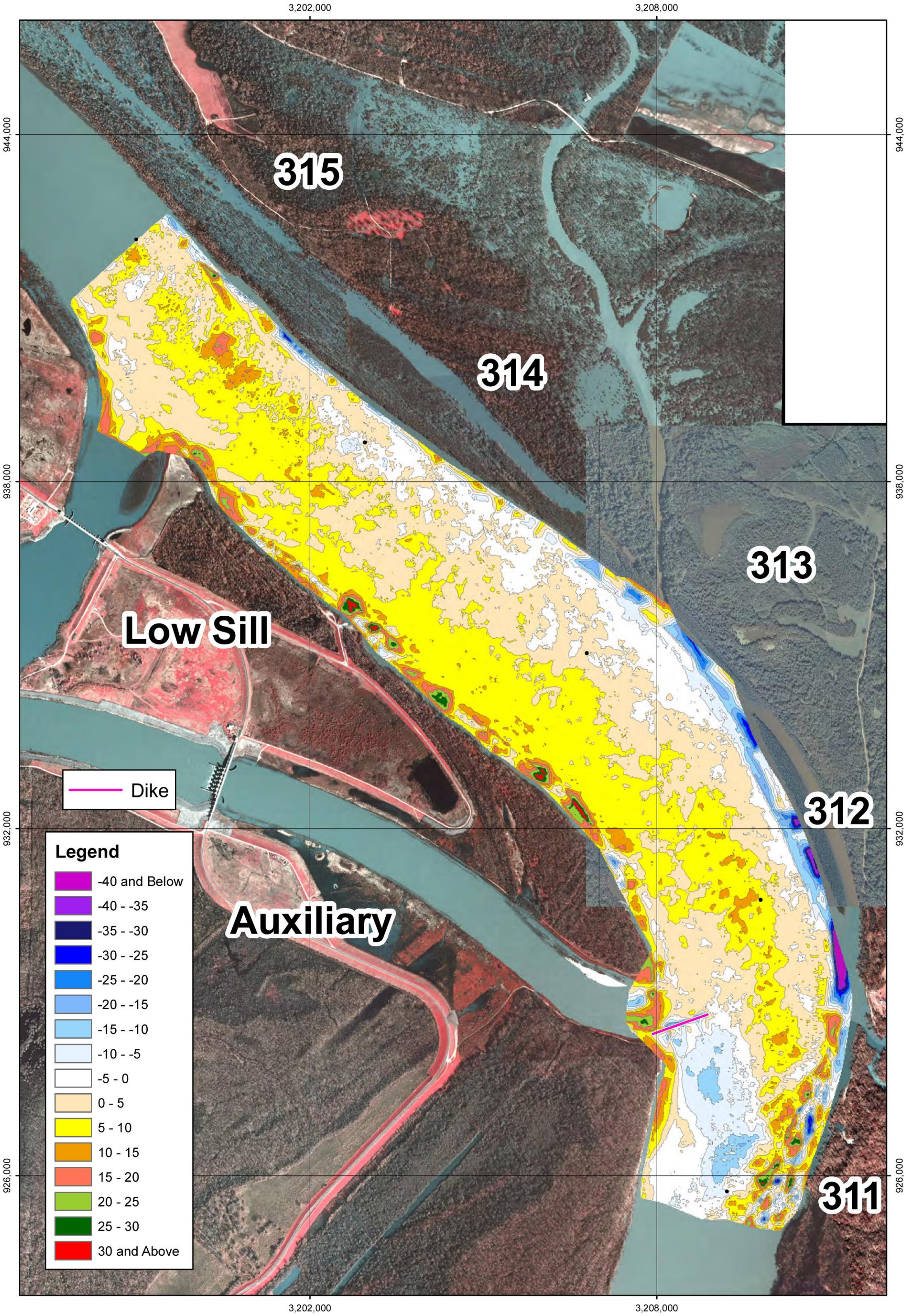

PLATE NUMBER 32

0 750 1,500 3,000 Feet

ISOPACH 2010 vs. 1999

U.S. ARMY ENGINEER DIVISION CORPS OF ENGINEERS ST. LOUIS, MISSOURI	DRAWN BY: I. NGUYEN	REVIEWED BY: J. BROWN, P.E.
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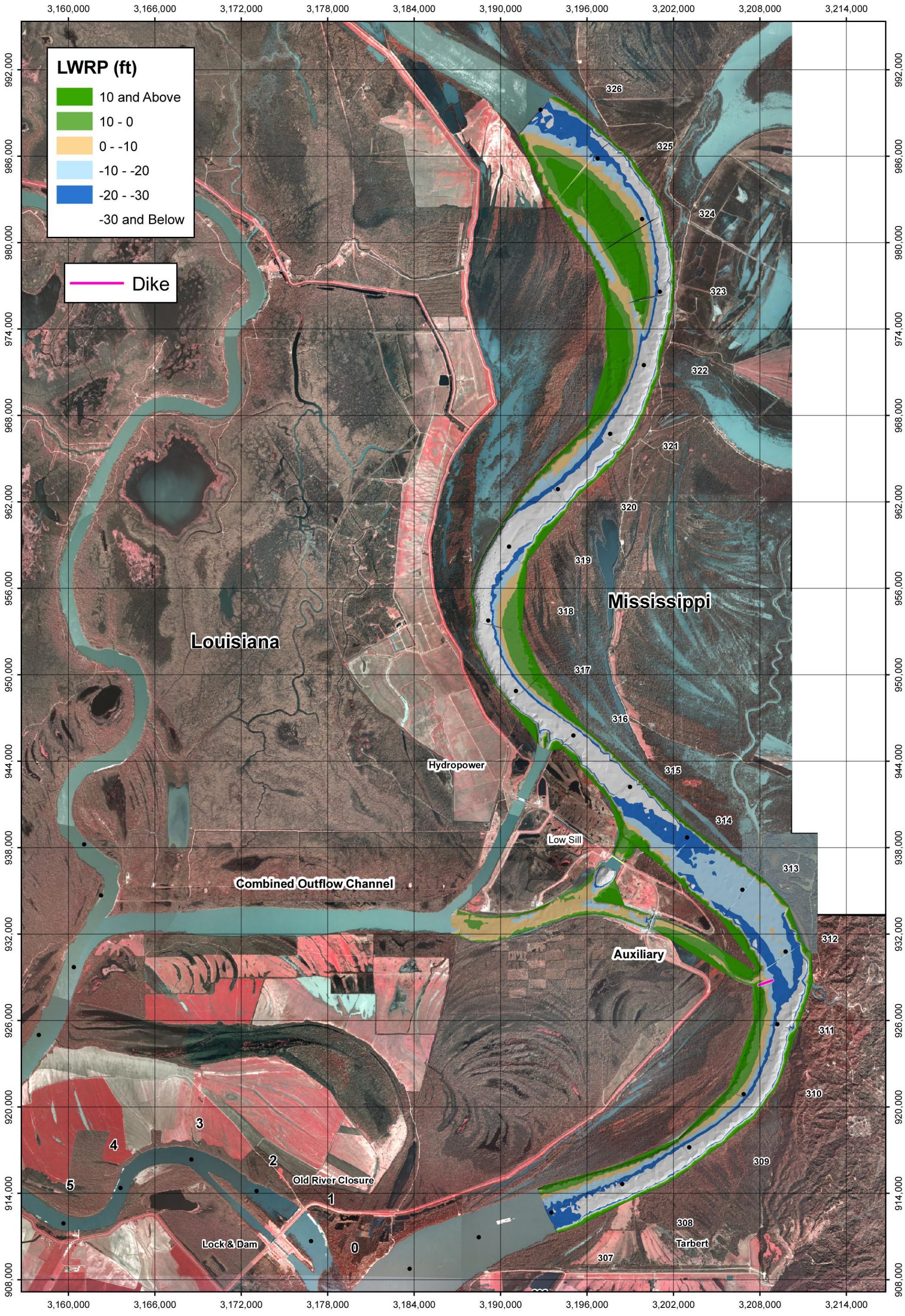

PLATE NUMBER 33

0 3,000 6,000 12,000 Feet

2010 HYDROGRAPHIC SURVEY - LWRP

U.S. ARMY ENGINEER DIVISION CORPS OF ENGINEERS ST. LOUIS, MISSOURI	DRAWN BY: I. NGUYEN	REVIEWED BY: J. BROWN, P.E.
	SUBMITTED BY: I. NGUYEN	CHECKED BY: A. COX
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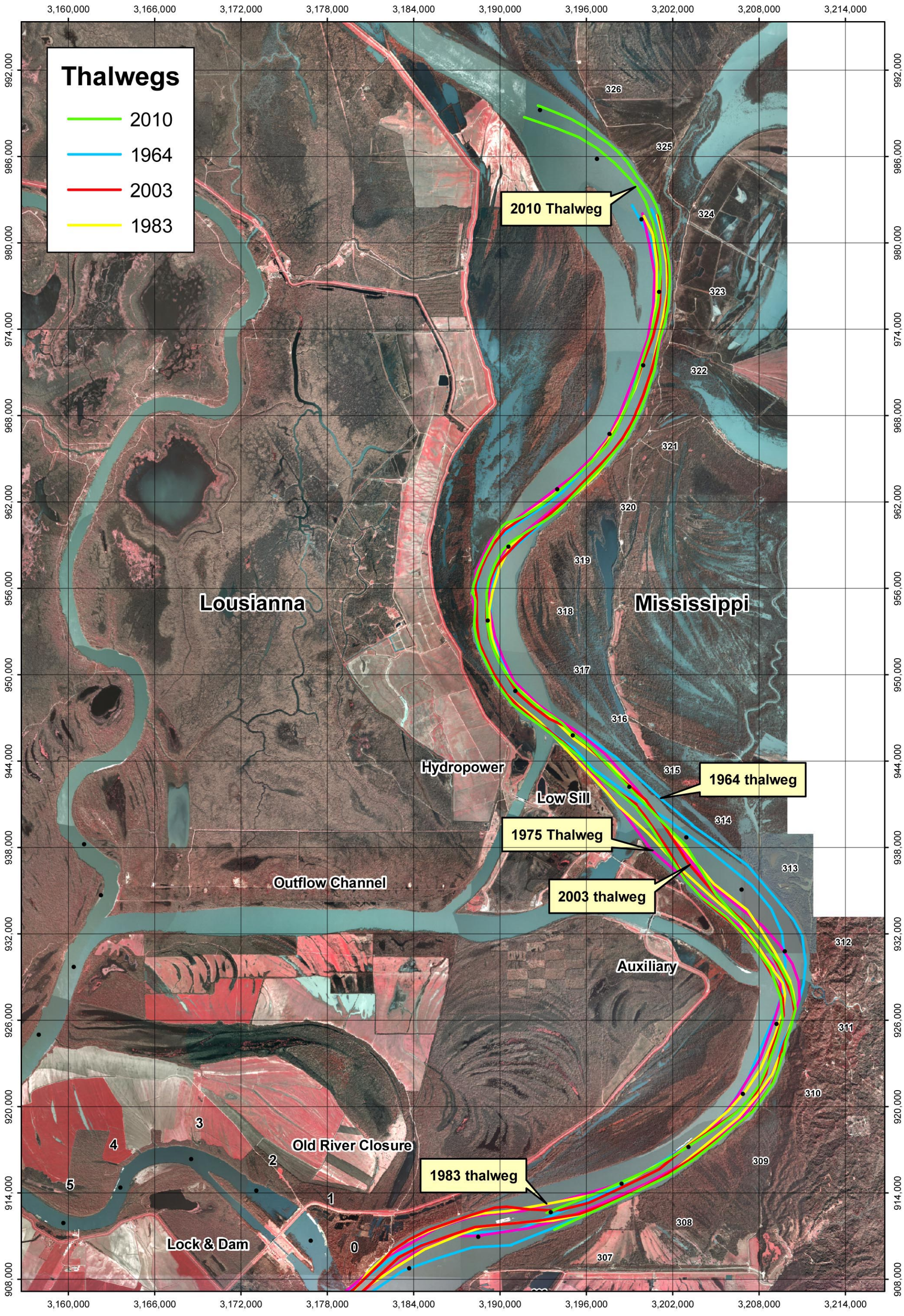

PLATE NUMBER 34

0 3,000 6,000 12,000 Feet

THALWEG

U.S. ARMY ENGINEER DIVISION CORPS OF ENGINEERS ST. LOUIS, MISSOURI	DRAWN BY: I. NGUYEN	REVIEWED BY: J. BROWN, P.E.
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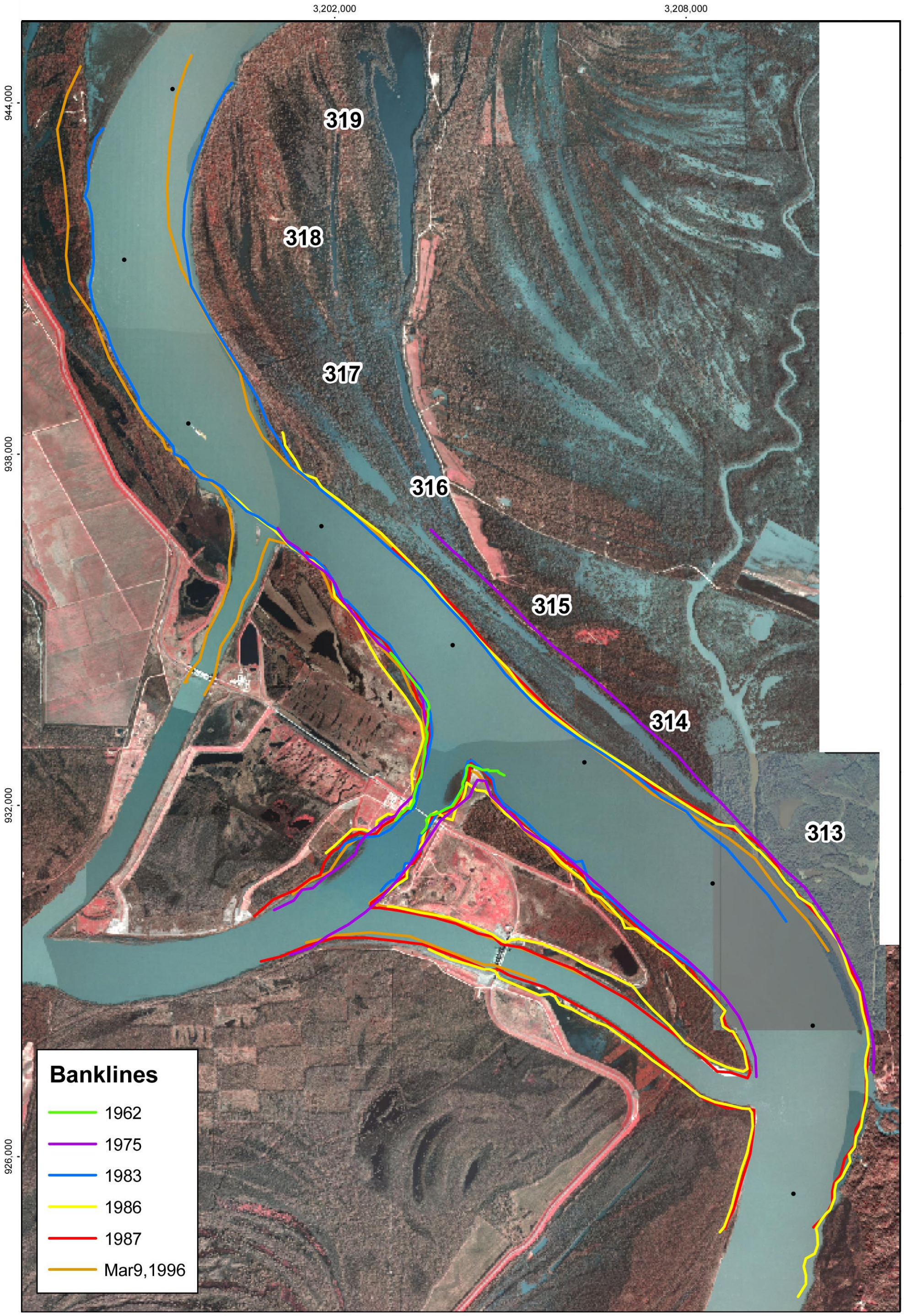

PLATE NUMBER 35

0 750 1,500 3,000 Feet

HISTORIC BANKLINES

U.S. ARMY ENGINEER DIVISION CORPS OF ENGINEERS ST. LOUIS, MISSOURI	DRAWN BY: I. NGUYEN	REVIEWED BY: J. BROWN, P.E.
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U.S ARMY ENGINEER DIVISION CORPS OF ENGINEERS ST.LOUIS, MISSOURI	DRAWN BY: I. NGUYEN	SUBMITTED BY: I. NGUYEN	PLOT DATE: MARCH 2011
LOWER MISSISSIPPI RIVER NEW ORLEANS DISTRICT OLD RIVER HSR MODEL			FILE NAME: OLD RIVER HSR MODEL.DOC

REVIEWED BY: J. BROWN, P.E.	CHECKED BY: A. COX	APPROVED BY: R. DAVINROY, P.E.

MODEL PHOTOGRAPH

PLATE NUMBER
36

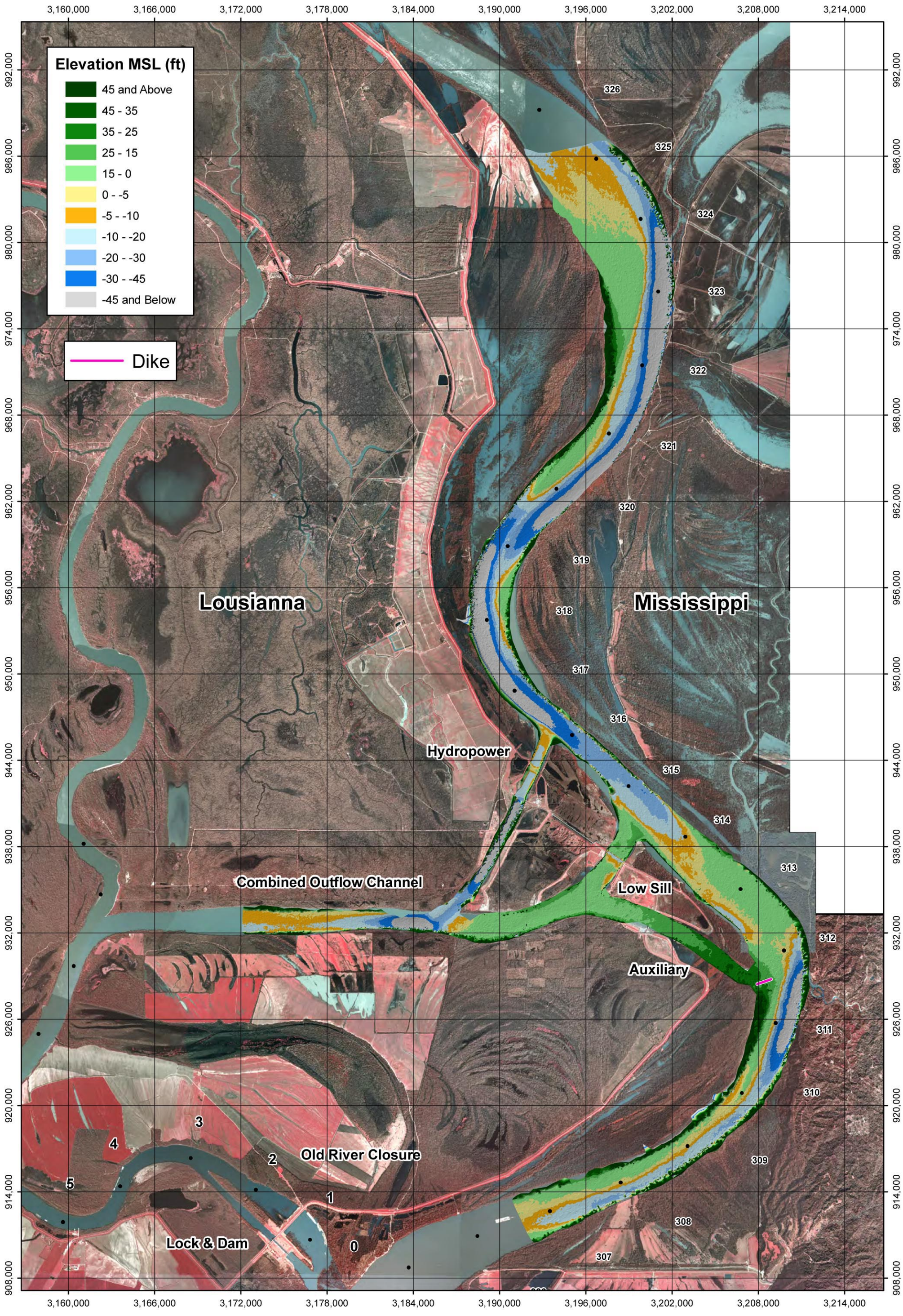

PLATE NUMBER 37

0 3,000 6,000 12,000 Feet

REPLICATION TEST

U.S. ARMY ENGINEER DIVISION CORPS OF ENGINEERS ST. LOUIS, MISSOURI	DRAWN BY: I. NGUYEN	REVIEWED BY: J. BROWN, P.E.
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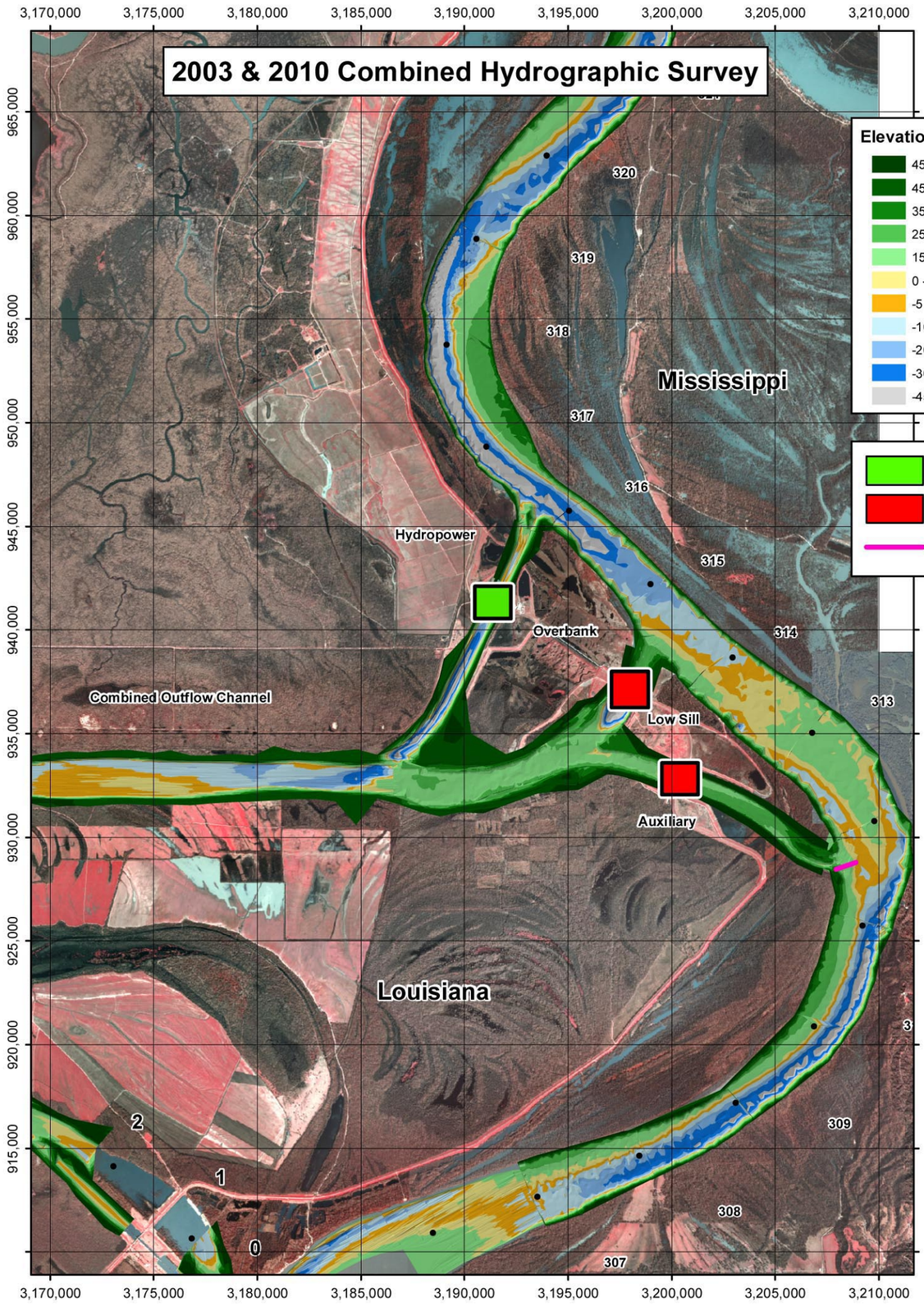

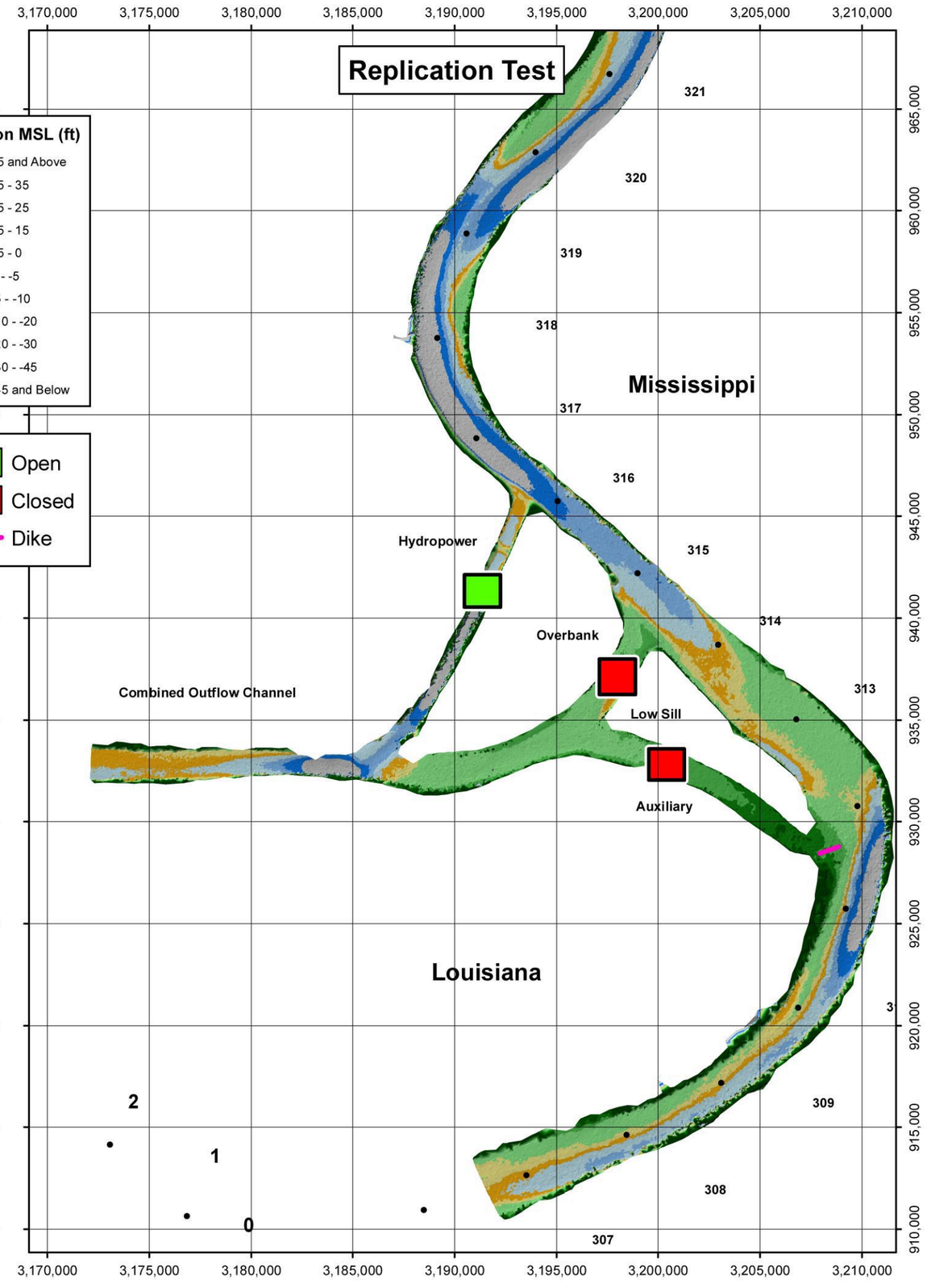

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SUBMITTED BY: I. NGUYEN	CHECKED BY: A. COX
PLOT DATE: MARCH 2011	APPROVED BY: R. DAVINROY, P.E.
FILE NAME: ...OLD RIVER HSR MODEL.MXD	

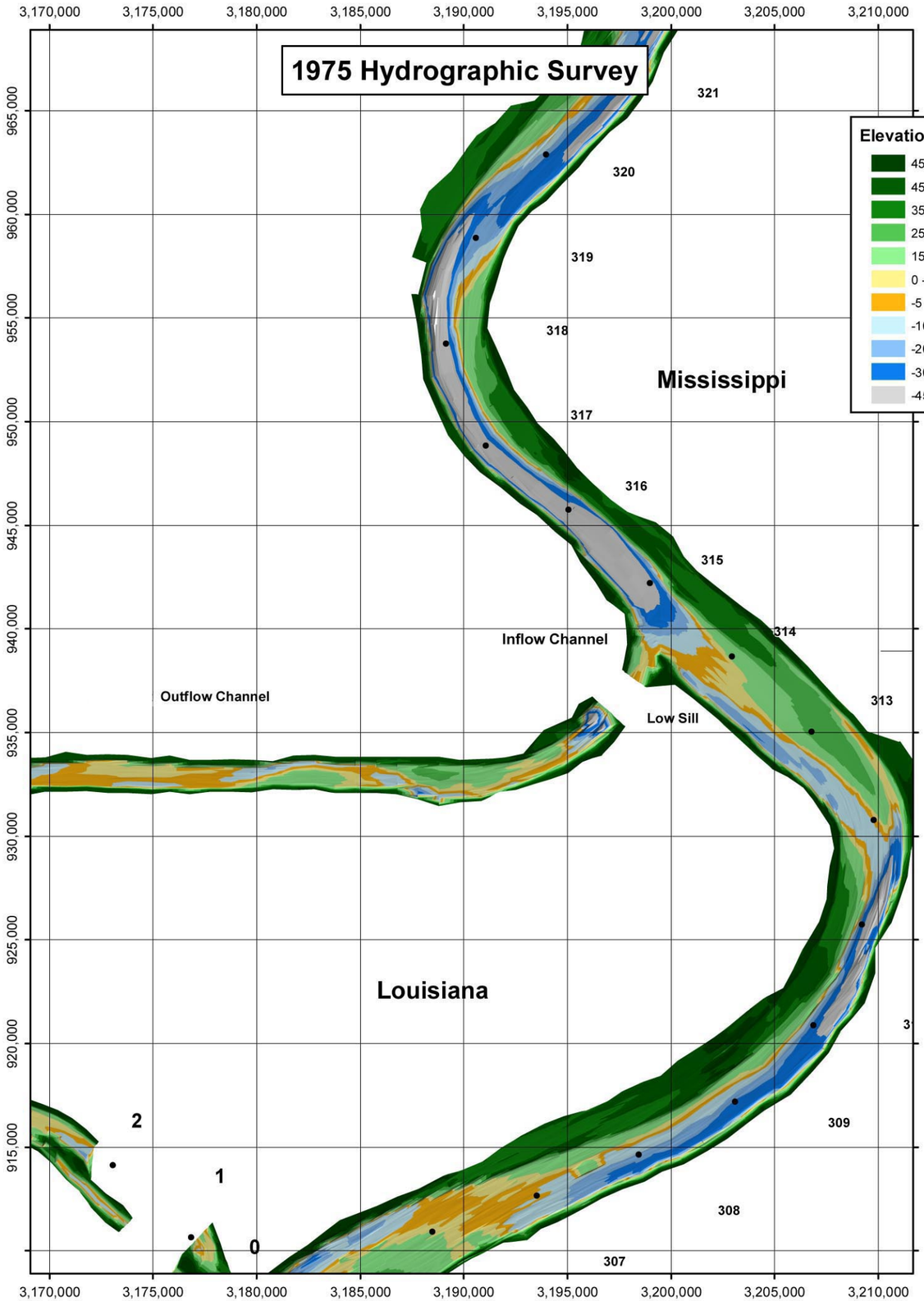
U.S. ARMY ENGINEER DIVISION
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

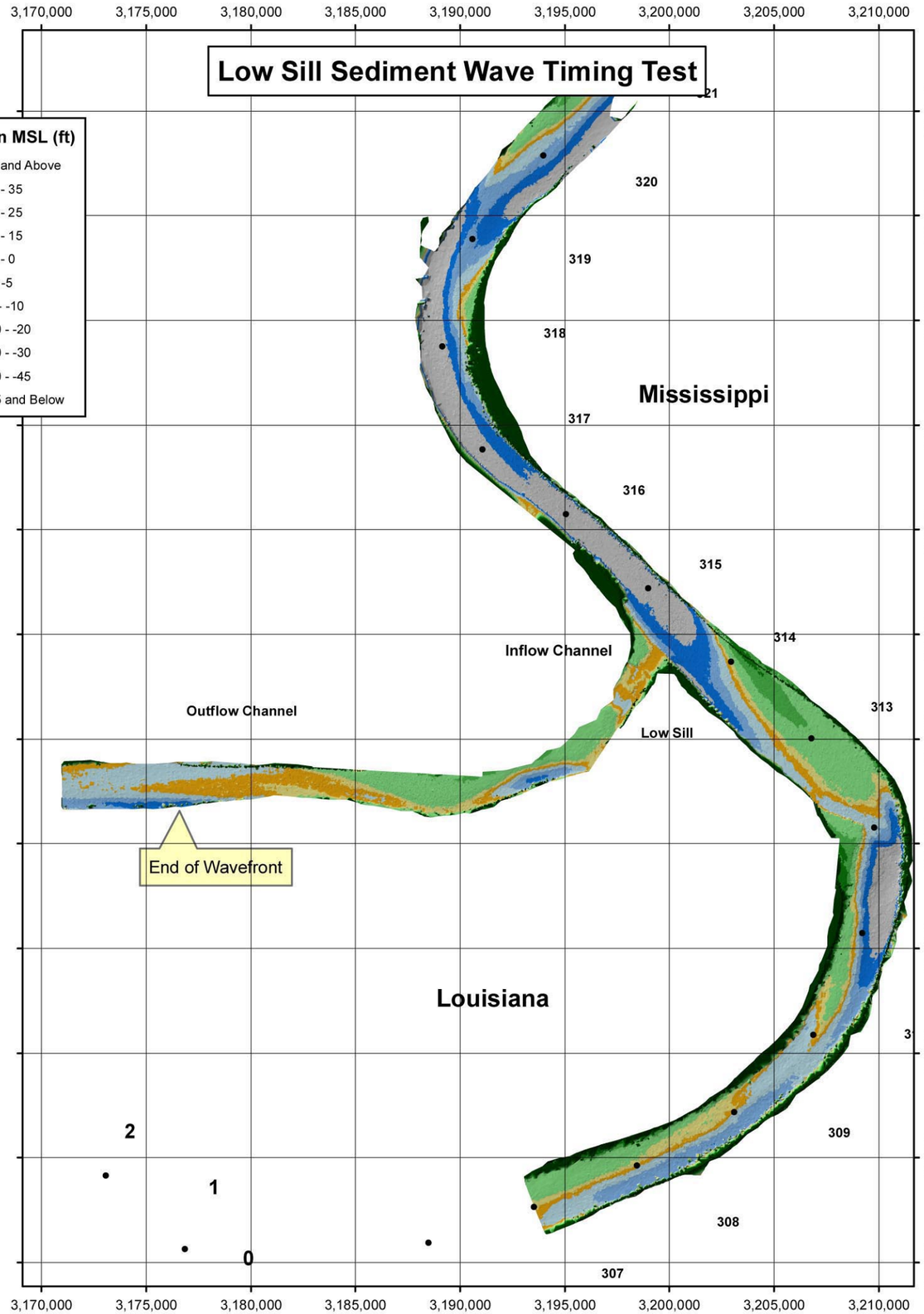
LOWER MISSISSIPPI RIVER
NEW ORLEANS DISTRICT
OLD RIVER HSR MODEL

0 2,500 5,000 10,000 Feet

REPLICATION TEST

PLATE NUMBER
38





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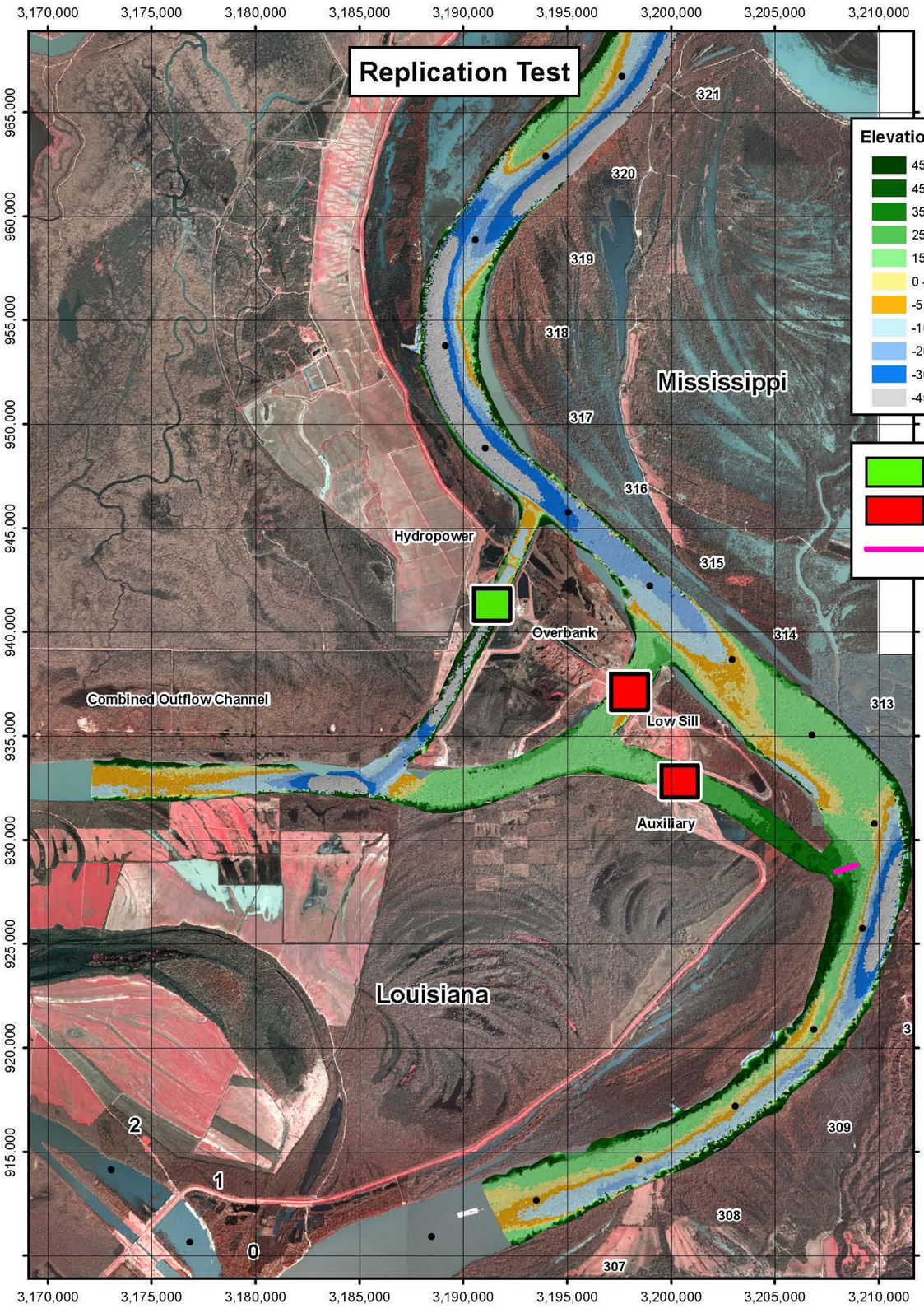
U.S. ARMY ENGINEER DIVISION
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

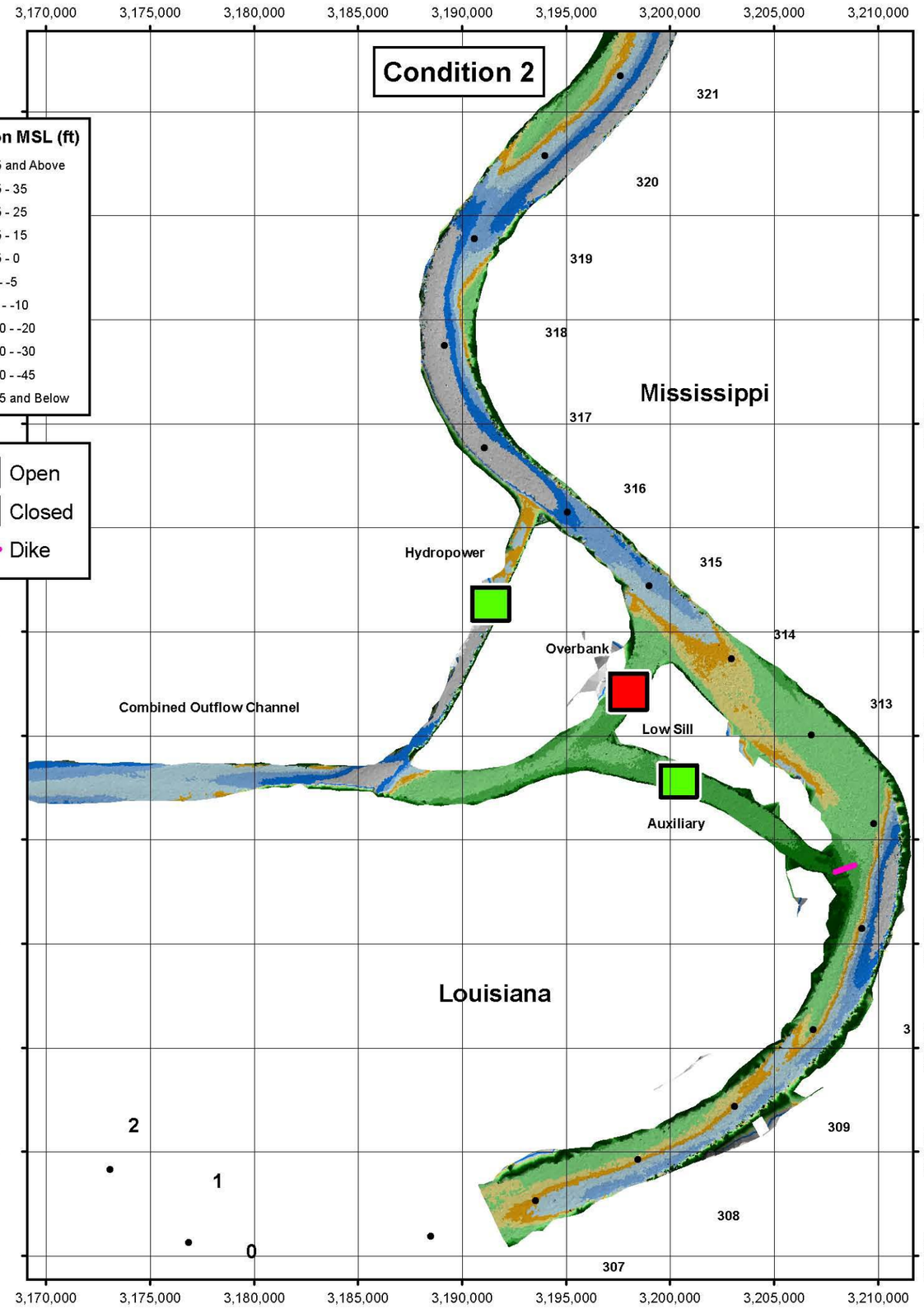
LOWER MISSISSIPPI RIVER
NEW ORLEANS DISTRICT
OLD RIVER HSR MODEL

0 2,500 5,000 10,000 Feet

LOW SILL SEDIMENT WAVE
TIMING TEST - 30 MINS

PLATE NUMBER
39





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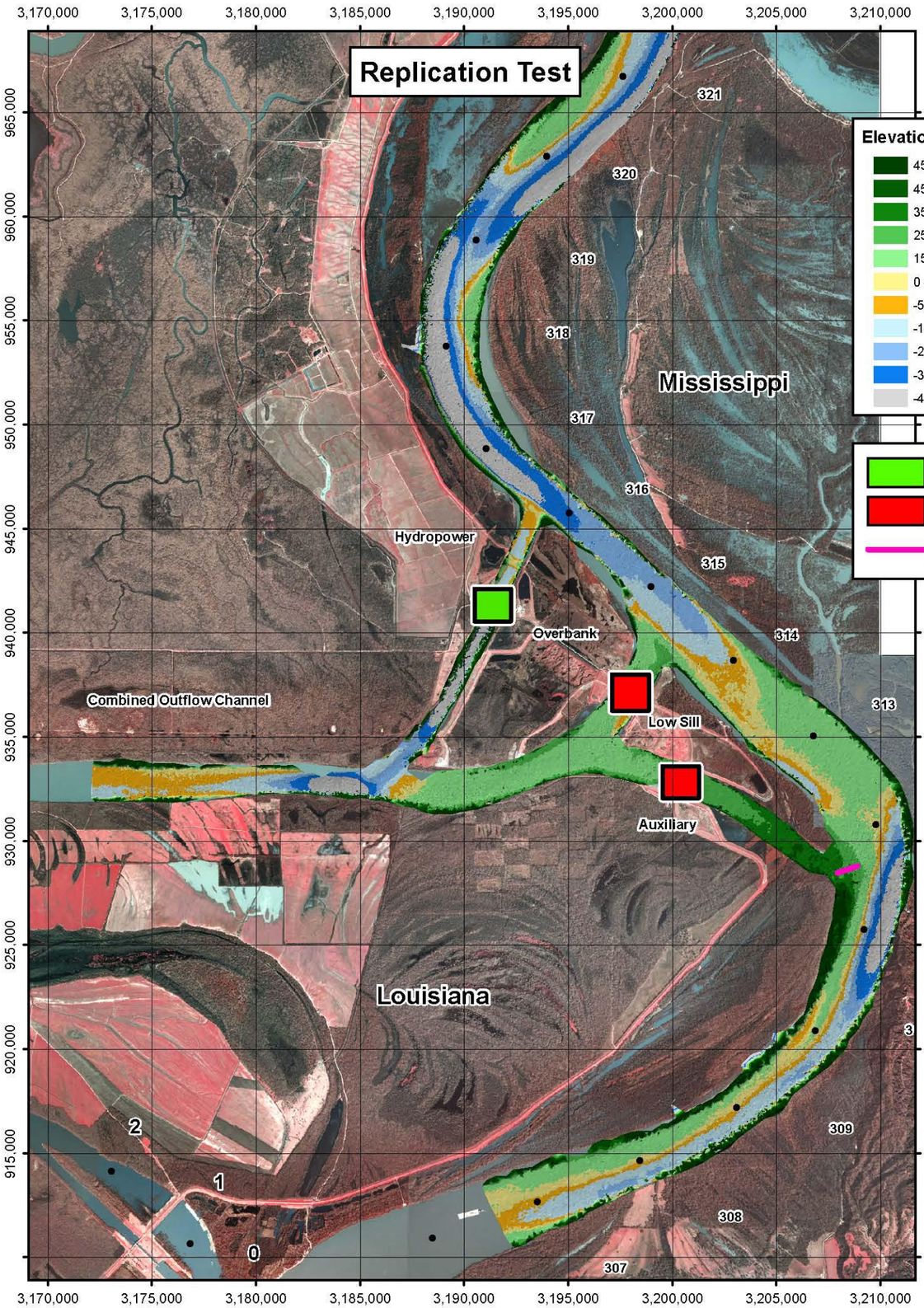
U.S. ARMY ENGINEER DIVISION
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

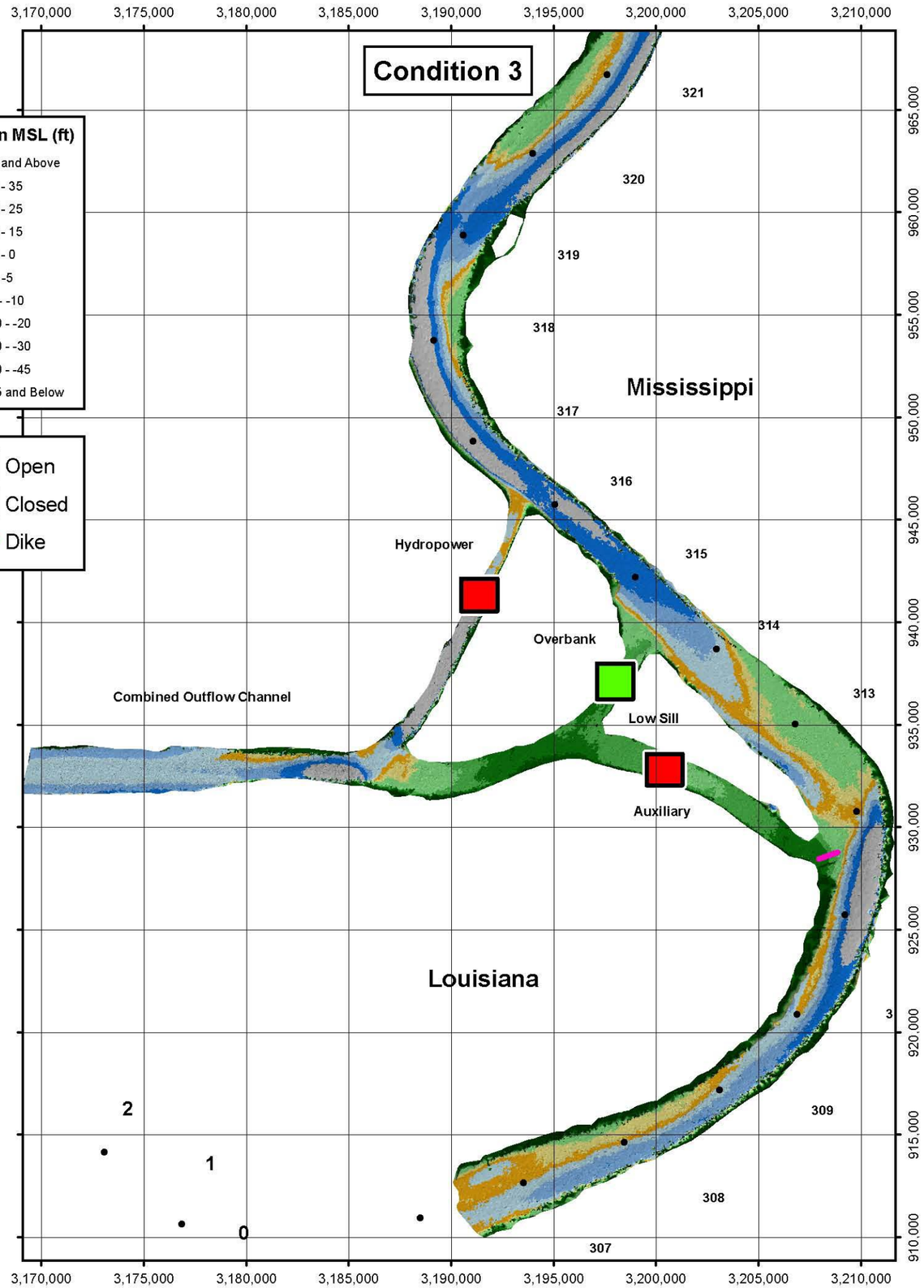
LOWER MISSISSIPPI RIVER
NEW ORLEANS DISTRICT
OLD RIVER HSR MODEL

0 2,500 5,000 10,000 Feet

CONDITION 2

PLATE NUMBER
40





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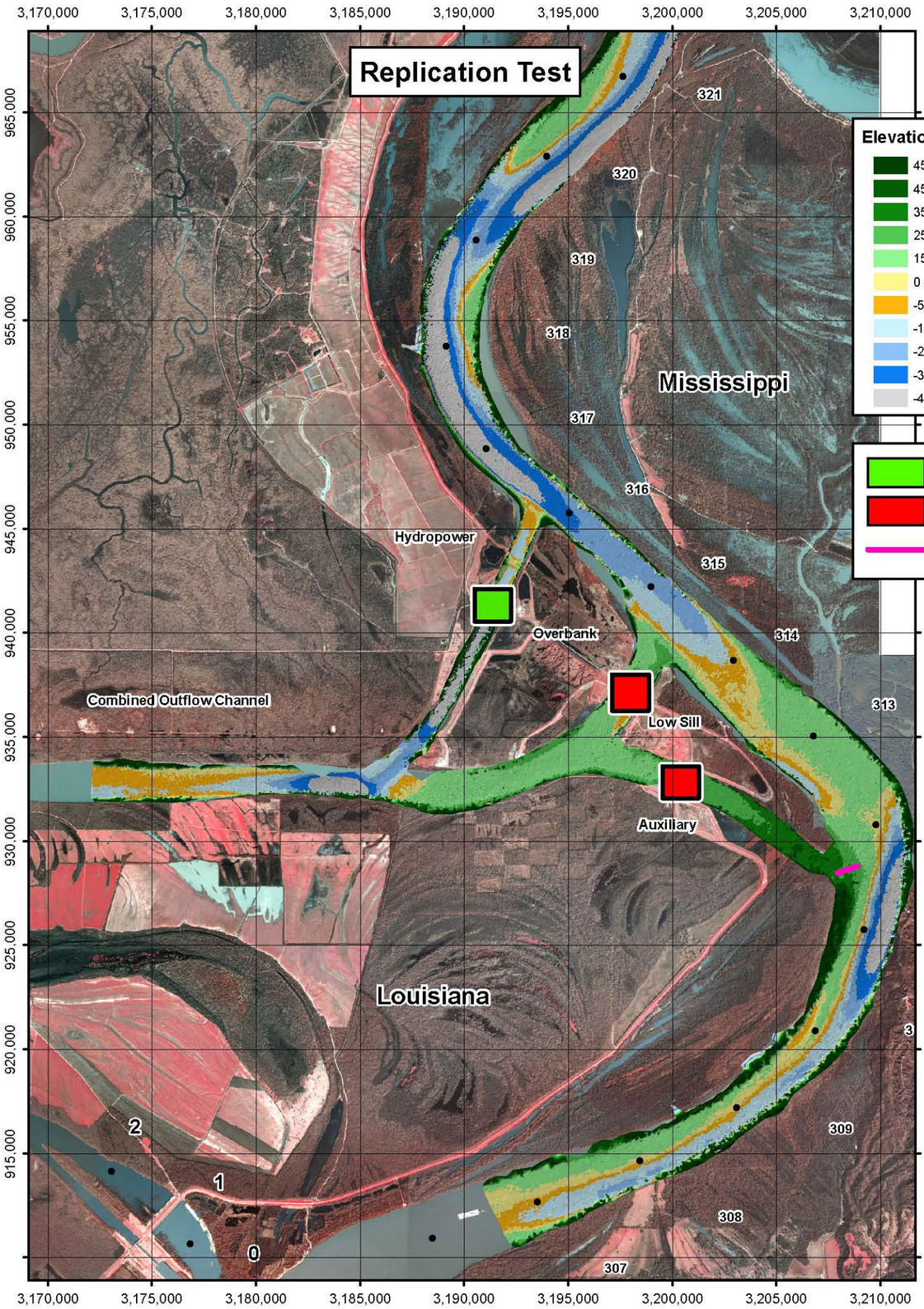
U.S. ARMY ENGINEER DIVISION
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

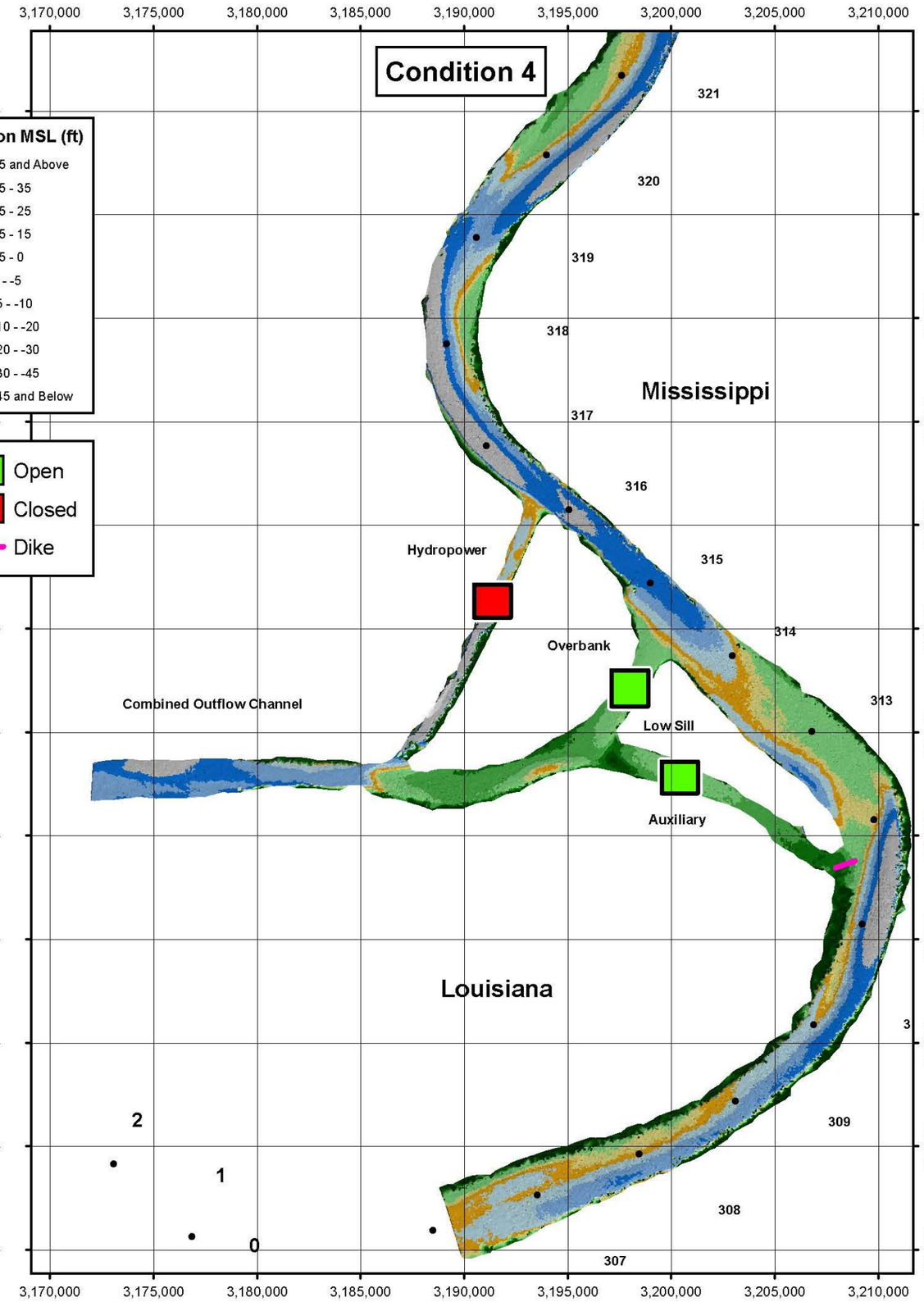
LOWER MISSISSIPPI RIVER
NEW ORLEANS DISTRICT
OLD RIVER HSR MODEL

0 2,500 5,000 10,000 Feet

CONDITION 3

PLATE NUMBER
41





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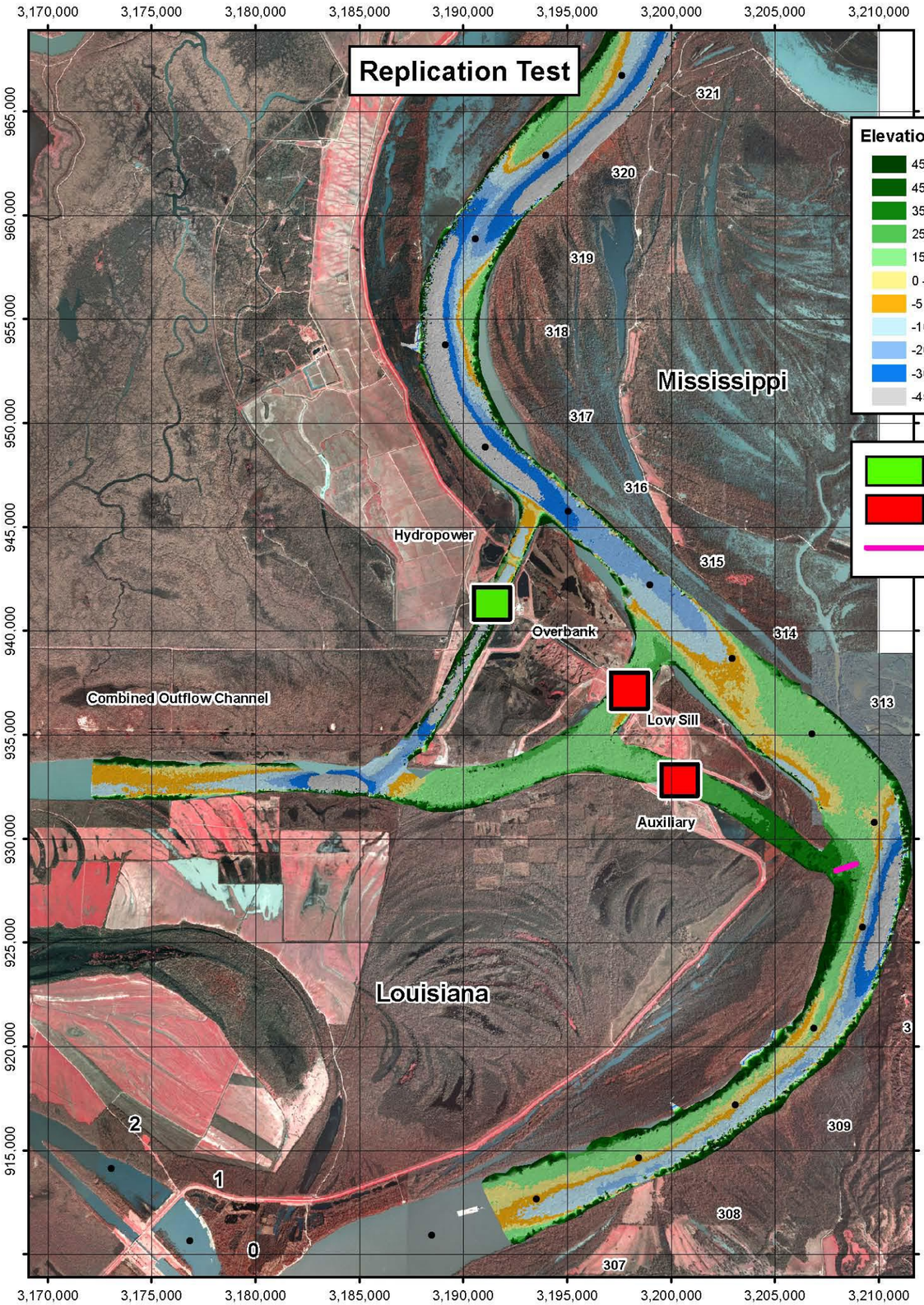
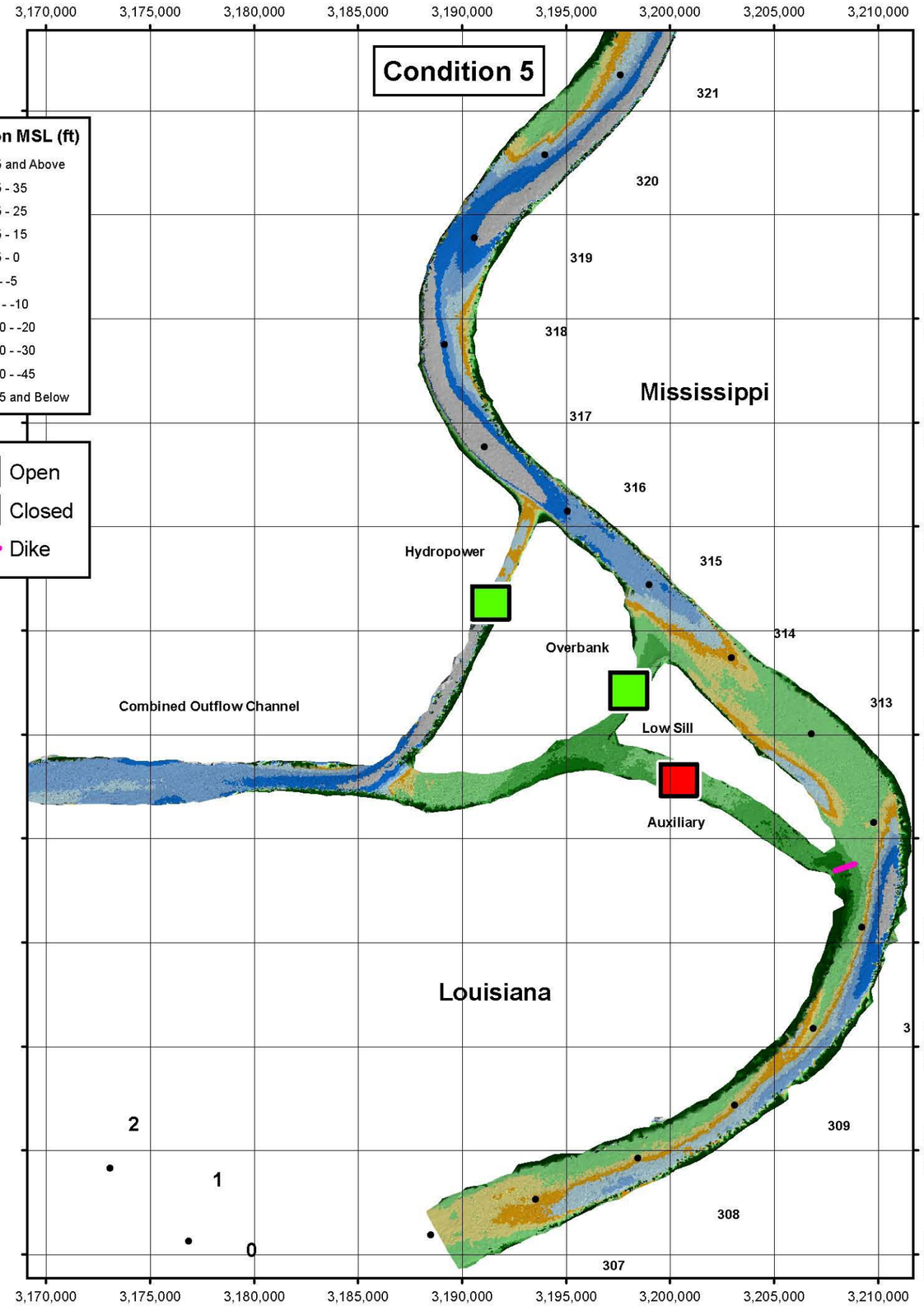
LOWER MISSISSIPPI RIVER NEW ORLEANS DISTRICT OLD RIVER HSR MODEL	

0 2,500 5,000 10,000 Feet

CONDITION 4

PLATE NUMBER
42





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FILE NAME: ...OLD RIVER HSR MODEL.MXD	

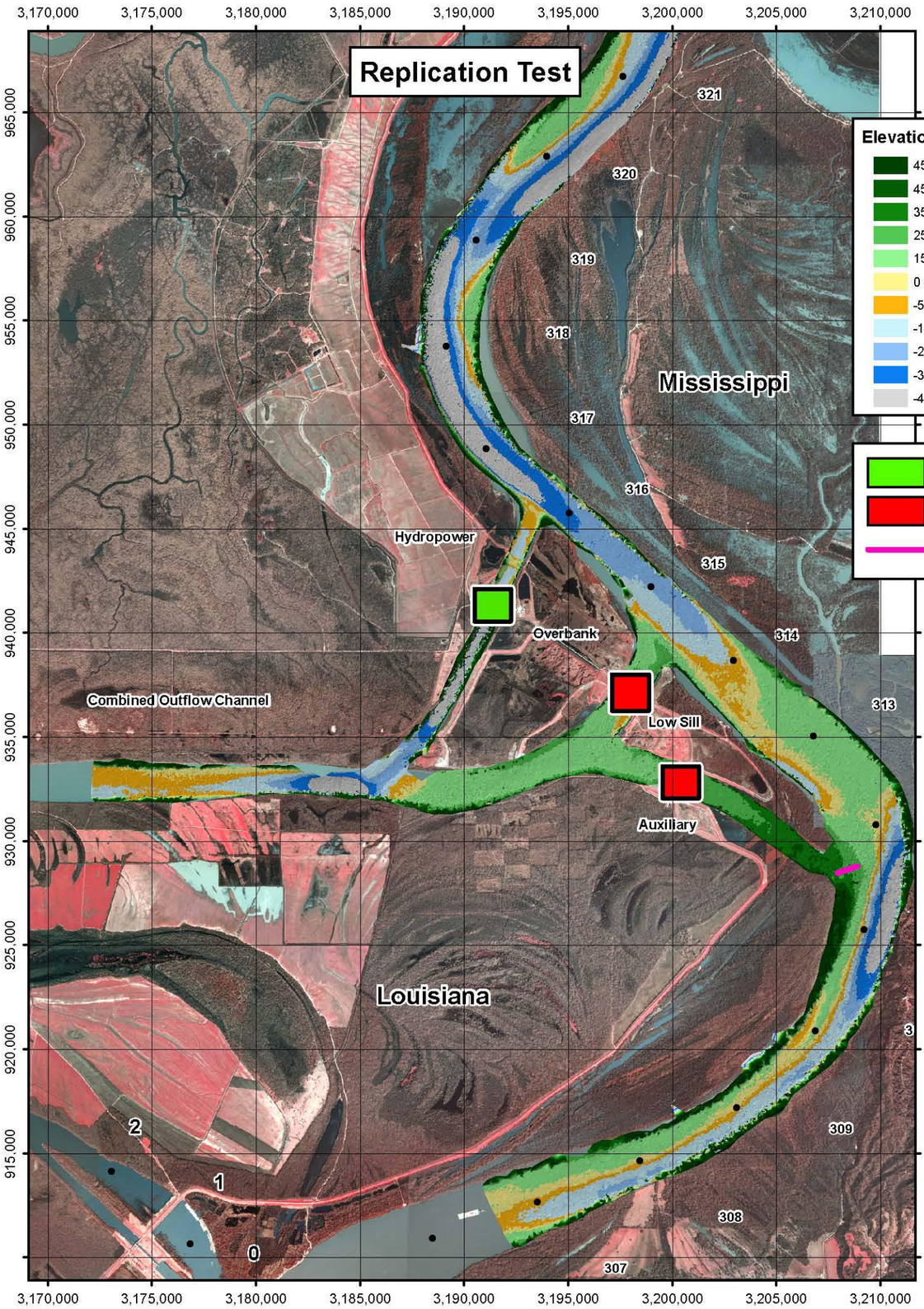
U.S. ARMY ENGINEER DIVISION
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

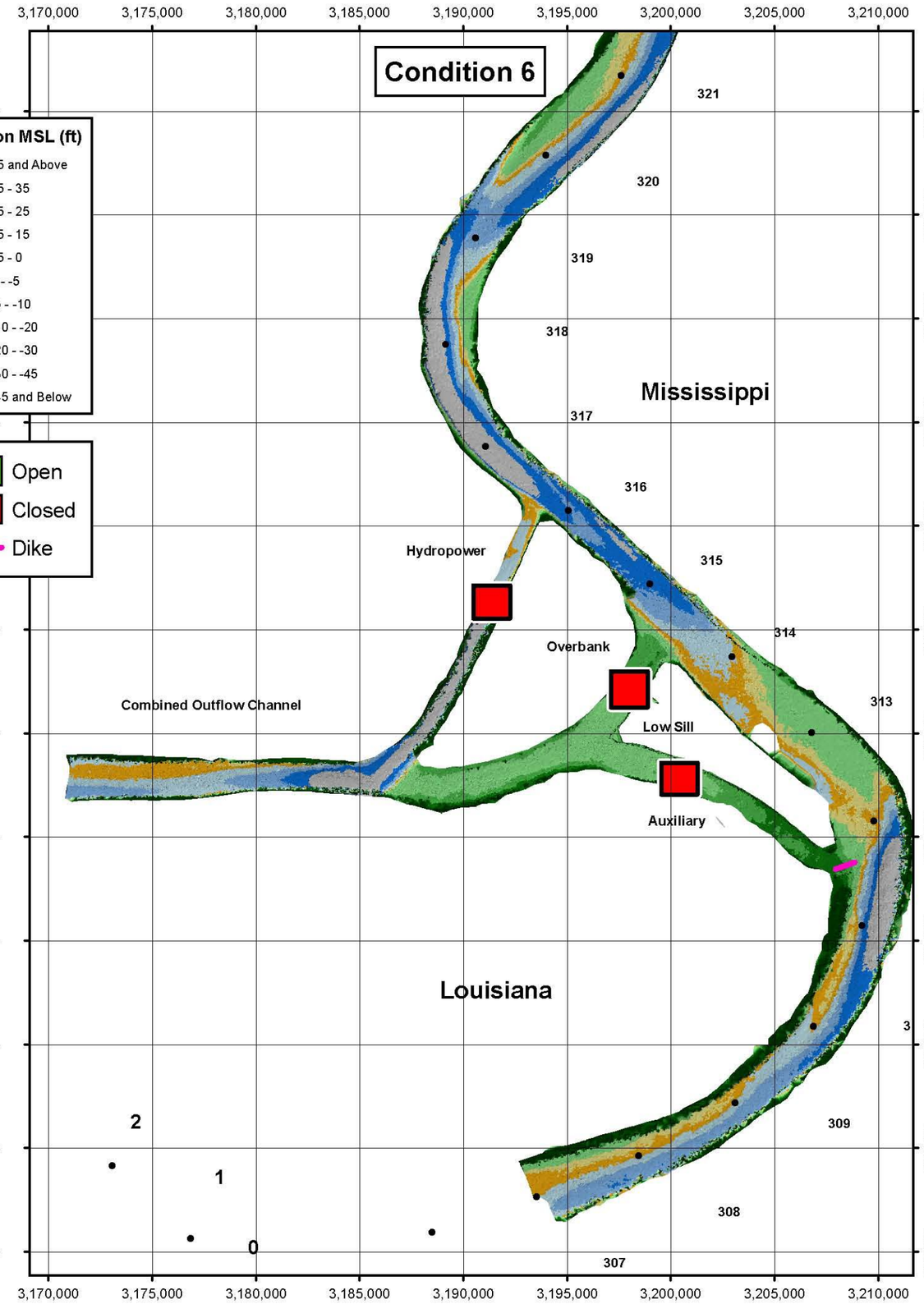
LOWER MISSISSIPPI RIVER
NEW ORLEANS DISTRICT
OLD RIVER HSR MODEL

0 2,500 5,000 10,000 Feet

CONDITION 5

PLATE NUMBER
43





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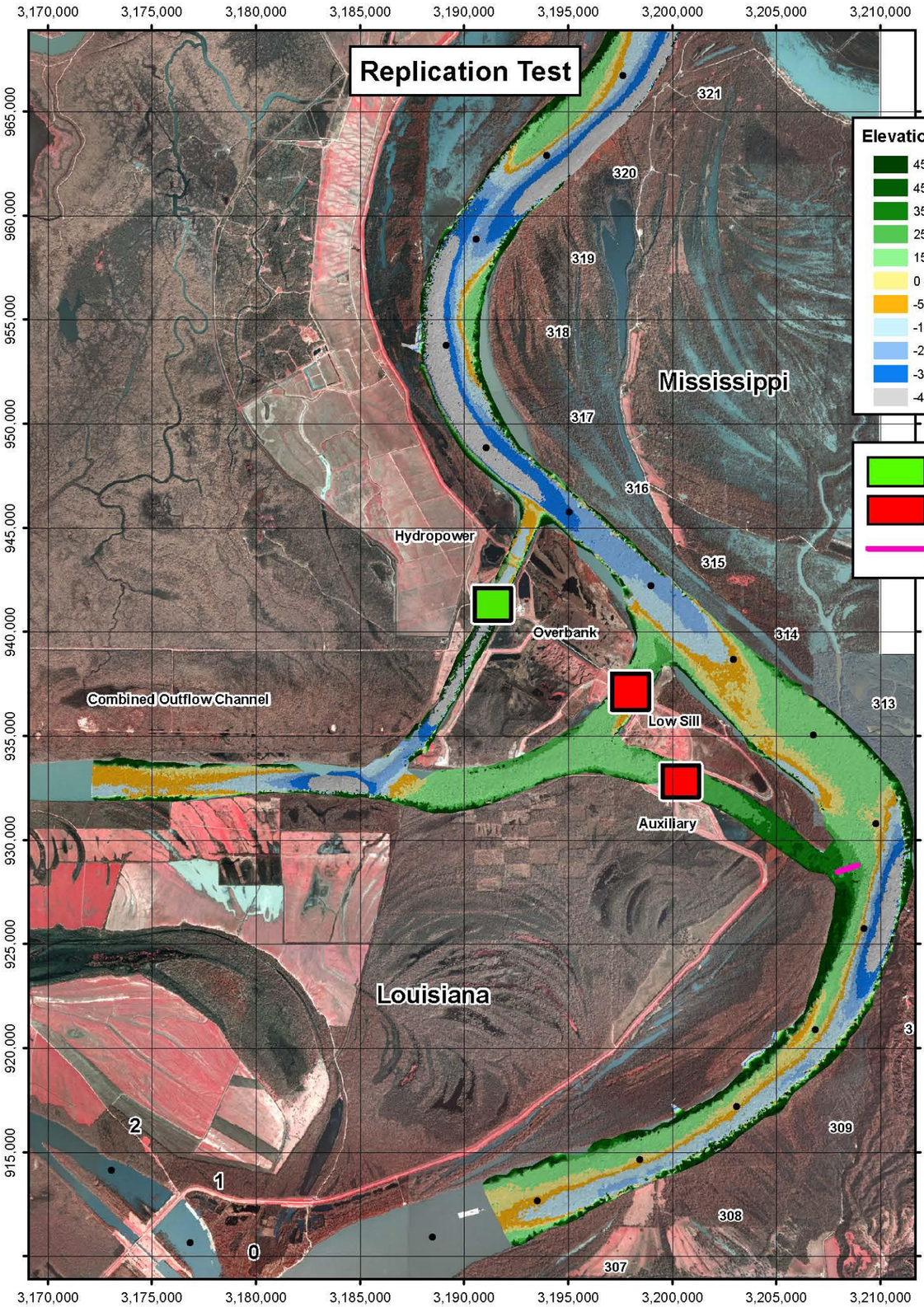
U.S. ARMY ENGINEER DIVISION
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

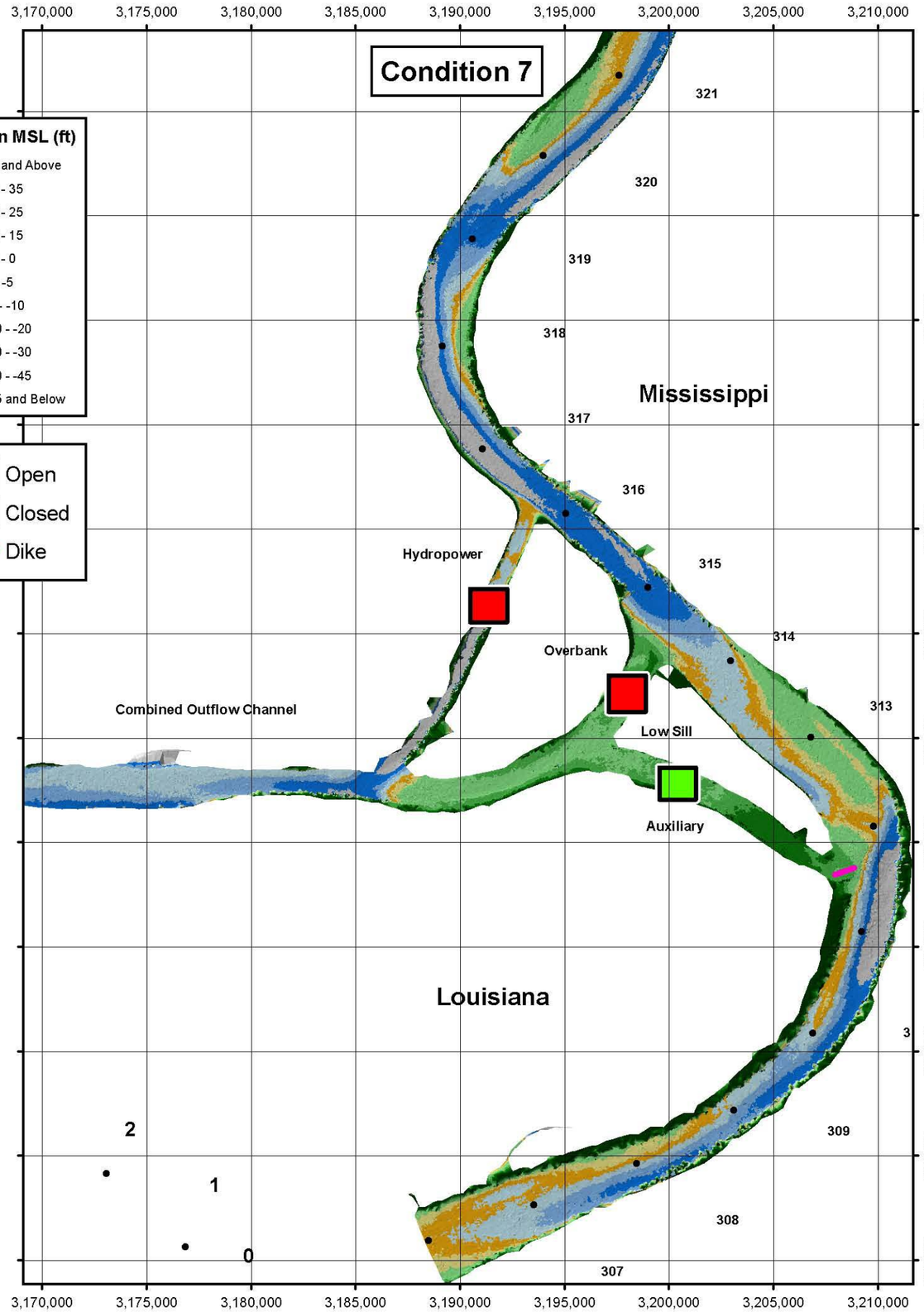
LOWER MISSISSIPPI RIVER
NEW ORLEANS DISTRICT
OLD RIVER HSR MODEL

0 2,500 5,000 10,000 Feet

CONDITION 6

PLATE NUMBER
44





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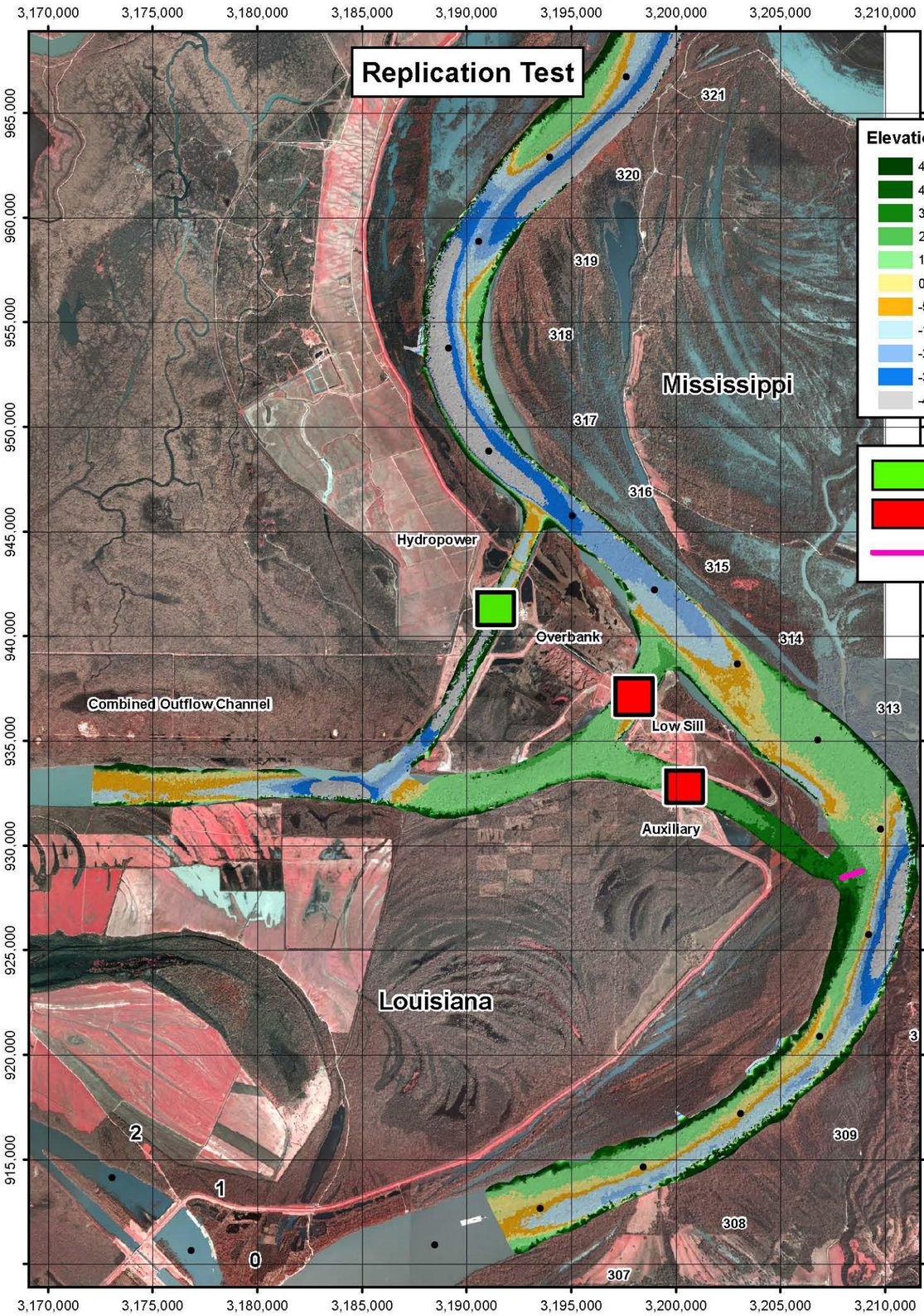
U.S. ARMY ENGINEER DIVISION
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

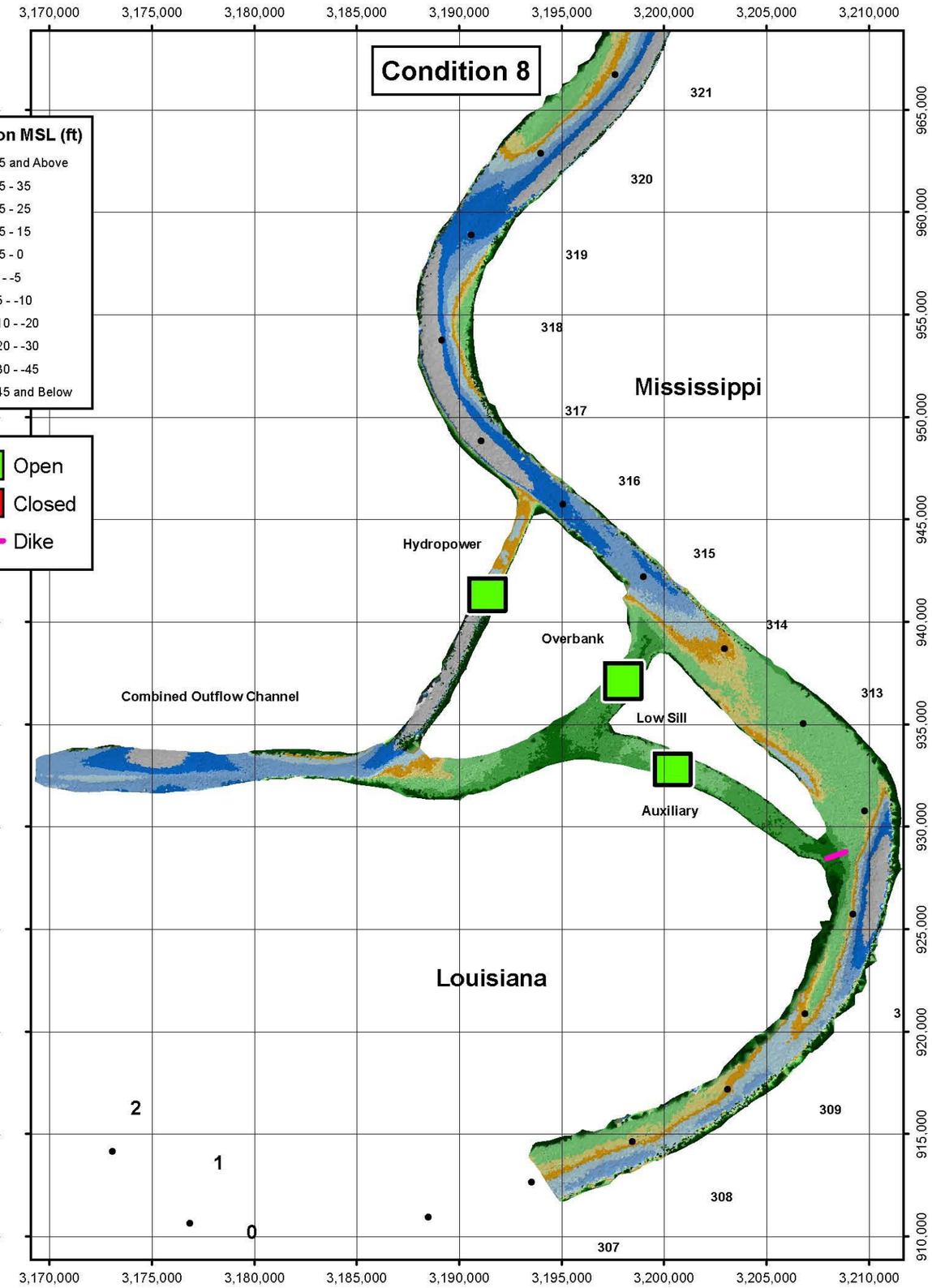
LOWER MISSISSIPPI RIVER
NEW ORLEANS DISTRICT
OLD RIVER HSR MODEL

0 2,500 5,000 10,000 Feet

CONDITION 7

PLATE NUMBER
45





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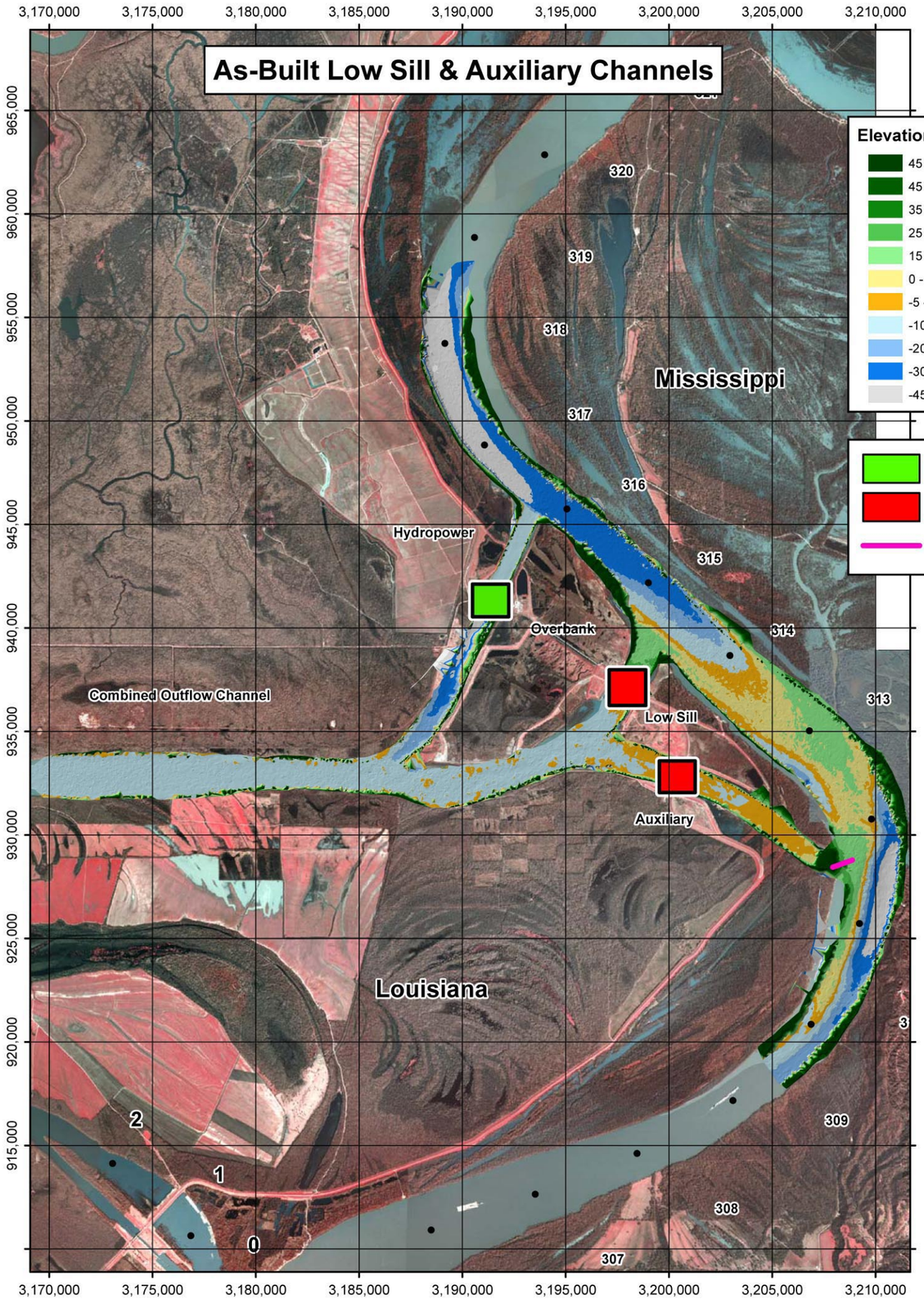
U.S. ARMY ENGINEER DIVISION
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

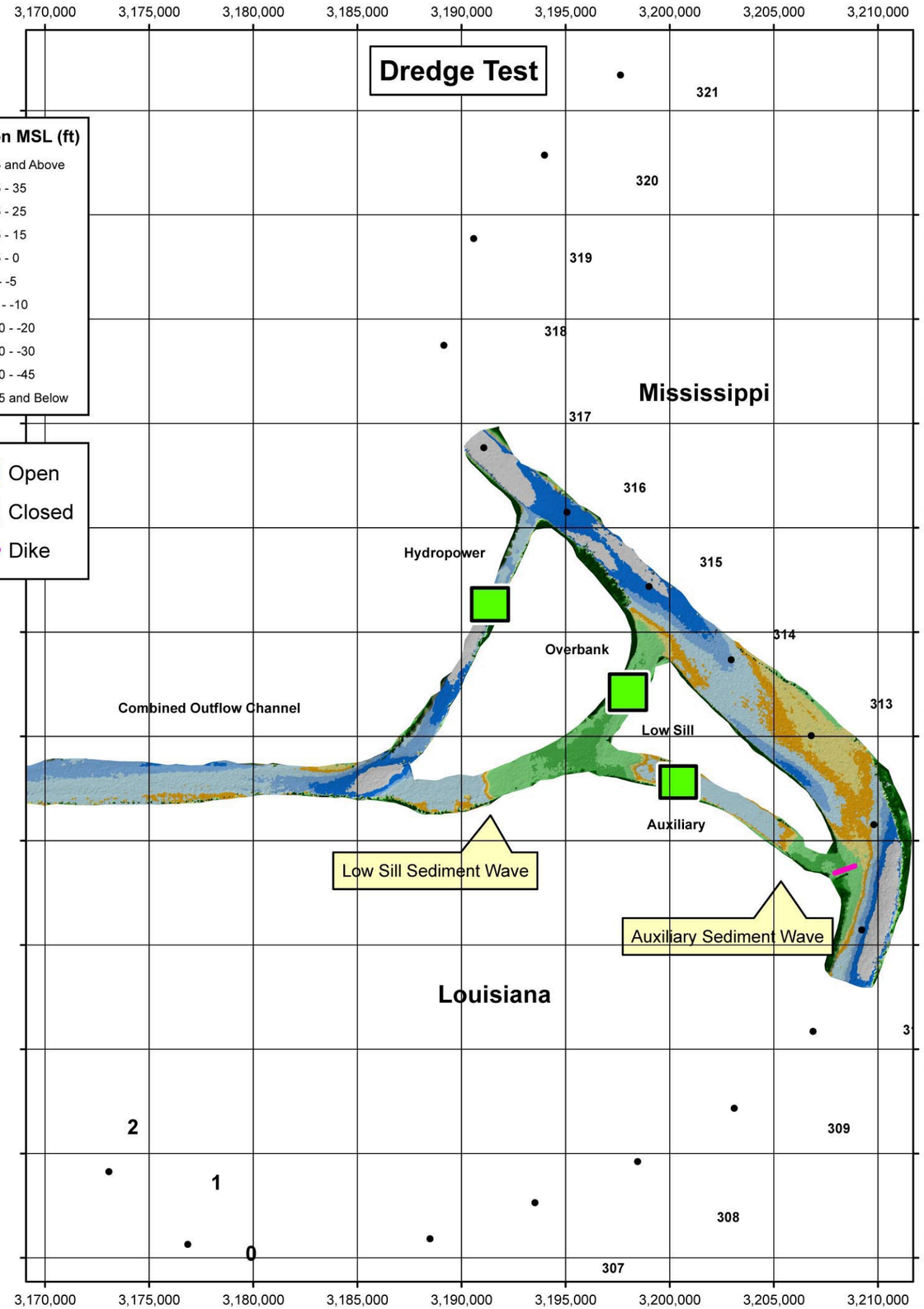
LOWER MISSISSIPPI RIVER
NEW ORLEANS DISTRICT
OLD RIVER HSR MODEL

0 2,500 5,000 10,000 Feet

CONDITION 8

PLATE NUMBER
46





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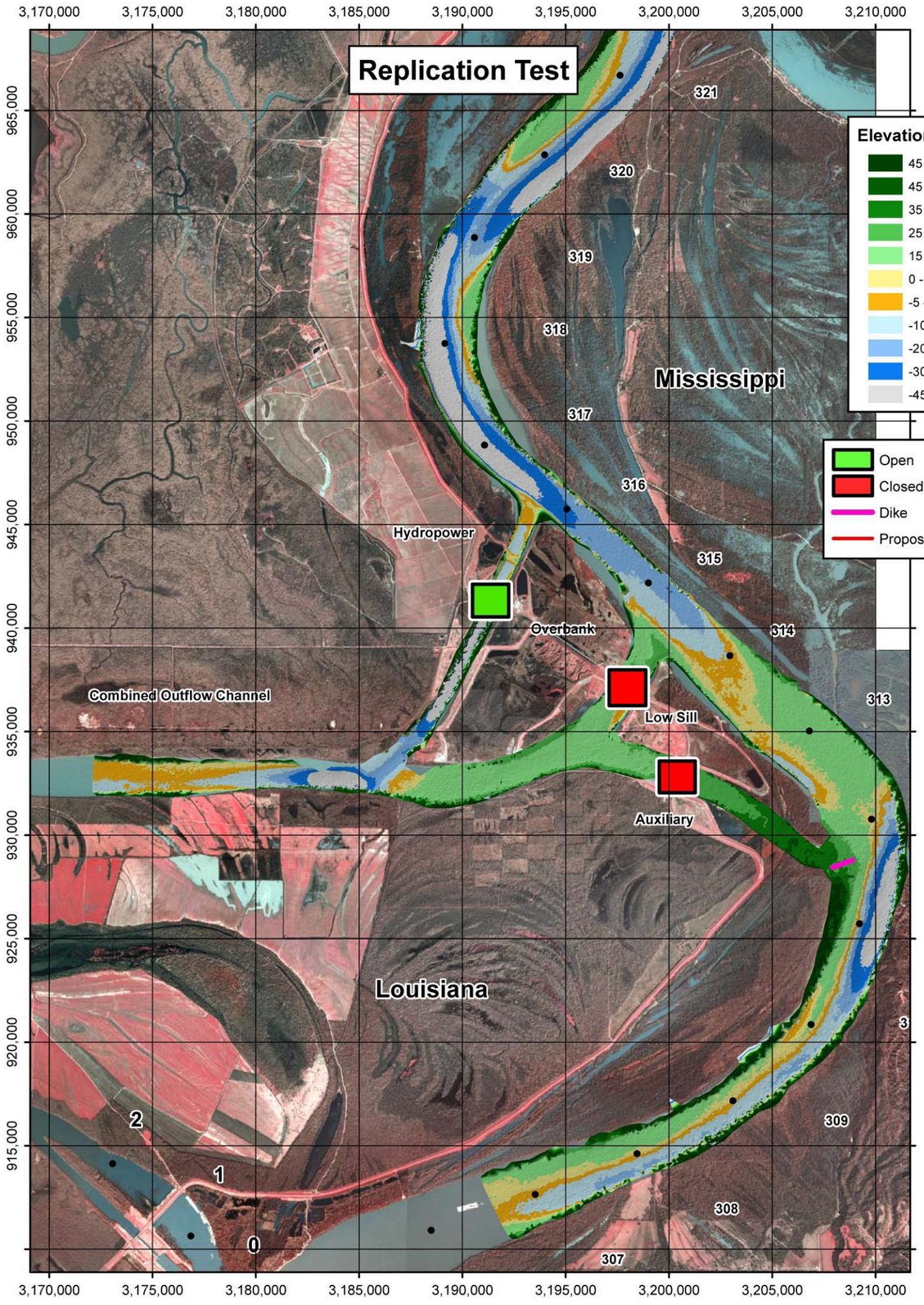
U.S. ARMY ENGINEER DIVISION
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

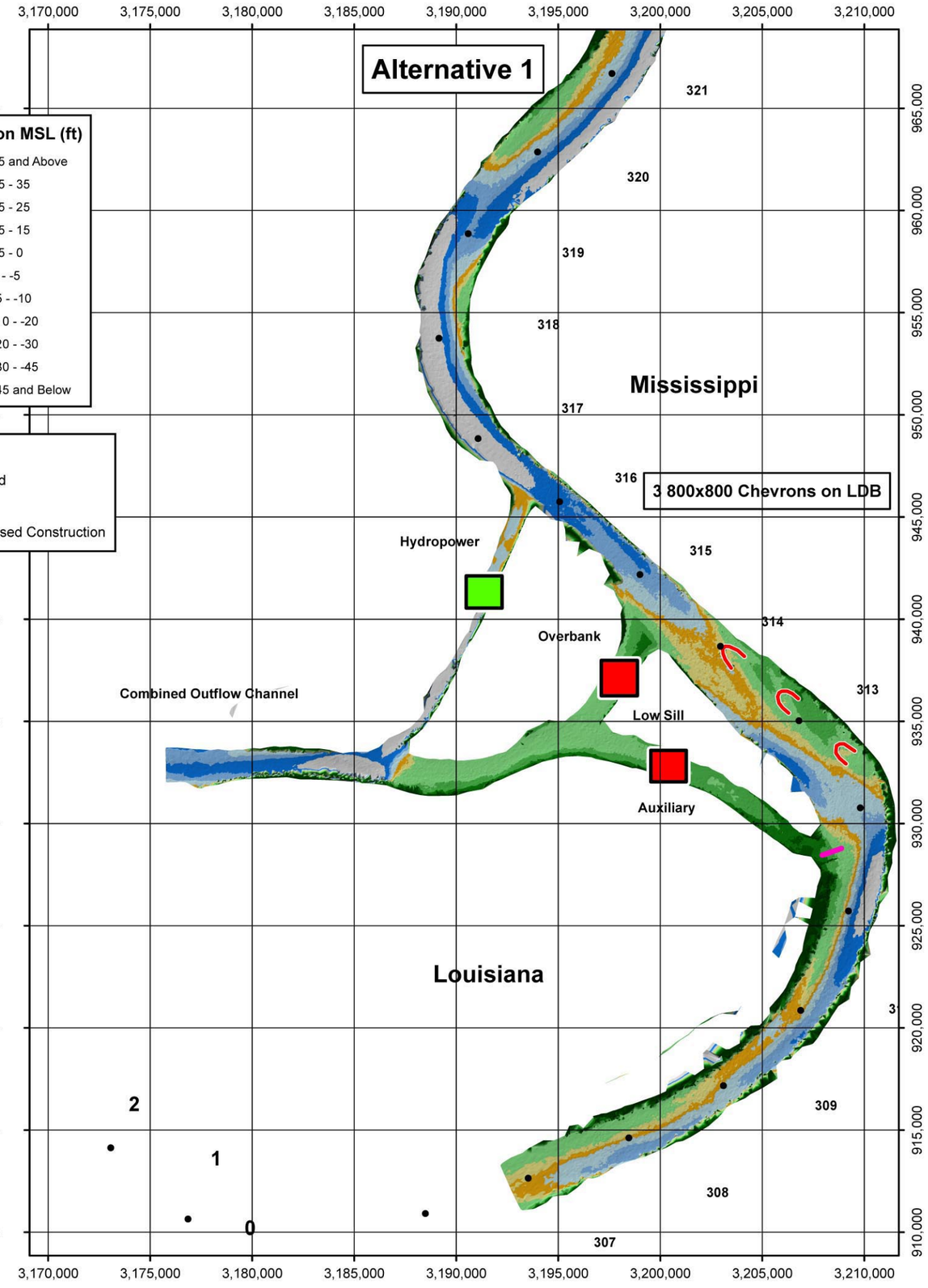
LOWER MISSISSIPPI RIVER
NEW ORLEANS DISTRICT
OLD RIVER HSR MODEL

0 2,500 5,000 10,000 Feet

DREDGE TEST - 20 MINS

PLATE NUMBER
47





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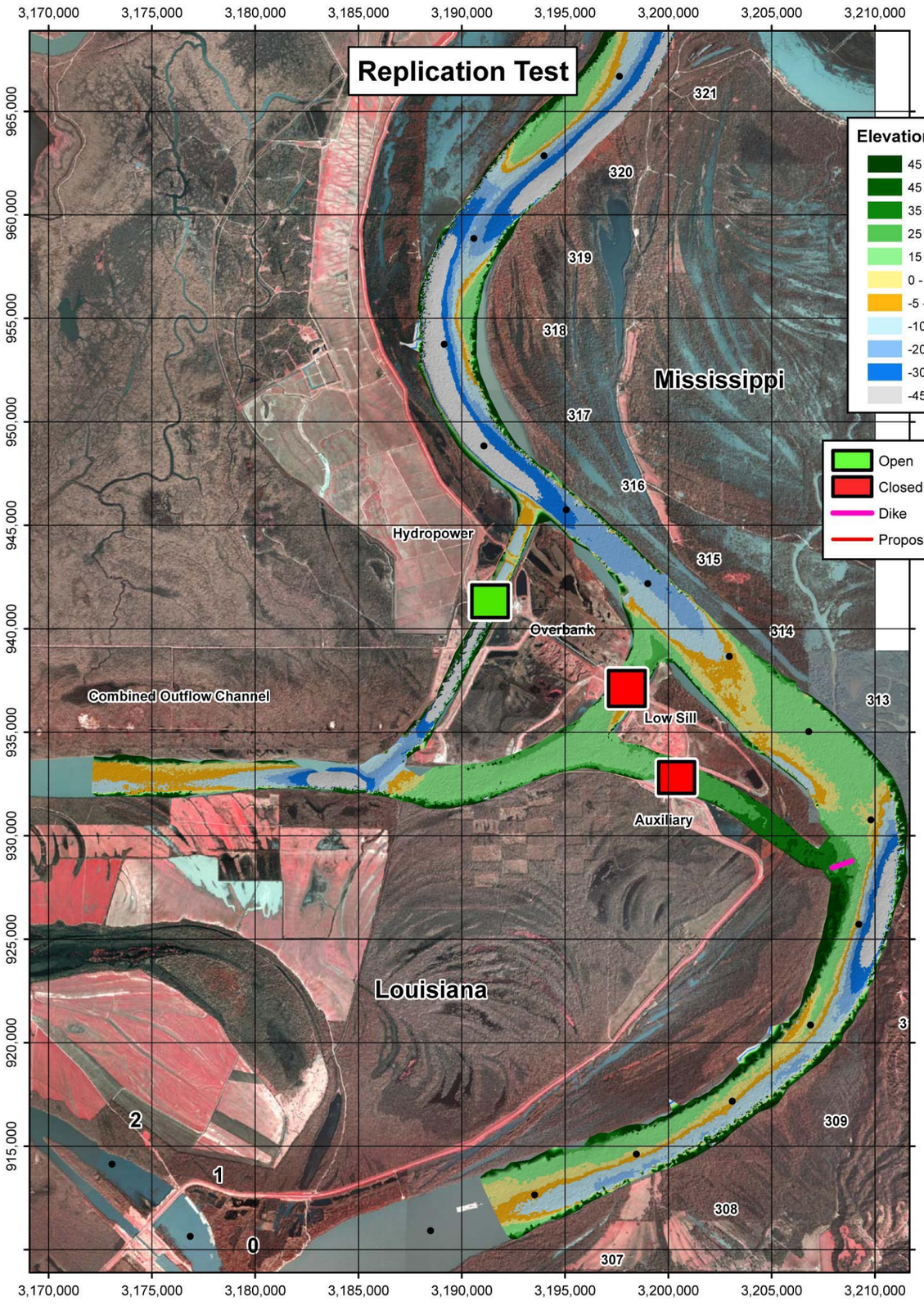
U.S. ARMY ENGINEER DIVISION
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

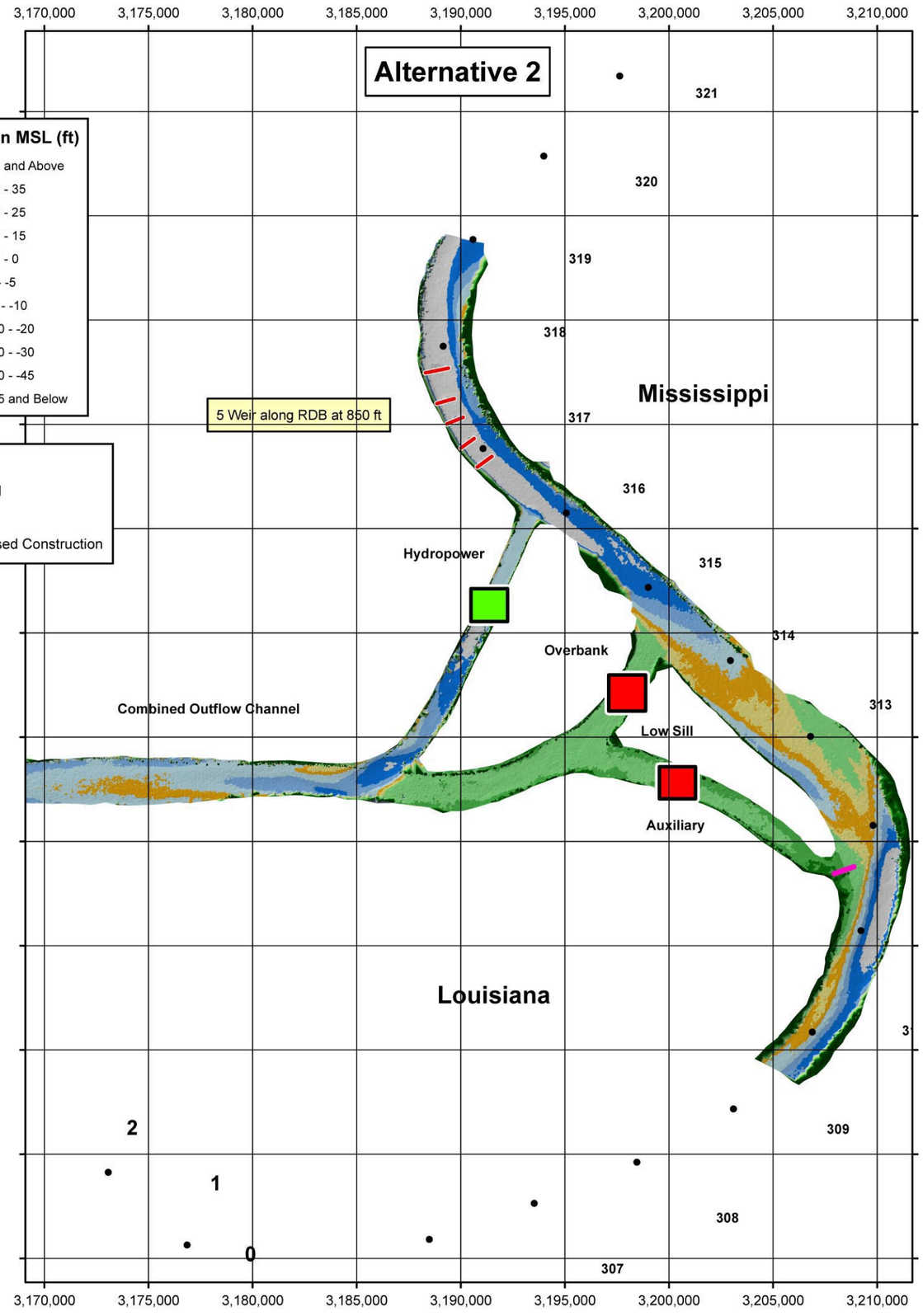
LOWER MISSISSIPPI RIVER
NEW ORLEANS DISTRICT
OLD RIVER HSR MODEL

0 2,500 5,000 10,000 Feet

ALTERNATIVE 1 - 3 CHEVRONS

PLATE NUMBER
48





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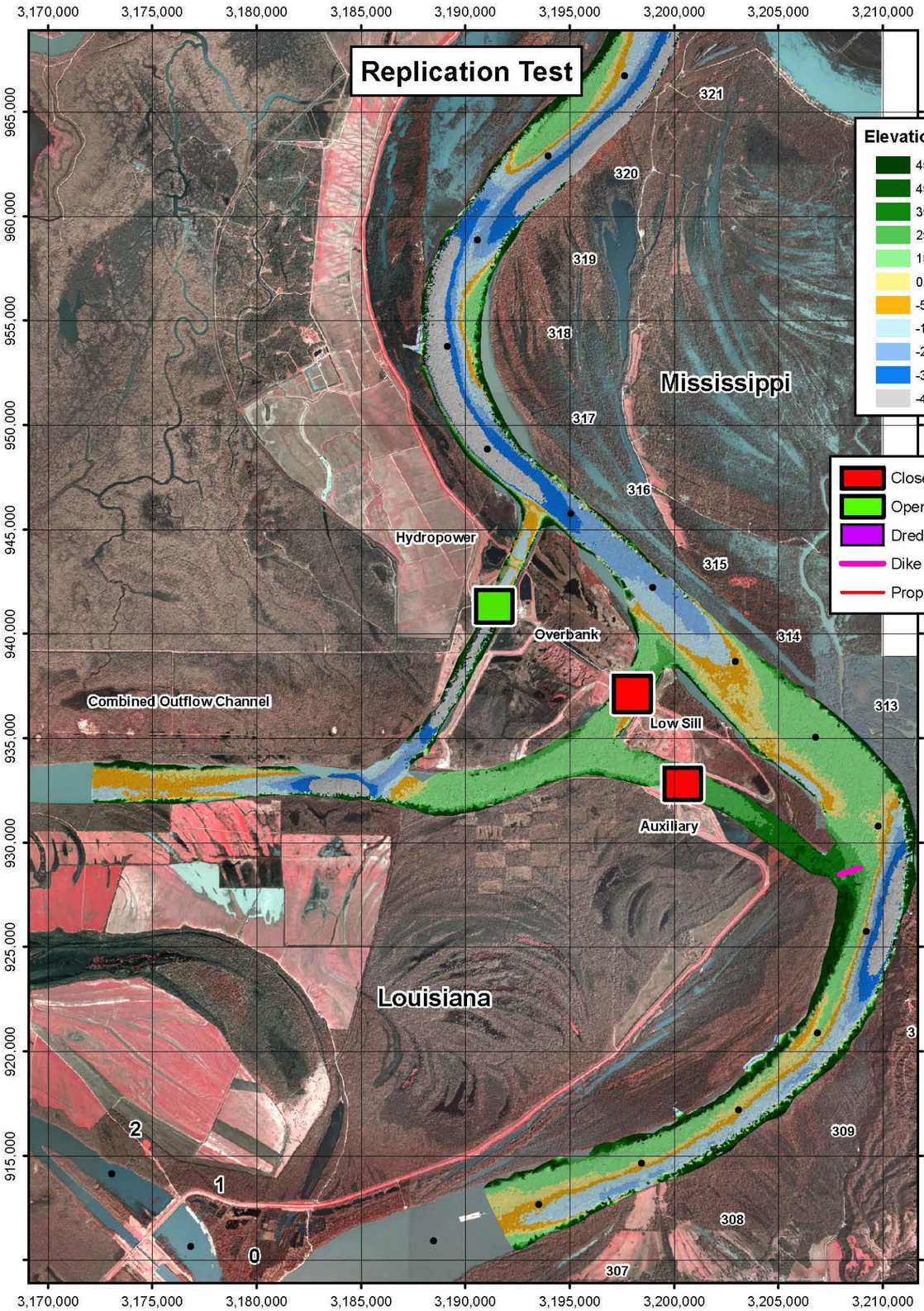
U.S. ARMY ENGINEER DIVISION
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

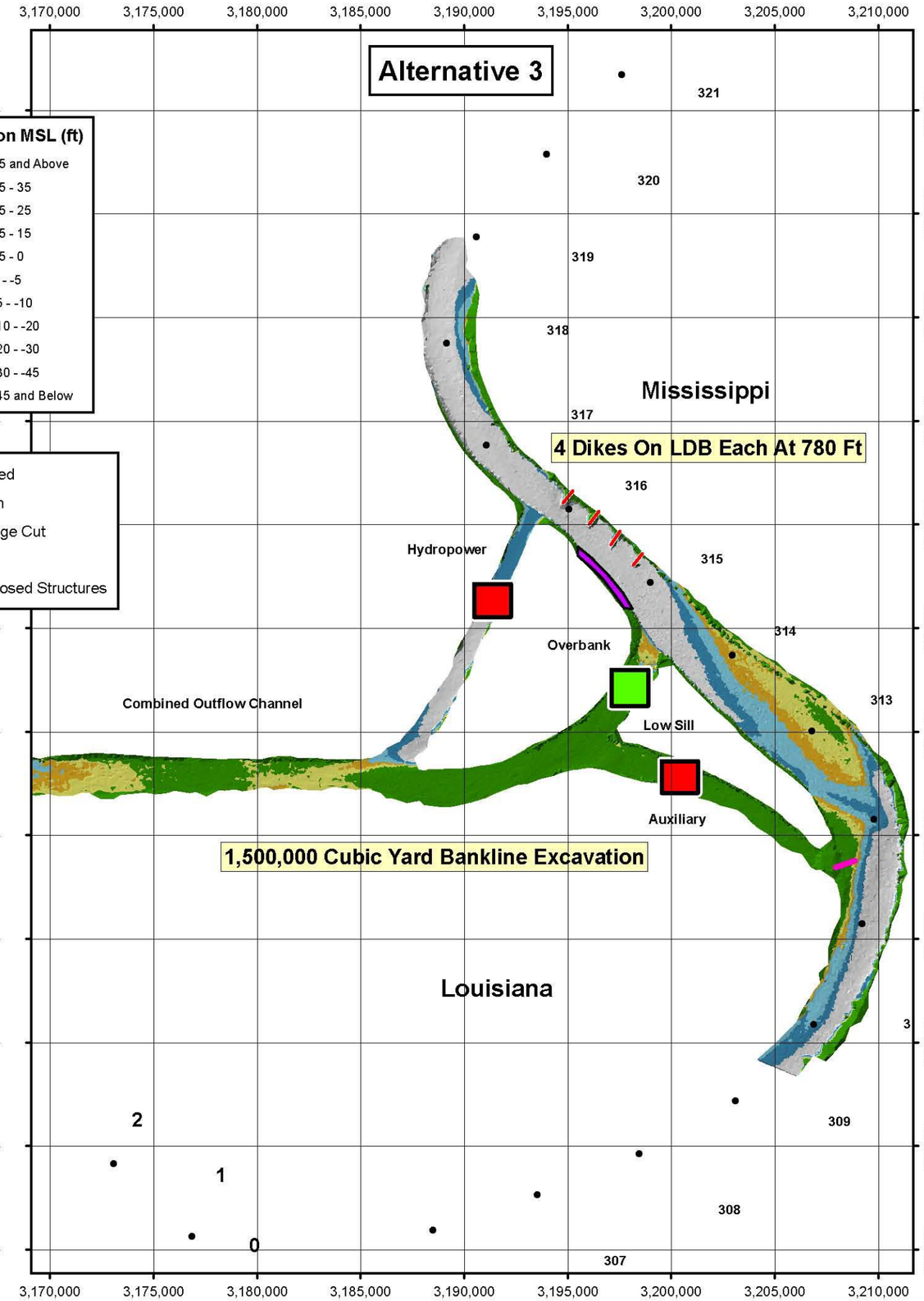
LOWER MISSISSIPPI RIVER
NEW ORLEANS DISTRICT
OLD RIVER HSR MODEL

0 2,500 5,000 10,000 Feet

ALTERNATIVE 2

PLATE NUMBER
49





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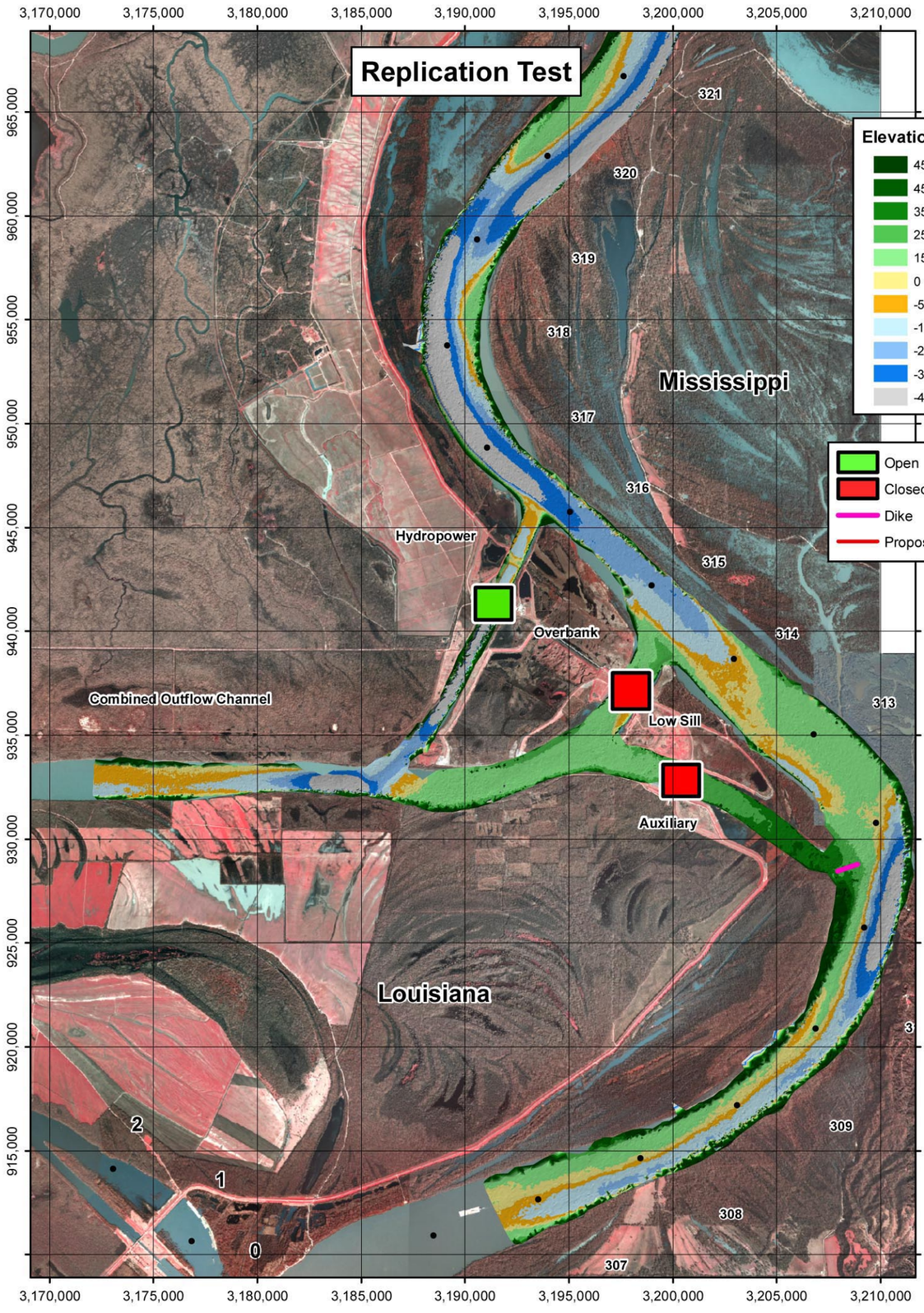
U.S. ARMY ENGINEER DIVISION
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

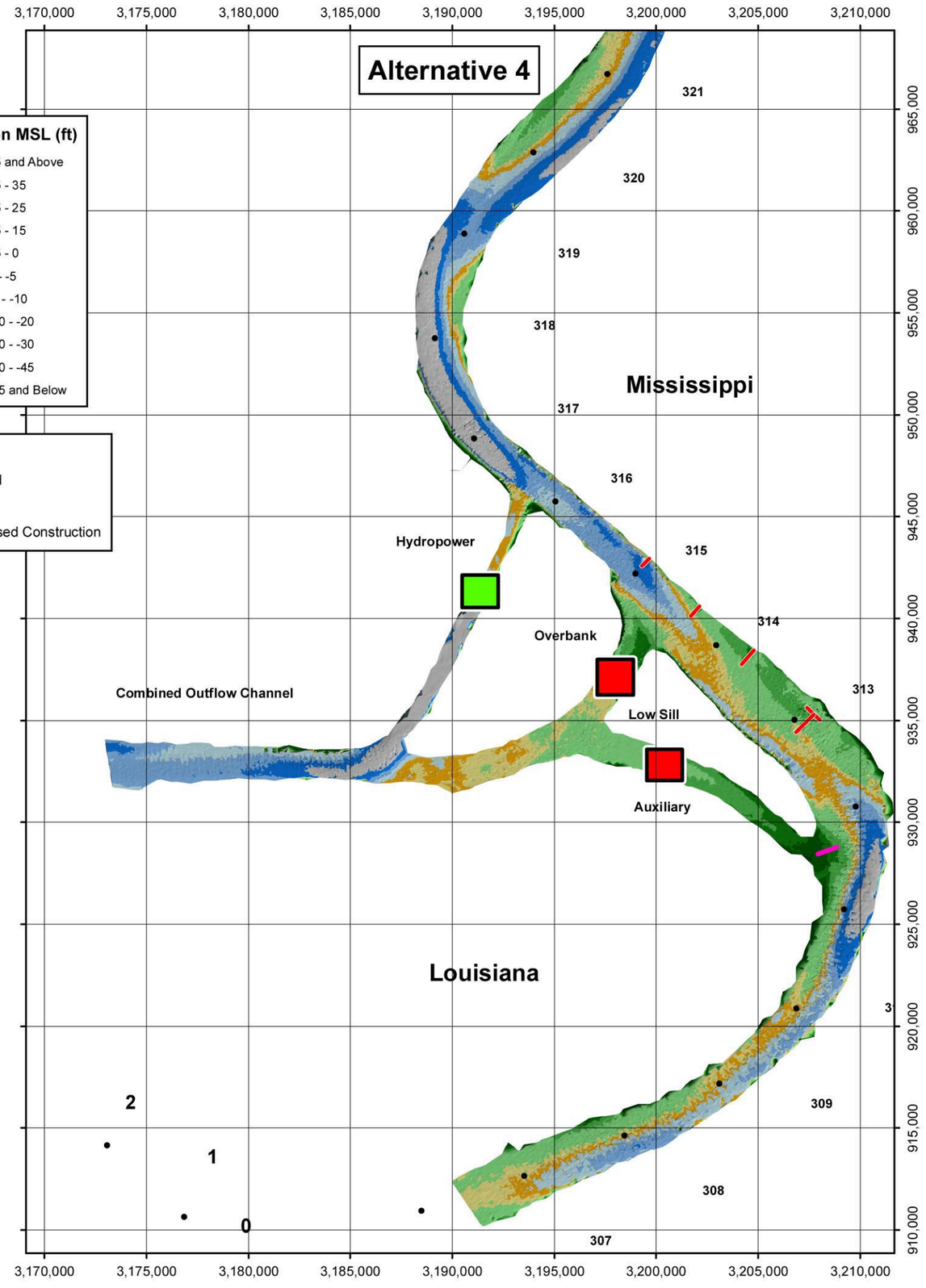
LOWER MISSISSIPPI RIVER
NEW ORLEANS DISTRICT
OLD RIVER HSR MODEL

0 2,500 5,000 10,000 Feet

ALTERNATIVE 3

PLATE NUMBER
50





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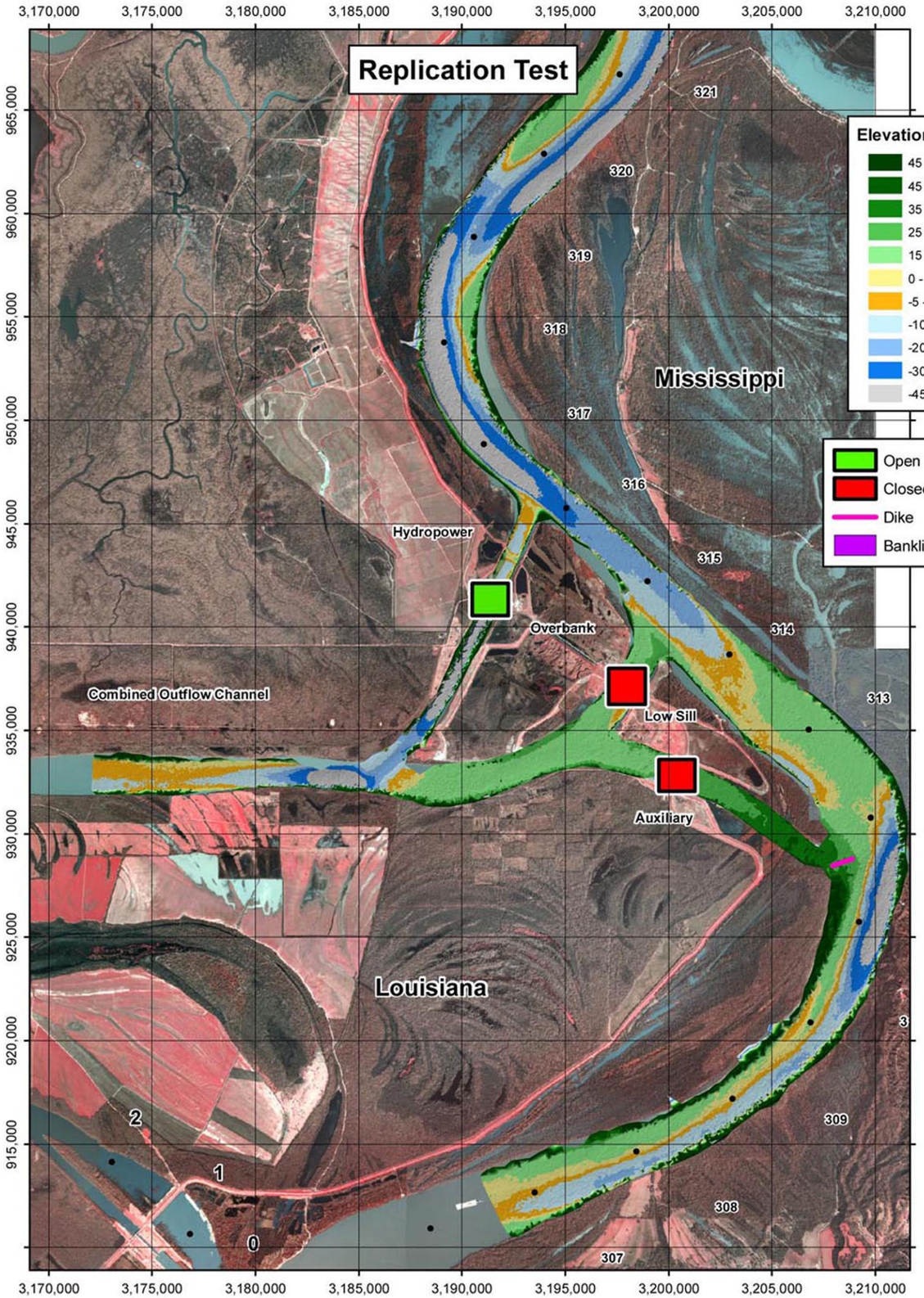
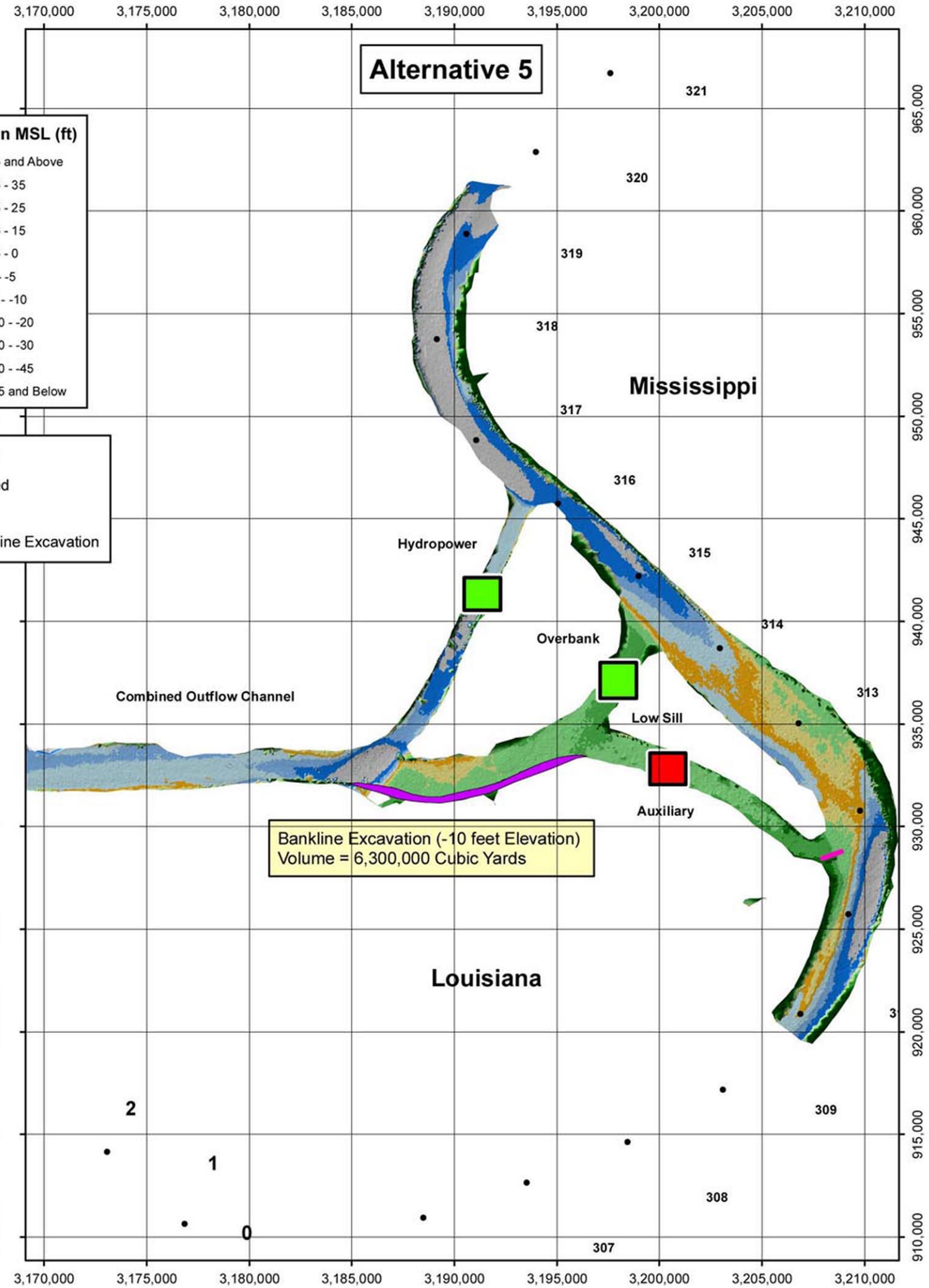
DRAWN BY: I. NGUYEN	SUBMITTED BY: I. NGUYEN
PLOT DATE: MARCH 2011	FILE NAME: ...OLD RIVER HSR MODEL.MXD
U.S. ARMY ENGINEER DIVISION CORPS OF ENGINEERS ST. LOUIS, MISSOURI	LOWER MISSISSIPPI RIVER NEW ORLEANS DISTRICT OLD RIVER HSR MODEL

0 2,500 5,000 10,000 Feet

ALTERNATIVE 4 - MVN MASTER PLAN

PLATE NUMBER
51





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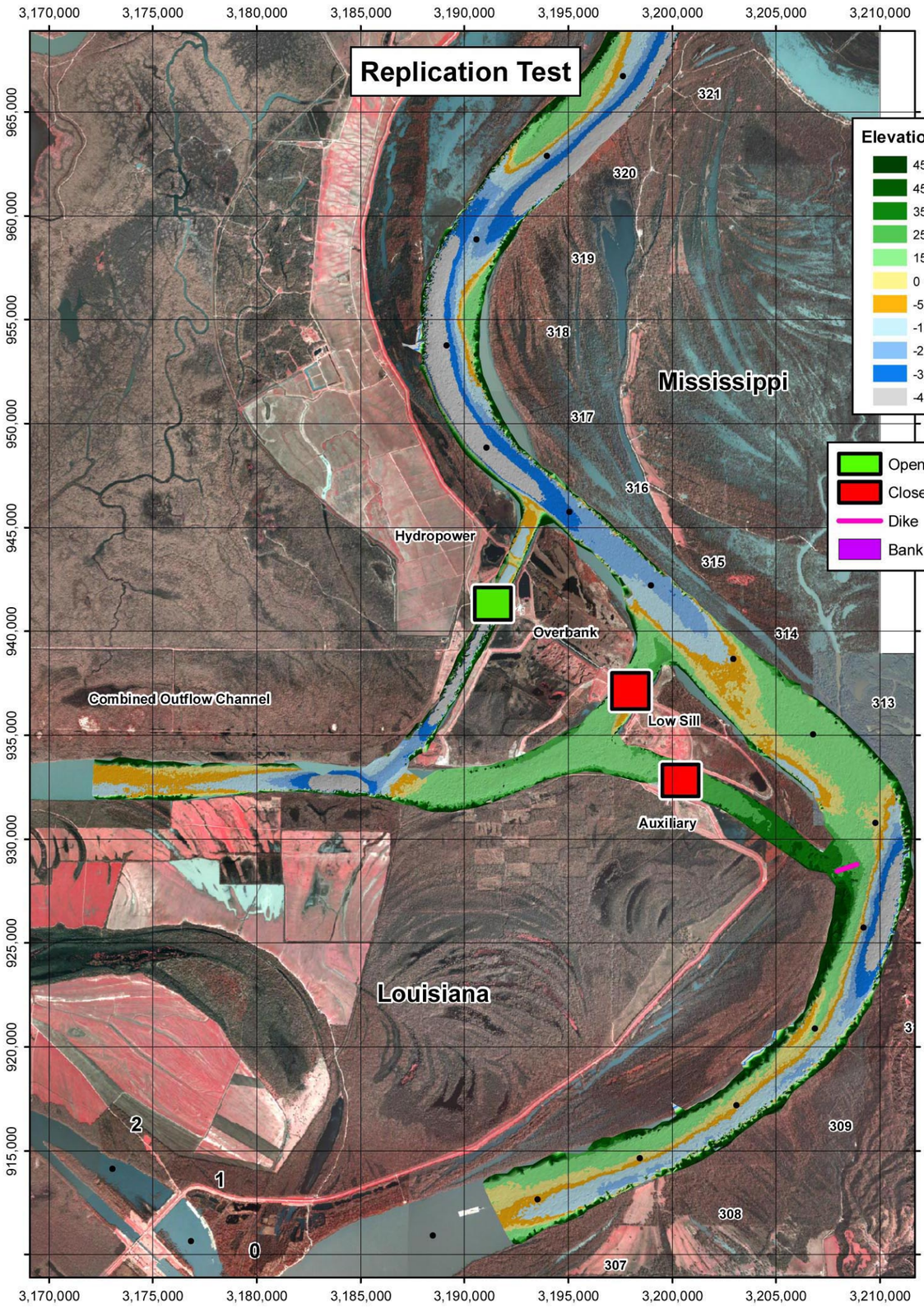
U.S. ARMY ENGINEER DIVISION
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

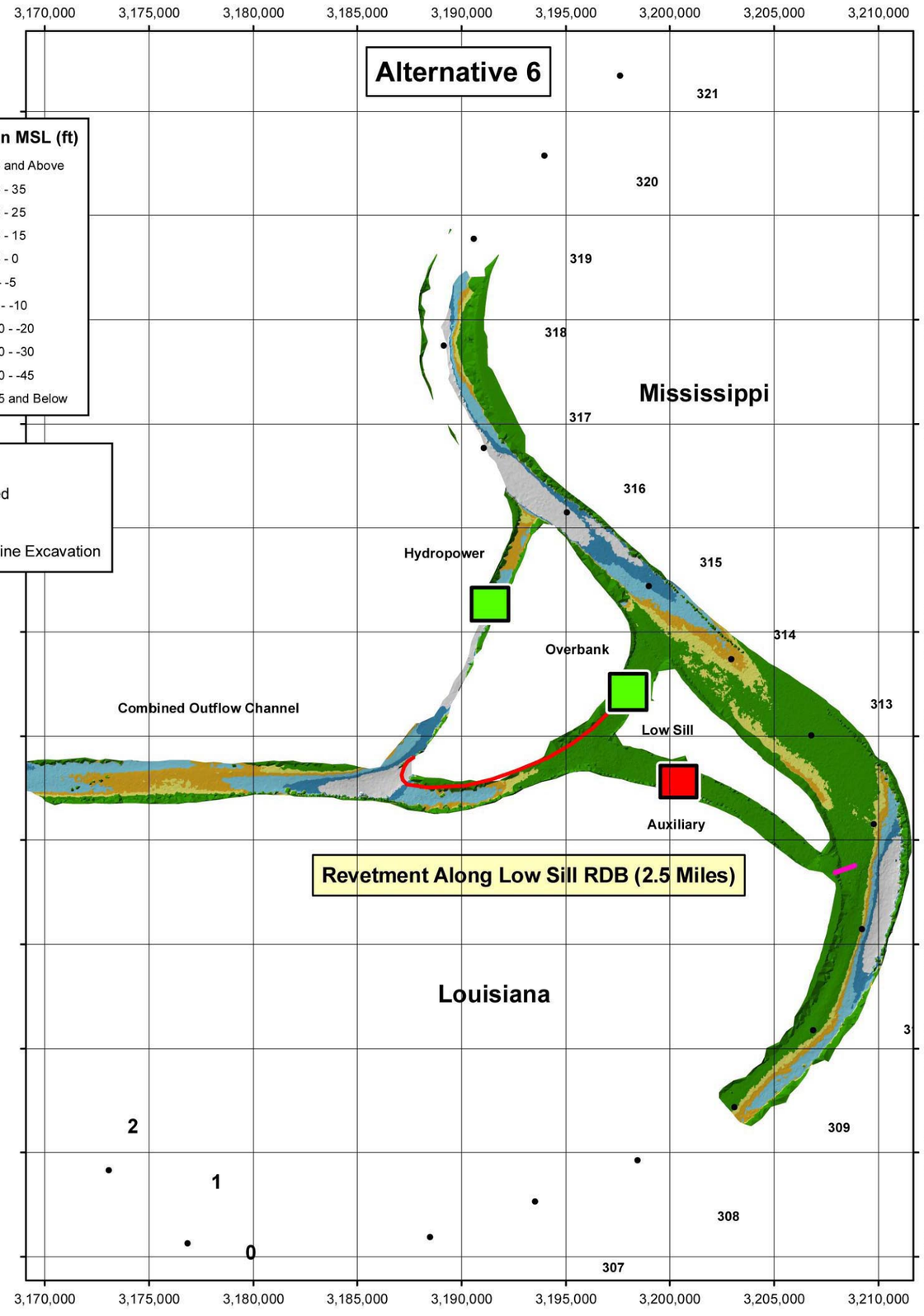
LOWER MISSISSIPPI RIVER
NEW ORLEANS DISTRICT
OLD RIVER HSR MODEL

0 2,500 5,000 10,000 Feet

ALTERNATIVE 5 - EXPANSION TEST

PLATE NUMBER
52





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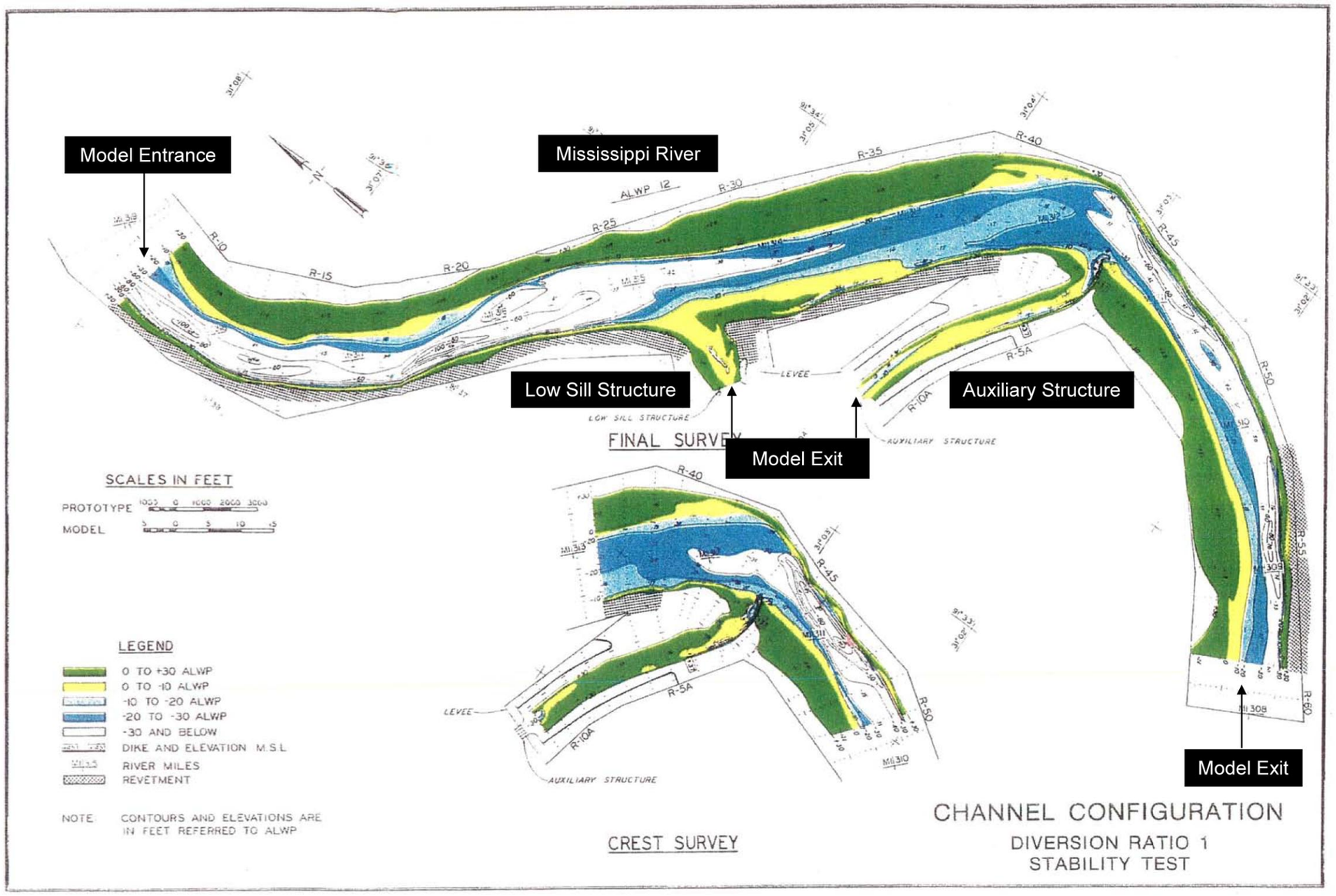
U.S. ARMY ENGINEER DIVISION
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

LOWER MISSISSIPPI RIVER
NEW ORLEANS DISTRICT
OLD RIVER HSR MODEL

0 2,500 5,000 10,000 Feet

ALTERNATIVE 6 - CONSTRICTION

PLATE NUMBER
53



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LOWER MISSISSIPPI RIVER NEW ORLEANS DISTRICT OLD RIVER HSR MODEL	PLOT DATE: MARCH 2011	APPROVED BY: R. DAVINROY, P.E.	CHECKED BY: A. COX
	FILE NAME: OLD RIVER HSR MODEL.DOC		

WES OLD RIVER PLANFORM 1977

PLATE NUMBER
54

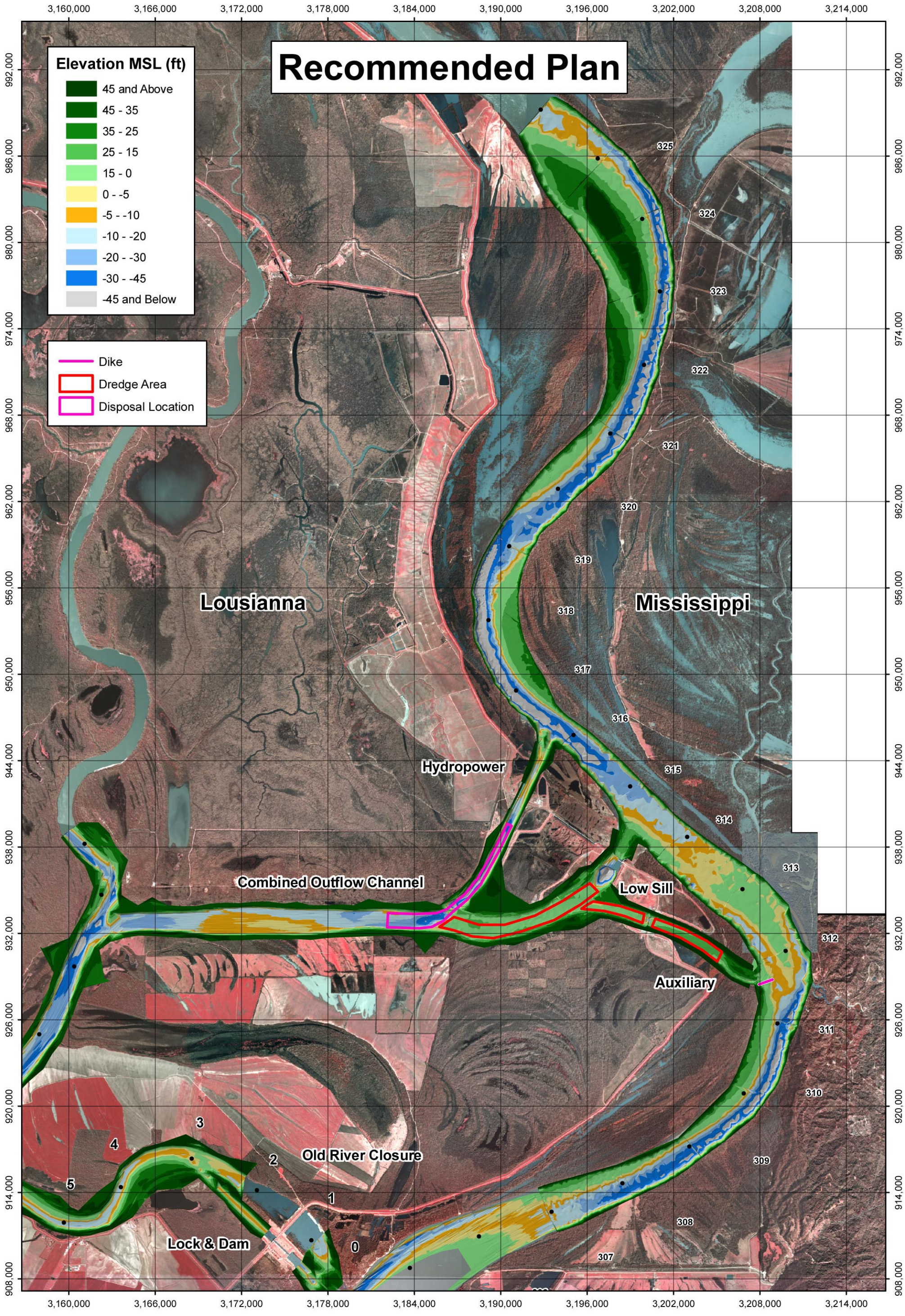

PLATE NUMBER 55

0 3,000 6,000 12,000 Feet

RECOMMENDED PLAN

U.S. ARMY ENGINEER DIVISION CORPS OF ENGINEERS ST. LOUIS, MISSOURI	DRAWN BY: I. NGUYEN	REVIEWED BY: J. BROWN, P.E.
	SUBMITTED BY: I. NGUYEN	CHECKED BY: A. COX
LOWER MISSISSIPPI RIVER NEW ORLEANS DISTRICT OLD RIVER HSR MODEL	PLOT DATE: MARCH 2011	APPROVED BY: R. DAVINROY, P.E.
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N W E S

APPLIED RIVER ENGINEERING CENTER

US Army Corps of Engineers St. Louis District