Technical Report M66

SALT LAKE CHUTE HSR MODEL
Mississippi River Miles 143.0 – 134.0

HYDRAULIC SEDIMENT RESPONSE MODEL INVESTIGATION

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INTRODUCTION

The U.S. Army Corps of Engineers, St. Louis District, conducted a study of the flow and sediment transport response in the Salt Lake Chute reach of the Mississippi River between River Miles (RM) 143.0 and 134.0 approximately ten miles upstream of St. Genevieve, Missouri. This study was funded by the U.S. Army Corps of Engineers, St. Louis District's Biological Opinion Program. The objective of the model study was to produce a report that outlined the results of an analysis of various river engineering measures intended to enhance the environmental diversity of the reach around Salt Lake Chute. The river engineering measures included, but was not limited to, island creation and sandbar separation.

The study was conducted between June, 2012 and December, 2013 using a physical Hydraulic Sediment Response (HSR) model at the Applied River Engineering Center, St. Louis District in St. Louis, Missouri. The model study was performed by Bradley Krischel, Hydraulic Engineer, under direct supervision of Mr. Robert Davinroy, P.E., Chief of River Engineering Section for the St. Louis District. See Table 1 for other personnel involved in the study.

Table 1: Other Personnel Involved in the Study

Name	Position	District/Company
Leonard Hopkins, P.E.	Hydrologic and Hydraulic Branch Chief	St. Louis District
Dave Gordon, P.E.	Chief of Hydraulic Design Section	St. Louis District
Michael Rodgers, P.E.	Project Manager for River Works Projects	St. Louis District
Jasen Brown, P.E.	Hydraulic Engineer	St. Louis District
Edward Brauer, P.E.	Hydraulic Engineer	St. Louis District
Timothy Lauth, P.E.	Hydraulic Engineer	St. Louis District
Ashley Cox	Hydraulic Engineer	St. Louis District
Peter Russell, P.E.	Hydraulic Design	St. Louis District
Dawn Lamm	Hydraulic Design	St. Louis District
Jason Floyd	Engineering Technician	St. Louis District
Adam Rockwell	Cartographic Technician	St. Louis District
Brian Johnson	Chief of Environmental Planning Section	St. Louis District
Lance Engle	Dredging Project Manager	St. Louis District
Jennifer Brown	Regulatory Project Manager	St. Louis District
Shawn Kempshall	River Surveyor	St. Louis District
Sarah Markenson	Real Estate	St. Louis District
Romanda Walker	Public Affairs	St. Louis District
Kathryn Mccain	Ecologist	St. Louis District
Lauren Briggs	AREC Co-op	St. Louis District
Charles Wardle	AREC Co-op	St. Louis District
Butch Atwood	Mississippi River Fisheries Biologist	Illinois Dept. of Natural Resources
Matt Mangan	Biologist	U.S. Fish and Wildlife Service
Donovan Henry	Biologist	U.S. Fish and Wildlife Service
David Ostendorf	Resource Staff Scientist	Missouri Dept. of Conservation
Danny Brown	Resource Staff Scientist	Missouri Dept. of Conservation
Mark Boone	Program Advisor	Missouri Dept. of Conservation
Dave Knuth	Fisheries Management Biologist	Missouri Dept. of Conservation
Ed Henleben	Senior Operations Manager	River Industry Action Committee (RIAC)
Bernie Heroff	Port Captain	American River Transportation Co./ RIAC
Shannon Hughes	River Field Port Captain	Kirby Inland Marine
Ryan Christensen	Waterways Assistant Chief	U.S. Coast Guard

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BACKGROUND

1. Study Purpose and Goals

The purpose of this study was to find a solution to enhance the environmental diversity near the Salt Lake Chute complex and produce a report that communicates the results of the Hydraulic Sediment Response (HSR) model study.

The goals of this study were to:

i. Evaluate a variety of remedial measures utilizing an HSR model with the objective of identifying the most effective and economical plan to create a more diverse habitat in and around the Salt Lake Chute complex. In order to determine the best alternative, 3 criteria were used to evaluate each alternative:

   a. The alternative should enhance the environmental diversity of the sandbar located within the dike field (adjacent to Salt Lake Island).
   b. The alternative should also enhance the environmental diversity within Salt Lake Chute.
   c. The alternative should maintain the navigation channel requirements of at least 9 foot of depth and 300 foot of width.

ii. Communicate to other engineers, river industry personnel, and environmental agency personnel the results of the HSR model tests and the plans for improvements.

2. Study Reach

The study comprised a 9 mile stretch of the Mississippi River, between RM 143.0 – 134.0 in St. Genevieve County near St. Genevieve, Missouri. Plate 1 is a location and vicinity map of the study reach. Discussed below are a variety of features found within the reach.

A majority of the property on the LDB was used for agriculture. There were levees along the Illinois side of the river. The levee districts from upstream to downstream were: Harrisonville, Fort Chartres and Ivy Landing Number 5, and Stringtown Number 4. The bluff line in Missouri was the boundary on the RDB. Located on the RDB near RM 140.0 was the Ameren Rush Island Power Plant and near RM 138.8 was the Holcim Concrete Plant and associated harbor.

There were a total of 53 river training structures and revetment within the entire study reach and are shown on Plate 2. See Table 2 for the river training structures' history and existing conditions. Revetment was sporadically in place on both the left and right descending banks, mostly in round-outs behind dikes. The other significant stretches of revetment was near the power plant, rock quarry and their harbor on the RDB from RM 140.1 to RM 135.7, and then again on the RDB from RM 134.9 to RM 132.5.

Table 2: Study Reach River Structure History

River Training Structure	Description
Dike 143.00R	Constructed prior to or during the 1968-1971 map. (Stone)
Dike 142.50R	Constructed prior to or during the February 1959 hydrosurvey map. (Stone)
Dike 142.40R	Constructed prior to or during the September 1929 aerial photographs.
Dike 142.30R	Constructed prior to or during the 1968-1971 map. (Stone)
Dike 142.20L	Constructed prior to or during the September 1929 aerial photographs. Currently buried in sand or significantly degraded.
Dike 142.10L	Constructed prior to or during the September 1929 aerial photographs. (Stone)
Dike 142.00L	Constructed prior to or during the September 1929 aerial photographs. (Pilings)

Dike 141.80L	Constructed prior to or during the September 1929 aerial photographs. Restored dike in August of 2000. (Stone)
Dike 141.70R	Constructed prior to or during the 1968-1971 map.
Dike 141.40R	Constructed prior to or during the February 1959 hydrosurvey map. Restored dike in August of 2000. Currently appears to be slightly degraded or notched by bankline. (Stone)
Dike 141.40L	Constructed prior to or during the February 1959 hydrosurvey map. Restored dike in August of 2000. (Stone)
Dike 141.10R	Constructed prior to or during the February 1959 hydrosurvey map. Restored dike in August of 2000. (Stone)
Dike 141.10L	Constructed prior to or during the September 1929 aerial photographs. (Stone)
Dike 140.90R	Constructed prior to or during the February 1959 hydrosurvey map. (Pilings)
Dike 140.80L	Constructed prior to or during the February 1959 hydrosurvey map. Restored dike in September of 2000. (Stone)
Dike 140.60R	Constructed prior to or during the February 1959 hydrosurvey map. (Pilings)
Dike 140.60L	Constructed prior to or during the February 1959 hydrosurvey map. (Stone)
Dike 140.50R	Constructed prior to or during the February 1959 hydrosurvey map. Slightly degraded at the end of the structure. (Stone)
Dike 140.50L	Constructed prior to or during the 1968-1971 map. Slightly degraded. (Stone)
Dike 140.30R	Constructed prior to or during the February 1959 hydrosurvey map. (Pilings)
Dike 140.30L	Constructed prior to or during the 1942 channel improvement plan. (Stone)
Dike 140.10L	Constructed prior to or during the February 1959 hydrosurvey map. (Pilings)
Dike 140.00L	Constructed prior to or during the February 1959 hydrosurvey map. Slightly degraded. (Pilings and Stone)
Dike 139.80L	Constructed prior to or during the February 1959 hydrosurvey map. (Stone)
Dike 139.50L	Constructed prior to or during the September 1929 aerial photographs. Slightly degraded. (Stone)
Dike 139.40R	Constructed prior to or during the February 1959 hydrosurvey map. (Stone)
Dike 139.30L	Constructed prior to or during the February 1959 hydrosurvey map. (Stone)
Dike 139.30L (Chute)	Constructed prior to or during the February 1959 hydrosurvey map. (Stone)
Dike 139.00L	Constructed prior to or during the February 1959 hydrosurvey map. (Stone)
Dike 139.00L (Chute)	Constructed prior to the February 1959 hydrosurvey map. The dike was raised to 14 ft St. Louis Gage in December of 1984.

	Slightly degraded stone dike with logs located in the notch. (Pilings and Stone)
Dike 138.80L	Constructed prior to or during the February 1959 hydrosurvey map. The dike was raised to 14 ft St. Louis Gage, in January 1985. (Stone)
Dike 138.45L (Chute)	Constructed prior to the February 1959 hydrosurvey map. (Pilings)
Dike 138.40L	Constructed prior to or during the February 1959 hydrosurvey map. Slightly degraded. (Stone)
Dike 138.10L	Constructed prior to or during the February 1959 hydrosurvey map. Restored dike in March of 2007. (Stone)
Dike 138.10L (Chute)	Constructed prior to the February 1959 hydrosurvey map. (Stone)
Dike 137.60L	Constructed prior to or during the February 1959 hydrosurvey map. (Stone)
Dike 137.60L (Chute)	Constructed prior to or during September 1929 aerial photograph. (Pilings)
Dike 137.00L	Constructed prior to or during the September 1929 aerial photographs. The dike was repaired in 1985. The dike was raised to 14 ft St. Louis Gage in March 2007. The dike flank was also repaired. (Stone)
Dike 137.00L (Chute)	Constructed in 1906. (Pilings)
Dike 136.80L	Constructed prior to or during the February 1959 hydrosurvey map. (Stone)
Dike 136.80L (Chute)	Constructed prior to or during the February 1959 hydrosurvey map. Stone dike with logs located in the notch. (Pilings and Stone)
Dike 136.50L	Constructed prior to or during the September 1929 aerial photographs. The dike was raised to 14 ft St. Louis Gage in 1984. The dike was restored in September of 2000. The trail dike is significantly degraded and the rest of the dike appears to be at a different angle than the arc shape shown in GIS. (Stone)
Dike 136.00L	Constructed prior to or during the February 1959 hydrosurvey map. The dike was raised to 14 ft St. Louis Gage in November of 1984. (Stone)
Dike 135.70L	Constructed prior to or during the September 1929 aerial photographs. The dike was raised to 14 ft St. Louis Gage in December of 1984. (Stone)
Dike 135.60L	Constructed prior to or during the February 1959 hydrosurvey map. (Stone)
Dike 135.30L	Constructed prior to or during the February 1959 hydrosurvey map. (Stone)
Dike 135.20L	Constructed prior to or during the February 1959 hydrosurvey map. (Stone)
Dike 134.90L	Constructed prior to or during the 1928-1929 aerial

	photographs. Currently appears to be a notch. (Stone)
Dike 134.80L	Constructed prior to or during the February 1959 hydrosurvey map. (Stone)
Dike 134.70R	Constructed prior to or during the February 1959 hydrosurvey map. (Stone)
Dike 134.60L	Constructed prior to or during the February 1959 hydrosurvey map. (Stone)
Dike 134.30L	Constructed prior to or during the September 1929 aerial photographs. (Pilings and Stone)
Dike 134.00L	Constructed prior to or during the February 1959 hydrosurvey map. (Stone)

A. Geomorphology

To understand the planform of the river near Salt Lake Chute, an investigation was conducted on the historical changes, both natural and manmade, that lead up to the present day condition. Plate 3 shows geomorphic planform changes from RM 143.0 to RM 134.0, encompassing the years from 1817 - 2011. Plate 3 demonstrates how dynamic the river is and the variation of planform changes over time. Based on the comparison of historic aerial photographs and maps, Salt Lake Chute did not exist until sometime between 1942 and 1956. The chute developed after a majority of the river training structures were constructed and had time to influence the river. The chute developed as a result of dikes falling into disrepair after major flood events.

From 1817 to 1866, the river shifted westward approximately 1,300 ft and significantly widened from RM 143.0 to RM 139.0. As seen on Plate 4, in 1866 there were four islands in that reach, compared to only two in 1817. The Missouri bankline was constant from RM 138.4 to the end of the study reach due to the bluff line. The Illinois bankline meandered eastward approximately 800 ft. River training structures were not introduced into this reach until between 1908 and 1928, so all planform changes until that point occurred naturally.

The river continued to undergo major changes from 1866 to 1881, shown on Plate 5. The banklines still fluctuated from RM 143.0 to RM 139.0, slightly widening and then narrowing. The Illinois bankline underwent a significant change from RM 140.6 to

RM 137.6, meandering approximately 7,700 ft at the widest location. The changes in the upstream reach alone increased the number of islands from four in 1866 to eight in 1881. From RM 137.6 to RM 134.0 the Illinois bankline meandered west approximately 1,500 ft.

From 1881 to 1908 the river continued to transform, as seen on Plate 6. The RDB stayed fairly constant and the LDB widened approximately 750 ft from RM 143.0 to RM 140.6. The Illinois bankline meandered westward an average of 2,100 ft from RM 140.5 to RM 137.6. The Missouri bankline gradually moved westward approximately 2,200 ft from RM 139.0 to RM 137.0. There were eight smaller islands in 1881 and only three larger islands in 1908. The LDB bankline meandered eastward on average 2,800 ft from RM 137.6 to RM 135.2. The river slightly meandered slightly eastward from RM 134.9 to the end of the study reach.

The river continued to transition from 1908 to 1928, shown on Plate 7. The Missouri bankline remained the same, but the Illinois bankline meandered slightly eastward from RM 143.0 to RM 140.5. The RDB widened on average 2,000 ft from RM 139.4 to RM 137.0. The LDB meandered westward approximately 3,000 ft from RM 140.5 to RM 137.0. The Missouri bankline stayed constant from RM 137.0 to 134.0. The Illinois bankline slightly widened from RM 135.7 to RM 134.8. There were three islands in 1908 and there were six islands in 1928. There were approximately 14 river training structures built during this time frame.

From 1928 to 1956 the river still experienced changes to the planform, most likely due to 35 river training structures constructed at that time. The Missouri and Illinois banklines remained constant from RM 143.0 to RM 140.0. The RDB meandered slightly eastward from RM 139.3 to RM 137.6 and then remained constant to the end of the study reach. The LDB meandered westward on average 1,000 ft from RM 140.0 to RM 134.3. There were six islands in 1928 and seven islands in 1956, shown on Plate 8.

There were no significant changes to the banklines throughout the study reach from 1956 to 1968, as seen on Plate 9. This is due to the construction of the river training structures in previous years locking in the basic planform of the reach. There were seven islands in 1956 and only four islands in 1968.

From 1968 to 1986 there were no major changes to the banklines throughout the study reach, shown on Plate 10. There were four islands in 1968 and five islands in 1986. Over that time period, the three islands near RM 140.6, RM 139.2, and RM 136.1 slightly increased in size. There were only four river training structures constructed during this time frame.

The banklines in the upstream reach of the model study completed their final major transformation from 1986 to 2003, as seen on Plate 11. The narrow side channels that once separated the large islands that existed near the Missouri bankline at RM 142.0 and near the Illinois bankline at RM 140.6 accreted. Therefore the islands became part of the banklines and the overall channel narrowed to approximately 2,200 ft wide from RM 142.0 to RM 139.5. There were five islands in 1986 and only three islands in 2003. Salt Lake Chute and the island at this time had reached the present day conditions. A majority of the existing revetment was placed during this time frame.

There were no significant measurable shifts or transformations of the planform from 2003 to 2011, shown on Plate 12. There were minor changes to the banklines, due to sporadic round outs behind some downstream angled dikes. Salt Lake Island's bank nearest the main channel had meandered slightly eastward due to round outs and scour from downward angled dikes.   Additional revetment was placed during this time period.

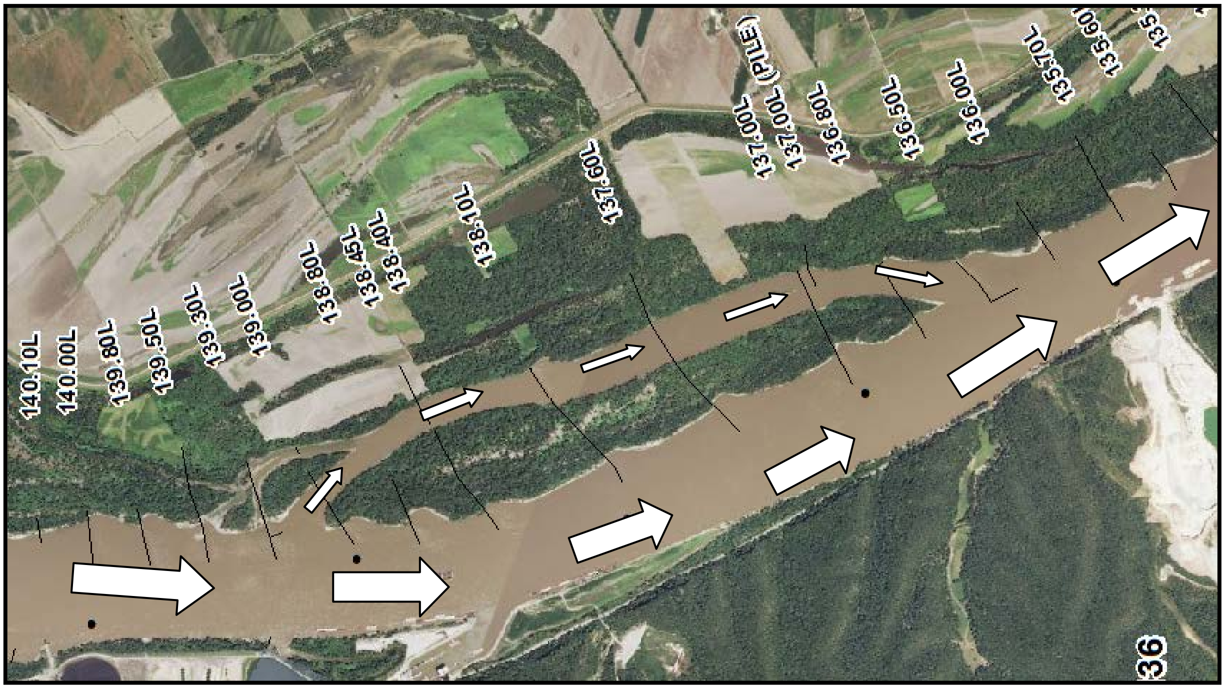
A side channel analysis based on historical and recent aerial photographs and hydrographic surveys was lead by Tom Keevin and conducted by Erin Guntren (MVS personnel) in FY 2012. Their analysis looked at the area changes of side channels based on aerial photographs and the volume changes based on cross sections taken from hydrographic surveys. They also determined choke points (the highest elevation controlling water flow or connectivity through a side channel). The choke point for Salt Lake Chute was found to be a dike structure at an elevation of +11.8 ft LWRP. Based on typical monthly river stages and the choke point, connectivity was determined. During a typical hydrographic year, Salt Lake Chute is connected for approximately 5 months. Based on cross sections from side channel hydrographic surveys conducted in all seasons since 1956, both area and volume of the chute have fluctuated. The side channel decreased in area and volume from 1956 to 1986. From 1986 to 1993 the side channel slightly increased in area, but slightly decreased in volume. Again the side channel decreased in area and volume from 1993 to 2001. However, the side channel increased in area and volume from 2001 to 2011.

Plates 13 – 19 show historical aerials, planform maps, and historical surveys. The plates were used as a historical reference, but were not used in the analysis of the model study.

B. Existing Flow Mechanics

The Salt Lake Chute reach has a deep main channel and one shallow side channel. The main channel depths range from -10 ft to -30 ft LWRP. There is a structure in Salt Lake Chute at +11.8 ft LWRP, which prevents flows from passing through from the entrance to the exit of the channel anytime the stage is lower than +11.8 ft. Typically, there is flow through the side channel from late spring through early summer. During the rest of the year, flow in the chute is fairly stagnant (water does not flow through as a result of the elevation of exposed sandbars) and backwater effects occur. Furthermore, the main channel energy is highly dominant compared to the energy observed in the side channel. See Graphic 1 for a generalized schematic of the existing flow mechanics in the study reach.

Graphic 1: Salt Lake Chute Study Reach with General (Stage>11.8ft LWRP) Flow Trends



C. Channel Characteristics and General Trends

i. Bathymetry

Range line and multi-beam hydrographic surveys of the Mississippi River from 2001 to 2012 within the HSR Model extents, are shown on Plates 20 - 24. Plate 25 shows pre-dredge conditions in 2003. For this study, the bathymetric data was referenced to the Low Water Reference Plane (LWRP).

Recent surveys were used to determine general trends because they showed the most recent construction and the resultant river bed changes. The following bathymetric trends remained relatively constant from 2001 - 2012 after comparison of the above mentioned hydrographic surveys:

Table 3: Study Reach Bathymetry Trends

River Miles	Description
141.0 – 140.0	The thalweg was along the RDB, and a large bar developed on the LDB in the dike field.

140.0 – 139.0	The thalweg crossed from the RDB to the LDB near RM 139.9 and scoured off the tips of the dikes. The main channel slightly shallowed when the thalweg lost energy as it transitioned back to the RDB. The mouth to Salt Lake Chute was very shallow, 0 ft to +13 ft LWRP.
139.0 – 136.0	In the crossing there were small scour holes off the tip of the LDB dikes near RM 138.8. The thalweg crossed to the RDB near RM 183.4. There was a large sand bar in the LDB dike field. The thalweg widened and crossed to the LDB near RM 137.0. Salt Lake Chute lacked bathymetric diversity, with elevations from +4 ft LWRP to +18 ft LWRP. There was one scour hole behind Dike 138.10L, reaching -30 ft LWRP.
136.0 – 135.0	The thalweg crossed to the RDB near RM 136.0 and then immediately crossed back to the LDB near RM 135.7. There was some scour off the tips of the dikes on the LDB. The entire main channel was self maintaining with navigable depths, with only 1 dredge cut in 2003.

There was sufficient depth for navigation throughout the main channel in the reach. However, the dike fields along Salt Lake Chute that contributed to the depth also caused a lack of bathymetric diversity near the island bankline. The dikes were not rootless or notched, which significantly reduced bathymetry or velocity changes in the dike field. There were some dikes that were degraded, which allowed some scour to develop immediately downstream of those particular dikes. The sandbar located on the main channel side of Salt Lake Chute, on average was approximately 500 ft wide and gradually transitioned from a +10 ft LWRP (Low Water Reference Plane) nearest the bankline out towards the main channel where it was near 0 ft LWRP. The side channel also lacked bathymetric diversity. There were no large plunge holes and only minor scour occurred at a couple of locations near the upstream end of the chute.

ii. Site Data

On June 20, 2012, engineers and technicians visited the Salt Lake Chute reach to examine bank lines, structures, and any data that could not otherwise be gathered in the office. At the Brickey's gage (RM 136.0), the river stage was +11.30 ft (369.08 ft in elevation, 12.88 ft LWRP). The water was at a low stage, so the tops of newly constructed and repaired structures could be seen. The water covered some degraded structures. The following observations were made:

- Dike 143.00R: Rock structure was visible.

- Dike 142.50R: Rock structure was visible.
- Dike142.30R: Rock structure was visible.
- Dike 142.20L: Structure was not visible.
- Dike 142.10L: Rock structure was visible.
- Dike 142.00L: Pile structure was visible.
- Dike 141.80L: Rock structure was visible.
- Dike 141.40R: Rock structure was visible. The dike was notched or degraded near the bank.
- Dike 141.40L: Rock structure was visible.
- Dike 141.10R: Rock structure was visible.
- Dike 141.10L: Rock structure was visible.
- Dike 140.90R: Pile structure was visible.
- Dike 140.80L: Rock structure was visible.
- Dike 140.60R: Pile structure was visible.
- Dike 140.60L: Rock structure was visible.
- Dike 140.50R: Rock structure was visible, but appeared to be somewhat degraded near the end of the structure. Small stone was seen towards the end of the dike by the navigation channel.
- Dike 140.50L: Rock structure was visible and was degraded.
- Dike 140.30R: Pile structure was visible.
- Dike 140.30L: Rock structure was visible.
- Dike 140.10L: Pile structure was visible.
- Dike 140.00L: Both piles and rock were visible at this structure, but appeared to be degraded.
- Dike 139.80L: Rock structure was visible.
- Dike 139.50L: Rock structure was visible, but appeared to be degraded.
- Dike 139.40R: Rock structure was visible.
- Dike 139.30L: Rock structure was visible.
- Dike 139.30L (Chute): Rock structure was visible.
- Dike 139.00L: Rock structure was visible.
- Dike 139.00L (Chute): Pile structure was visible with a notch.

- Dike 138.80L: Rock structure was visible.
- Dike 138.40L: Rock structure was visible, but appeared to be degraded.
- Dike 138.45L (Chute): Pile structure was visible.
- Dike 138.10L: Rock structure was visible.
- Dike 138.10L (Chute): Rock structure was visible.
- Dike 137.60L: Pile structure was visible.
- Dike 137.60L (Chute): Rock structure was visible, but appeared to be degraded.
- Dike 137.00L: Rock structure was visible.
- Dike 137.00L (Chute): Pile structure was visible.
- Dike 136.80L: Rock structure was visible.
- Dike 136.80L (Chute): The rock structure was visible with a notch. Located in the notch were piles.
- Dike 136.50L: Rock structure extending perpendicular from bankline was visible. The trail on the end of the perpendicular dike was not visible. The structure appeared to be built at a different angle than the structure drawn in the Master Plan.
- Dike 136.00L: Rock structure was visible.
- Dike 135.70L: Rock structure was visible.
- Dike 135.60L: Rock structure was visible.
- Dike 135.30L: Rock structure was visible.
- Dike 135.20L: Rock structure was visible, but appeared degraded at the end towards the navigation channel.
- Dike 134.90L: Rock structure was visible with a notch.
- Dike 134.80L: Rock structure was visible.
- Dike 134.70R: Rock structure was visible.

Pictures from the site visit can be seen on Plates 26 – 27.

HSR MODELING

1. Model Calibration and Replication

The HSR modeling methodology employed a calibration process designed to replicate the general 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 most recent available high resolution aerial photographs. Various other fixed boundaries were also introduced into the model including any channel improvement structures, underwater rock, clay and other non-mobile boundaries. These boundaries were based off of documentation such as plans and specifications as well as hydrographic surveys.

Second, "loose" boundary conditions of the model were replicated. 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, model tests were run using steady state discharge. Adjustment of the discharge, sediment volume, model slope, fixed boundaries, and entrance conditions were refined during these tests as part of calibration. The bed progressed from a static, flat, arbitrary bed into a fully-formed, dynamic, three dimensional mobile bed response. Repeated tests were simulated for the assurance of model stability and repeatability. When the general trends of the model bathymetry were similar to observed recent river bathymetry, and the tests were repeatable, the model was considered replicated and alternative testing began.

One important parameter to note was that in calibration, non-erodible bed material of higher specific gravity was used in a localized area on the model riverbed to represent clay, rock, and other non-erodible materials found in the prototype river bed. Because the non-erodible was required for calibration, the non-erodible remained in the model throughout the rest of the study (i.e. during alternative testing).

2. Scales and Bed Materials

The model employed a horizontal scale of 1 inch = 700 feet, or 1:8,400, and a vertical scale of 1 inch = 74 feet, or 1:888, for a 9.46 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.

3. Appurtenances

The HSR model planform insert was constructed according to the 2012 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 routed into dense polystyrene foam and modified during calibration with clay and polymesh. Leveler feet located on the bottom of the hydraulic flume controlled the slope of the model. The measured slope of the insert and flume was approximately 0.07 inch/inch. River training structures in the model were made of galvanized steel mesh to generate appropriate scaled roughness.

4. Flow Control

Flow into the model was regulated by a control valve, submersible pump, and a flow meter. 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 1.9 Gallons per Minute (GPM). This served as the average expected energy response of the river. Because of the constant variation experienced in the river, this steady state flow was used to replicate existing general conditions and empirically analyze the ultimate expected sediment response that could occur from future alternative actions.

5. Data Collection

Data from the HSR model was collected with a three dimensional (3D) laser scanner and a Laser Doppler Velocimeter (LDV). The operation of this equipment is described below.

The river bed in the model was surveyed with a high definition, 3D laser scanner that collects a dense cloud of xyz data points. These xyz data points were then georeferenced to real world coordinates and triangulated to create a 3D surface. The surface was then color coded by elevation using standard color tables that were also used in color coding prototype surveys. This process allowed a direct comparison between HSR model bathymetry surveys and prototype bathymetry surveys.

6. Replication Test

Once the model adequately replicated general prototype trends, 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, etc, were compared directly to the replicated condition. General trends were evaluated for any major differences positive or negative between the alternative test and the replication test by comparing the surveys of the two and also carefully observing the model while the actual testing was taking place.

Bathymetric trends were recorded from the model using a 3-D Laser Scanner. Replication was achieved after numerous favorable bathymetric comparisons of the prototype surveys were made to several surveys of the model. The resultant bathymetry served as the bathymetry replication test for the model and is shown on Plate 30.

Results of the HSR model base test bathymetry and a comparison to the 2001 through 2012 prototype surveys indicated the following trends:

Table 4: Study Reach and Prototype Bathymetry Trend Comparison

River Miles	Description
141.0 – 140.0	The model and the prototype showed the thalweg was along RDB, and a large bar developed on the LDB in the dike field. Like the prototype, the model showed thalweg depths ranging between -15 ft LWRP to -40 ft LWRP.
140.0 – 139.0	Like the prototype, the thalweg crossed from the RDB to the LDB between RM 140.0 and RM 139.8 in the model. In both the model and the prototype, scour was observed off of the tips of the dike field located along the LDB. The mouth of Salt Lake Chute was shallow, showing elevations greater than 0 ft LWRP in both the model and the prototype.
139.0 – 136.0	In both the model and the prototype, the thalweg transitioned from the LDB to the RDB between RM 139.0 and RM 138.5, and bed elevations of -10 ft to -15 ft LWRP were observed within the crossing. The model developed a large sand bar in the LDB dike field, which was also observed in the prototype. Salt Lake Chute lacked bathymetric diversity, with elevations from +5 ft LWRP to +18 ft LWRP observed in the model and the prototype.
136.0 – 135.0	The model and the prototype showed the thalweg crossing to the LDB between RM 136.0 and RM 135.5. There was some scour off the tips of the dikes located along the LDB in both the model and the prototype.

7. Design Alternative Tests

The testing process consisted of modeling alternative measures in the HSR model followed by analyses of the bathymetry and velocity results. The goal was to enhance the environmental diversity of the Salt Lake Chute reach while maintaining the navigation channel requirements of at least 12 foot of depth and 300 foot of width. The river engineering measures included, but was not limited to, island creation and sandbar separation. Evaluation of each alternative was accomplished through a qualitative comparison to the model replication test bathymetry (deposition and scour). The most promising alternatives were analyzed using flow visualization, which was compared to the replication flow visualization. See Appendix D for a detailed analysis of the flow visualization process for the Salt Lake Chute HSR model study.

A picture of the Salt Lake Chute HSR model can be found on Plate 28, and Plate 29 highlights the areas of focus for testing alternatives in the model.

A summary of each alternative can be found on the following pages.

Alternative 1:

Action	Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Notch	Dike	139.80	LDB	140	-10
Notch	Dike	139.50	LDB	250	-10
Remove	Dike	139.30	LDB	2,175	Existing Grade
Construct	Dike	139.30	LDB	1,350	+18.5
Remove	Dike	139.00	LDB	775	Existing Grade
Construct	Dike	138.80	LDB	215	+18.5
Remove	Dike	138.45	LDB	500	Existing Grade
Construct	Dike	138.40	LDB	265	+18.5
Construct	Dike	138.30	LDB	200	+18.5
Construct	Dike	138.15	LDB	280	+18.5
Remove	Dike	138.10	LDB	850	Existing Grade
Construct	Dike	137.90	LDB	160	+18.5
Construct	Dike	137.70	LDB	325	+18.5
Remove	Dike	137.60	LDB	930	Existing Grade
Construct	Dike	137.50	LDB	250	+18.5
Construct	Dike	137.30	LDB	250	+18.5
Construct	Dike	137.00	LDB	250	+18.5
Remove	Dike	137.00	LDB	800	Existing Grade
Remove	Dike	137.00	LDB	415	Existing Grade
Construct	Dike	136.85	LDB	250	+18.5
Remove	Dike	136.80	LDB	840	Existing Grade
Remove	Dike	136.50	LDB	275	Existing Grade

Alternative 1 Results: *Bathymetry (Plate 31) Analysis*

Enhance Environmental Diversity of Salt Lake Chute	Enhance Environmental Diversity of Sandbar	Maintain Navigation Channel Requirements	Additional Comments
No	No	Yes	This alternative was tested first because it is the same alternative recommended by Dave Gordon from a 2001 study of Salt Lake Chute. This was done to compare results from the two model studies. The idea behind this alternative was to divert some of the main channel flow into the side channel. However, there was no significant change in bathymetry.

Alternative 2:

Action	Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Remove	Dike	140.10	LDB	475	Existing Grade
Remove	Dike	140.00	LDB	1,200	Existing Grade
Notch	Dike	139.80	LDB	140	-10
Notch	Dike	139.50	LDB	250	-10
Remove	Dike	139.30	LDB	2,175	Existing Grade
Construct	Dike	139.00	LDB	1,350	+18.5
Remove	Dike	139.00	LDB	775	Existing Grade
Construct	Dike	138.80	LDB	215	+18.5
Remove	Dike	138.45	LDB	500	Existing Grade
Construct	Dike	138.40	LDB	265	+18.5
Construct	Dike	138.30	LDB	200	+18.5
Construct	Dike	138.15	LDB	280	+18.5
Remove	Dike	138.10	LDB	850	Existing Grade
Construct	Dike	137.90	LDB	160	+18.5
Construct	Dike	137.70	LDB	325	+18.5
Remove	Dike	137.60	LDB	930	Existing Grade
Construct	Dike	137.50	LDB	250	+18.5
Construct	Dike	137.30	LDB	250	+18.5
Construct	Dike	137.00	LDB	250	+18.5
Remove	Dike	137.00	LDB	800	Existing Grade
Remove	Dike	137.00	LDB	415	Existing Grade
Construct	Dike	136.85	LDB	250	+18.5
Remove	Dike	136.80	LDB	840	Existing Grade
Notch	Dike	136.50	LDB	275	-10

Alternative 2 Results: *Bathymetry (Plate 32) Analysis*

Enhance Environmental Diversity of Salt Lake Chute	Enhance Environmental Diversity of Sandbar	Maintain Navigation Channel Requirements	Additional Comments
No	No	Yes	This alternative was identical to Alternative 1 with the additional removal of Dikes 140.10L and 140.00L. The idea behind this alternative was to capture some of the main channel flow and divert some of it into the side channel. However, there was no significant change in bathymetry.

Alternative 3:

Action	Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Construct	Dike	140.10	LDB	460	+18.5
Remove	Dike	140.00	LDB	1,200	Existing Grade
Notch	Dike	139.80	LDB	260	-10
Notch	Dike	139.50	LDB	250	-10
Remove	Dike	139.30	LDB	2,175	Existing Grade
Construct	Dike	139.00	LDB	2,320	+18.5
Remove	Dike	139.00	LDB	775	Existing Grade
Construct	Dike	138.80	LDB	215	+18.5
Remove	Dike	138.45	LDB	500	Existing Grade
Construct	Dike	138.40	LDB	265	+18.5
Construct	Dike	138.30	LDB	200	+18.5
Construct	Dike	138.15	LDB	280	+18.5
Remove	Dike	138.10	LDB	850	Existing Grade
Construct	Dike	137.90	LDB	160	+18.5
Construct	Dike	137.70	LDB	325	+18.5
Remove	Dike	137.60	LDB	930	Existing Grade
Construct	Dike	137.50	LDB	250	+18.5
Construct	Dike	137.30	LDB	250	+18.5
Construct	Dike	137.00	LDB	250	+18.5
Remove	Dike	137.00	LDB	800	Existing Grade
Remove	Dike	137.00	LDB	415	Existing Grade
Construct	Dike	136.85	LDB	250	+18.5
Remove	Dike	136.80	LDB	840	Existing Grade
Notch	Dike	136.50	LDB	275	-10

Alternative 3 Results: *Bathymetry (Plate 33) Analysis*

Enhance Environmental Diversity of Salt Lake Chute	Enhance Environmental Diversity of Sandbar	Maintain Navigation Channel Requirements	Additional Comments
No	No	Yes	This alternative is similar to Alternatives 1 and 2 in that it was still trying to divert some of the main channel flow into the side channel. The structures just upstream of the entrance of Salt Lake Chute are slightly different than in the first two alternatives. These changes yielded no significant bathymetric changes.

Alternative 4:

Action	Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Extend	Dike	140.60	RDB	150	+18.5
Extend	Dike	140.50	RDB	250	+18.5
Extend	Dike	140.30	RDB	215	+18.5
Construct	Dike	140.10	LDB	460	+18.5
Remove	Dike	140.00	LDB	1,200	Existing Grade
Notch	Dike	139.80	LDB	260	-10
Construct	Dike	139.70	LDB	250 x 250	+18.5
Notch	Dike	139.50	LDB	250	-10
Remove	Dike	139.30	LDB	2,175	Existing Grade
Construct	Dike	139.00	LDB	2,320	+18.5
Remove	Dike	139.00	LDB	775	Existing Grade
Construct	Dike	138.80	LDB	215	+18.5
Remove	Dike	138.45	LDB	500	Existing Grade
Construct	Dike	138.40	LDB	265	+18.5
Construct	Dike	138.30	LDB	200	+18.5
Construct	Dike	138.15	LDB	280	+18.5
Remove	Dike	138.10	LDB	850	Existing Grade
Construct	Dike	137.90	LDB	160	+18.5
Construct	Dike	137.70	LDB	325	+18.5
Remove	Dike	137.60	LDB	930	Existing Grade
Construct	Dike	137.50	LDB	250	+18.5
Construct	Dike	137.30	LDB	250	+18.5
Construct	Dike	137.00	LDB	250	+18.5
Remove	Dike	137.00	LDB	800	Existing Grade
Remove	Dike	137.00	LDB	415	Existing Grade
Construct	Dike	136.85	LDB	250	+18.5
Remove	Dike	163.80	LDB	840	Existing Grade
Notch	Dike	136.50	LDB	275	-10

Alternative 4 Results: *Bathymetry (Plate 34) Analysis*

Enhance Environmental Diversity of Salt Lake Chute	Enhance Environmental Diversity of Sandbar	Maintain Navigation Channel Requirements	Additional Comments
No	No	Yes	Three dike structures were added along the RDB approximately one mile upstream of the Salt Lake Chute entrance. In addition, a combination of chevrons, dikes, and dike notches were used to attempt to divert some of the main channel flow into the side channel. Apart from some very small changes on the upstream end of the side channel, there was no bathymetric change.

Alternative 5:

Action	Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Extend	Dike	140.60	RDB	150	+18.5
Extend	Dike	140.50	RDB	250	+18.5
Extend	Dike	140.30	RDB	215	+18.5
Remove	Dike	140.00	LDB	1,200	Existing Grade
Notch	Dike	139.80	LDB	260	-10
Notch	Dike	139.50	LDB	250	-10
Remove	Dike	139.30	LDB	2,175	Existing Grade
Remove	Dike	139.00	LDB	775	Existing Grade
Construct	Dike	138.80	LDB	215	+18.5
Remove	Dike	138.45	LDB	500	Existing Grade
Construct	Dike	138.40	LDB	265	+18.5
Construct	Dike	138.30	LDB	200	+18.5
Construct	Dike	138.15	LDB	280	+18.5
Remove	Dike	138.10	LDB	850	Existing Grade
Construct	Dike	137.90	LDB	160	+18.5
Construct	Dike	137.70	LDB	325	+18.5
Remove	Dike	137.60	LDB	930	Existing Grade
Construct	Dike	137.50	LDB	250	+18.5
Construct	Dike	137.30	LDB	250	+18.5
Construct	Dike	137.00	LDB	250	+18.5
Remove	Dike	137.00	LDB	800	Existing Grade
Remove	Dike	137.00	LDB	415	Existing Grade
Construct	Dike	136.85	LDB	250	+18.5
Remove	Dike	136.80	LDB	840	Existing Grade
Notch	Dike	136.50	LDB	275	-10

Alternative 5 Results: *Bathymetry (Plate 35) Analysis*

Enhance Environmental Diversity of Salt Lake Chute	Enhance Environmental Diversity of Sandbar	Maintain Navigation Channel Requirements	Additional Comments
No	No	Yes	Similar to Alternative 4, this alternative also attempted to divert some of the main channel flow into the side channel using dike extensions along the RDB approximately one mile upstream of the Salt Lake Chute entrance. There was a combination of dike notches and removals along the LDB immediately upstream of the side channel entrance. No significant changes in bathymetry were observed.

Alternative 6:

Action	Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Extend	Dike	140.60	RDB	150	+18.5
Extend	Dike	140.50	RDB	250	+18.5
Extend	Dike	140.30	RDB	215	+18.5
Notch	Dike	140.00	LDB	225	-10
Notch	Dike	139.80	LDB	260	-10
Notch	Dike	139.50	LDB	250	-10
Remove	Dike	139.30	LDB	2,175	Existing Grade
Remove	Dike	139.00	LDB	775	Existing Grade
Construct	Dike	138.80	LDB	215	+18.5
Remove	Dike	138.45	LDB	500	Existing Grade
Construct	Dike	138.40	LDB	265	+18.5
Construct	Dike	138.30	LDB	200	+18.5
Construct	Dike	138.15	LDB	280	+18.5
Remove	Dike	138.10	LDB	850	Existing Grade
Construct	Dike	137.90	LDB	160	+18.5
Construct	Dike	137.70	LDB	325	+18.5
Remove	Dike	137.60	LDB	930	Existing Grade
Construct	Dike	137.50	LDB	250	+18.5
Construct	Dike	137.30	LDB	250	+18.5
Construct	Dike	137.00	LDB	250	+18.5
Remove	Dike	137.00	LDB	800	Existing Grade
Remove	Dike	137.00	LDB	415	Existing Grade
Construct	Dike	136.85	LDB	250	+18.5
Remove	Dike	136.80	LDB	840	Existing Grade
Notch	Dike	136.50	LDB	275	-10

Alternative 6 Results: *Bathymetry (Plate 36) Analysis*

Enhance Environmental Diversity of Salt Lake Chute	Enhance Environmental Diversity of Sandbar	Maintain Navigation Channel Requirements	Additional Comments
No	No	Yes	This alternative was identical to Alternative 5 with the exception of some variations to the notching/removal of structures along the LDB just upstream of the side channel entrance.

Alternative 7:

Action	Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Construct	Dike	138.30	LDB	600	+18.5
Notch	Dike	138.10	LDB	175	-10
Construct	Rootless Dike	137.90	LDB	150	+18.5
Notch	Dike	137.60	LDB	175	-10
Construct	Dike	137.30	LDB	175	+18.5
Notch	Dike	136.50	LDB	275	-10

Alternative 7 Results: *Bathymetry (Plate 37) Analysis*

Enhance Environmental Diversity of Salt Lake Chute	Enhance Environmental Diversity of Sandbar	Maintain Navigation Channel Requirements	Additional Comments
No	Yes	Yes	This alternative shifted the focus to trying to create more diversity on the main channel side of the island between RM 139.0 and RM 137.0. This alternative created some diversity on the existing bar located along the LDB of the main channel.

<u>Alternative 8:</u>

Action	Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Notch	Dike	138.10	LDB	175	-10
Construct	Dike	138.10	LDB	1,700	+18.5
Construct	Dike	137.80	LDB	200	+18.5
Notch	Dike	137.60	LDB	175	-10
Construct	Dike	137.30	LDB	250	+18.5
Notch	Dike	136.50	LDB	275	-10

Alternative 8 Results: *Bathymetry (Plate 38) Analysis*

Enhance Environmental Diversity of Salt Lake Chute	Enhance Environmental Diversity of Sandbar	Maintain Navigation Channel Requirements	Additional Comments
No	No	Yes	This alternative was also trying to create diversity on the main channel side of the island between RM 139.0 and RM 137.0. There was no significant change in bathymetry.

Alternative 9:

Action	Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Remove	Dike	140.10	LDB	475	Existing Grade
Notch	Dike	139.80	LDB	225	-10
Construct	Dike	139.65	LDB	350	+18.5
Notch	Dike	139.50	LDB	275	-10
Remove	Dike	139.30	LDB	2,175	Existing Grade
Construct	Dike	139.30	LDB	1,350	+18.5
Remove	Dike	139.00	LDB	775	Existing Grade
Construct	Dike	138.80	LDB	215	+18.5
Remove	Dike	138.45	LDB	500	Existing Grade
Construct	Dike	138.40	LDB	265	+18.5
Construct	Dike	138.30	LDB	200	+18.5
Construct	Dike	138.15	LDB	280	+18.5
Remove	Dike	138.10	LDB	850	Existing Grade
Construct	Dike	137.90	LDB	160	+18.5
Construct	Dike	137.70	LDB	325	+18.5
Remove	Dike	137.60	LDB	930	Existing Grade

Alternative 9 Results: *Bathymetry (Plate 39) Analysis*

Enhance Environmental Diversity of Salt Lake Chute	Enhance Environmental Diversity of Sandbar	Maintain Navigation Channel Requirements	Additional Comments
No	No	Yes	Similar to Alternative 3, this alternative focused on diverting a portion of the main channel flow into the side channel. There was no significant change in bathymetry.

Alternative 10:

Action	Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Construct	Chevron	137.75	LDB	900	+18.5
Remove	Dike	137.60	LDB	700	Existing Grade
Construct	Chevron Extensions	137.76	LDB	250 (each)	+18.5

Alternative 10 Results: *Bathymetry (Plate 40) Analysis*

Enhance Environmental Diversity of Salt Lake Chute	Enhance Environmental Diversity of Sandbar	Maintain Navigation Channel Requirements	Additional Comments
No	No	Yes	This alternative was trying to create more diversity on the bar located near RM 137.5 on the LDB of the main channel. The alternative did not create any significant change in bathymetry.

Alternative 11:

Action	Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Extend	Dike	139.40	RDB	275	+18.5
Notch	Dike	138.10	LDB	200	-10
Construct	Chevron	137.75	LDB	900	+18.5
Remove	Dike	137.60	LDB	700	Existing Grade
Construct	Chevron Extensions	137.76	LDB	250 (each)	+18.5

Alternative 11 Results: *Bathymetry (Plate 41) Analysis*

Enhance Environmental Diversity of Salt Lake Chute	Enhance Environmental Diversity of Sandbar	Maintain Navigation Channel Requirements	Additional Comments
No	No	Yes	This alternative was identical to Alternative 10 with the addition of extending Dike 139.40R and notching Dike 138.10L. The dike extension was to divert flow to the left descending bank while the notch was intended to allow more flow to hit the chevron, but neither created any significant change in bathymetry.

Alternative 12:

Action	Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Construct	Chevron	138.20	LDB	900	+18.5
Notch	Dike	138.10	LDB	200	-10
Construct	Chevron	137.75	LDB	900	+18.5
Remove	Dike	137.60	LDB	700	Existing Grade
Construct	Chevron Extensions	137.76	LDB	250 (each)	+18.5

Alternative 12 Results: *Bathymetry (Plate 42) Analysis*

Enhance Environmental Diversity of Salt Lake Chute	Enhance Environmental Diversity of Sandbar	Maintain Navigation Channel Requirements	Additional Comments
No	No	Yes	This alternative was similar to Alternative 11. The dike extension from Alternative 11 was removed, and instead a chevron was placed at RM 138.20 L. There was no significant change in bathymetry.

Alternative 13:

Action	Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Construct	Chevron	137.80	LDB	900	+18.5
Remove	Dike	137.60	LDB	700	Existing Grade
Construct	Chevron	137.40	LDB	900	+18.5

Alternative 13 Results: *Bathymetry (Plate 43) Analysis*

Enhance Environmental Diversity of Salt Lake Chute	Enhance Environmental Diversity of Sandbar	Maintain Navigation Channel Requirements	Additional Comments
No	No	Yes	Alternative 13 used a combination of two chevrons to try to create diversity on the existing bar near RM 137.5. However, no significant changes in bathymetry were observed.

Alternative 14:

Action	Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Notch	Dike	138.10	LDB	200	-10
Construct	Chevron	137.80	LDB	900	+15
Remove	Dike	137.60	LDB	700	Existing Grade
Construct	Chevron	137.40	LDB	900	+15

Alternative 14 Results: *Bathymetry (Plate 44) Analysis*

Enhance Environmental Diversity of Salt Lake Chute	Enhance Environmental Diversity of Sandbar	Maintain Navigation Channel Requirements	Additional Comments
No	No	Yes	This alternative built upon the idea used in Alternative 13 by adding a notch in Dike 138.10L. The notch was an attempt to allow more flow to interact with Chevron 137.80L. There was no significant change in bathymetry.

<u>Alternative 15:</u>

Action	Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Construct	Trail Dike	138.10	LDB	325	+18.5
Construct	Trail Dike	137.60	LDB	325	+18.5

Alternative 15 Results: *Bathymetry (Plate 45) Analysis*

Enhance Environmental Diversity of Salt Lake Chute	Enhance Environmental Diversity of Sandbar	Maintain Navigation Channel Requirements	Additional Comments
No	No	Yes	Alternative 15 consisted of adding a trail dike to Dike 138.10L and Dike 137.60L. The intention was to constrict the main channel flow in order to reduce the bar elevations to the main channel side of the trail dikes. However, there was no significant change in bathymetry.

Alternative 16:

Action	Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Construct	Trail Dike	138.10	LDB	275 (each)	+18.5
Construct	Trail Dike	137.60	LDB	275 (each)	+18.5

Alternative 16 Results: *Bathymetry (Plate 46) Analysis*

Enhance Environmental Diversity of Salt Lake Chute	Enhance Environmental Diversity of Sandbar	Maintain Navigation Channel Requirements	Additional Comments
No	No	Yes	Alternative 16 was an extension of Alternative 15. Runway trail dikes were added to Dike 138.10L and Dike 137.60L. No significant change in bathymetry was observed.

Alternative 17:

Action	Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Notch	Dike	139.50	LDB	300	-10
Remove	Dike	139.30	LDB	650	Existing Grade
Remove	Dike	139.00	LDB	750	Existing Grade
Construct	Trail Dike	138.10	LDB	430 (each)	+18.5
Remove	Dike	137.60	LDB	375	Existing Grade
Construct	Chevron	137.60	LDB	900	+18.5

Alternative 17 Results: *Bathymetry (Plate 47) Analysis*

Enhance Environmental Diversity of Salt Lake Chute	Enhance Environmental Diversity of Sandbar	Maintain Navigation Channel Requirements	Additional Comments
No	No	Yes	This alternative comprised a runway trail dike and chevron combination in an attempt to create diversity on the existing bar. However, there was no significant change in bathymetry.

<u>Alternative 18:</u>

Action	Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Remove	Dike	140.10	LDB	475	Existing Grade
Notch	Dike	139.80	LDB	225	-10
Construct	Dike	139.65	LDB	350	+18.5
Notch	Dike	139.50	LDB	275	-10
Remove	Dike	139.30	LDB	2,175	Existing Grade
Construct	Dike	139.30	LDB	1,350	+18.5
Remove	Dike	139.00	LDB	775	Existing Grade
Construct	Dike	138.80	LDB	215	+18.5
Remove	Dike	138.45	LDB	500	Existing Grade
Construct	Dike	138.40	LDB	265	+18.5
Construct	Dike	138.30	LDB	200	+18.5
Construct	Dike	138.15	LDB	280	+18.5
Remove	Dike	138.10	LDB	850	Existing Grade
Construct	Chevron	137.70	LDB	1,100	+18.5
Remove	Dike	137.60	LDB	1,600	Existing Grade
Construct	Trail Dike	137.60	LDB	175 (each)	+18.5

Alternative 18 Results: *Bathymetry (Plate 48) Analysis*

Enhance Environmental Diversity of Salt Lake Chute	Enhance Environmental Diversity of Sandbar	Maintain Navigation Channel Requirements	Additional Comments
No	No	Yes	This alternative shows a combination of trying to create diversity within the side channel and along the existing bar of the main channel. Although aggressive, there was still no significant change in bathymetry.

Alternative 19:

Action	Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Remove	Dike	139.00	LDB	980	Existing Grade
Construct	Rootless Dike	139.00	LDB	160	+18.5
Construct	Chevron	138.80	LDB	300 x 300	+18.5
Remove	Dike	138.40	LDB	820	Existing Grade
Construct	Rootless Dike	138.40	LDB	145	+18.5
Construct	Chevron	138.25	LDB	300 x 300	+18.5
Remove	Dike	138.10	LDB	1,200	Existing Grade
Construct	Rootless Dike	138.10	LDB	165	+18.5
Construct	Dike	137.85	LDB	180	+18.5
Construct	Chevron	137.60	LDB	300 x 300	+18.5
Construct	Dike	137.30	LDB	300	+18.5

Alternative 19 Results: *Bathymetry (Plate 49) Analysis*

Enhance Environmental Diversity of Salt Lake Chute	Enhance Environmental Diversity of Sandbar	Maintain Navigation Channel Requirements	Additional Comments
No	Yes	Yes	This alternative focused on creating diversity on the existing bar along the LDB of the main channel. The combination of rootless dikes and chevrons created a fair amount of diversity.

Alternative 20:

Action	Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Notch	Dike	139.80	LDB	230	-10
Notch	Dike	139.50	LDB	275	-10
Partially Remove	Dike	139.30	LDB	1,625	Existing Grade
Construct	Rootless Dike	139.10	LDB	300	+18.5
Partially Remove	Dike	139.00	LDB	775	Existing Grade
Construct	Dike	138.80	LDB	275	+18.5
Partially Remove	Dike	138.45	LDB	435	Existing Grade
Construct	Dike	138.45	LDB	250	+18.5
Construct	Dike	138.25	LDB	215	+18.5
Partially Remove	Dike	138.10	LDB	575	Existing Grade
Construct	Dike	138.10	LDB	215	+18.5
Remove	Dike	137.60	LDB	925	Existing Grade

Alternative 20 Results: *Bathymetry (Plate 50) Analysis*

Enhance Environmental Diversity of Salt Lake Chute	Enhance Environmental Diversity of Sandbar	Maintain Navigation Channel Requirements	Additional Comments
No	No	Yes	Alternative 20 attempted to divert a portion of the main channel flow into Salt Lake Chute, and to force the flow to the LDB of the side channel. This was done because most of the flow in the side channel was naturally moving to the LDB of the side channel. The dikes along the RDB of the side channel were used to constrict the side channel in hopes of creating depth diversity. However, this alternative did not create any significant change in bathymetry.

Alternative 21:

Action	Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Notch	Dike	139.80	LDB	230	-10
Notch	Dike	139.50	LDB	275	-10
Partially Remove	Dike	139.30	LDB	1,625	Existing Grade
Construct	Dike	139.10	LDB	300	+18.5
Partially Remove	Dike	139.00	LDB	775	Existing Grade
Construct	Dike	138.80	LDB	185	+18.5
Construct	Dike	138.80	LDB	185	+18.5
Construct	Dike	138.45	LDB	190	+18.5
Notch	Dike	138.45	LDB	245	-10
Construct	Dike	138.45	LDB	245	+18.5
Construct	Dike	138.25	LDB	135	+18.5
Construct	Dike	138.25	LDB	215	+18.5
Construct	Dike	138.10	LDB	240	+18.5
Notch	Dike	138.10	LDB	280	-10
Construct	Dike	138.10	LDB	270	+18.5
Construct	Dike	137.90	LDB	220	+18.5
Construct	Dike	137.90	LDB	220	+18.5
Construct	Dike	137.60	LDB	250	+18.5
Notch	Dike	137.60	LDB	325	-10
Construct	Dike	137.60	LDB	275	+18.5

Alternative 21 Results: *Bathymetry (Plate 51) Analysis*

Enhance Environmental Diversity of Salt Lake Chute	Enhance Environmental Diversity of Sandbar	Maintain Navigation Channel Requirements	Additional Comments
No	No	Yes	Alternative 21 attempted to divert a portion of the main channel flow into Salt Lake Chute, and to greatly constrict the side channel using dike structures. The goal was to cause the side channel to scour by the extreme constriction, but no significant bathymetry changes were observed.

Alternative 22:

This alternative was the final alternative tested, and was used as a check to see if a large planform change would have any effect on the side channel. The alternative consisted of creating a new side channel that led to the existing side channel. Since the thalweg crossed from the RDB to the LDB at RM 140.0, the new side channel entrance was chosen to start at that location. Plate 52 shows the planform change and resulting bathymetry for this alternative.

Alternative 22 Results: *Bathymetry (Plate 52) Analysis*

Enhance Environmental Diversity of Salt Lake Chute	**Enhance Environmental Diversity of Sandbar**	**Maintain Navigation Channel Requirements**	**Additional Comments**
No	No	Yes	This alternative still did not have success in creating diversity within Salt Lake Chute although a major change in planform existed. This test re-iterated what had been observed in all other tests of trying to increase diversity within the side channel; very little sediment transport and change in bathymetry.

CONCLUSIONS

1. Evaluation and Summary of the Model Tests

Alternatives	Enhance Environmental Diversity of Salt Lake Chute	Enhance Environmental Diversity of Sandbar	Maintain Navigation Channel Requirements
Alternative 1	No	No	Yes
Alternative 2	No	No	Yes
Alternative 3	No	No	Yes
Alternative 4	No	No	Yes
Alternative 5	No	No	Yes
Alternative 6	No	No	Yes
Alternative 7	No	Yes	Yes
Alternative 8	No	No	Yes
Alternative 9	No	No	Yes
Alternative 10	No	No	Yes
Alternative 11	No	No	Yes
Alternative 12	No	No	Yes
Alternative 13	No	No	Yes
Alternative 14	No	No	Yes
Alternative 15	No	No	Yes
Alternative 16	No	No	Yes
Alternative 17	No	No	Yes
Alternative 18	No	No	Yes
Alternative 19	No	Yes	Yes
Alternative 20	No	No	Yes
Alternative 21	No	No	Yes
Alternative 22	No	No	Yes

In order to determine the best alternative, certain criteria, based on the study purpose and goals, were used to evaluate each alternative. The first and most important consideration was that the alternative had to enhance environmental diversity near the Salt Lake Chute complex. The second condition was that the alternative had to maintain the navigation channel requirements of at least 12 foot of depth and 300 foot of width. Although Alternative 7 (Plate 37) showed minimal improvements to diversity near the Salt Lake Chute complex while maintaining the navigation channel requirements, it was not recommended. The alternative was not recommended primarily because the changes were not significant enough to warrant the cost of construction. Many of the alternatives tested increased the amount of flow entering the side channel, but none of the tests were able to create significant changes in bathymetry. As stated before, the most promising alternatives were analyzed using flow visualization, which was compared to the replication flow visualization. Appendix D explains the flow visualization process and results in detail.

2. Recommendations

Alternative 19, Plate 49, was recommended as the most desirable alternative because of its observed ability to significantly increase diversity along the existing bar of the main channel. Alternative 19 was able to create diversity on the existing bar of the main channel, and our stakeholders agreed that creating diversity on this existing bar would be beneficial to the environmental habitat. In addition, this alternative did not negatively impact the existing navigation channel.

The recommended design included the following:

- RM 139.00L: Remove Dike (980')
  - Remove to existing grade
- RM 139.00L: Construct Rootless Dike (160')
  - Structure top elevation = +18.5 ft LWRP
- RM 138.80L: Construct Chevron (300' x 300')
  - Structure top elevation = +18.5 ft LWRP
- RM 138.40L: Remove Dike (820')
  - Remove to existing grade

- RM 138.40L: Construct Rootless Dike (145’)
  - Structure top elevation = +18.5 ft LWRP
- RM 138.25L: Construct Chevron (300’ x 300’)
  - Structure top elevation = +18.5 ft LWRP
- RM 138.10L: Remove Dike (1,200’)
  - Remove to existing grade
- RM 138.10L: Construct Rootless Dike (165’)
  - Structure top elevation = +18.5 ft LWRP
- RM 137.85L: Construct Dike (180’)
  - Structure top elevation = +18.5 ft LWRP
- RM 137.60L: Construct Chevron (300’ x 300’)
  - Structure top elevation = +18.5 ft LWRP
- RM 137.30L: Construct Dike (300’)
  - Structure top elevation = +18.5 ft LWRP

3. Interpretation of Model Test 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 biases introduced as a result of the inherent complexities that exist in the prototype. Anomalies in actual hydrographic events, such as prolonged periods of high or low flows are not reflected in these results, nor are complex physical phenomena, such as the existence of underlying rock formations or other non-erodible variables. Water surfaces were not analyzed and flood flows were not simulated in this study.

This model study was intended to serve as a tool for the river engineer to guide in assessing the general trends that could be expected to occur in the Mississippi River from a variety of 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 requirements.

FOR MORE INFORMATION

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http://mvs-wc.mvs.usace.army.mil/arec/

APPENDIX

A. Report Plates

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5. Geomorphology: 1866 vs. 1881 – 1:30,000
6. Geomorphology: 1881 vs. 1908 – 1:30,000
7. Geomorphology: 1908 vs. 1928 – 1:30,000
8. Geomorphology: 1928 vs. 1956 – 1:30,000
9. Geomorphology: 1956 vs. 1968 – 1:30,000
10. Geomorphology: 1968 vs. 1986 – 1:30,000
11. Geomorphology: 1986 vs. 2003 – 1:30,000
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21. 2005 Hydrographic Survey – 1:30,000
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34. Alternative 4 – 1:33,000
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37. Alternative 7 – 1:33,000
38. Alternative 8 – 1:33,000
39. Alternative 9 – 1:33,000
40. Alternative 10 – 1:33,000
41. Alternative 11 – 1:33,000
42. Alternative 12 – 1:33,000
43. Alternative 13 – 1:33,000
44. Alternative 14 – 1:33,000
45. Alternative 15 – 1:33,000
46. Alternative 16 – 1:33,000
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Appendix B: HSR Model Theory

The principle behind the use of a hydraulic sediment response model is similitude, the linking of parameters between a model and prototype so that behavior in one can predict behavior in the other.

There are two different types of similitude; mathematical similitude and empirical similitude. Mathematical similitude is founded on the scale relationship between all linear dimensions (geometric similarity), a scale relationship between all components of velocity (kinematic), or both geometric and kinematic similarity with the ratio of all common point forces equal (dynamic similarity).

In contrast to mathematical similitude, empirical similitude is based on the belief that the laws of mathematical similitude can be relaxed as long as other more fundamental relationships are preserved between the model and the prototype. All physical models used in the past by USACE employed, to some degree, empirical similitude. Numerous definitions of what relationships must be preserved have been put forward concerning physical sediment models. These relationships often deal with the scalability of elements of sediment transport processes or surface or structure roughness. Hydraulic sediment response models depend on similitude in the morphologic response, i.e. the ability of the model to replicate known prototype parameters associated with the bed response in the river under study. Bed response includes thalweg location, scour and deposition within the channel and at various river structures, and the overall resultant bed configuration. These parameters are directly compared to what is observed from prototype surveys.

Detailed cross-sectional analysis of prototype and model surveys defining bed response and bed configuration have shown that HSR model variation from the prototype is often approximately that of the natural variation observed in the prototype. This correspondence allows hydraulic engineers to use the HSR model with confidence and introduce alternatives in the model to approximate the bed response that can be expected to occur in the prototype.

HSR models were developed from empirical large scale coal bed models utilized by the USACE Waterways Experiment Station (Environmental Research and Development Center). These models were used by MVS from 1940 to the mid 1990s. For a more thorough explanation of the HSR model development, please refer to the following link:

http://www.mvs.usace.army.mil/arec/Documents/hsr_models/Hydraulic_Sediment_Response_Modeling_Replication_Accuracy_TPM53.pdf

Appendix C: Cross Section Comparison

To verify the predictive capabilities of the HSR model used for this study, cross sections were developed for the replication model condition and two prototype bathymetries, the 2001 and 2010 river surveys. The 2001 and 2010 surveys were chosen because they were the most recent surveys of the last 10 years that had full coverage of the model extents. From these cross sections, the cross-sectional areas and percent differences were calculated. Due to the numerous fleeting areas within the reach, the prototype surveys rarely contained bank to bank bathymetry. Because of this limitation, cross sections were trimmed to where the two prototype surveys and model survey were present. The cross sections were modeled and area calculations were performed using Bentley's InRoads and MicroStation software. The cross sections were cut at 2,000 foot intervals along the sailing line for the same locations for all three surveys. The survey areas in close proximity to the model's entrance and exit conditions were not used, so only stations 100+00 through 380+00 were used. Furthermore, it should be noted that this is a limited data set, and a more detailed analysis was not completed due to constraints in time and funding. See Figures 1 and 2 on the following pages for graphical cross-sectional comparisons.

The initial comparison was calculated between the replicated model scan and the 2001 bathymetry. The cross sections were generated with a vertical distortion of 15 feet horizontal for 1 foot vertical, which dictated using 15 as a correction factor for the area calculations. The results of the area calculations are presented on the next page in Table 4. The average percent difference between the cross-sectional areas, model to prototype, was 10.7%, with a low of 2.8% and a high of 31.5%.

The second comparison was between the replicated model scan and the 2010 bathymetry. The cross sections were generated with a vertical distortion of 15 feet horizontal for 1 foot vertical, which dictated using 15 as a correction factor for the area calculations. The results of the area calculations are presented in Table 5. The average percent difference between the cross-sectional areas, model to prototype, was 8.4%, with a low of 0.9% and a high of 22.1%.

Cross sections were generated in the same manner comparing the 2001 and 2010 bathymetries to get a measure of the natural variation of the channel. The average percent difference was 13.1%; the lowest percent difference was 0.4% and the highest was 21.6%. The natural variation of the channel compared well with the average percent difference of 9.6% between the model and prototype.

Figure 1:

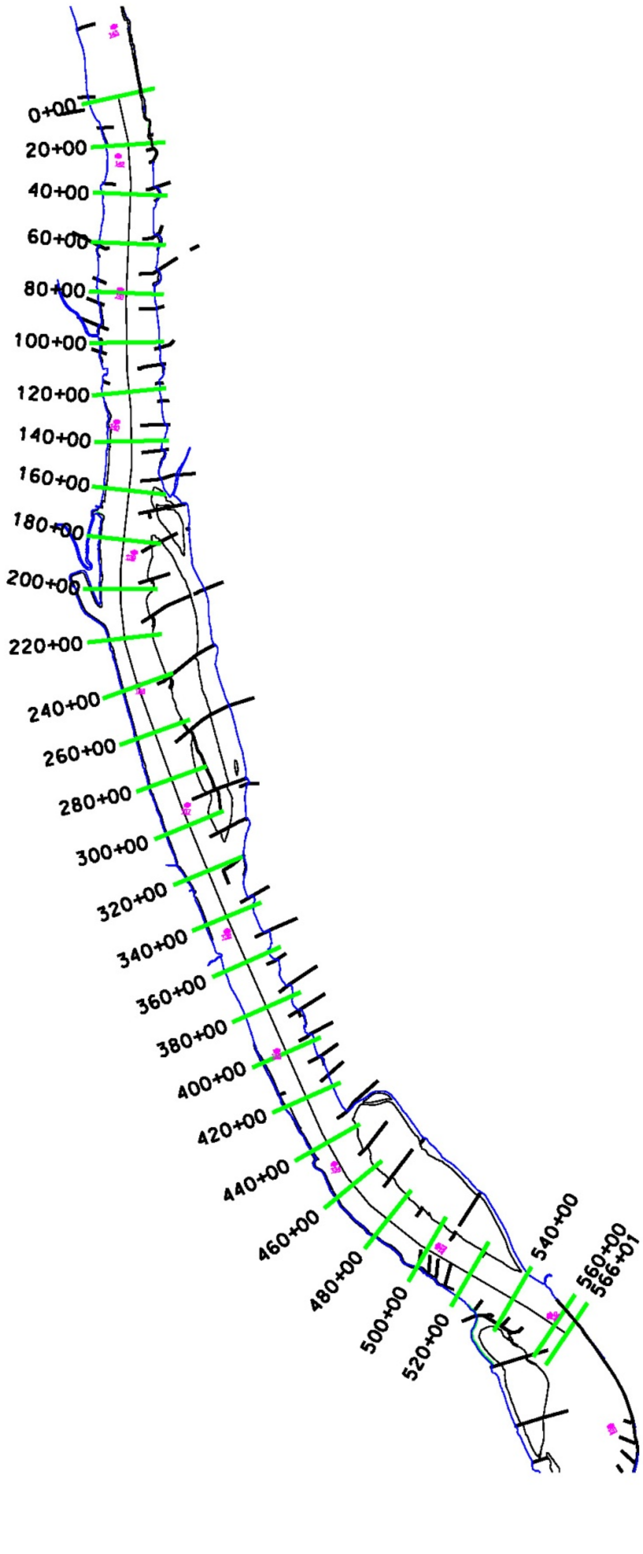
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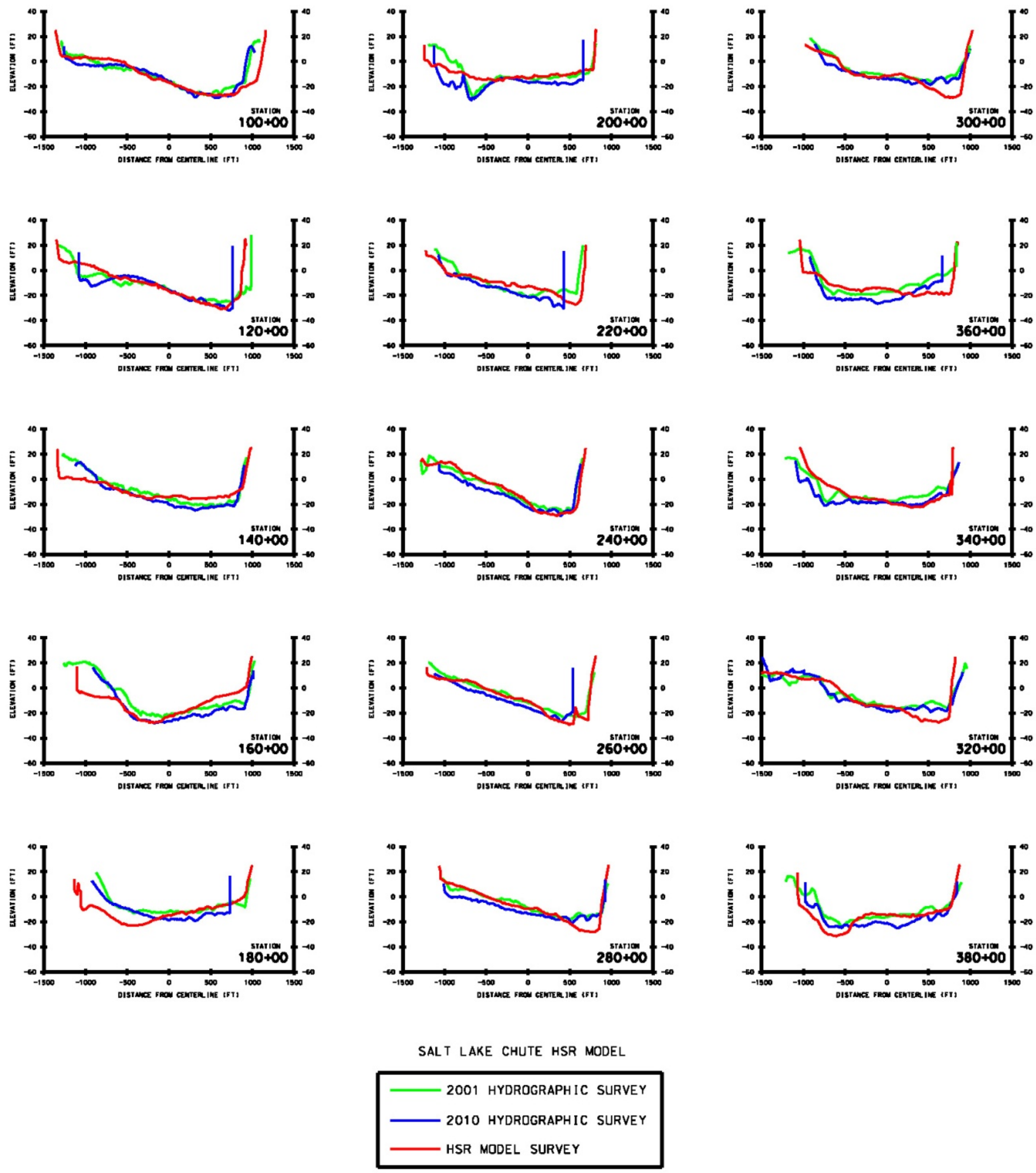
Figure 2: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STATION 220+00
STATION 360+00
STATION 140+00
STATION 240+00
STATION 340+00
STATION 160+00
STATION 260+00
STATION 320+00
STATION 180+00
STATION 280+00
STATION 380+00
ELEVATION (FT)
DISTANCE FROM CENTERLINE (FT)
SALT LAKE CHUTE HSR MODEL
2001 HYDROGRAPHIC SURVEY
2010 HYDROGRAPHIC SURVEY
HSR MODEL SURVEY

Table 4: Cross Section Comparison Model Replication Scan and 2001 Bathymetry

Cross Section Station	Area Without Correction		Corrected Area		Percent Difference
	Model Replication (ft^2)	2001 Survey (ft^2)	True Model Replication (ft^2)	True 2001 Survey (ft^2)	
100+00	786911.95	719084.20	52460.80	47938.95	9.0%
120+00	709618.03	770802.70	47307.87	51386.85	8.3%
140+00	657248.86	622670.95	43816.59	41511.40	5.4%
160+00	719727.00	634694.52	47981.80	42312.97	12.6%
180+00	682574.35	496915.37	45504.96	33127.69	31.5%
200+00	611626.38	594562.35	40775.09	39637.49	2.8%
220+00	569146.84	538038.06	37943.12	35869.20	5.6%
240+00	510985.13	494547.61	34065.68	32969.84	3.3%
260+00	522757.38	480056.24	34850.49	32003.75	8.5%
280+00	528014.55	472223.00	35200.97	31481.53	11.2%
300+00	596535.81	491736.05	39769.05	32782.40	19.3%
320+00	583992.53	530079.77	38932.84	35338.65	9.7%
340+00	611044.98	593256.99	40736.33	39550.47	3.0%
360+00	655539.93	577234.89	43702.66	38482.33	12.7%
380+00	753362.87	632416.97	50224.19	42161.13	17.5%
				Average	**10.7%**

Table 5: Cross Section Comparison Model Replication and 2010 Bathymetry

Cross Section Station	Area Without Correction		Corrected Area		Percent Difference
	Model Replication (ft^2)	2010 Survey (ft^2)	True Model Replication (ft^2)	True 2010 Survey (ft^2)	
100+00	786911.95	743397.20	52460.80	49559.81	5.7%
120+00	709618.03	693151.32	47307.87	46210.09	2.3%
140+00	657248.86	705811.20	43816.59	47054.08	7.1%
160+00	719727.00	762995.20	47981.80	50866.35	5.8%
180+00	682574.35	546877.56	45504.96	36458.50	22.1%
200+00	611626.38	734735.66	40775.09	48982.38	18.3%
220+00	569146.84	552192.62	37943.12	36812.84	3.0%
240+00	510985.13	584400.07	34065.68	38960.00	13.4%
260+00	522757.38	481894.22	34850.49	32126.28	8.1%
280+00	528014.55	586843.17	35200.97	39122.88	10.6%
300+00	596535.81	568996.42	39769.05	37933.09	4.7%
320+00	583992.53	578956.33	38932.84	38597.09	0.9%
340+00	611044.98	724429.24	40736.33	48295.28	17.0%
360+00	655539.93	684691.62	43702.66	45646.11	4.4%
380+00	753362.87	767900.52	50224.19	51193.37	1.9%
				Average	**8.4%**

Table 5: Cross Section Comparison 2001 Bathymetry and 2010 Bathymetry

Cross Section Station	Area Without Correction		Corrected Area		Percent Difference
	2001 Survey (ft^2)	2010 Survey (ft^2)	True 2001 Survey (ft^2)	True 2010 Survey (ft^2)	
100+00	719084.20	743397.20	47938.95	49559.81	3.3%
120+00	770802.70	693151.32	51386.85	46210.09	10.6%
140+00	622670.95	705811.20	41511.40	47054.08	12.5%
160+00	634694.52	762995.20	42312.97	50866.35	18.4%
180+00	496915.37	546877.56	33127.69	36458.50	9.6%
200+00	594562.35	734735.66	39637.49	48982.38	21.1%
220+00	538038.06	552192.62	35869.20	36812.84	2.6%
240+00	494547.61	584400.07	32969.84	38960.00	16.7%
260+00	480056.24	481894.22	32003.75	32126.28	0.4%
280+00	472223.00	586843.17	31481.53	39122.88	21.6%
300+00	491736.05	568996.42	32782.40	37933.09	14.6%
320+00	530079.77	578956.33	35338.65	38597.09	8.8%
340+00	593256.99	724429.24	39550.47	48295.28	19.9%
360+00	577234.89	684691.62	38482.33	45646.11	17.0%
380+00	632416.97	767900.52	42161.13	51193.37	19.4%
				Average	**13.1%**

Appendix D: Flow Visualization Analysis

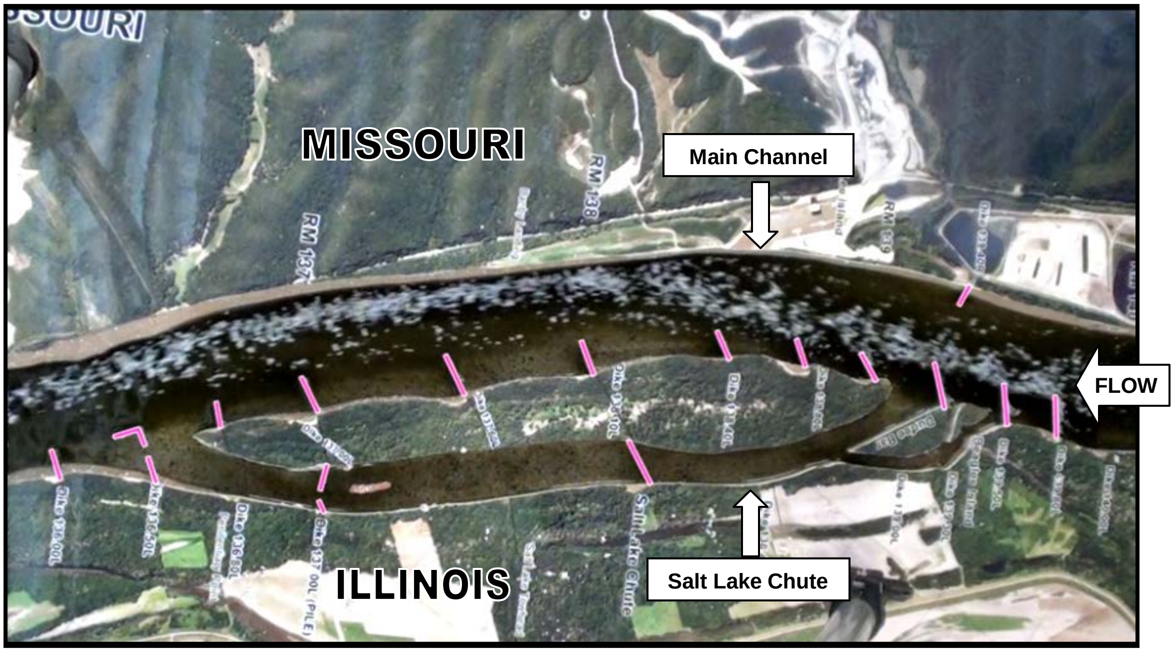
After running alternatives in the Salt Lake Chute HSR model and analyzing the results, the modeler observed that certain alternatives appeared to increase flow into the side channel by varying degrees, yet the bed elevation remained unchanged. Therefore, it was determined to use flow visualization techniques to study alternatives that had significant changes in bathymetry or large increases of flow entering the side channel.

Flow visualization is a tool used to monitor the flow patterns in an HSR model. The preferred method at the Applied River Engineering Center is to dye the water black and seed the water surface with dry white sediment (Poly-Urea grit) at the model entrance. The dry sediment floats on the top of the water surface and provides a visual representation of surface flow patterns in the model. A high definition video camera is used to record approximately 30 seconds of the sediment floating through the study area. The recording is processed with software that reduces the original recording to approximately 20% of the original speed. The video speed reduction allows viewers to more easily track the flow patterns.

The first condition recorded was the model replication test, or existing condition, as seen in Figure 1 on the following page.

(Please note that there is a DVD available with this report in order to view the described videos. Furthermore, Youtube hyperlinks will be provided in the online version of the report. To access the Youtube videos simply click on the still image of the video, and it will direct you to the associated Youtube video.)

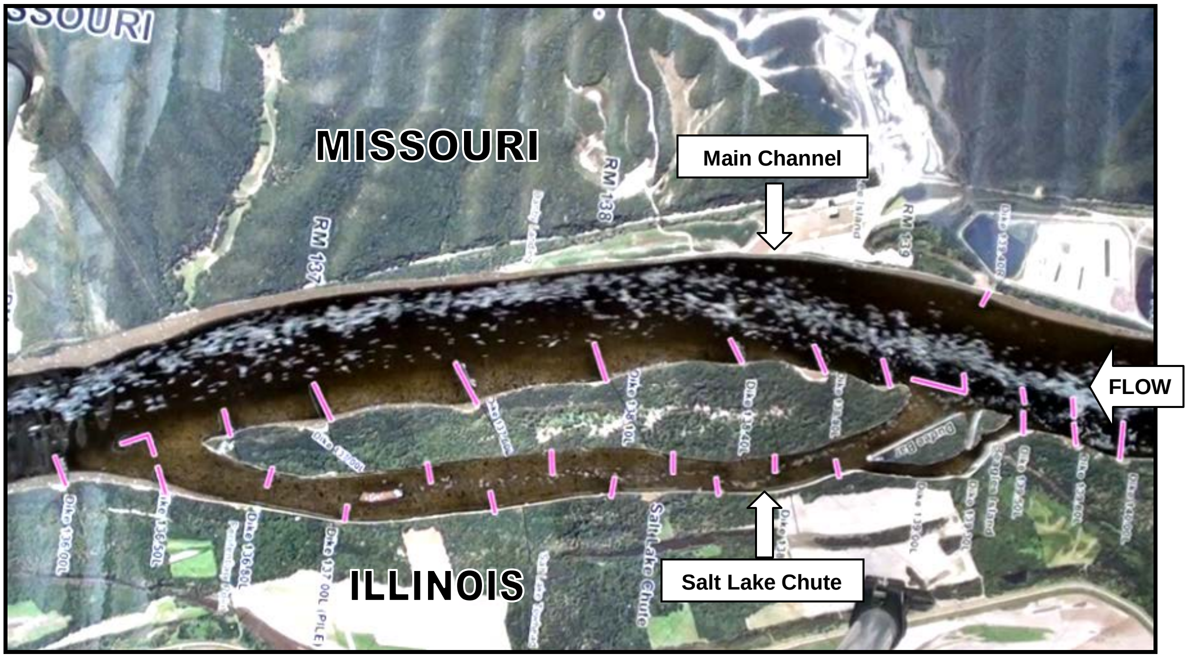
Figure 1: Flow Visualization of Model Replication (Existing Conditions)



As seen in the snapshot of existing conditions, the resultant flow was concentrated near the LDB on the right-hand side of Figure 1. The flow crossed to the RDB near the location of the main entrance to Salt Lake Chute. The resultant flow remained along the RDB until RM 136.0, which is to the left of Figure 1's extents. Figure 1 clearly shows the dominant flow of the main channel. Very little dry sediment entered the side channel, which was most likely due to the location of existing dikes immediately upstream of the side channel entrance.

The next condition recorded was Alternative 1 as shown in Figure 2 on the following page (see Plate 31 for bathymetry results and structure details). The alternative included a series of new dikes, dike notches, and dike removals.

Figure 2: Flow Visualization of Alternative 1



The focus of Alternative 1 was to increase the amount of flow into the side channel in addition to adding alternating structures within the side channel. The amount of flow entering the side channel was increased due to alterations of the dikes existing upstream of the side channel entrance. However, the additional flow within the side channel did not provide sufficient energy to create bathymetric changes near the new structures. This result held true for all other alternatives tested within the side channel. Figure 3 shows the flow visualization for Alternative 3 (see Plate 33 for bathymetry results and structure details). This alternative was very similar to Alternative 1 except there was a more significant dike structure diverting flow into the side channel. Because of the increased flow provided to the side channel, a sinuous flow pattern created within the side channel became more apparent. Figure 4 shows the flow visualization for Alternative 21 (see Plate 51 for bathymetry results and structure details). This alternative had increased flow and very aggressive constriction within the side channel, yet the bathymetry remained unchanged. After analyzing these alternatives, it was determined that additional flow could be diverted into the side channel, but the additional energy would not be sufficient enough to create any significant changes in bathymetry.

Figure 3: Flow Visualization of Alternative 3

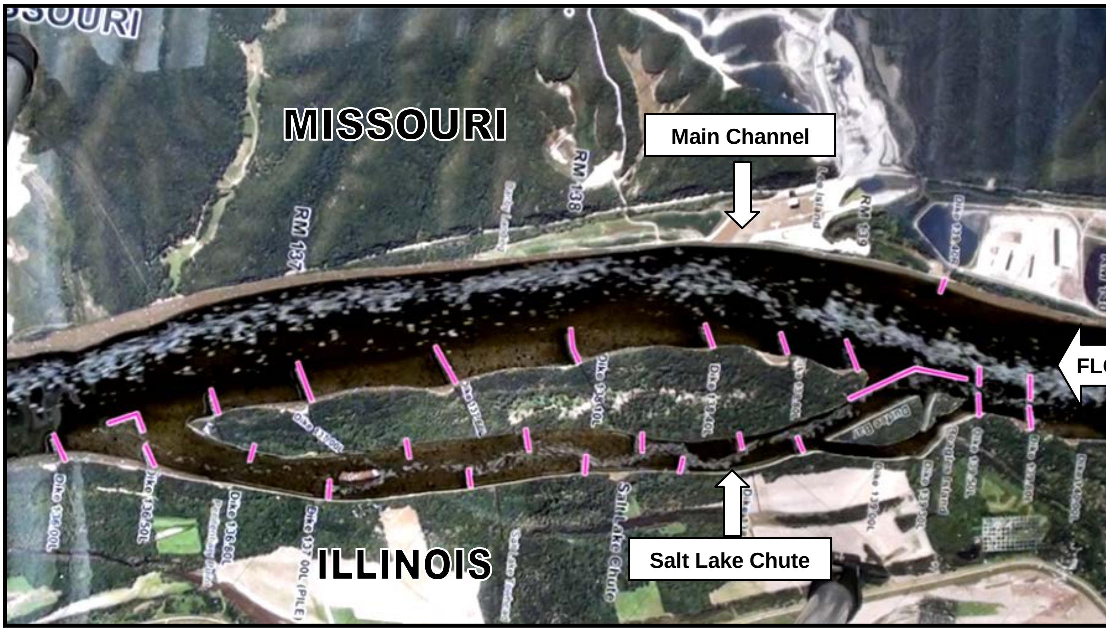
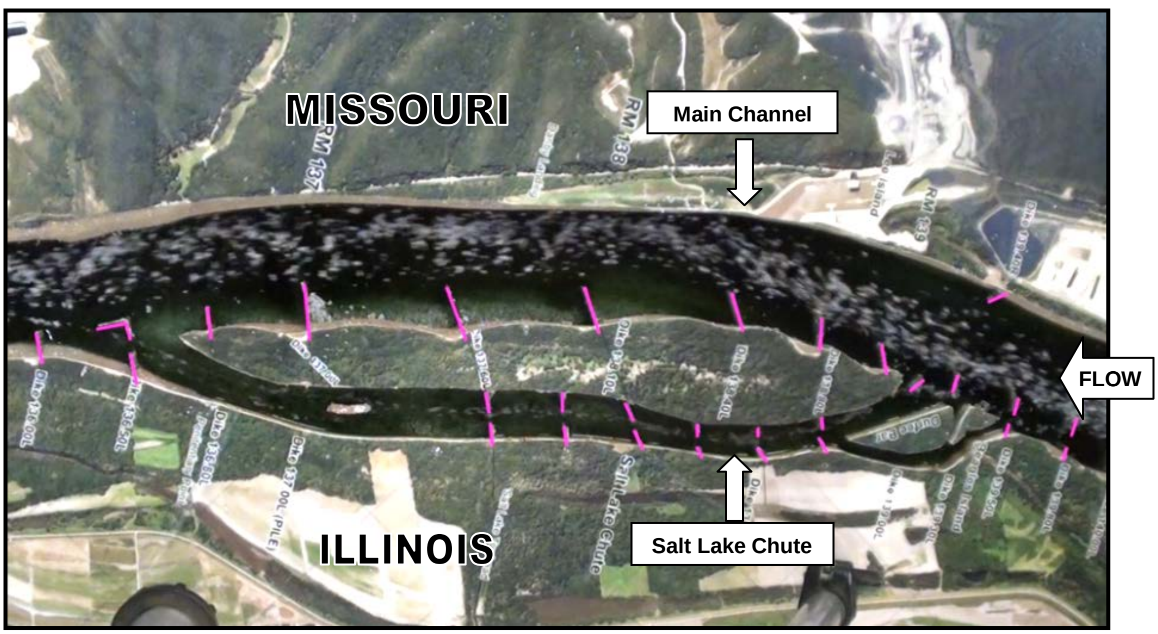
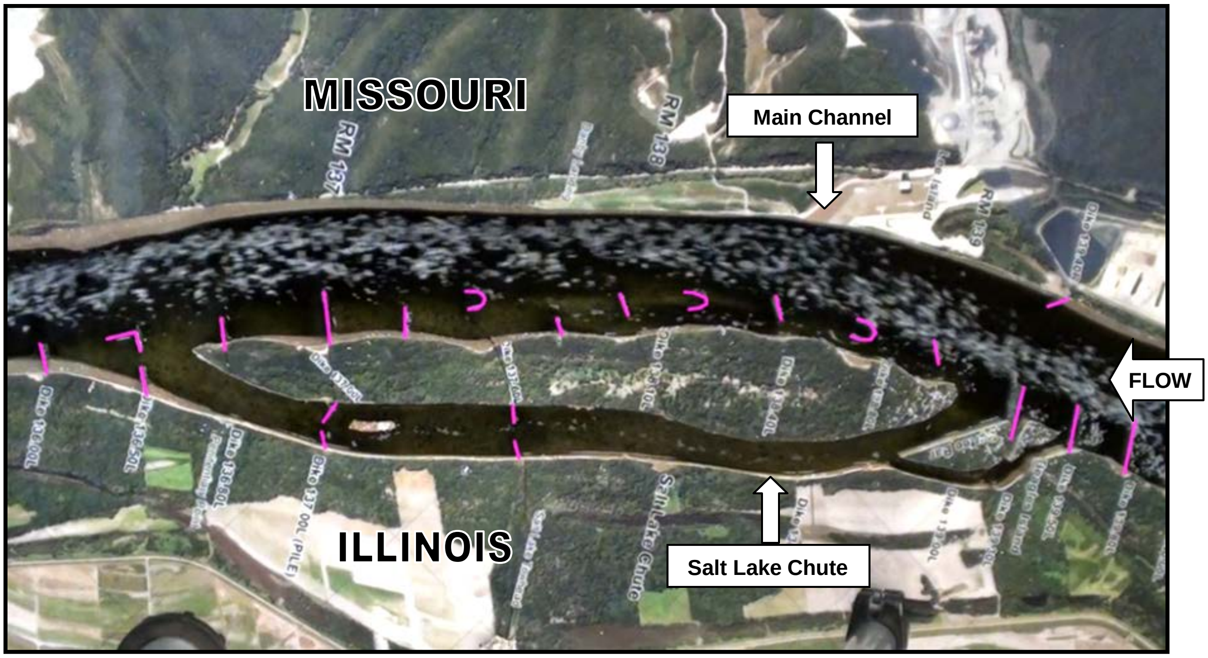


Figure 4: Flow Visualization of Alternative 21



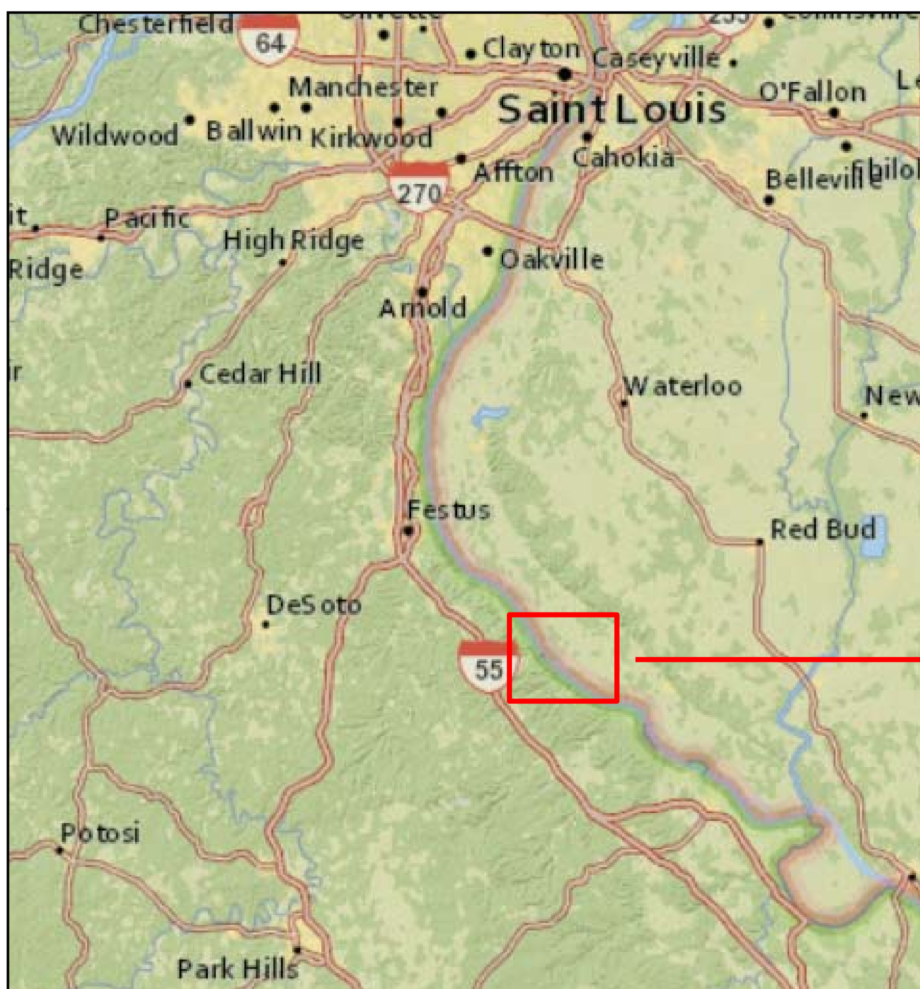
Flow visualization was also recorded for the recommended alternative, Alternative 19 (see Plate 49 for bathymetry results and structure details). The alternative focused on creating diversity on the main channel side of Salt Lake Island. Figure 5 shows the flow visualization for Alternative 19, which included dike construction, chevron construction, and the partial removal of dikes to create rootless structures.

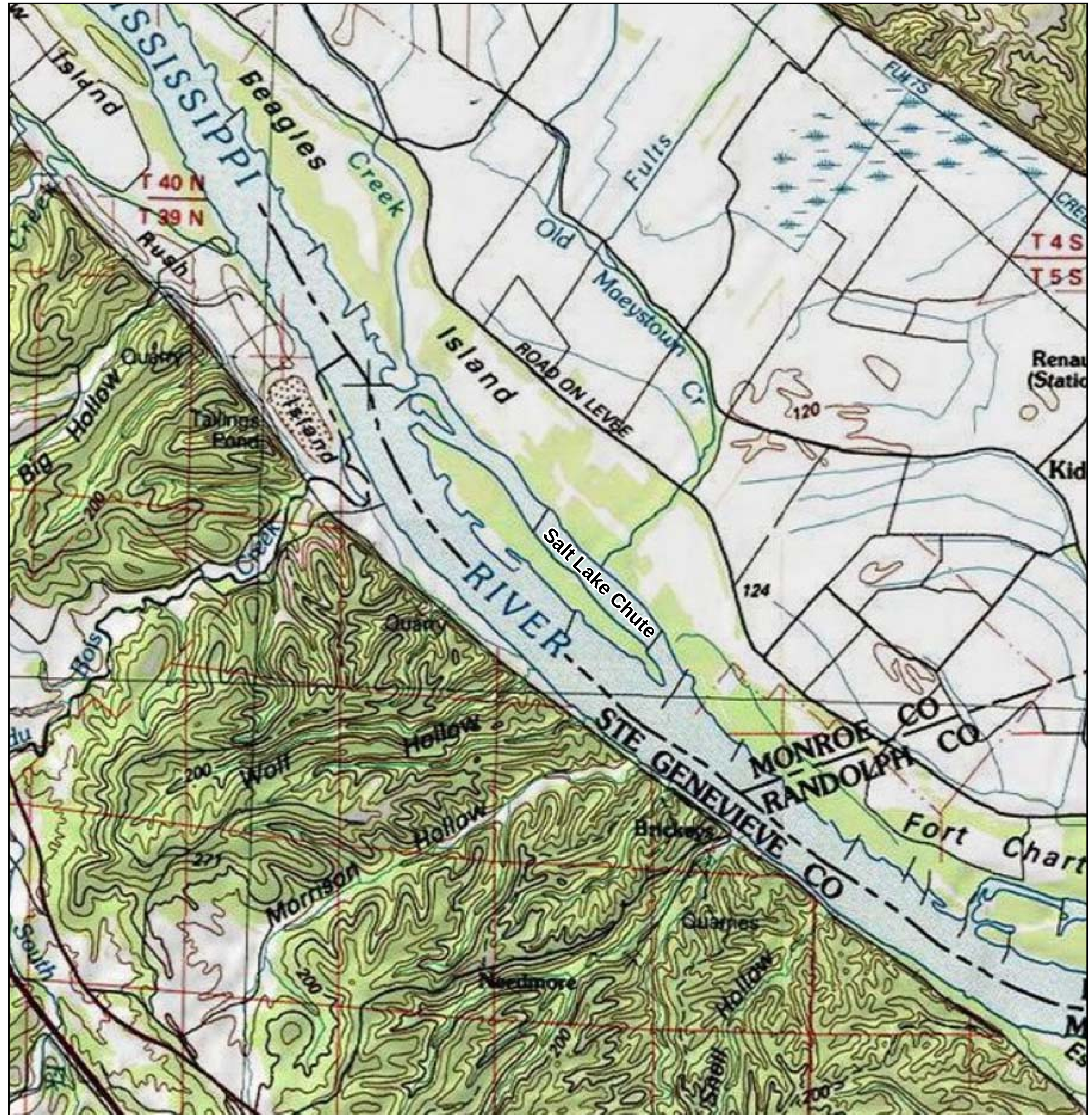
Figure 5: Flow Visualization of Alternative 19



As seen in the snapshot for Alternative 19, the main channel flow remained dominant. There was a small amount flow entering the side channel, but again, this had no significant effect on the side channel bathymetry. Along the bank on the main channel side of Salt Lake Island there was a small amount of flow visible. The amount of sediment floating on the water in this area appeared to be approximately the same as what was visible in the side channel. However, once the bathymetry was analyzed (see Plate 49), it became apparent that there was significantly more energy being utilized by the structures on the main channel side of the island. The existing bar, which originally had elevations above 0 ft LWRP, now showed a split flow with elevations ranging from -10 ft to above 0 ft LWRP. Furthermore, there was a scour hole with elevations of -15 ft LWRP on the island side of Dike 137.85.

As stated before, flow visualization was used as a supplemental tool to determine areas of increased flow patterns, but significant changes in bathymetry was the ultimate factor for determining a successful alternative.





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U.S. ARMY ENGINEER DIVISION
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ST. LOUIS, MISSOURI

Mississippi River Basin
St. Louis District
Salt Lake Chute
HSR Model

DESIGNED BY: B Krischel
DRAWN BY: B Krischel
REVIEWED BY: A Cox
CHECKED BY: R Davinroy, P.E.
SUBMITTED: B Krischel
APPROVED: R Davinroy, P.E.
FILE NAME: L:\Salt Lake Chute\Plates
PLOT DATE: 06/20/2013

Salt Lake Chute
Location & Vicinity Map

PLATE NUMBER
1

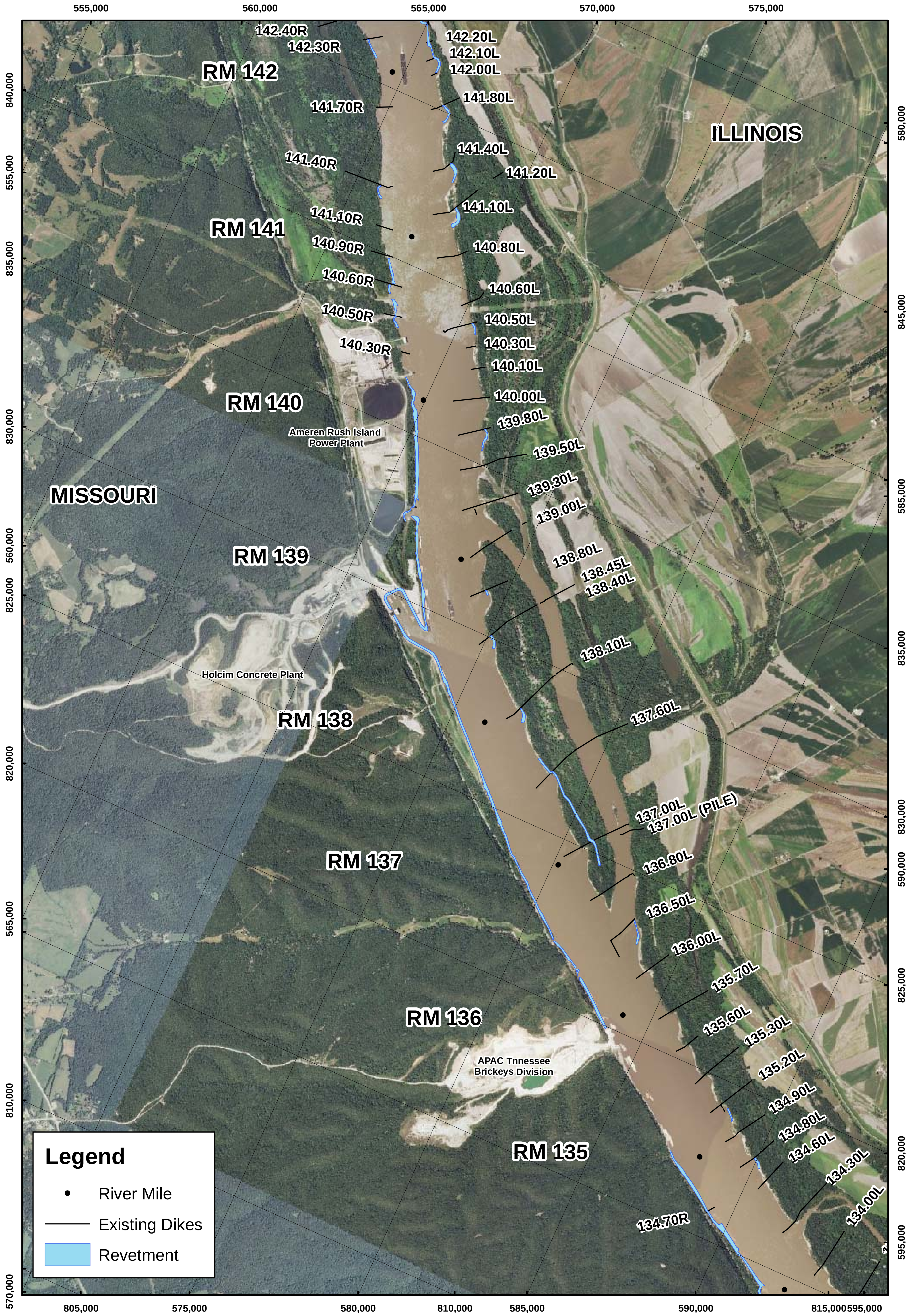

PLATE NUMBER	2

0 800 1,600 3,200 4,800
Feet

Nomenclature & Dike Locations
2010 Aerial Photograph

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Mississippi River Basin St. Louis District Salt Lake Chute HSR Model	SUBMITTED: B. Krischel	APPROVED: R. Davinroy, P.E.	
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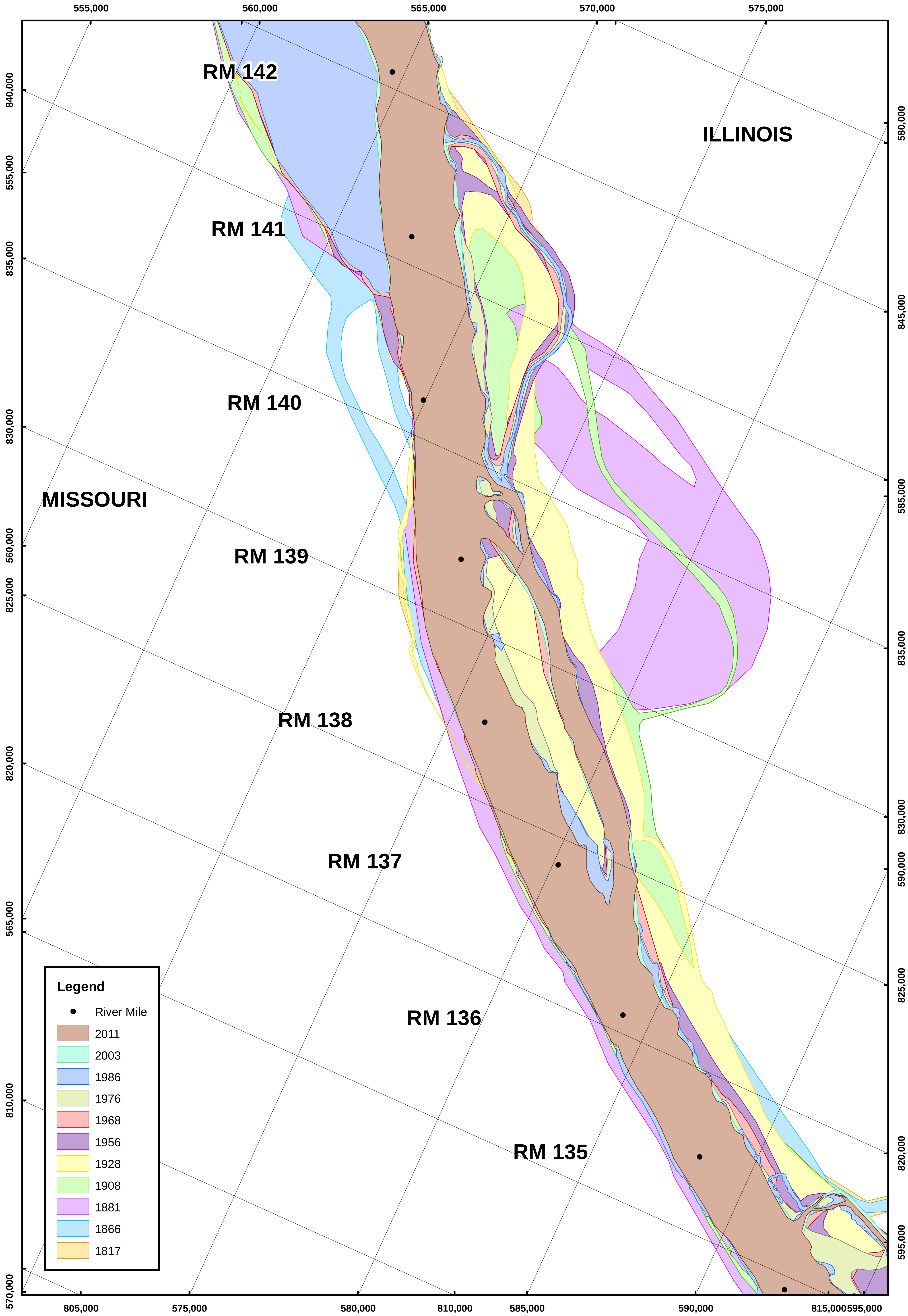

PLATE NUMBER 3

0 800 1,600 3,200 4,800
Feet

Geomorphology Planform: 1817 - 2011

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St. Louis District
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HSR Model

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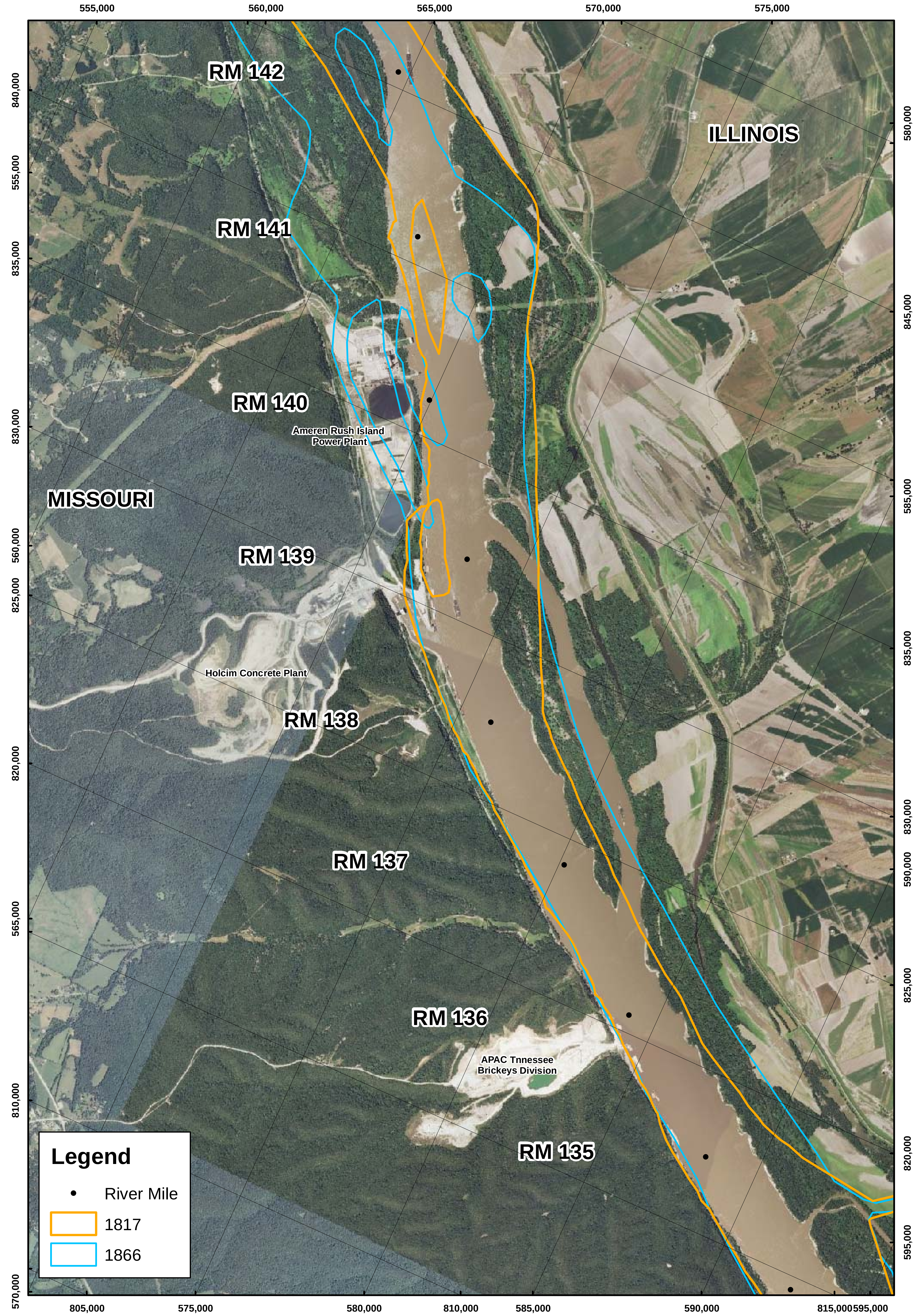

PLATE NUMBER 4

0 800 1,600 3,200 4,800
Feet

Geomorphology: 1817 vs 1866

2010 Aerial Photograph

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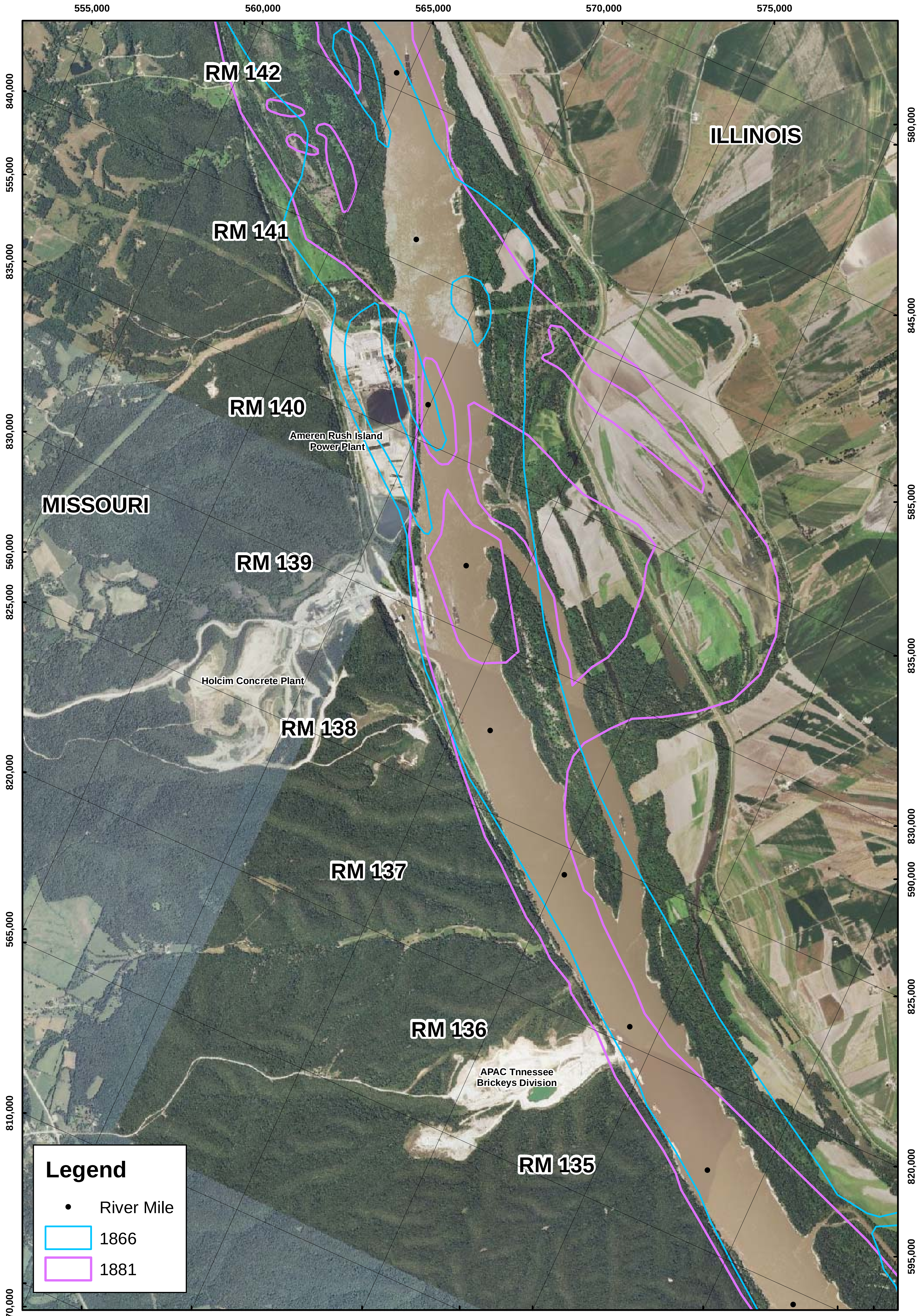

PLATE NUMBER 5

0 800 1,600 3,200 4,800
Feet

Geomorphology: 1866 vs 1881

2010 Aerial Photograph

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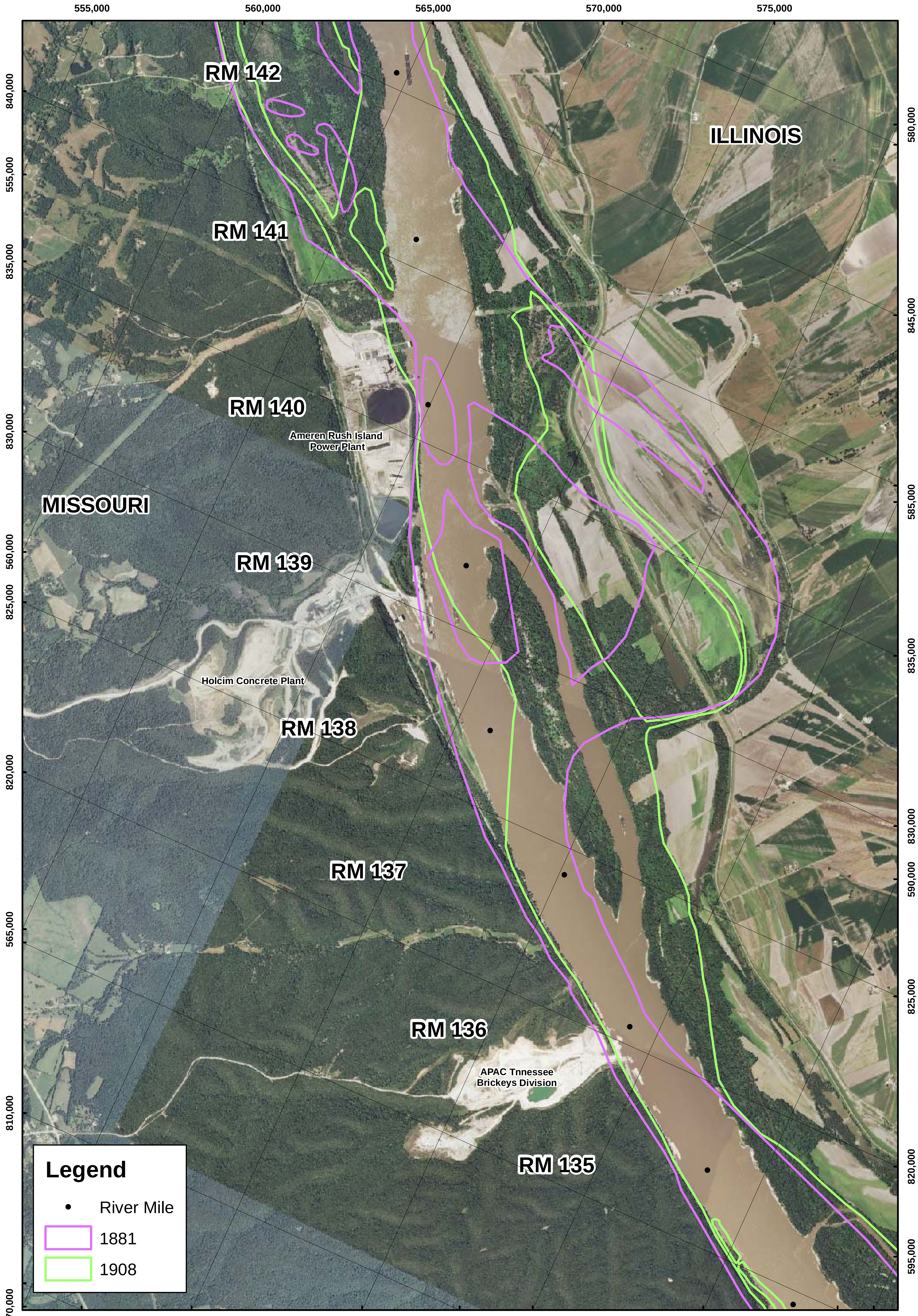

PLATE NUMBER 6

0 800 1,600 3,200 4,800
Feet

Geomorphology: 1881 vs. 1908

2010 Aerial Photograph

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St. Louis District
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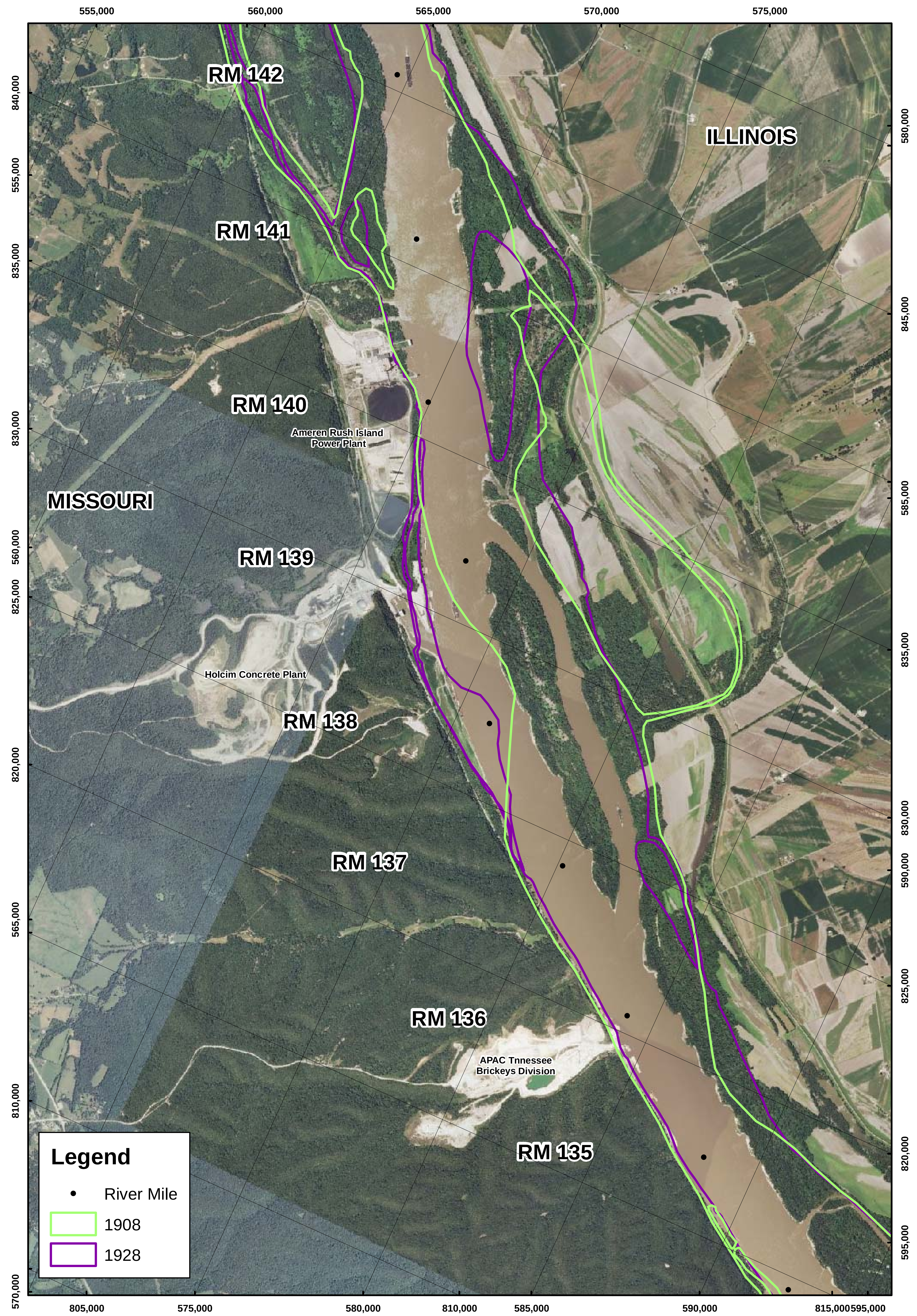

PLATE NUMBER 7

0 800 1,600 3,200 4,800
Feet

Geomorphology: 1908 vs. 1928

2010 Aerial Photograph

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B. Krischel	A. Cox	R. Davinroy, P.E.
SUBMITTED:	APPROVED:	
B. Krischel	R. Davinroy, P.E.	
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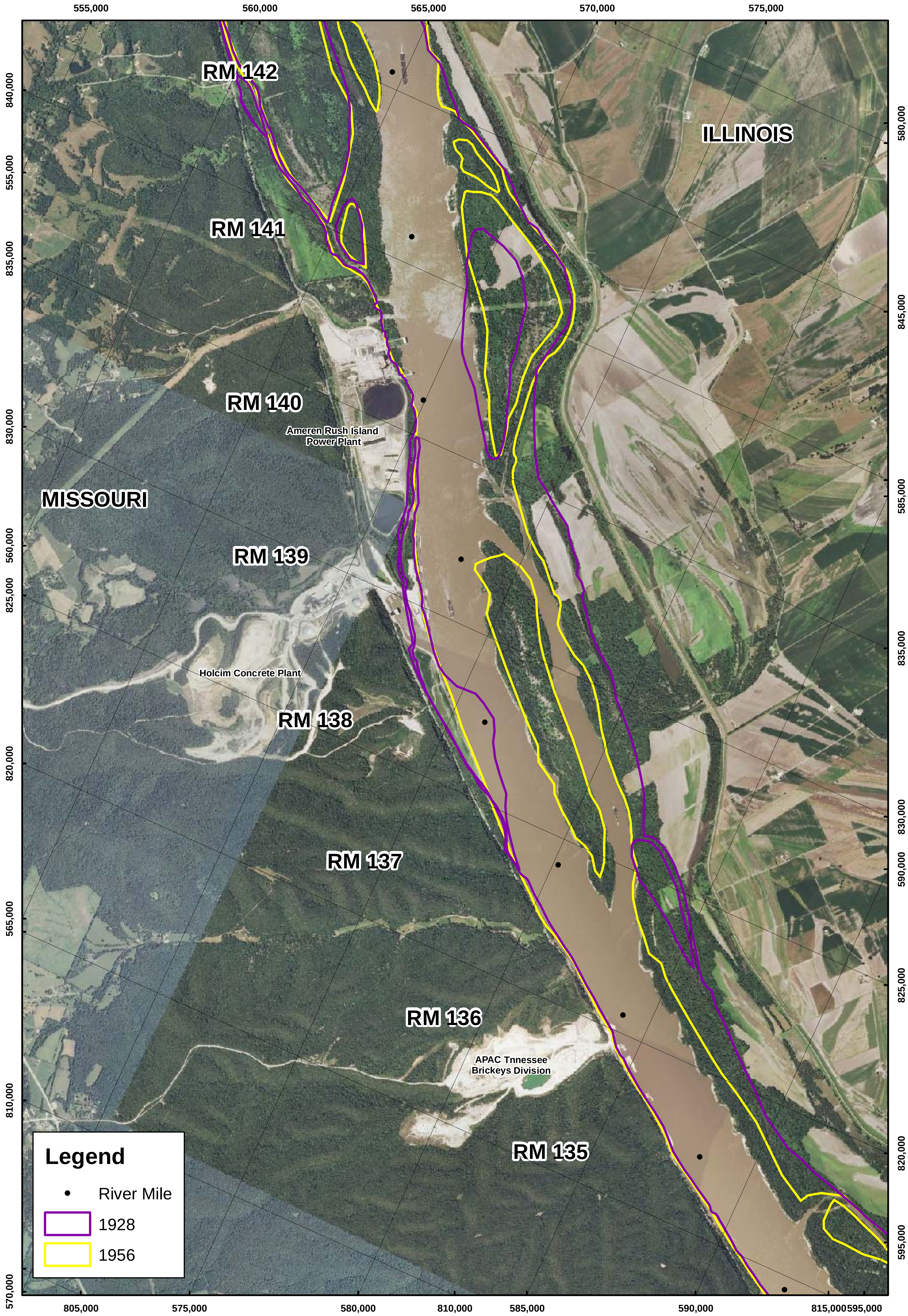

PLATE NUMBER **8**

0 800 1,600 3,200 4,800
Feet

Geomorphology: 1928 vs. 1956

2010 Aerial Photograph

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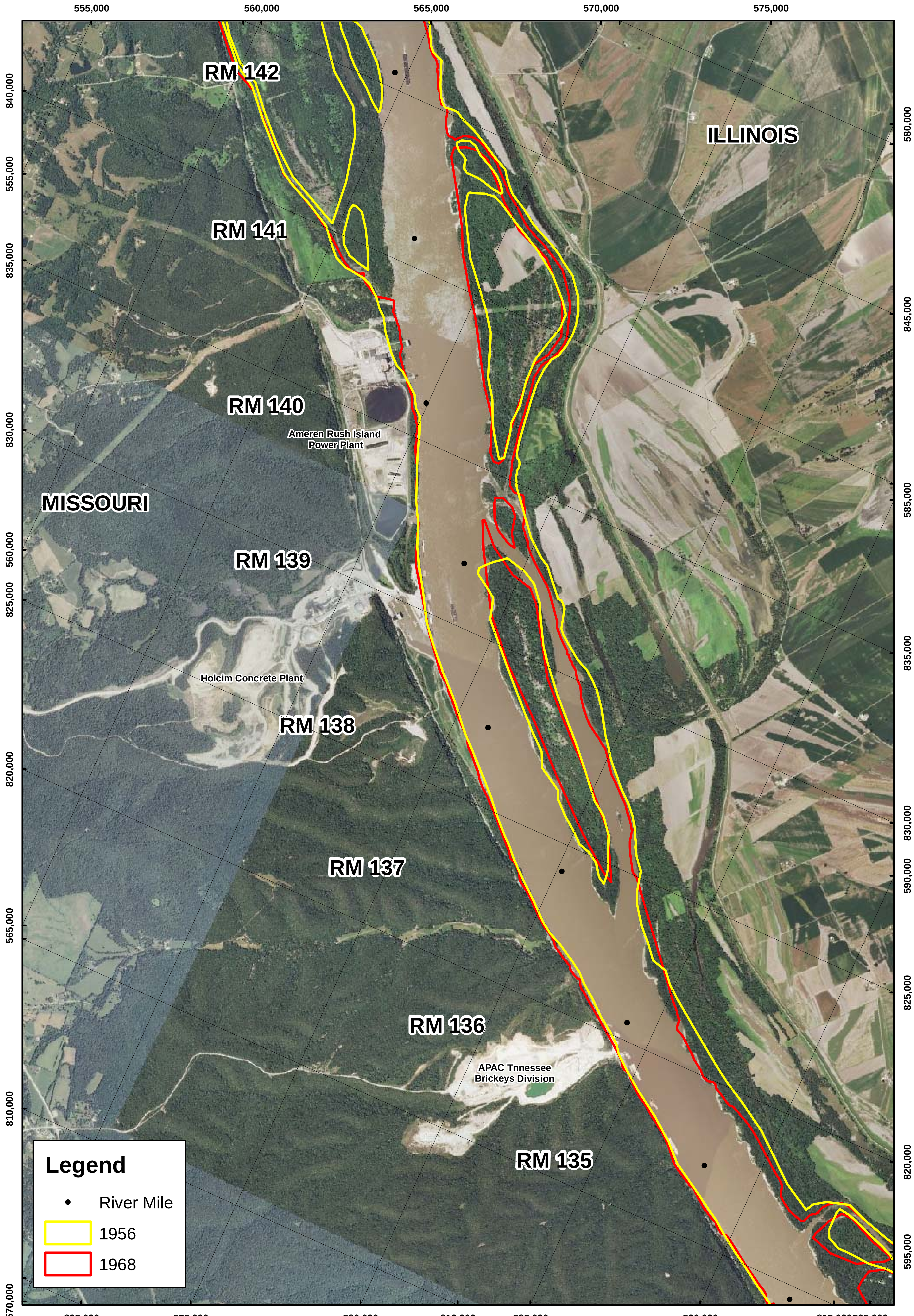

PLATE NUMBER 9

0 800 1,600 3,200 4,800
Feet

Geomorphology: 1956 vs 1968

2010 Aerial Photograph

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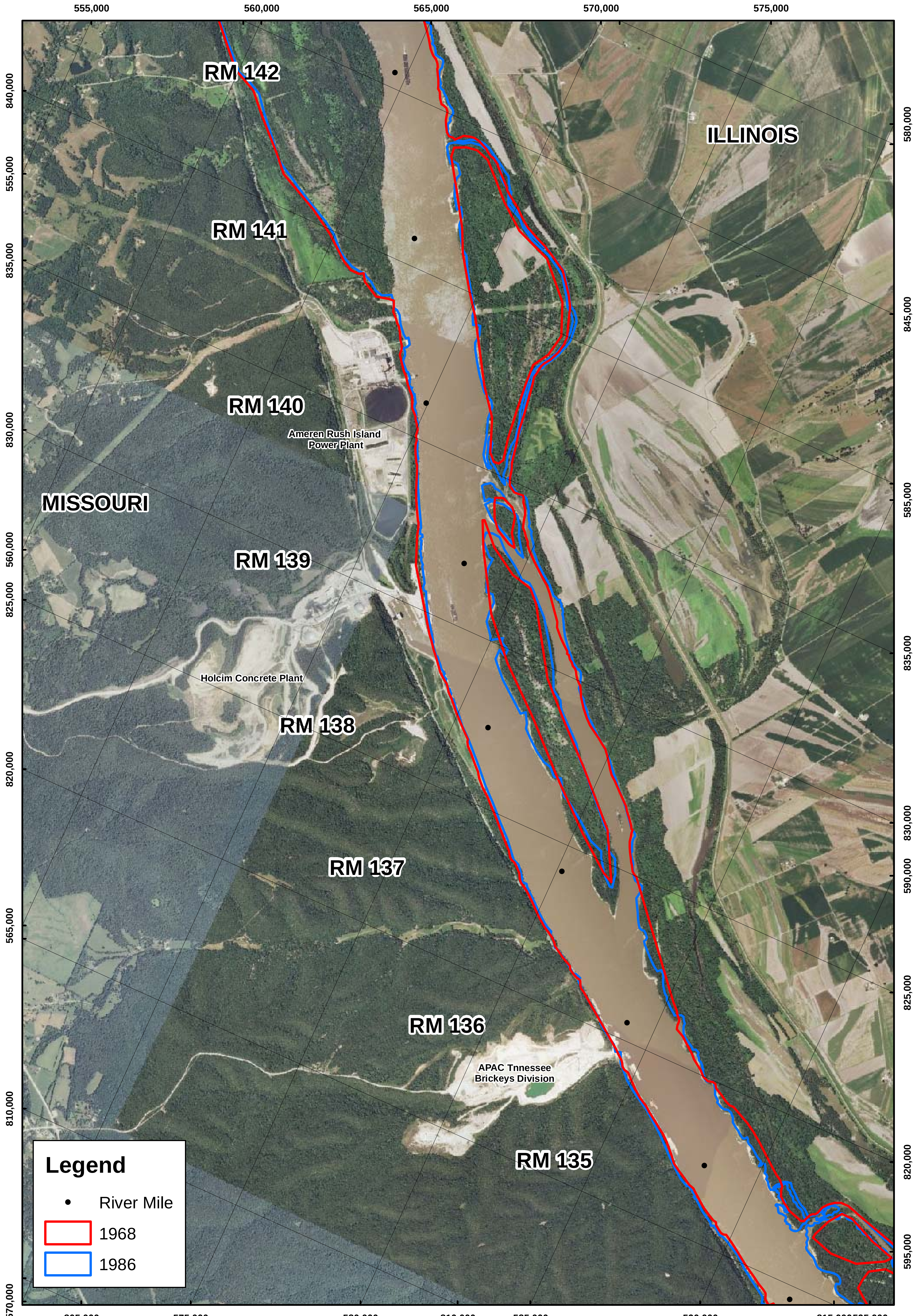

PLATE NUMBER **10**

0 800 1,600 3,200 4,800
Feet

Geomorphology: 1968 vs 1986

2010 Aerial Photograph

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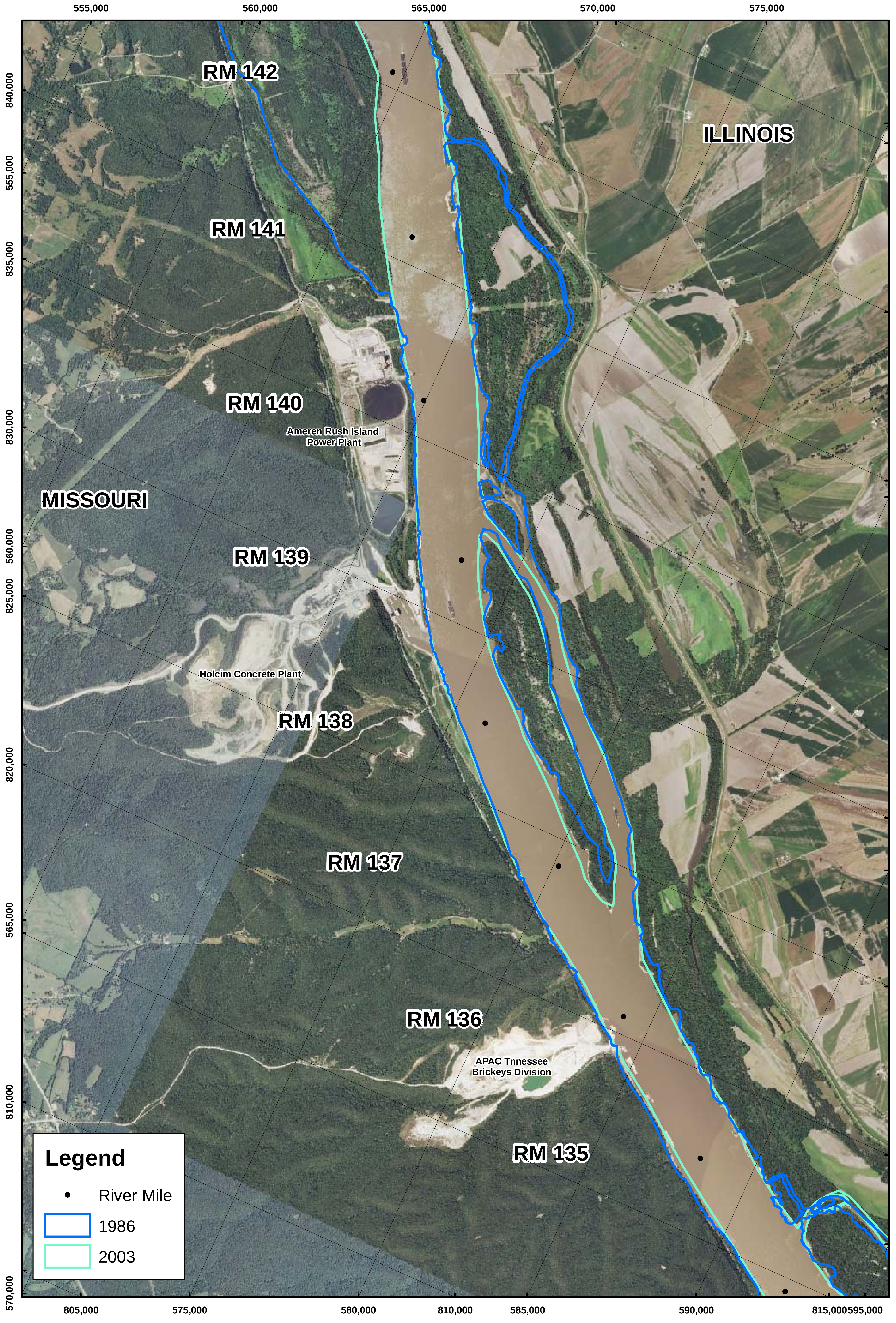

PLATE NUMBER **11**

Geomorphology: 1986 vs. 2003

2010 Aerial Photograph

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PLATE NUMBER **12**

0 800 1,600 3,200 4,800 Feet

Geomorphology: 2003 vs. 2011

2010 Aerial Photograph

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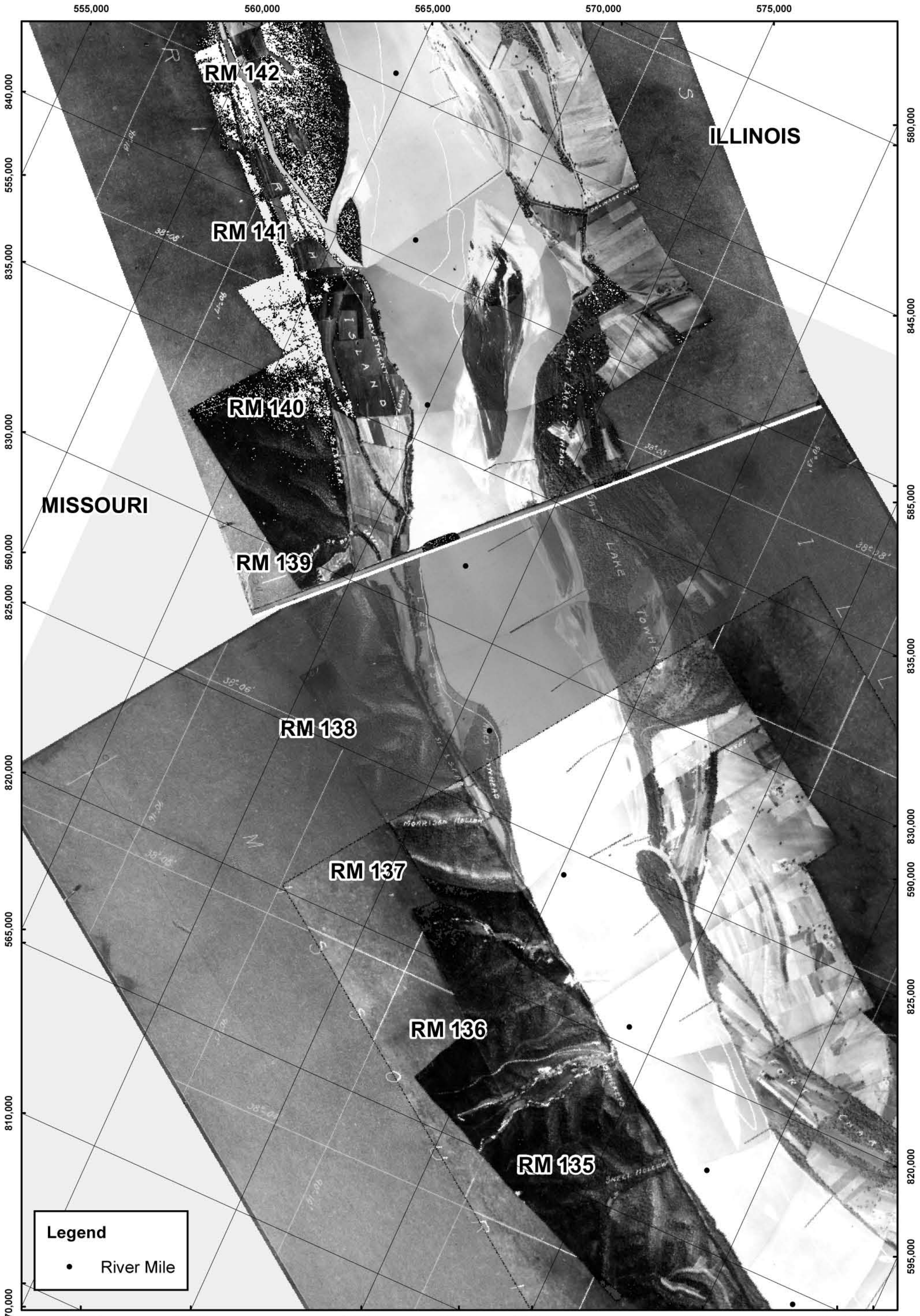

PLATE NUMBER **13**

0 800 1,600 3,200 4,800
Feet

1928 - 1929 Aerial Photography Overlay

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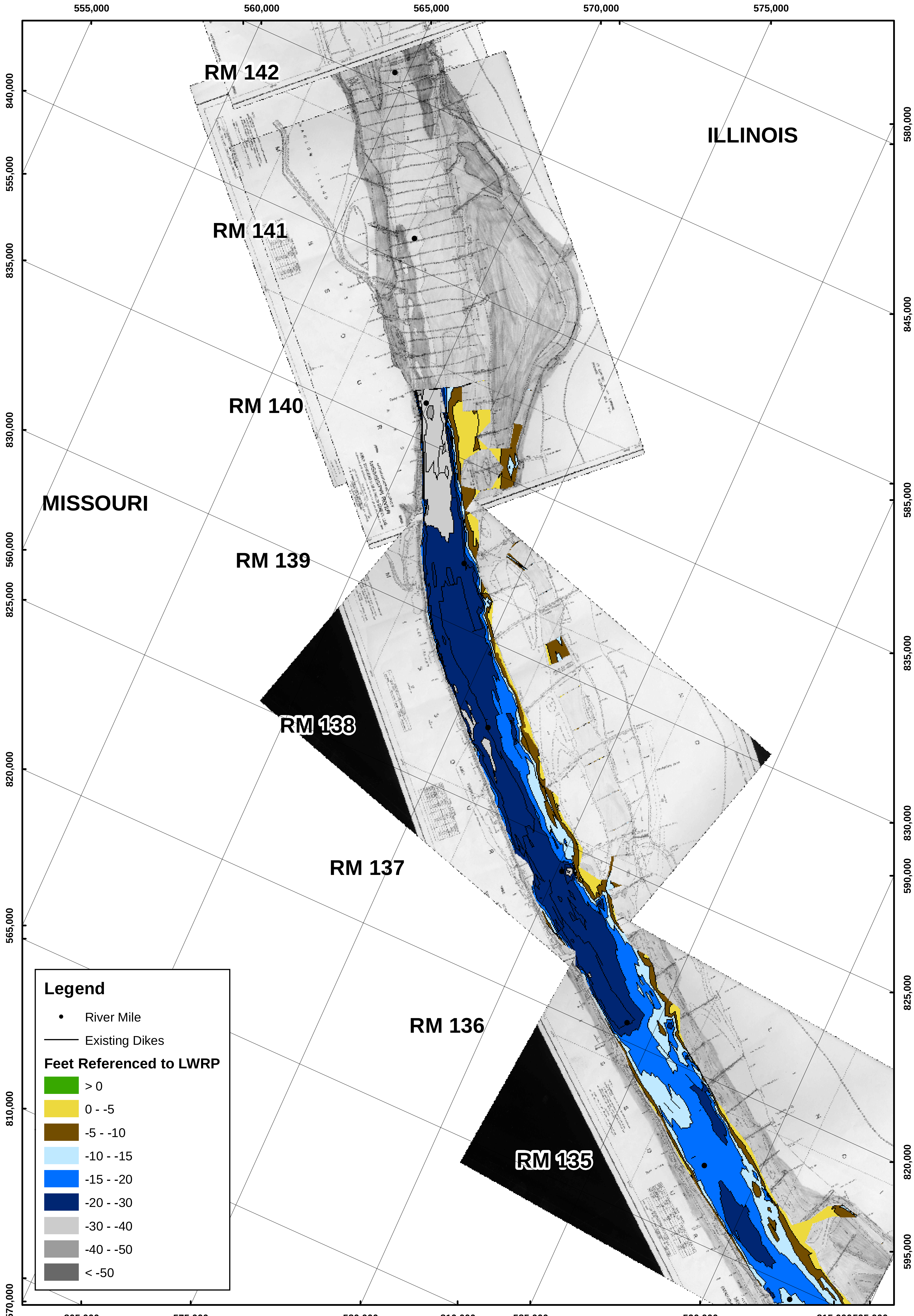

PLATE NUMBER 14

0 800 1,600 3,200 4,800
Feet

1939 - 1956 Hydrographic Survey Overlay

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Mississippi River Basin
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B. Krischel	1939 - 1956	01/31/2014
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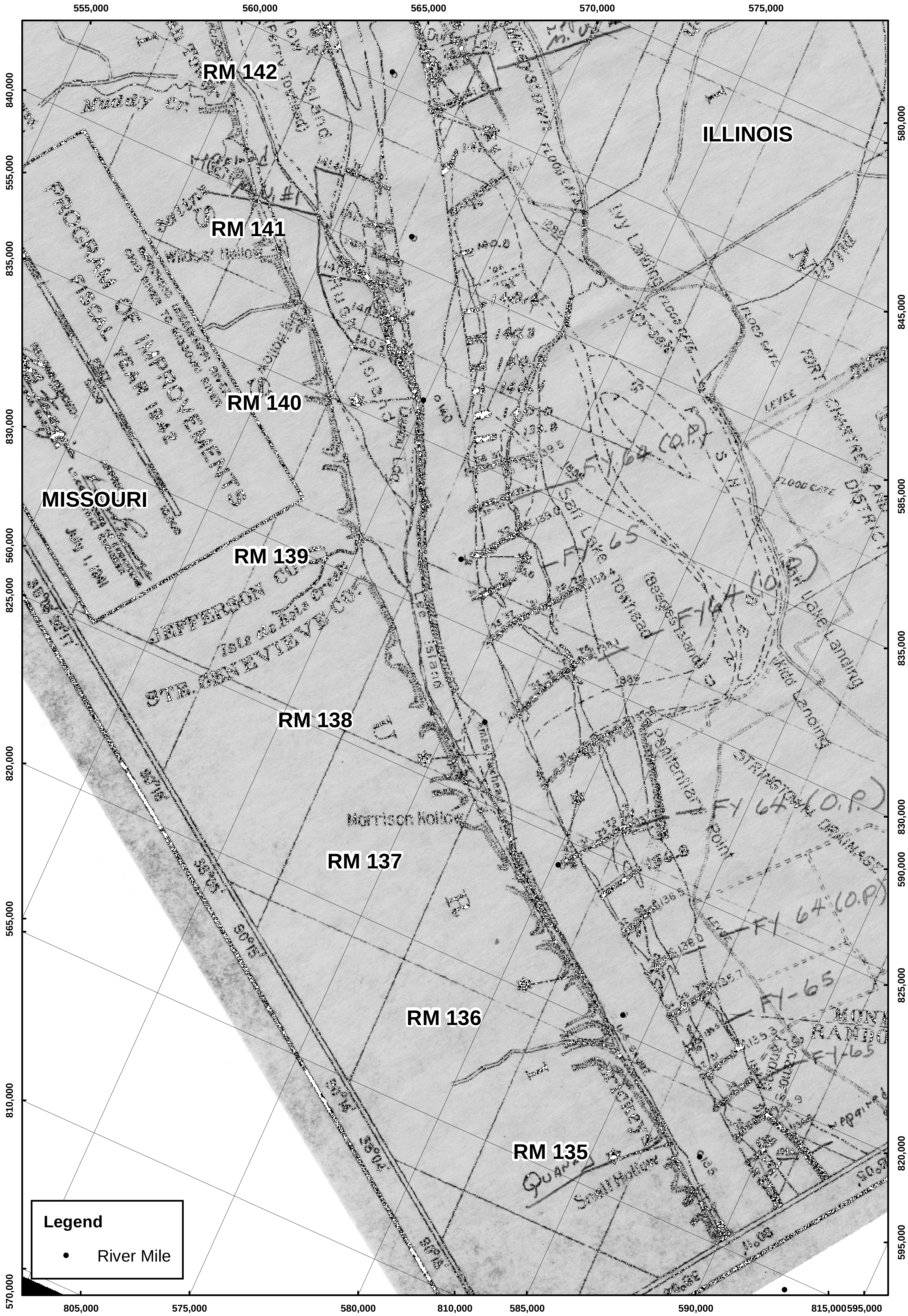

PLATE NUMBER 15

0 800 1,600 3,200 4,800
Feet

1942 Improvement Master Plan

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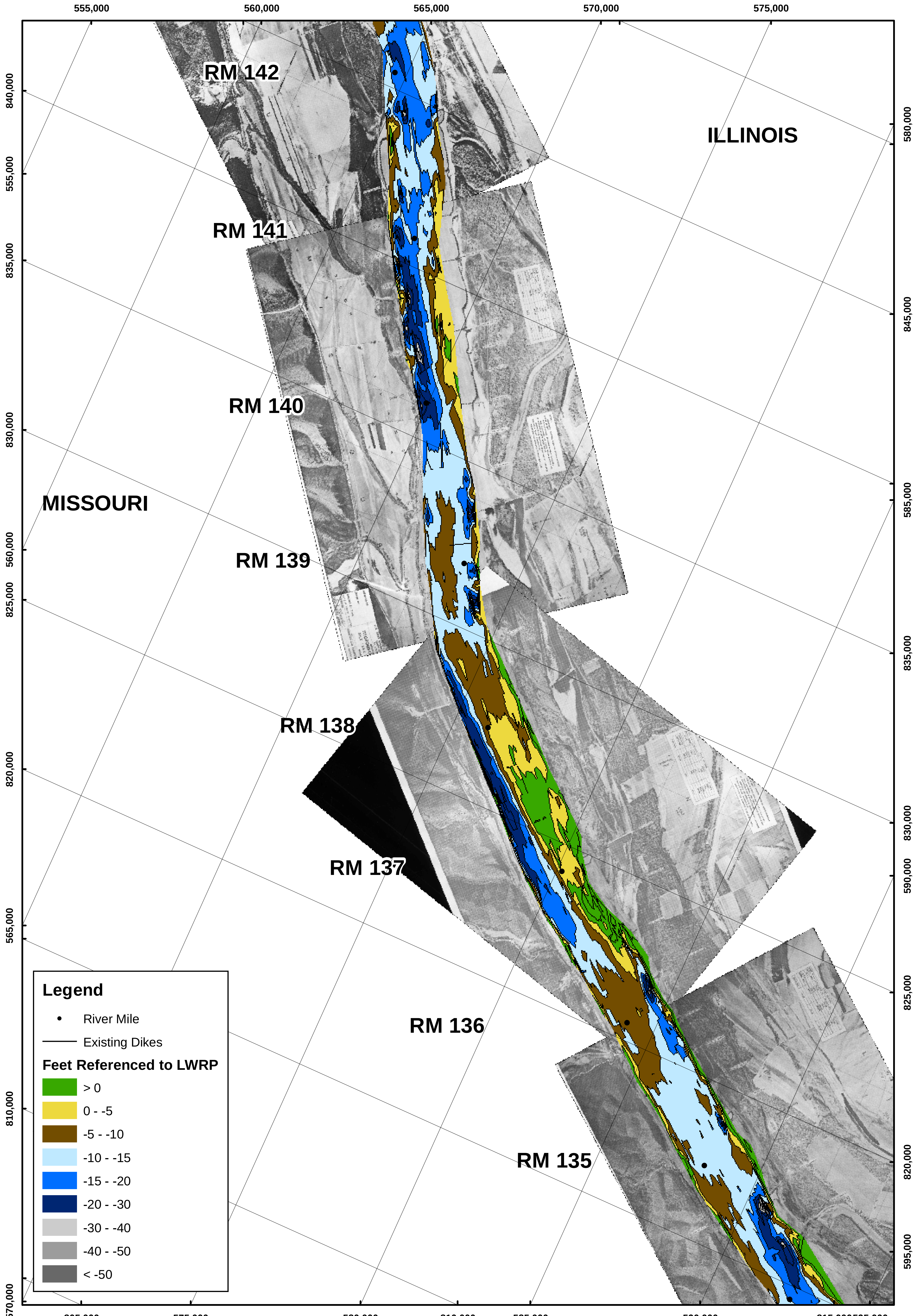

PLATE NUMBER 16

0 800 1,600 3,200 4,800 Feet

1968 - 1971 Hydrographic Survey Overlay

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St. Louis District
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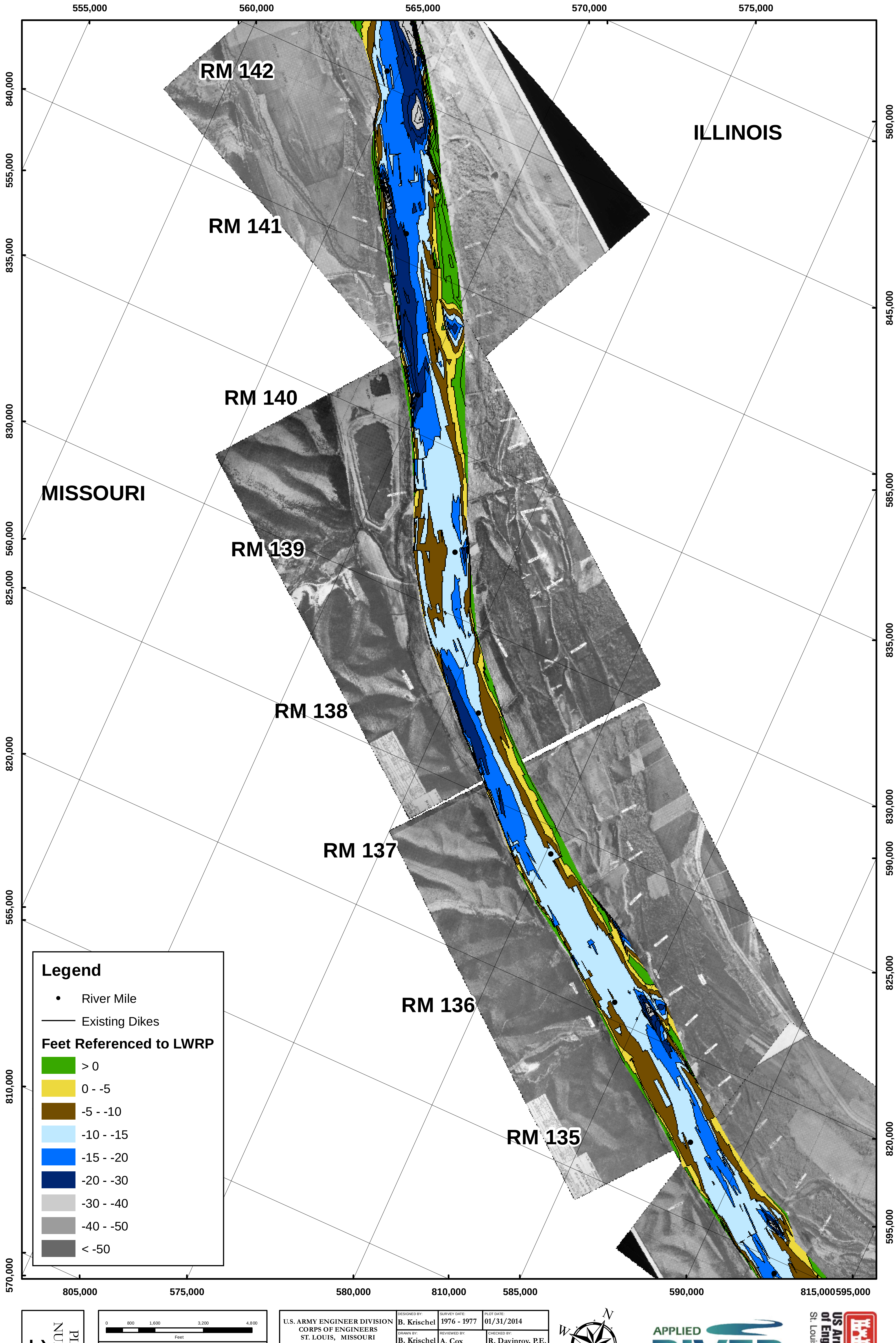

PLATE NUMBER 17

0 800 1,600 3,200 4,800
Feet

1976 - 1977 Hydrographic Survey Overlay

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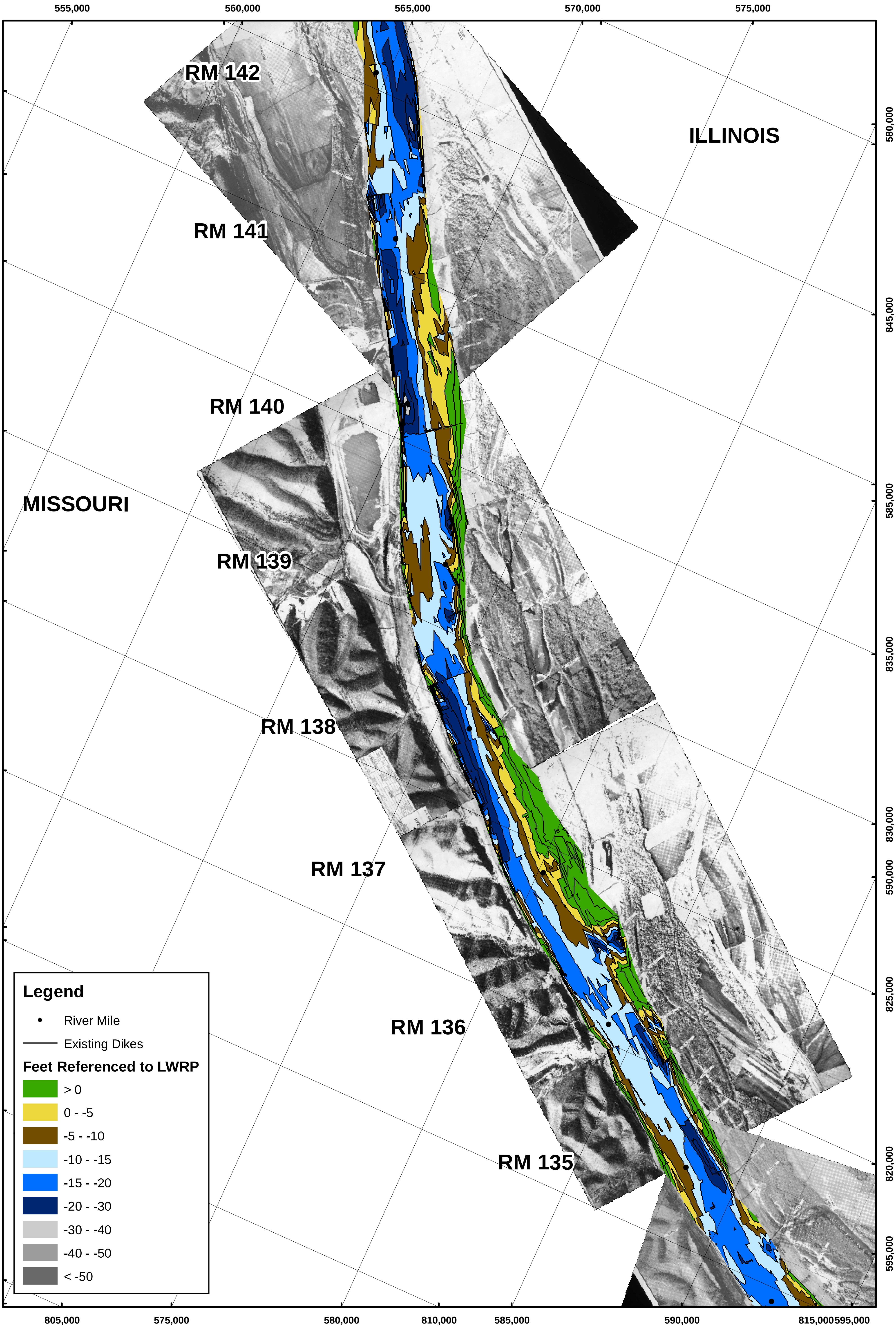

PLATE NUMBER **18**

0 800 1,600 3,200 4,800
Feet

1982 - 1983 Hydrographic Survey Overlay

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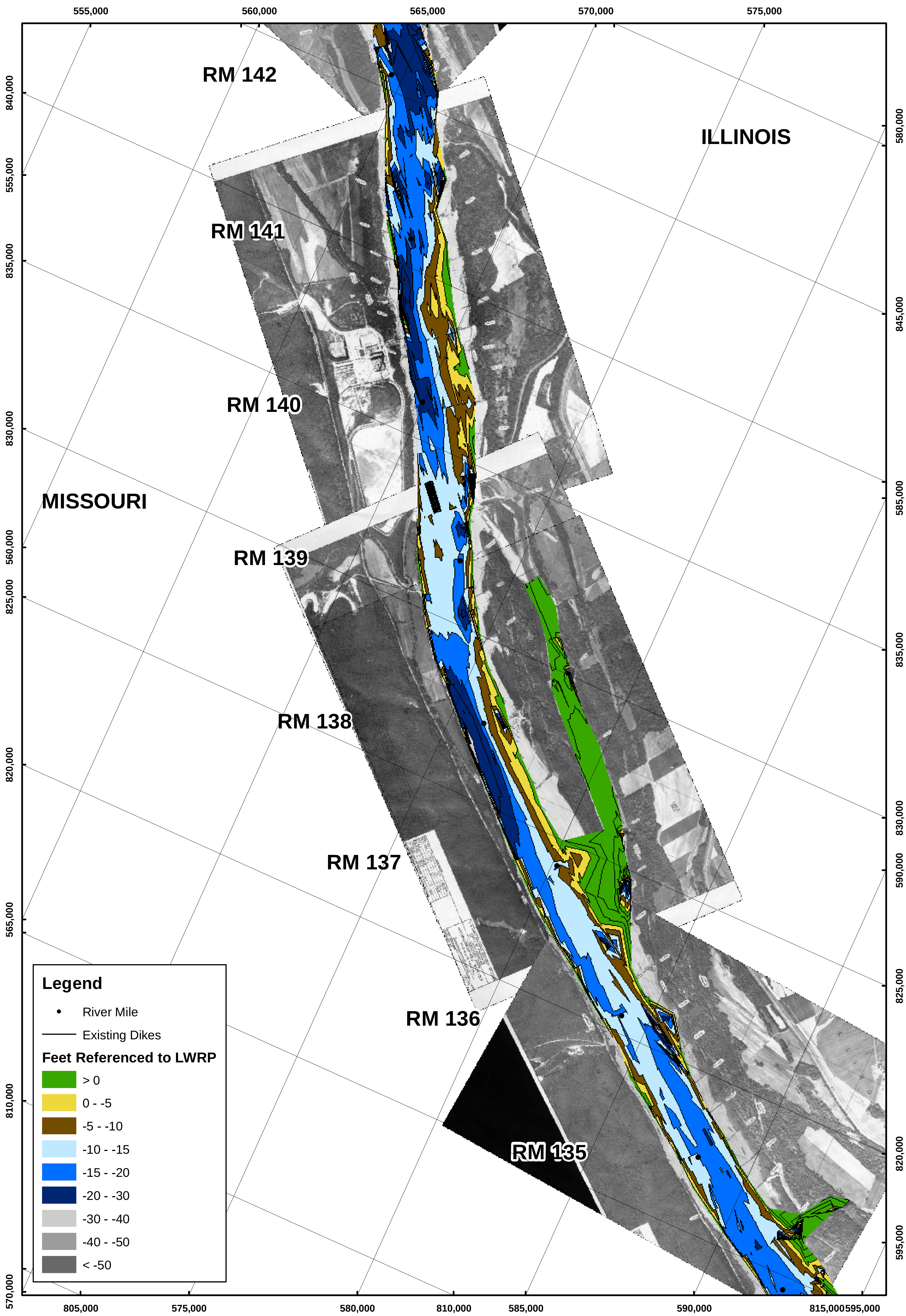

PLATE NUMBER **19**

1986 - 1987 Hydrographic Survey Overlay

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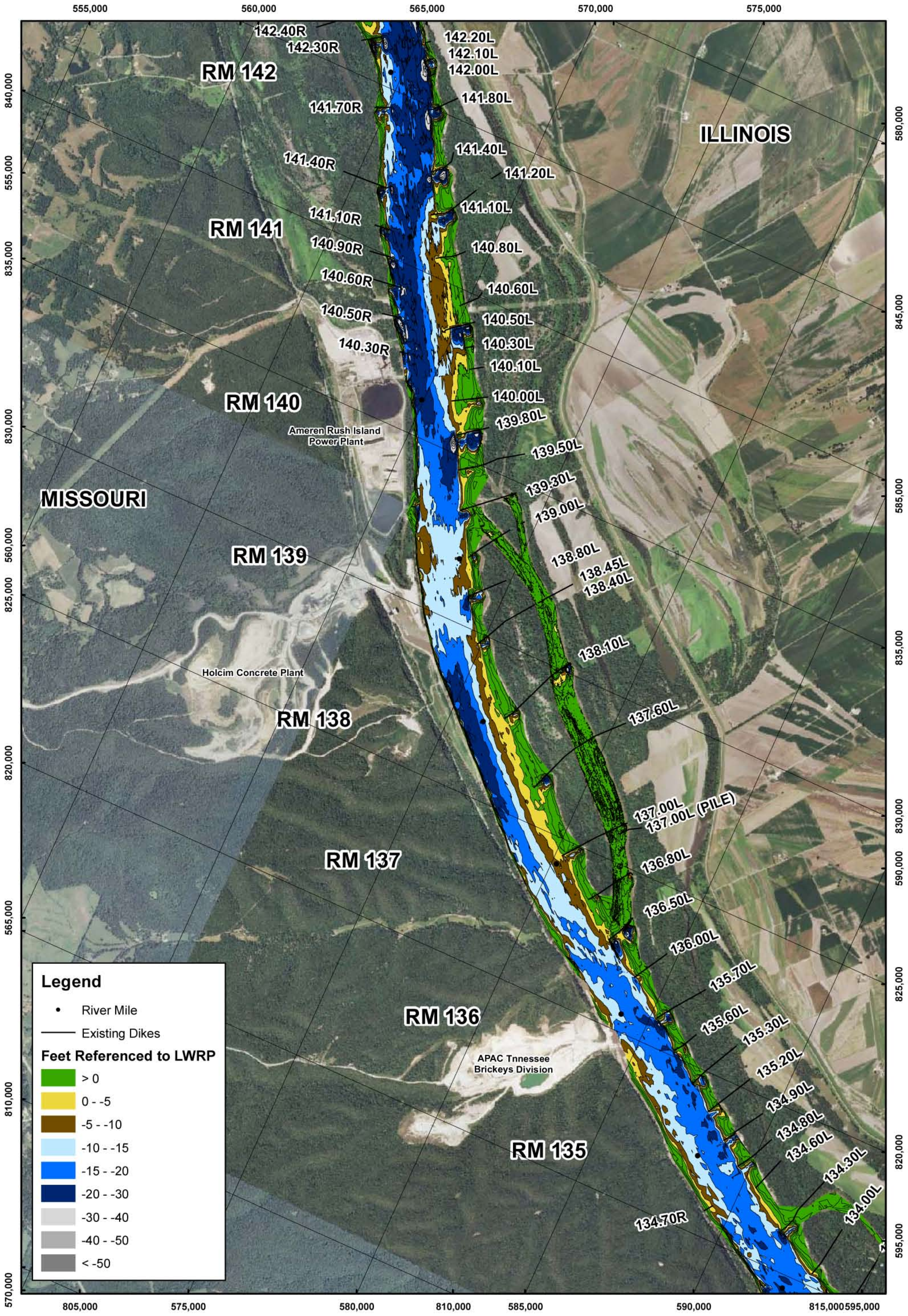

PLATE NUMBER **20**

0 800 1,600 3,200 4,800 Feet

2001 Main Channel and 1999 Side Channel Hydrographic Surveys

2010 Aerial Photograph

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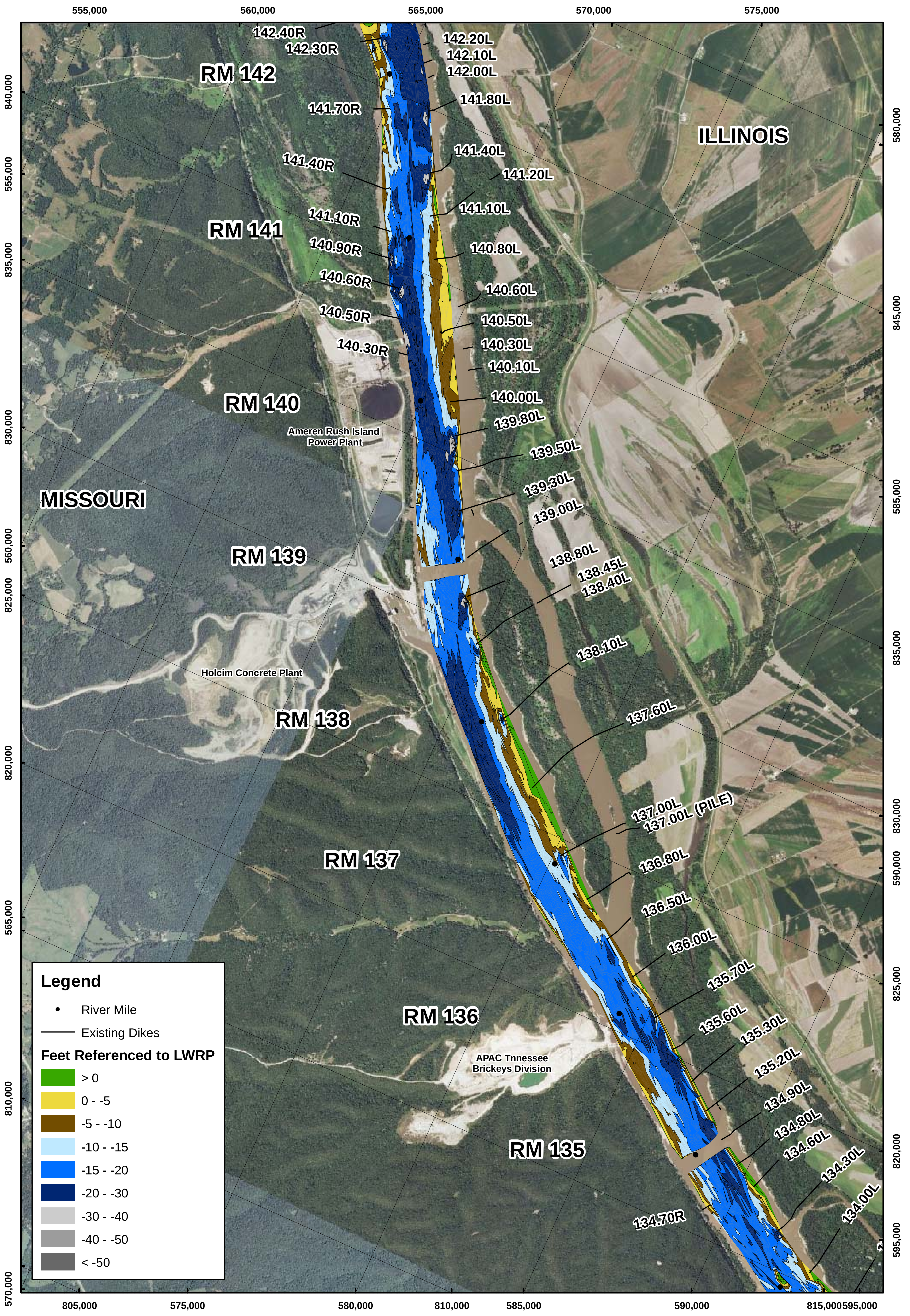

PLATE NUMBER 21

0 800 1,600 3,200 4,800
Feet

2005 Hydrographic Survey
2010 Aerial Photograph

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Mississippi River Basin
St. Louis District
Salt Lake Chute
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B. Krischel	2005	01/31/2014
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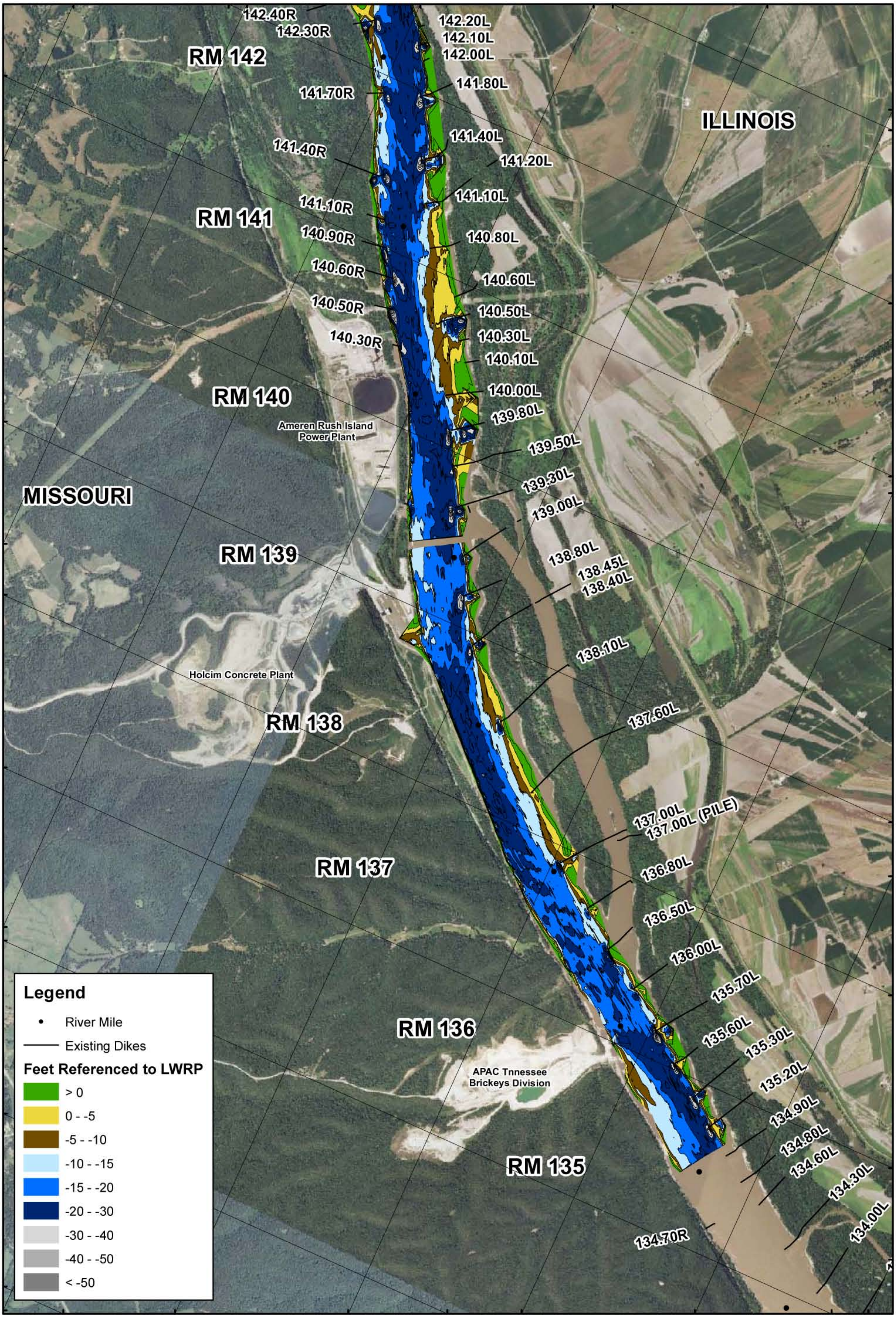

PLATE NUMBER 22

0 800 1,600 3,200 4,800
Feet

2007 Hydrographic Survey

2010 Aerial Photograph

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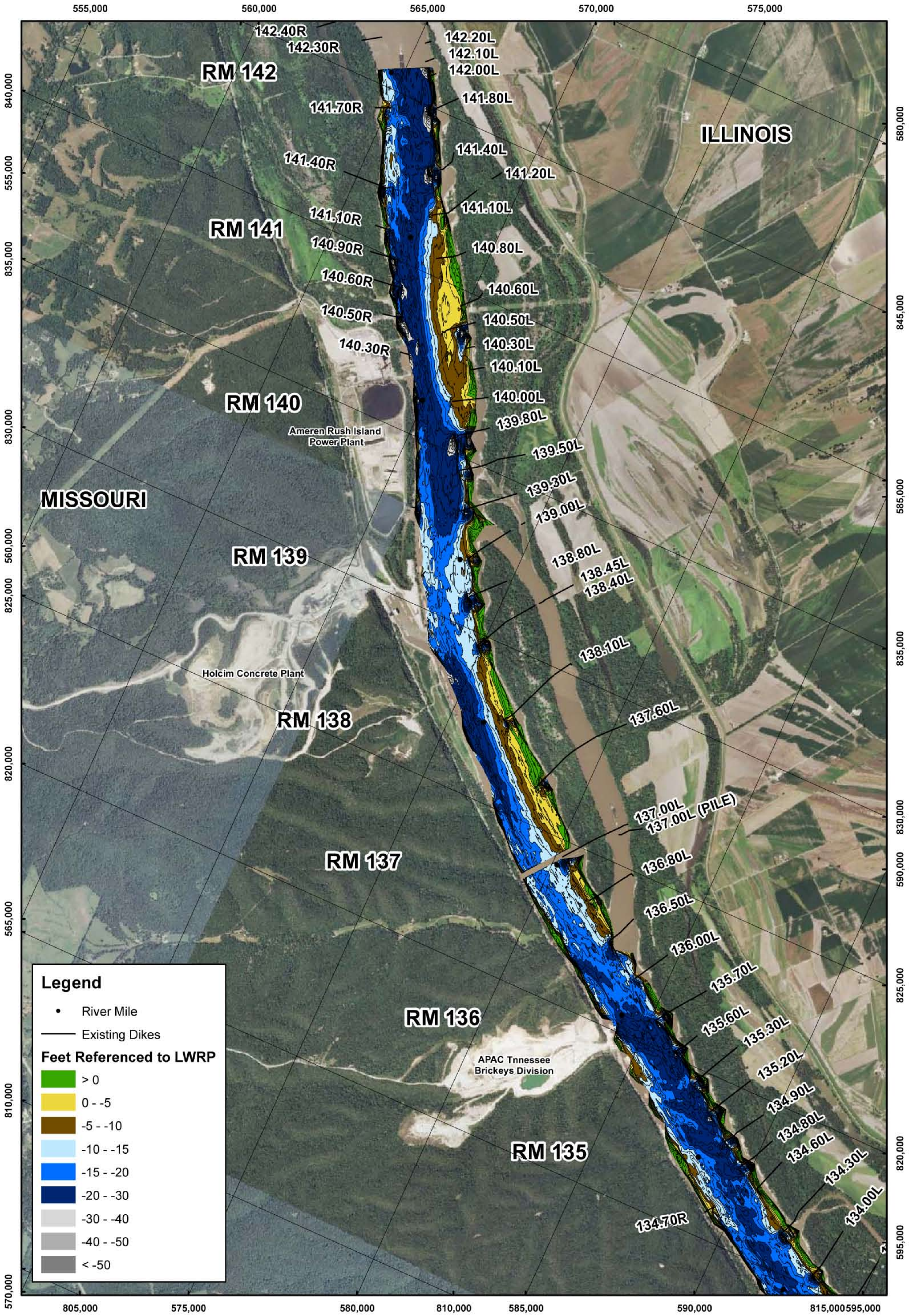

PLATE NUMBER 23

0 800 1,600 3,200 4,800 Feet

2010 Hydrographic Survey
2010 Aerial Photograph

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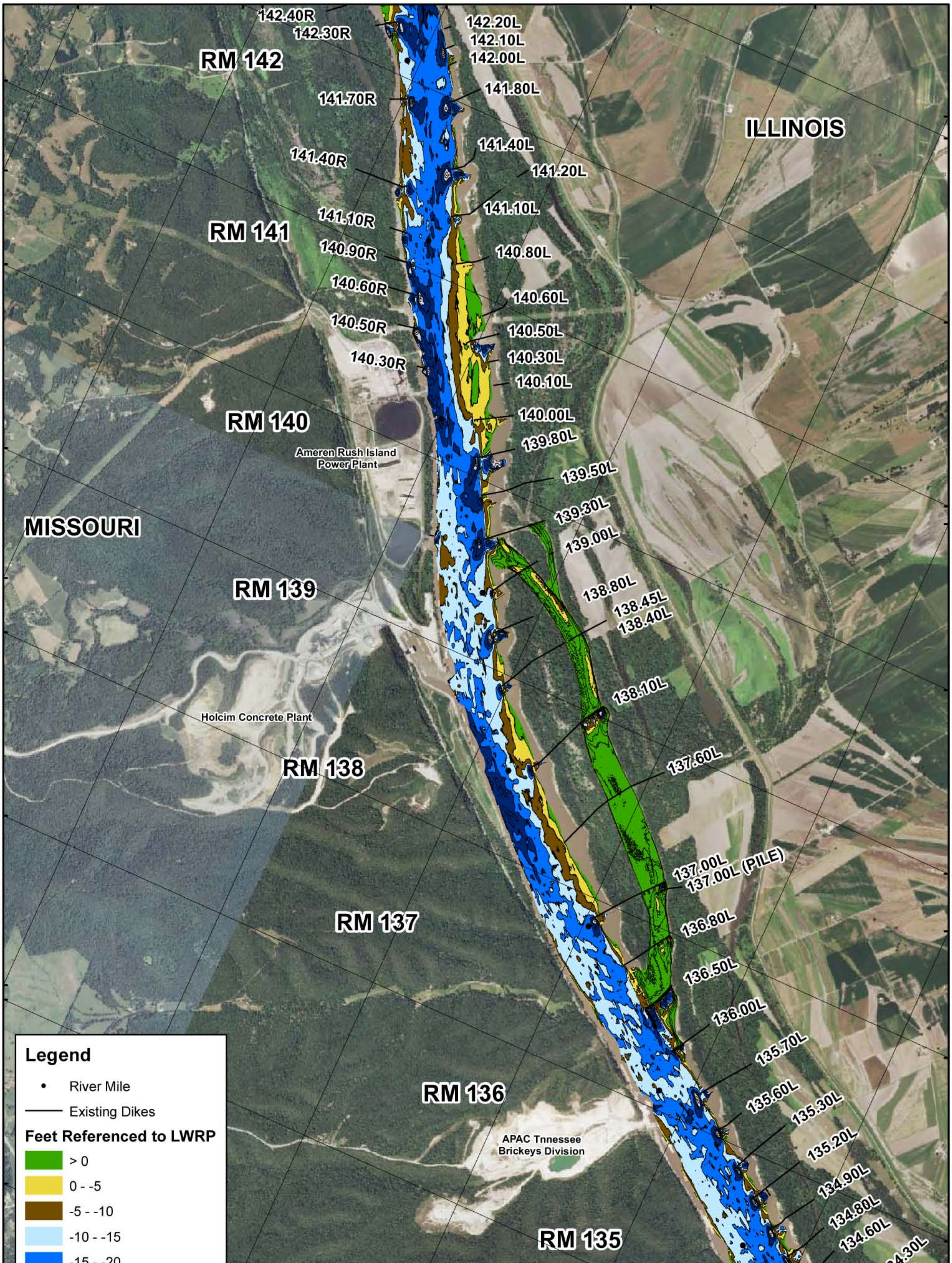

PLATE NUMBER 24

0 800 1,600 3,200 4,800
Feet

2012 Main Channel and
2011 Side Channel Hydrographic Surveys
2010 Aerial Photograph

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Mississippi River Basin St. Louis District Salt Lake Chute HSR Model	SUBMITTED: B. Krischel	APPROVED: R. Davinroy, P.E.	
	FILE NAME: L:\Salt Lake Chute HSR Model Study\Plates\		

APPLIED RIVER ENGINEERING CENTER

US Army Corps of Engineers
St. Louis District

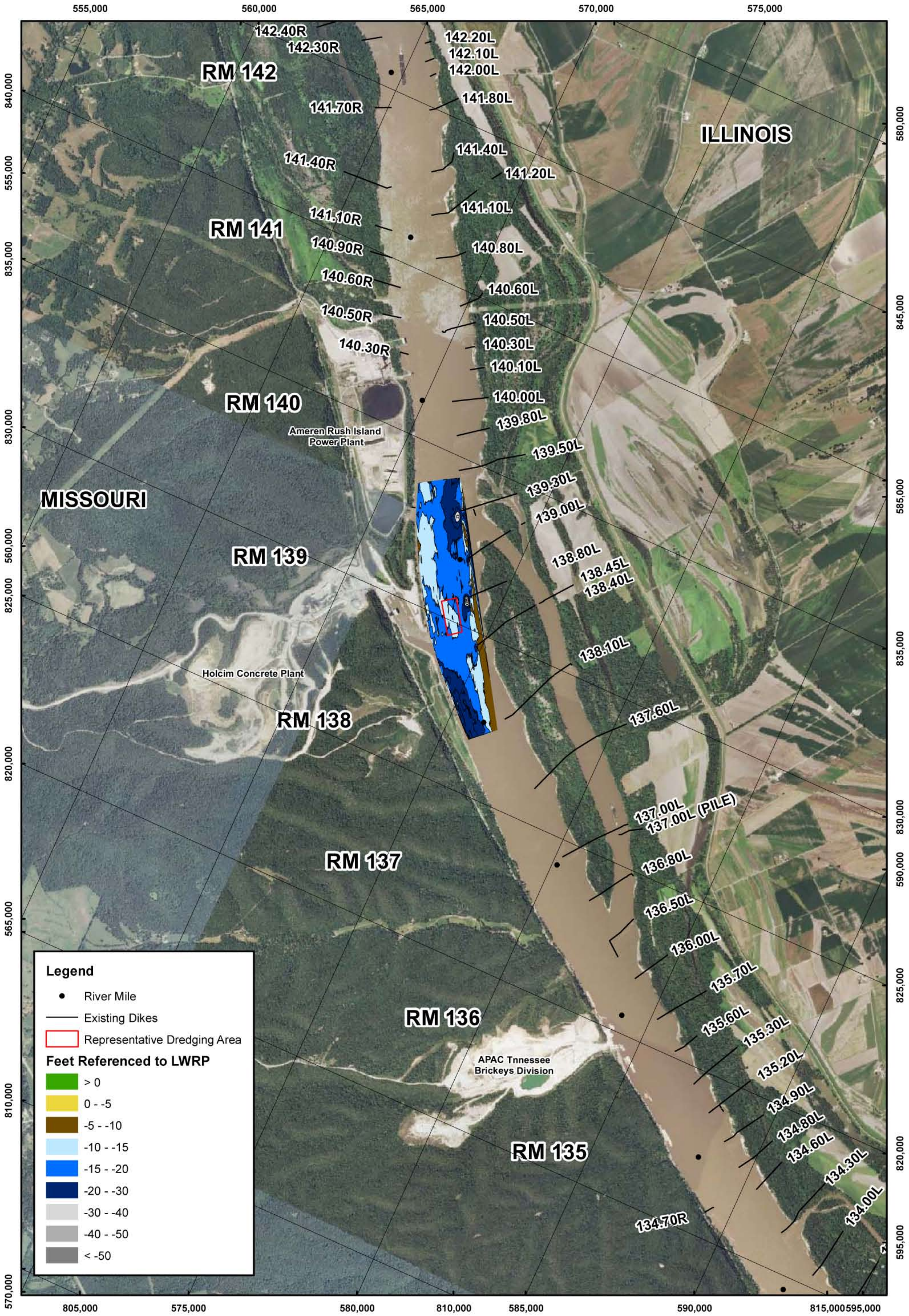

PLATE NUMBER 25

2003 Pre-Dredge Hydrographic Survey

2010 Aerial Photograph

0 800 1,600 3,200 4,800 Feet

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

Mississippi River Basin
St. Louis District
Salt Lake Chute
HSR Model

DESIGNED BY:	SURVEY DATE:	PLOT DATE:
B. Krischel	02/11/03	01/31/2014
DRAWN BY: B. Krischel	REVIEWED BY: A. Cox	CHECKED BY: R. Davinroy, P.E.
SUBMITTED: B. Krischel		APPROVED: R. Davinroy, P.E.

FILE NAME: L:\Salt Lake Chute HSR Model Study\Plates\

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Looking downstream at the entrance to Salt Lake Chute RM 139.2

Looking upstream at the end of Salt Lake Chute near RM 136.5
(Salt Lake Island on left, Illinois bankline on right side)

Bankline erosion on the LDB of Salt Lake Chute

Looking upstream in Salt Lake Chute at Dike 138.1L

Looking upstream in Salt Lake Chute at Pile Dike 138.45L

US Army Corps of Engineers
St. Louis District®

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N W E S

DESIGNED BY: A COX
DRAWN BY: A COX
REVIEWED BY: B KRISCHEL
CHECKED BY: R. DAVINROY, P.E.
SUBMITTED: B KRISCHEL
APPROVED: R DAVINROY, P.E.
FILE NAME: ...SALTLAKECHUTE/PLATES
PLOT DATE: 01/31/14

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

Mississippi River Basin
St. Louis District
Salt Lake Chute
HSR Model

Salt Lake Chute
Field Photographs
Date Photographed: June 20, 2012

PLATE NUMBER
26

Looking downstream at the entrance to Salt Lake Chute RM 139.2

Looking downstream at the secondary entrance by Durfee Bar near RM 139.5

Looking upstream at the end of Salt Lake Chute near RM 136.5
(Salt Lake Island on left, Illinois bankline on right side)

Bankline erosion on the LDB of Salt Lake Chute

Looking upstream in Salt Lake Chute at Dike 138.1L

Looking upstream in Salt Lake Chute at Pile Dike 138.45L

US Army Corps of Engineers
St. Louis District®

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N
W E
S

DESIGNED BY: A COX	DRAWN BY: A COX	SUBMITTED: A COX	FILE NAME: ...SALTLAKECHUTE/PLATES
	REVIEWED BY: B KRISCHEL		
	CHECKED BY: R DAVINROY, P.E.	APPROVED: R DAVINROY, P.E.	PLOT DATE: 01/31/14

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

Mississippi River Basin
St. Louis District
Salt Lake Chute
HSR Model

Salt Lake Chute
Field Photographs
Date Photographed: June 20, 2012
And Aerial Photos on
September 24, 2012

PLATE NUMBER

27

US Army Corps of Engineers
St. Louis District

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DESIGNED BY: B KRISCHEL		CHECKED BY: R DAVINROY, P.E.
DRAWN BY: B KRISCHEL	REVIEWED BY: A COX	
SUBMITTED: B KRISCHEL		APPROVED: R DAVINROY, P.E.
FILE NAME: 28_HSR Model Picture		

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

Mississippi River Basin
St. Louis District
Salt Lake Chute
HSR Model

Salt Lake Chute
HSR Model

PLATE NUMBER
28

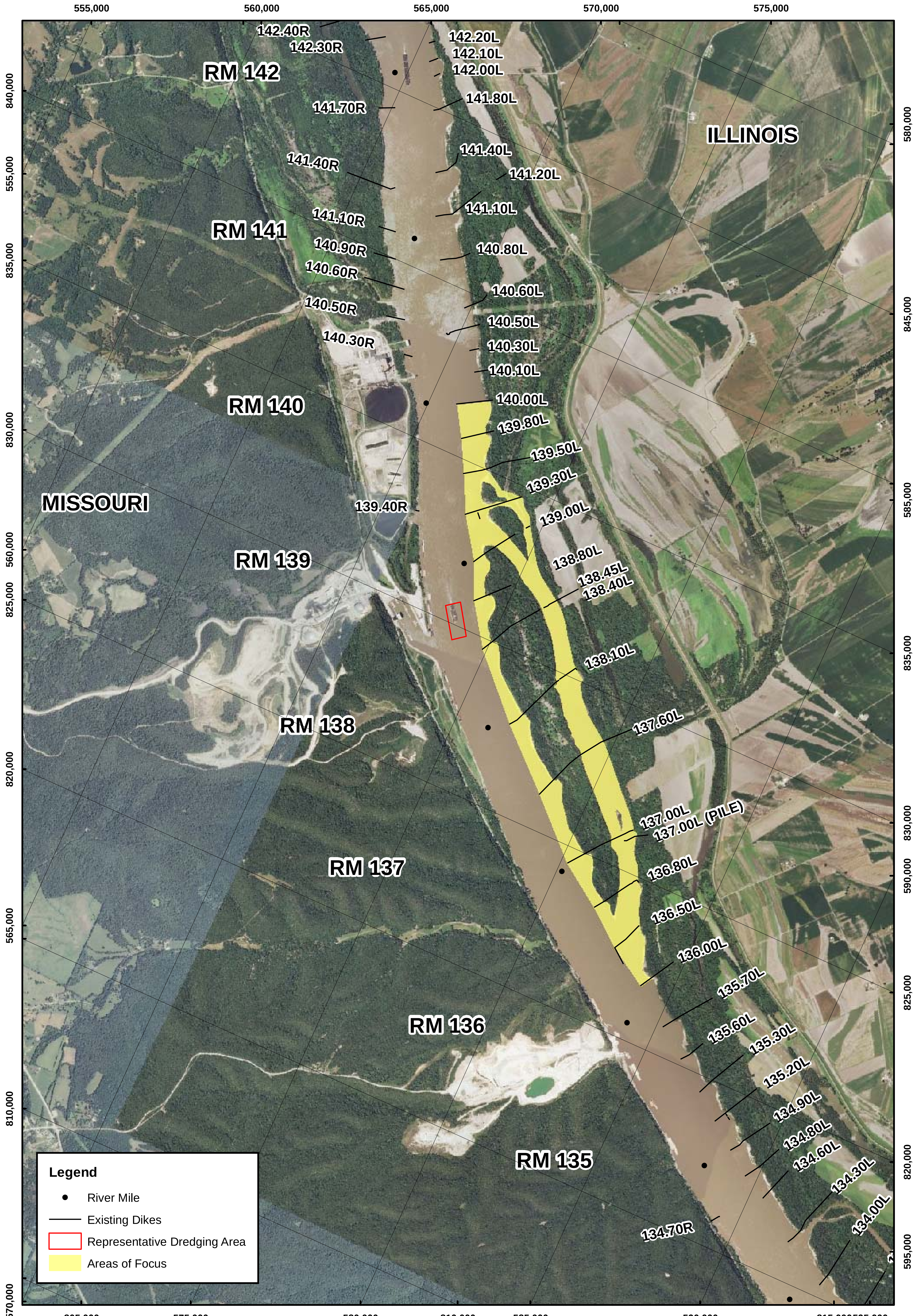

PLATE NUMBER 29

0 800 1,600 3,200 4,800
Feet

Areas of Focus
2010 Aerial Photograph

U.S. ARMY ENGINEER DIVISION CORPS OF ENGINEERS ST. LOUIS, MISSOURI	DESIGNED BY: B. Krischel	SURVEY DATE:	PLOT DATE: 01/31/14
	DRAWN BY: B. Krischel	REVIEWED BY: A. Cox	CHECKED BY: R. Davinroy, P.E.
Mississippi River Basin St. Louis District Salt Lake Chute HSR Model	SUBMITTED: B. Krischel	APPROVED: R. Davinroy, P.E.	
	FILE NAME: L:\Salt Lake Chute HSR Model Study\Plates\		

APPLIED RIVER ENGINEERING CENTER

US Army Corps of Engineers St. Louis District

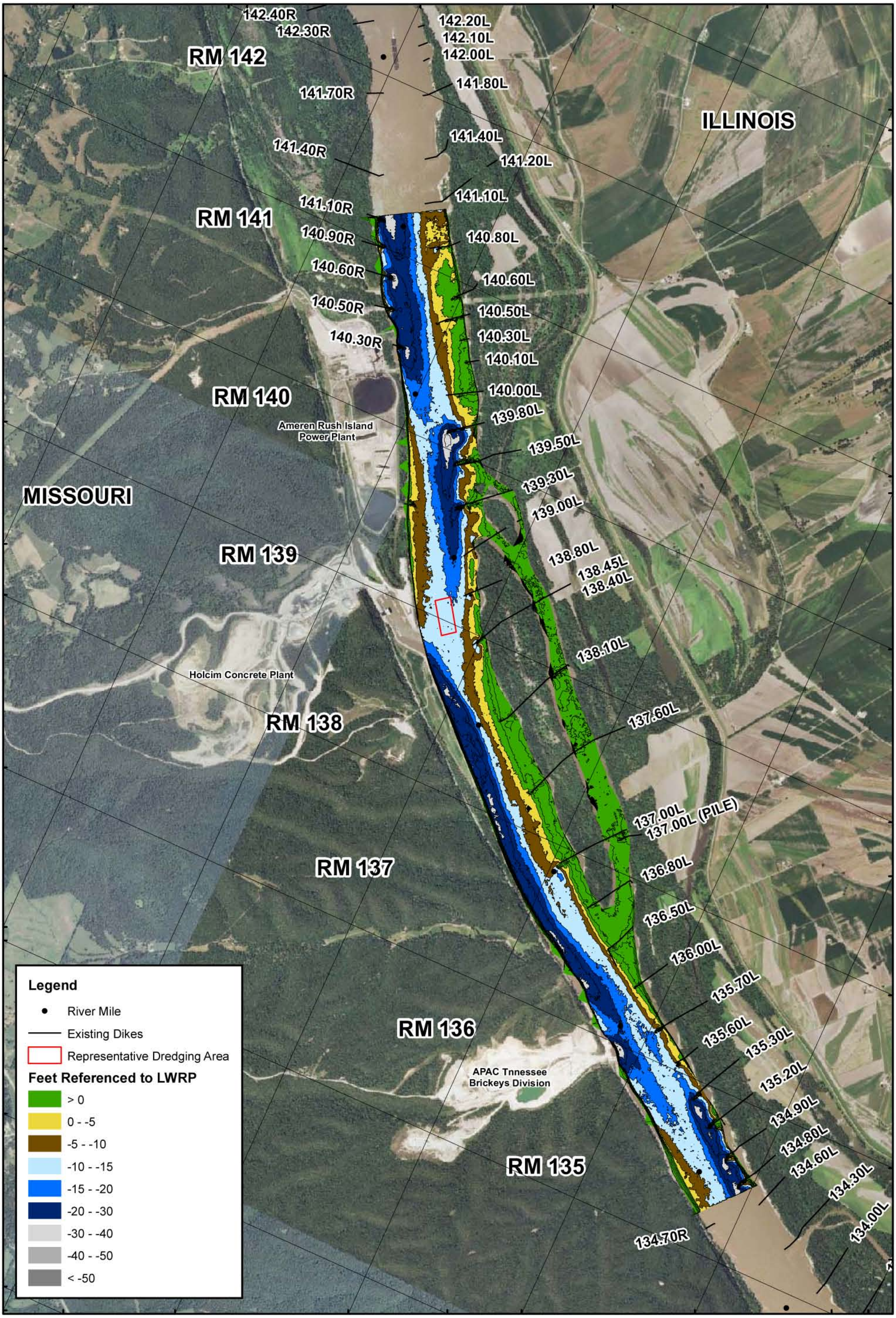

PLATE NUMBER 30

0 800 1,600 3,200 4,800 Feet

Model Replication
2010 Aerial Photograph

U.S. ARMY ENGINEER DIVISION CORPS OF ENGINEERS ST. LOUIS, MISSOURI	DESIGNED BY: B. Krischel	SURVEY DATE: 03/07/13	PLOT DATE: 01/31/2014
	DRAWN BY: B. Krischel	REVIEWED BY: A. Cox	CHECKED BY: R. Davinroy, P.E.
Mississippi River Basin St. Louis District Salt Lake Chute HSR Model	SUBMITTED: B. Krischel	APPROVED: R. Davinroy, P.E.	
	FILE NAME: L:\Salt Lake Chute HSR Model Study\Plates\		

APPLIED RIVER ENGINEERING CENTER

US Army Corps of Engineers St. Louis District

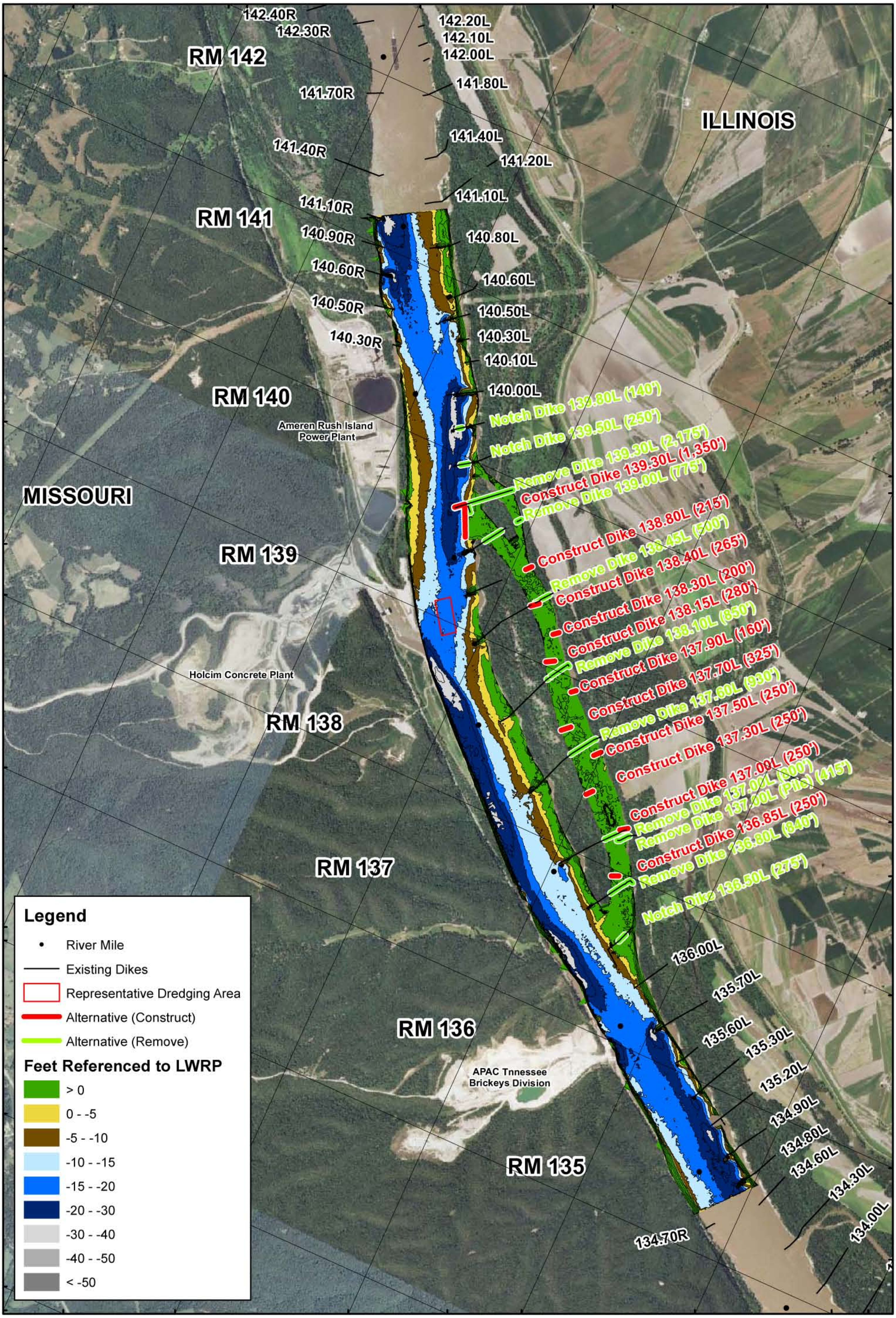

PLATE NUMBER 31

0 800 1,600 3,200 4,800
Feet

Alternative 1
2010 Aerial Photograph

U.S. ARMY ENGINEER DIVISION CORPS OF ENGINEERS ST. LOUIS, MISSOURI	DESIGNED BY: B. Krischel	SURVEY DATE: 04/10/13	PLOT DATE: 01/31/2014
	DRAWN BY: B. Krischel	REVIEWED BY: A. Cox	CHECKED BY: R. Davinroy, P.E.
Mississippi River Basin St. Louis District Salt Lake Chute HSR Model	SUBMITTED: B. Krischel	APPROVED: R. Davinroy, P.E.	
	FILE NAME: L:\Salt Lake Chute HSR Model Study\Plates\		

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St. Louis District

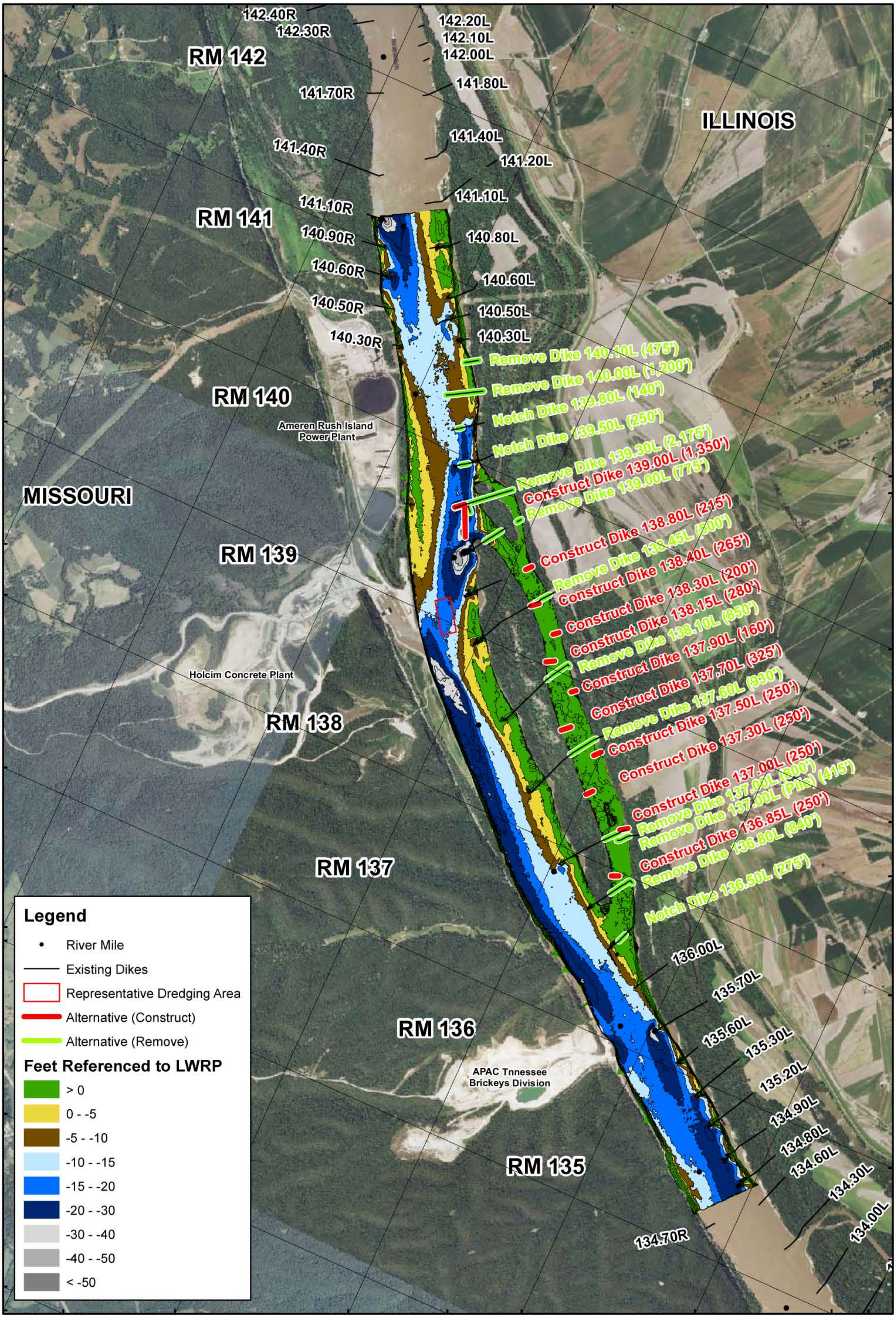

PLATE NUMBER 32

0 800 1,600 3,200 4,800
Feet

Alternative 2
2010 Aerial Photograph

U.S. ARMY ENGINEER DIVISION CORPS OF ENGINEERS ST. LOUIS, MISSOURI	DESIGNED BY: B. Krischel	SURVEY DATE: 04/18/13	PLOT DATE: 01/31/2014
	DRAWN BY: B. Krischel	REVIEWED BY: A. Cox	CHECKED BY: R. Davinroy, P.E.
Mississippi River Basin St. Louis District Salt Lake Chute HSR Model	SUBMITTED: B. Krischel	APPROVED: R. Davinroy, P.E.	
	FILE NAME: L:\Salt Lake Chute HSR Model Study\Plates\		

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US Army Corps of Engineers
St. Louis District

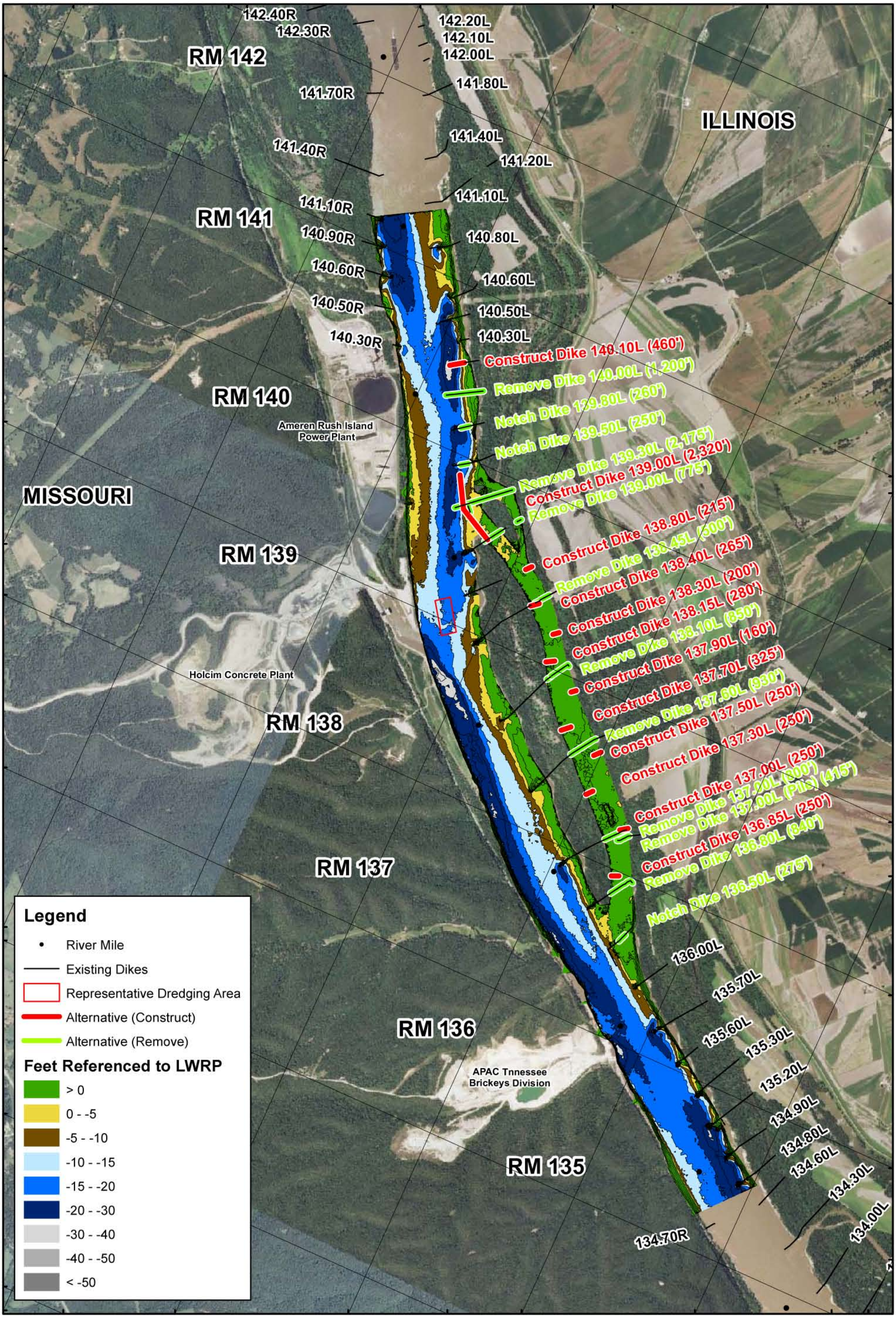

PLATE NUMBER 33

0 800 1,600 3,200 4,800
Feet

Alternative 3
2010 Aerial Photograph

U.S. ARMY ENGINEER DIVISION CORPS OF ENGINEERS ST. LOUIS, MISSOURI	DESIGNED BY: B. Krischel	SURVEY DATE: 04/30/13	PLOT DATE: 01/31/2014
	DRAWN BY: B. Krischel	REVIEWED BY: A. Cox	CHECKED BY: R. Davinroy, P.E.
Mississippi River Basin St. Louis District Salt Lake Chute HSR Model	SUBMITTED: B. Krischel	APPROVED: R. Davinroy, P.E.	
	FILE NAME: L:\Salt Lake Chute HSR Model Study\Plates\		

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US Army Corps of Engineers St. Louis District

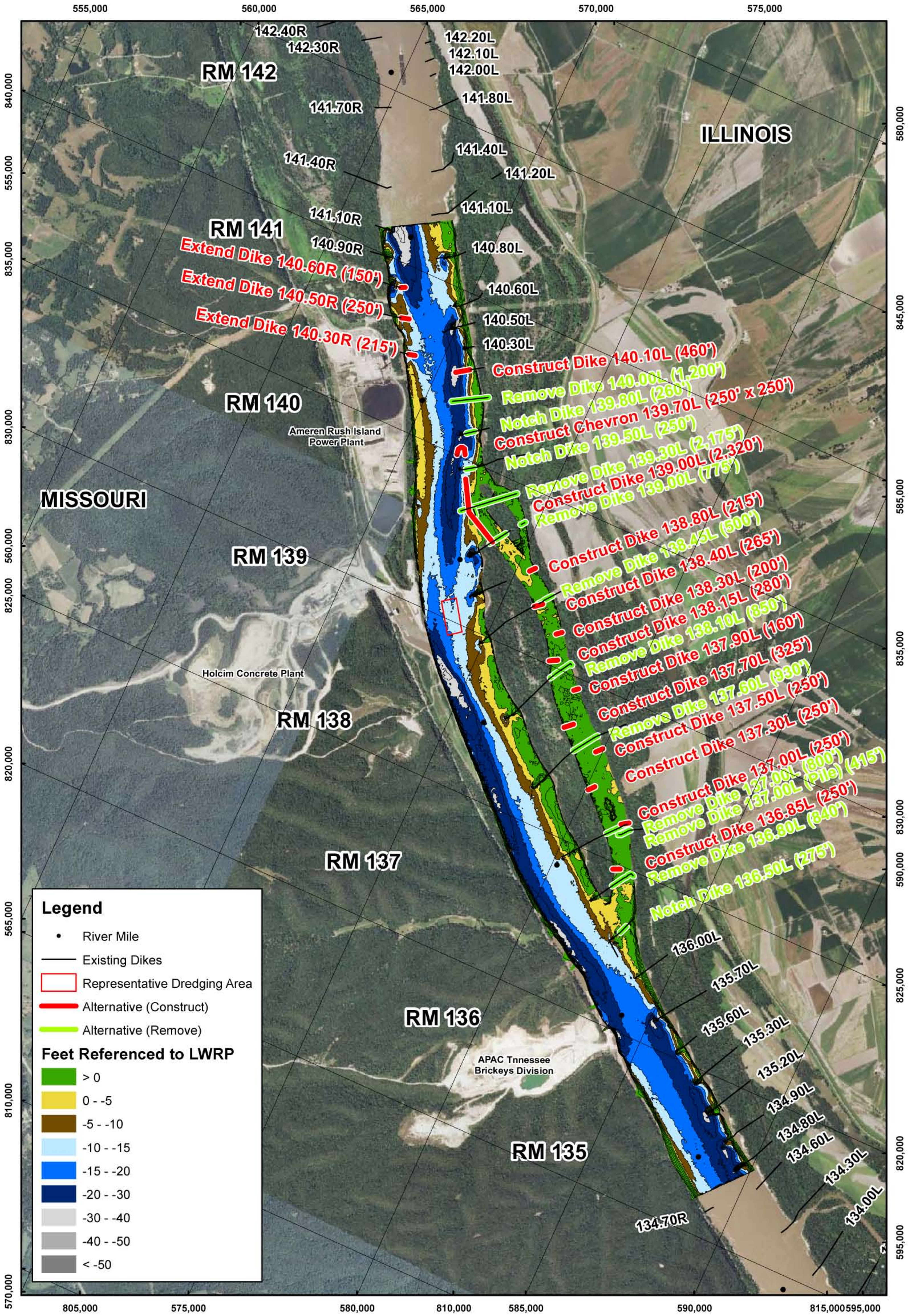

PLATE NUMBER 34

0 800 1,600 3,200 4,800 Feet

Alternative 4
2010 Aerial Photograph

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

DESIGNED BY	SURVEY DATE	PLOT DATE
B. Krischel	05/08/13	01/31/2014
DRAWN BY	REVIEWED BY	CHECKED BY
B. Krischel	A. Cox	R. Davinroy, P.E.
SUBMITTED	APPROVED	
B. Krischel	R. Davinroy, P.E.	

Mississippi River Basin
St. Louis District
Salt Lake Chute
HSR Model

FILE NAME: L:\Salt Lake Chute HSR Model Study\Plates\

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US Army Corps of Engineers St. Louis District

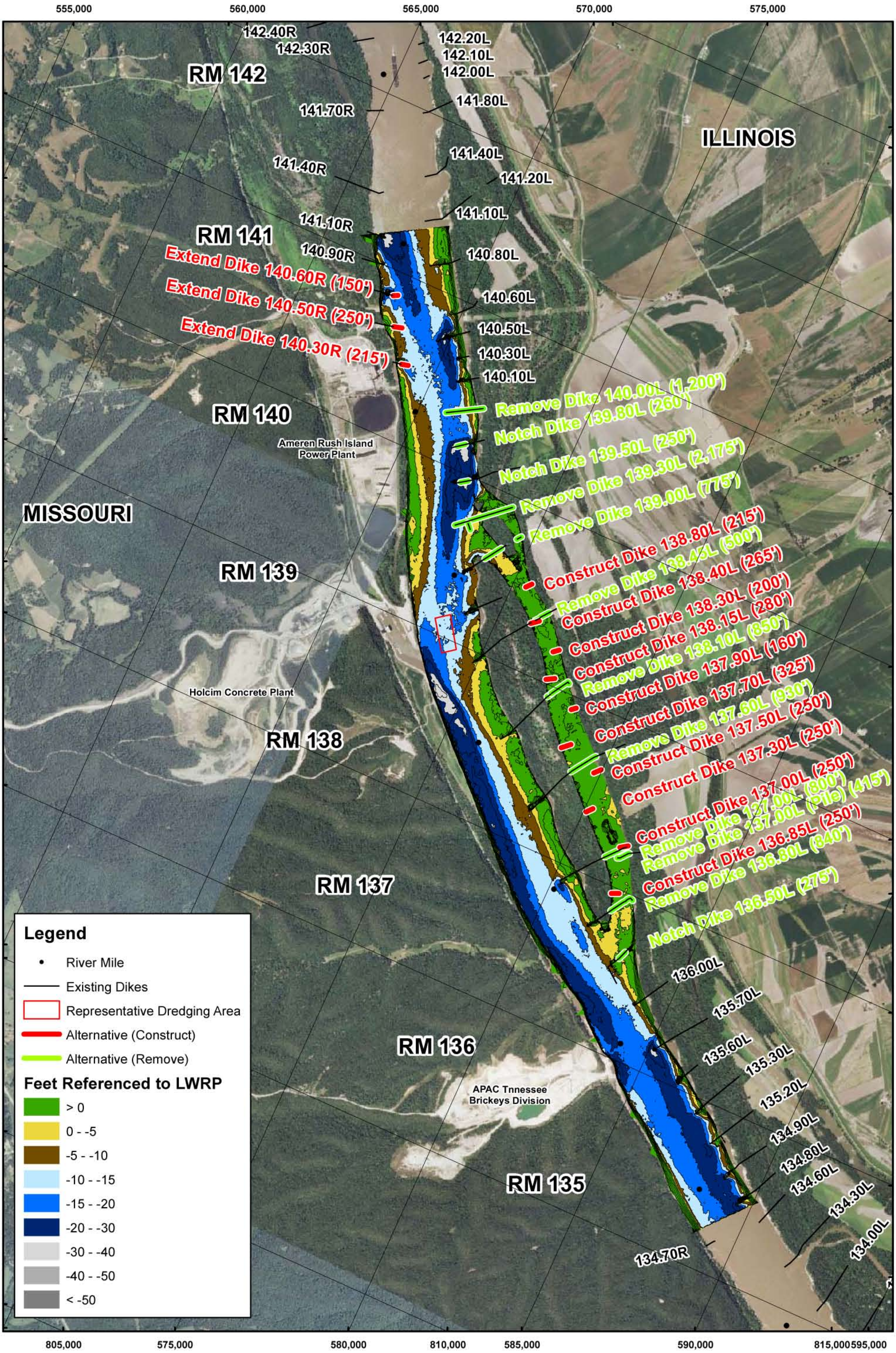

PLATE NUMBER 35

0 800 1,600 3,200 4,800 Feet

Alternative 5
2010 Aerial Photograph

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

DESIGNED BY:	SURVEY DATE:	PLOT DATE:
B. Krischel	05/14/13	01/31/2014
DRAWN BY: B. Krischel	REVIEWED BY: A. Cox	CHECKED BY: R. Davinroy, P.E.
SUBMITTED: B. Krischel	APPROVED: R. Davinroy, P.E.	

Mississippi River Basin
St. Louis District
Salt Lake Chute
HSR Model

FILE NAME: L:\Salt Lake Chute HSR Model Study\Plates\

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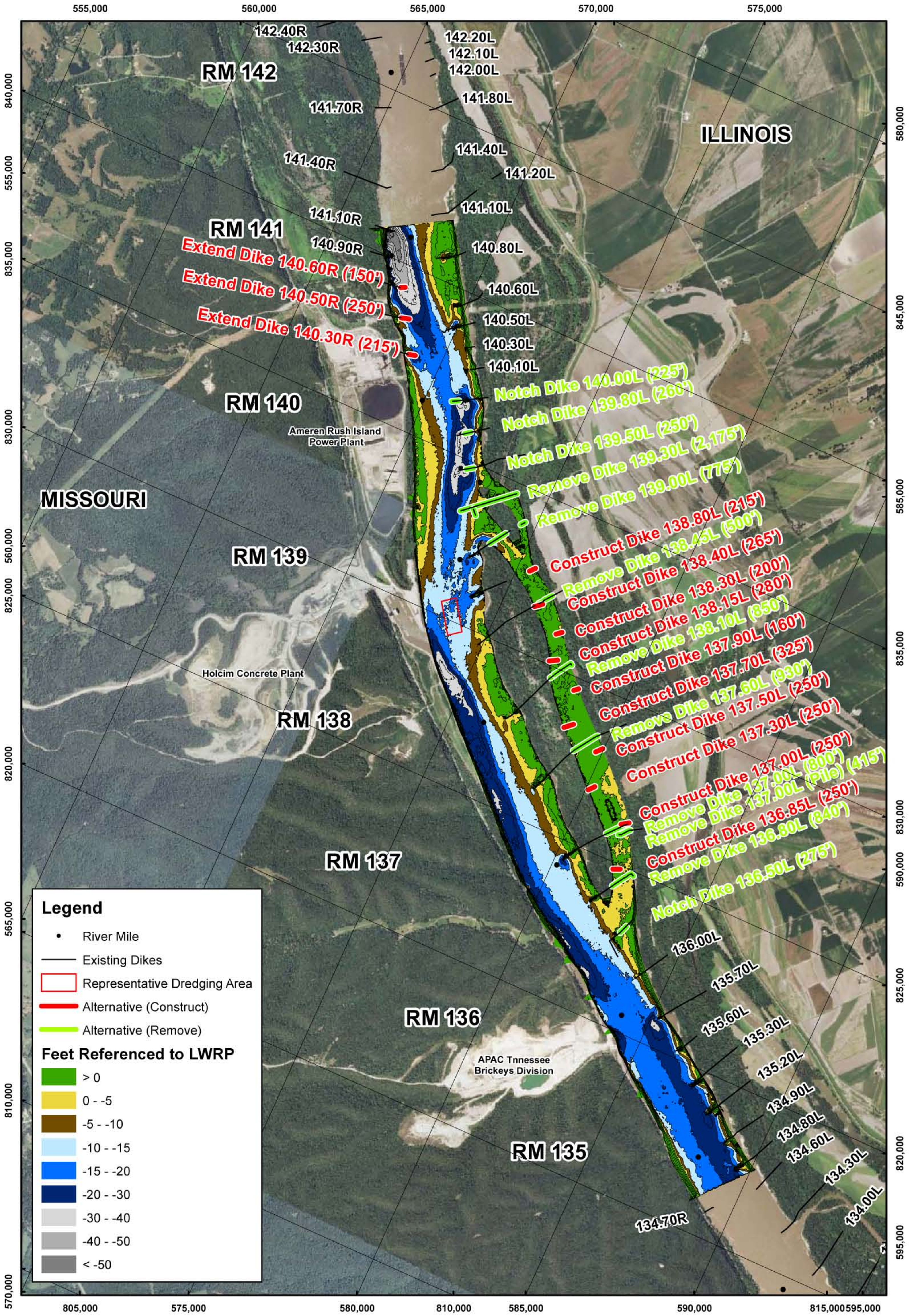

PLATE NUMBER 36

0 800 1,600 3,200 4,800 Feet

Alternative 6

2010 Aerial Photograph

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

Mississippi River Basin
St. Louis District
Salt Lake Chute
HSR Model

DESIGNED BY:	SURVEY DATE:	PLOT DATE:
B. Krischel	05/24/13	01/31/2014
DRAWN BY: B. Krischel	REVIEWED BY: A. Cox	CHECKED BY: R. Davinroy, P.E.
SUBMITTED: B. Krischel	APPROVED: R. Davinroy, P.E.	

FILE NAME: L:\Salt Lake Chute HSR Model Study\Plates\

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St. Louis District

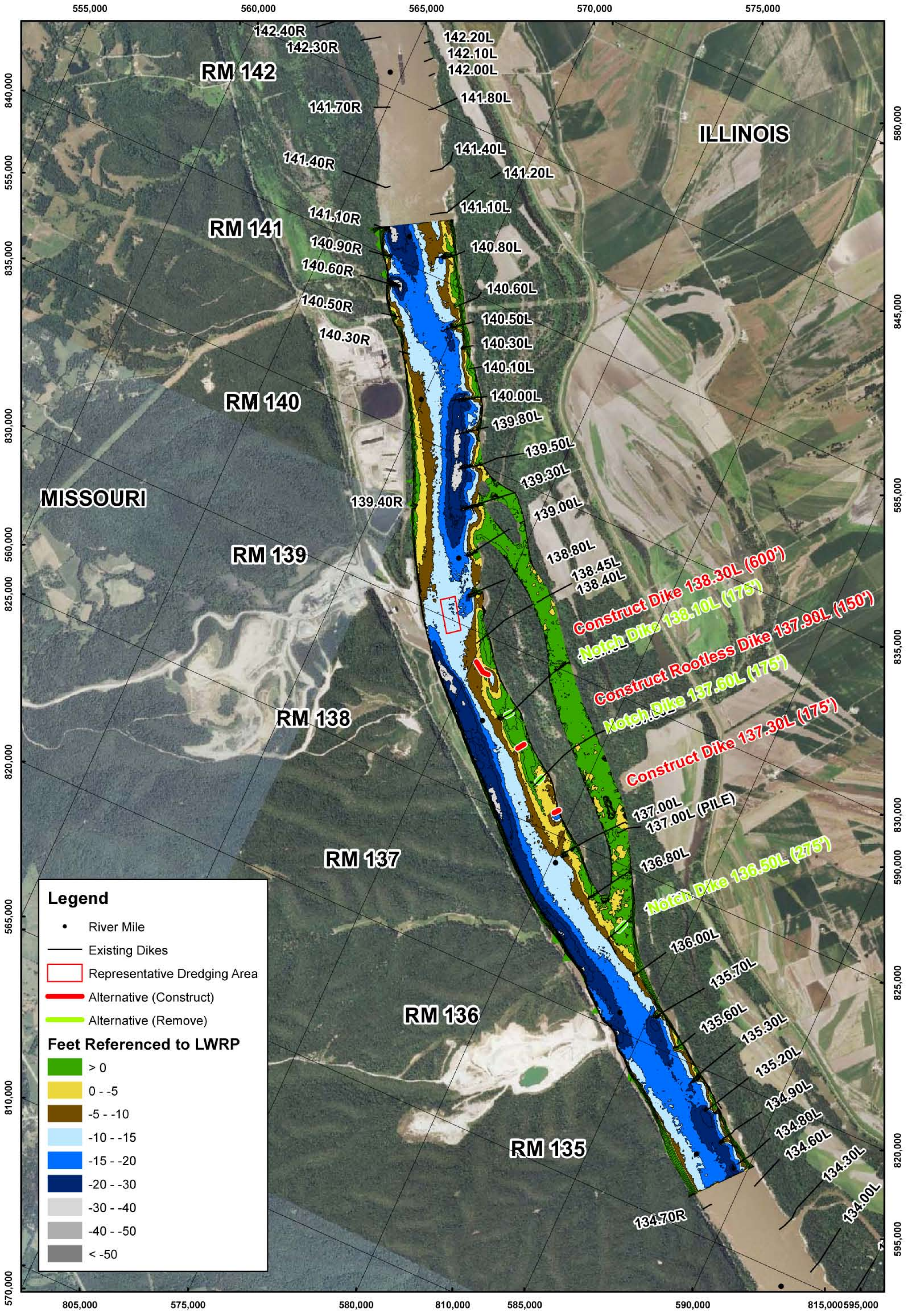

PLATE NUMBER 37

0 800 1,600 3,200 4,800
Feet

Alternative 7
2010 Aerial Photograph

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

Mississippi River Basin
St. Louis District
Salt Lake Chute
HSR Model

DESIGNED BY: B. Krischel	SURVEY DATE: 06/05/13	PLOT DATE: 01/31/14
DRAWN BY: B. Krischel	REVIEWED BY: A. Cox	CHECKED BY: R. Davinroy, P.E.
SUBMITTED: B. Krischel	APPROVED: R. Davinroy, P.E.	
FILE NAME: L:\Salt Lake Chute HSR Model Study\Plates\		

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US Army Corps of Engineers St. Louis District

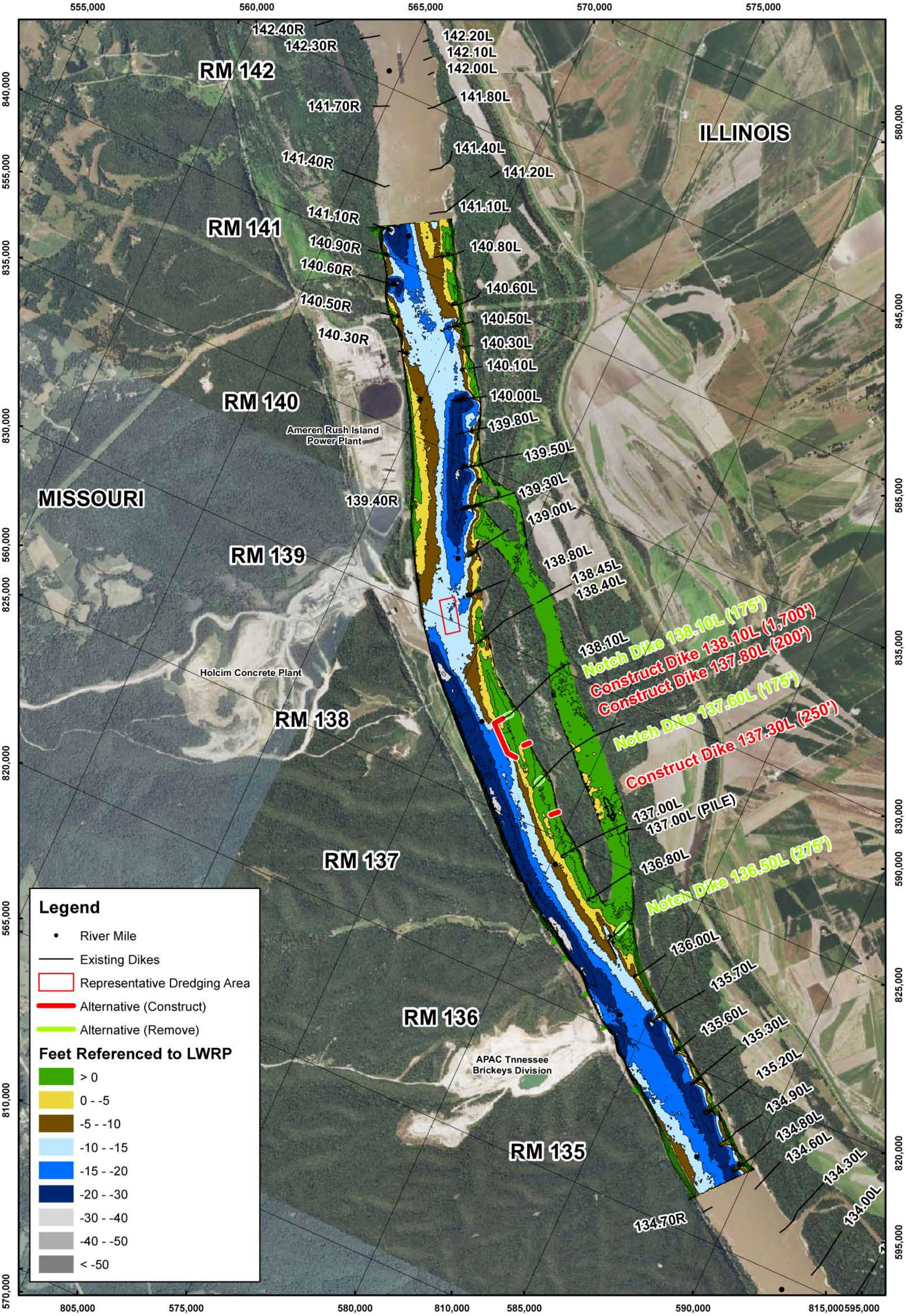

PLATE NUMBER 38

0 800 1,600 3,200 4,800
Feet

Alternative 8
2010 Aerial Photograph

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

Mississippi River Basin
St. Louis District
Salt Lake Chute
HSR Model

DESIGNED BY: B. Krischel	SURVEY DATE: 06/17/13	PLOT DATE: 01/31/2014
DRAWN BY: B. Krischel	REVIEWED BY: A. Cox	CHECKED BY: R. Davinroy, P.E.
SUBMITTED: B. Krischel	APPROVED: R. Davinroy, P.E.	
FILE NAME: L:\Salt Lake Chute HSR Model Study\Plates\		

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US Army Corps of Engineers
St. Louis District

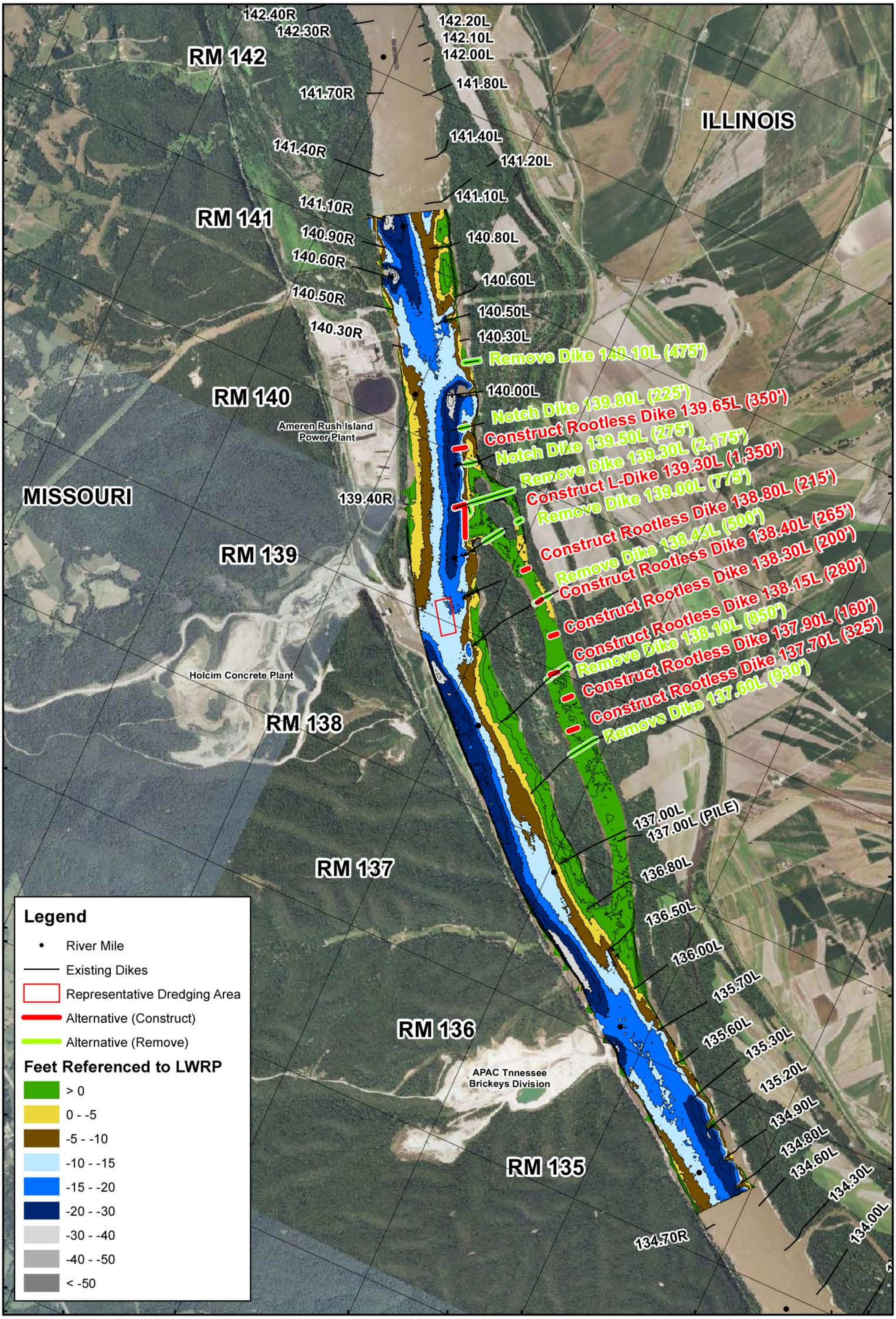

PLATE NUMBER 39

0 800 1,600 3,200 4,800 Feet

Alternative 9

2010 Aerial Photograph

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

Mississippi River Basin
St. Louis District
Salt Lake Chute
HSR Model

DESIGNED BY:	SURVEY DATE:	PLOT DATE:
B. Krischel	06/25/13	01/31/2014
DRAWN BY: B. Krischel	REVIEWED BY: A. Cox	CHECKED BY: R. Davinroy, P.E.
SUBMITTED: B. Krischel		APPROVED: R. Davinroy, P.E.
FILE NAME: I:\Salt Lake Chute HSR Model Study\Plates\		

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US Army Corps of Engineers
St. Louis District

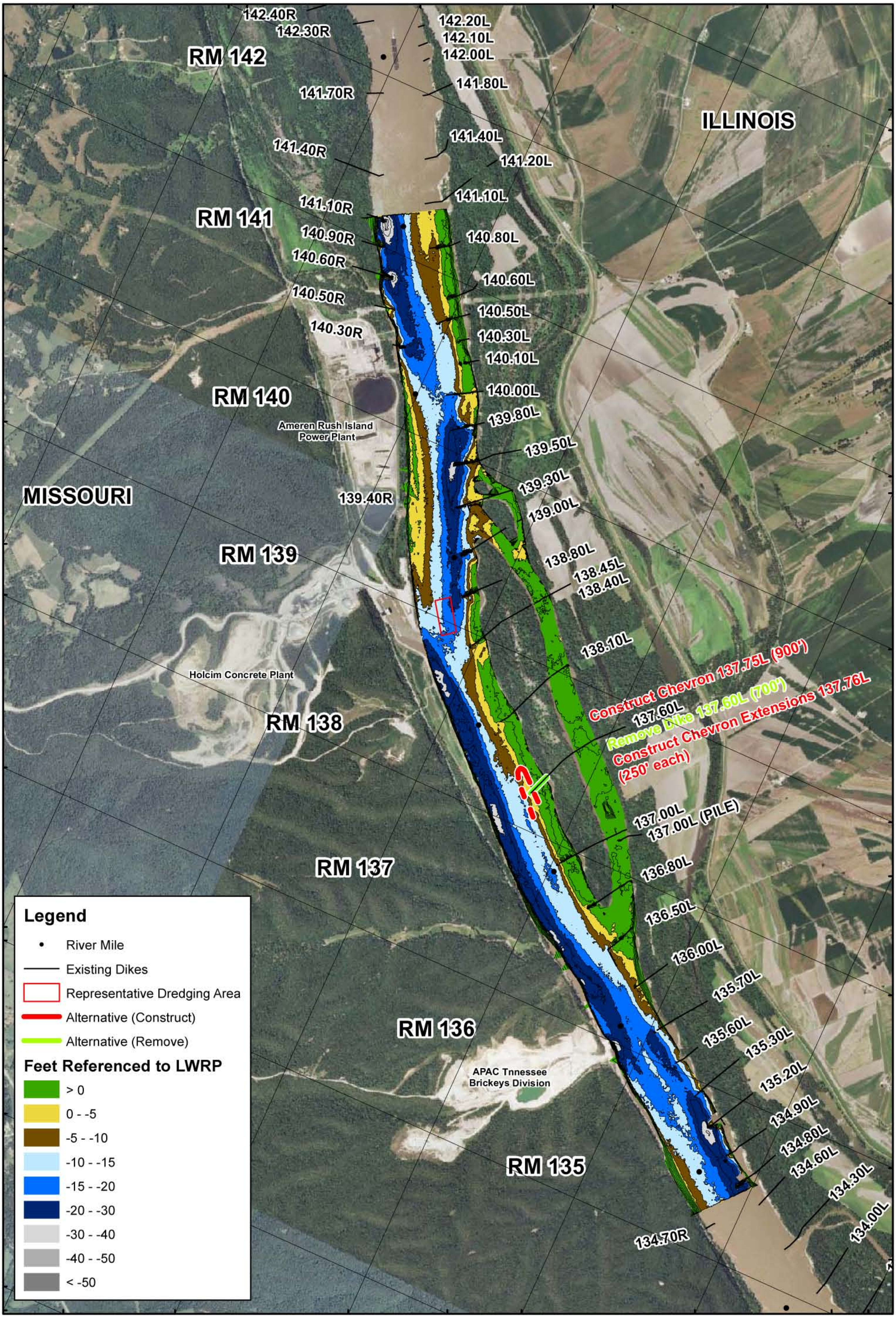

PLATE NUMBER 40

Feet 0 800 1,600 3,200 4,800

Alternative 10
2010 Aerial Photograph

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

Mississippi River Basin
St. Louis District
Salt Lake Chute
HSR Model

DESIGNED BY: B. Krischel	SURVEY DATE: 07/03/13	PLOT DATE: 01/31/2014
DRAWN BY: B. Krischel	REVIEWED BY: A. Cox	CHECKED BY: R. Davinroy, P.E.
SUBMITTED: B. Krischel	APPROVED: R. Davinroy, P.E.	
FILE NAME: L:\Salt Lake Chute HSR Model Study\Plates\		

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US Army Corps of Engineers St. Louis District

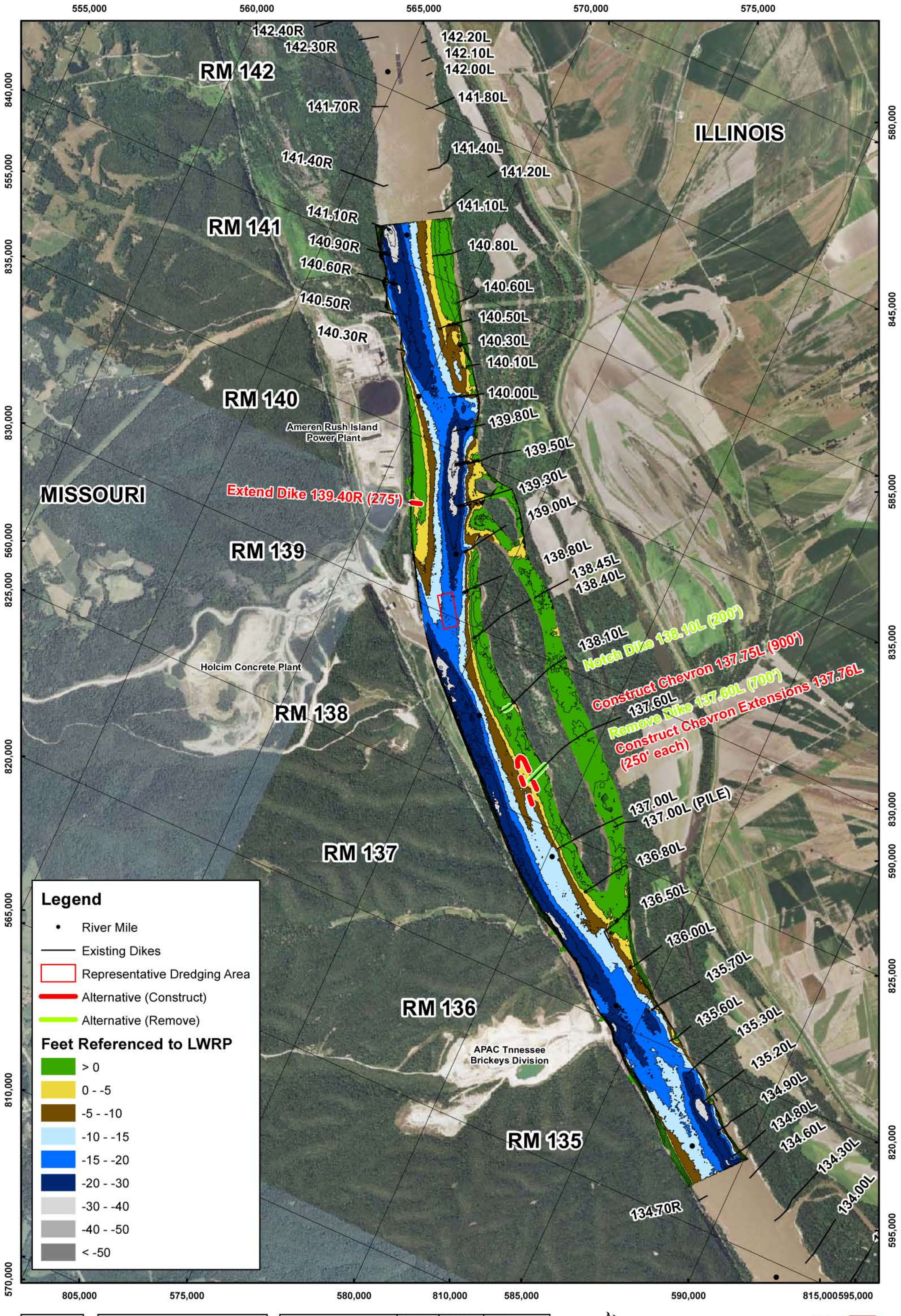

PLATE NUMBER 41

0 800 1,600 3,200 4,800
Feet

Alternative 11
2010 Aerial Photograph

U.S. ARMY ENGINEER DIVISION CORPS OF ENGINEERS ST. LOUIS, MISSOURI	DESIGNED BY: B. Krischel	SURVEY DATE: 07/17/13	PLOT DATE: 01/31/2014
	DRAWN BY: B. Krischel	REVIEWED BY: A. Cox	CHECKED BY: R. Davinroy, P.E.
Mississippi River Basin St. Louis District Salt Lake Chute HSR Model	SUBMITTED: B. Krischel	APPROVED: R. Davinroy, P.E.	
	FILE NAME: L:\Salt Lake Chute HSR Model Study\Plates\		

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US Army Corps of Engineers
St. Louis District

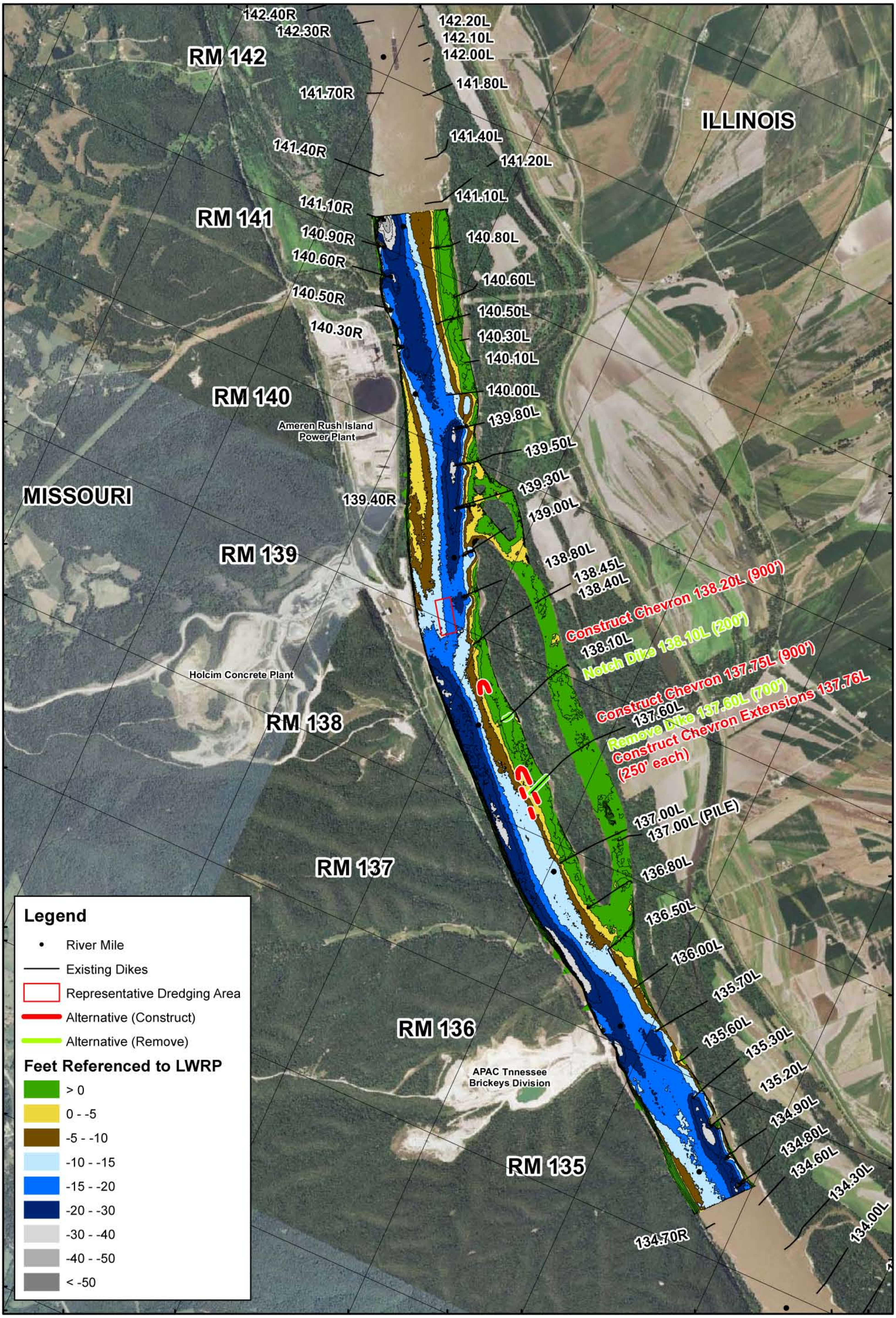

PLATE NUMBER 42

0 800 1,600 3,200 4,800 Feet

Alternative 12
2010 Aerial Photograph

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

Mississippi River Basin
St. Louis District
Salt Lake Chute
HSR Model

DESIGNED BY: B. Krischel	SURVEY DATE: 07/30/13	PLOT DATE: 01/31/2014
DRAWN BY: B. Krischel	REVIEWED BY: A. Cox	CHECKED BY: R. Davinroy, P.E.
SUBMITTED: B. Krischel	APPROVED: R. Davinroy, P.E.	

FILE NAME: L:\Salt Lake Chute HSR Model Study\Plates\

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US Army Corps of Engineers St. Louis District

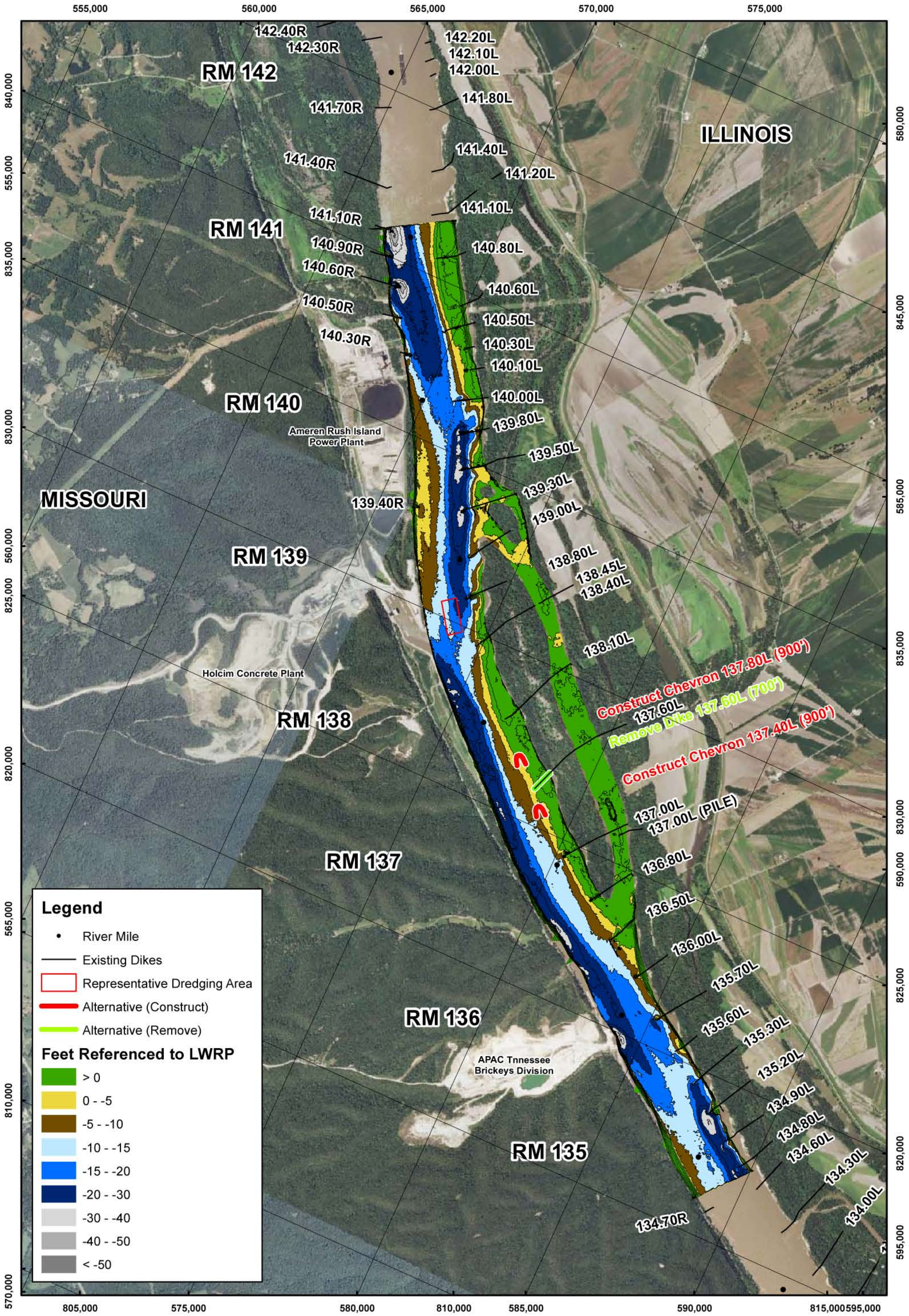

PLATE NUMBER 43

Alternative 13
2010 Aerial Photograph

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

Mississippi River Basin
St. Louis District
Salt Lake Chute
HSR Model

DESIGNED BY: B. Krischel	SURVEY DATE: 08/08/13	PLOT DATE: 01/31/2014
DRAWN BY: B. Krischel	REVIEWED BY: A. Cox	CHECKED BY: R. Davinroy, P.E.
SUBMITTED: B. Krischel		APPROVED: R. Davinroy, P.E.

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US Army Corps of Engineers
St. Louis District

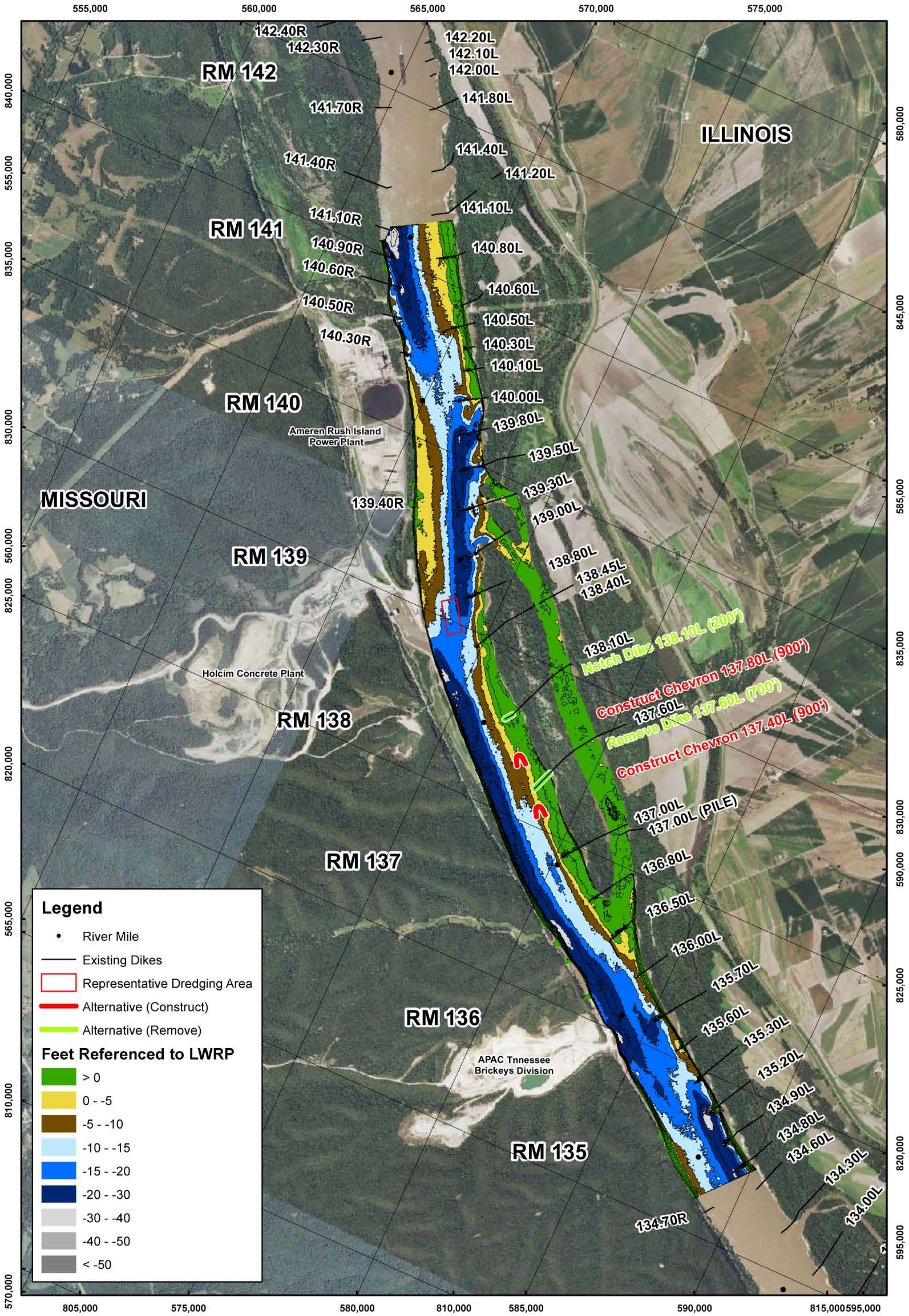

PLATE NUMBER 44

0 800 1,600 3,200 4,800
Feet

Alternative 14
2010 Aerial Photograph

U.S. ARMY ENGINEER DIVISION CORPS OF ENGINEERS ST. LOUIS, MISSOURI	Designed by: B. Krischel	Survey date: 08/22/13	Plot date: 01/31/2014
	Drawn by: B. Krischel	Reviewed by: A. Cox	Checked by: R. Davinroy, P.E.
Mississippi River Basin St. Louis District Salt Lake Chute HSR Model	Submitted: B. Krischel	Approved: R. Davinroy, P.E.	
	File name: L:\Salt Lake Chute HSR Model Study\Plates\		

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US Army Corps of Engineers St. Louis District

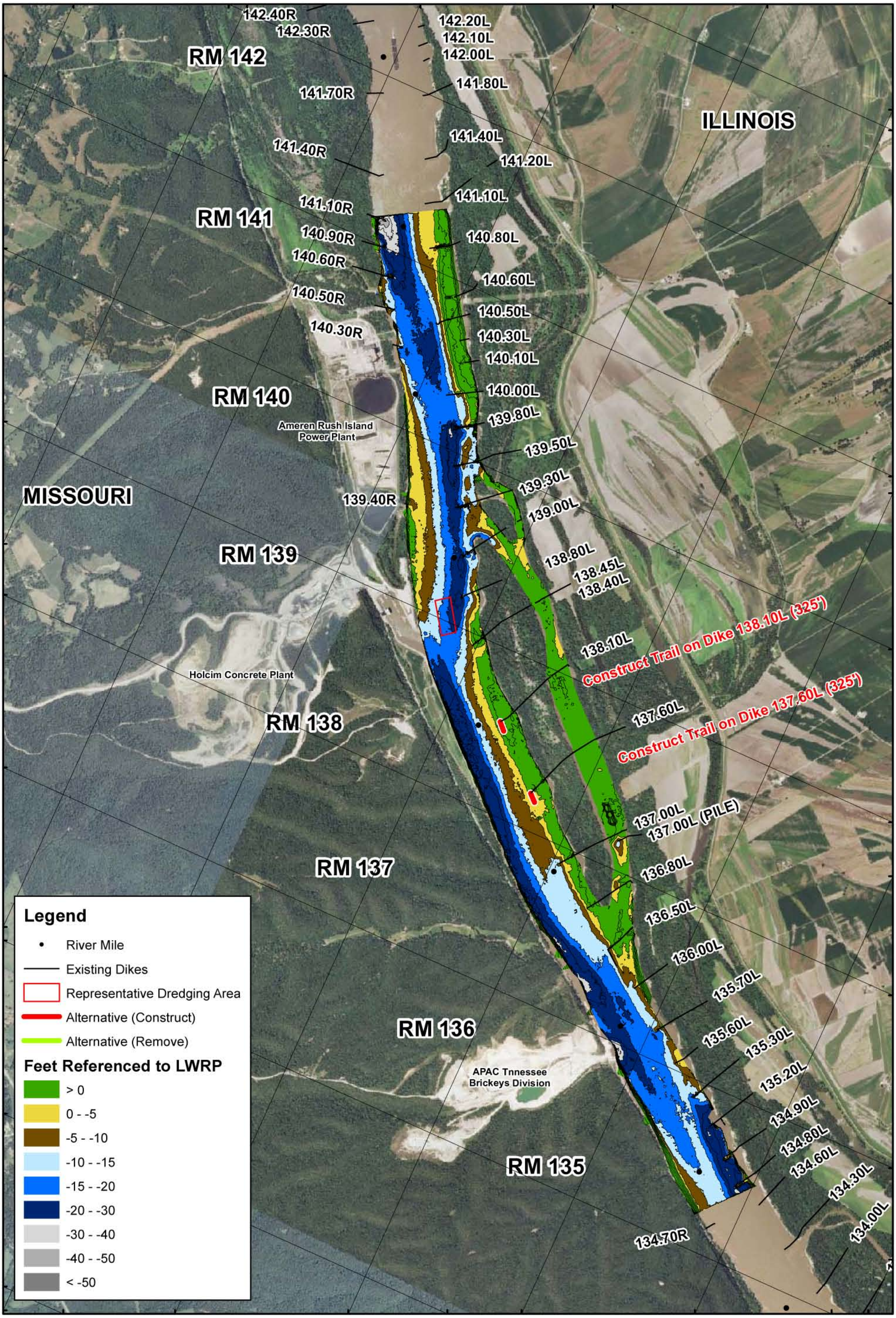

PLATE NUMBER 45

Alternative 15
2010 Aerial Photograph

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

Mississippi River Basin
St. Louis District
Salt Lake Chute
HSR Model

DESIGNED BY	SURVEY DATE	PLOT DATE
B. Krischel	08/28/13	01/31/2014
DRAWN BY	REVIEWED BY	CHECKED BY
B. Krischel	A. Cox	R. Davinroy, P.E.
SUBMITTED	APPROVED	
B. Krischel	R. Davinroy, P.E.	

APPLIED RIVER ENGINEERING CENTER

US Army Corps of Engineers
St. Louis District

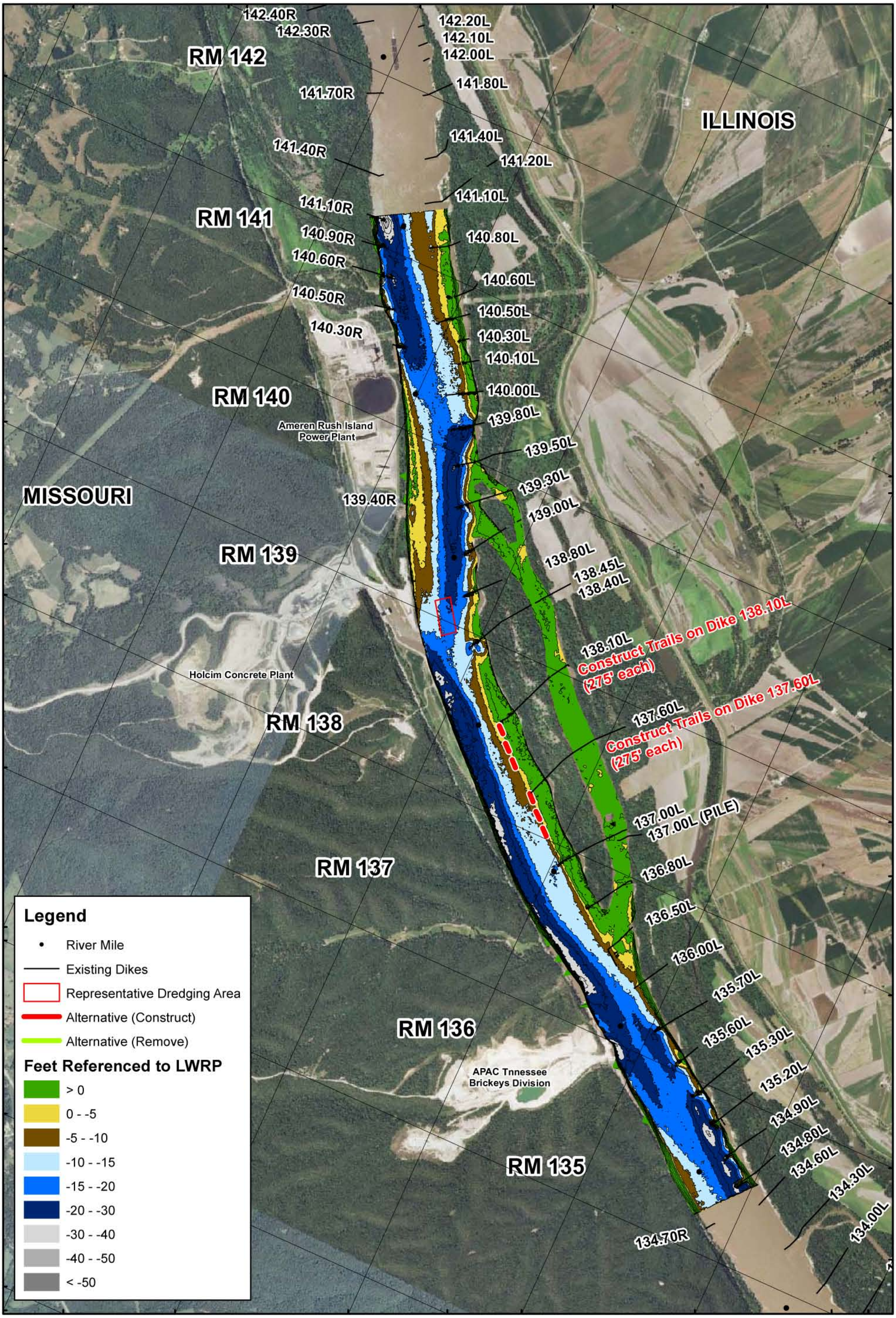

PLATE NUMBER 46

0 800 1,600 3,200 4,800 Feet

Alternative 16
2010 Aerial Photograph

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

Mississippi River Basin
St. Louis District
Salt Lake Chute
HSR Model

DESIGNED BY: B. Krischel	SURVEY DATE: 09/04/13	PLOT DATE: 01/31/2014
DRAWN BY: B. Krischel	REVIEWED BY: A. Cox	CHECKED BY: R. Davinroy, P.E.
SUBMITTED: B. Krischel	APPROVED: R. Davinroy, P.E.	

FILE NAME: L:\Salt Lake Chute HSR Model Study\Plates\

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US Army Corps of Engineers
St. Louis District

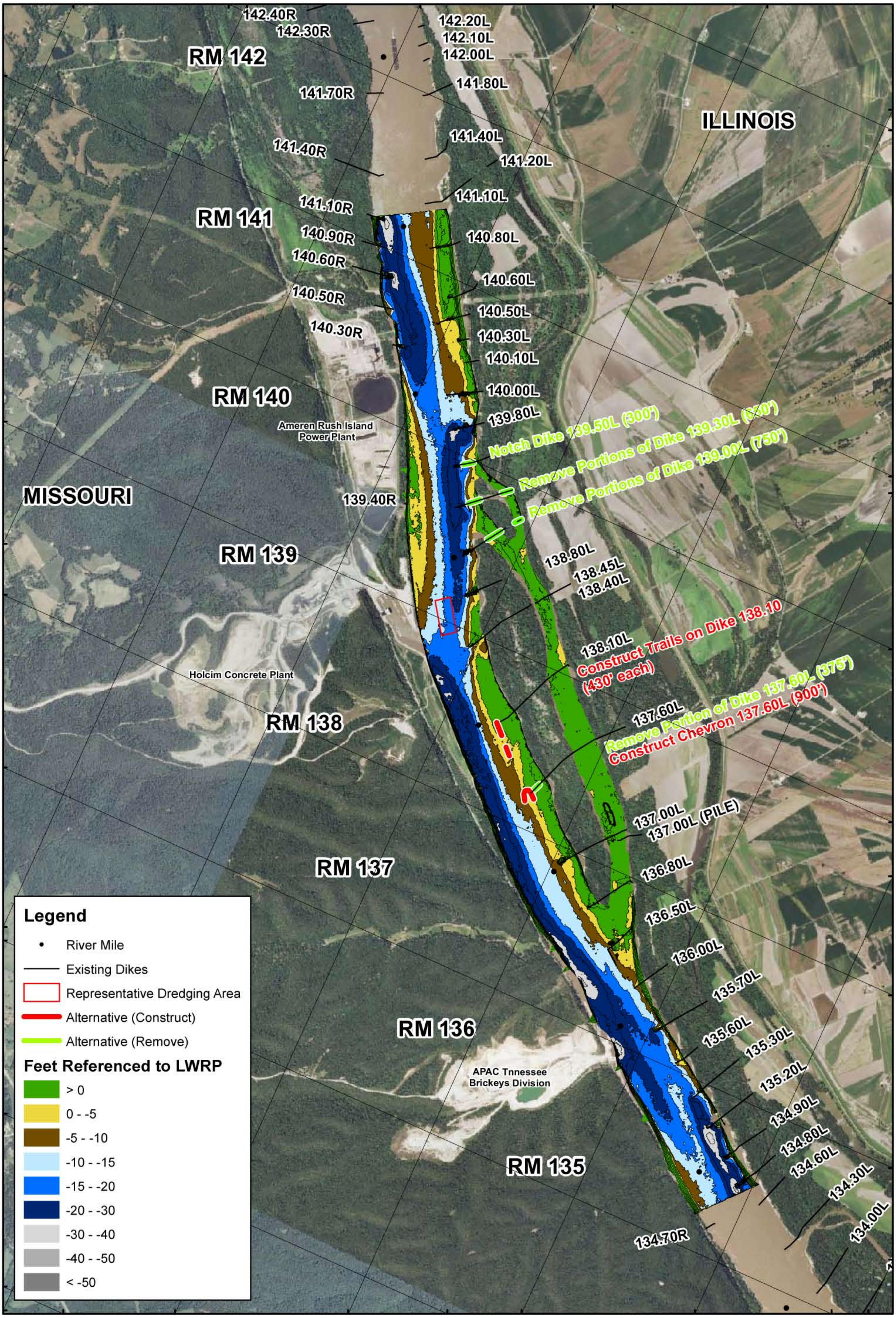

PLATE NUMBER 47

Alternative 17
2010 Aerial Photograph

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

Mississippi River Basin
St. Louis District
Salt Lake Chute
HSR Model

DESIGNED BY: B. Krischel	SURVEY DATE: 09/11/13	PLOT DATE: 01/31/2014
DRAWN BY: B. Krischel	REVIEWED BY: A. Cox	CHECKED BY: R. Davinroy, P.E.
SUBMITTED: B. Krischel	APPROVED: R. Davinroy, P.E.	

FILE NAME: L:\Salt Lake Chute HSR Model Study\Plates\

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US Army Corps of Engineers
St. Louis District

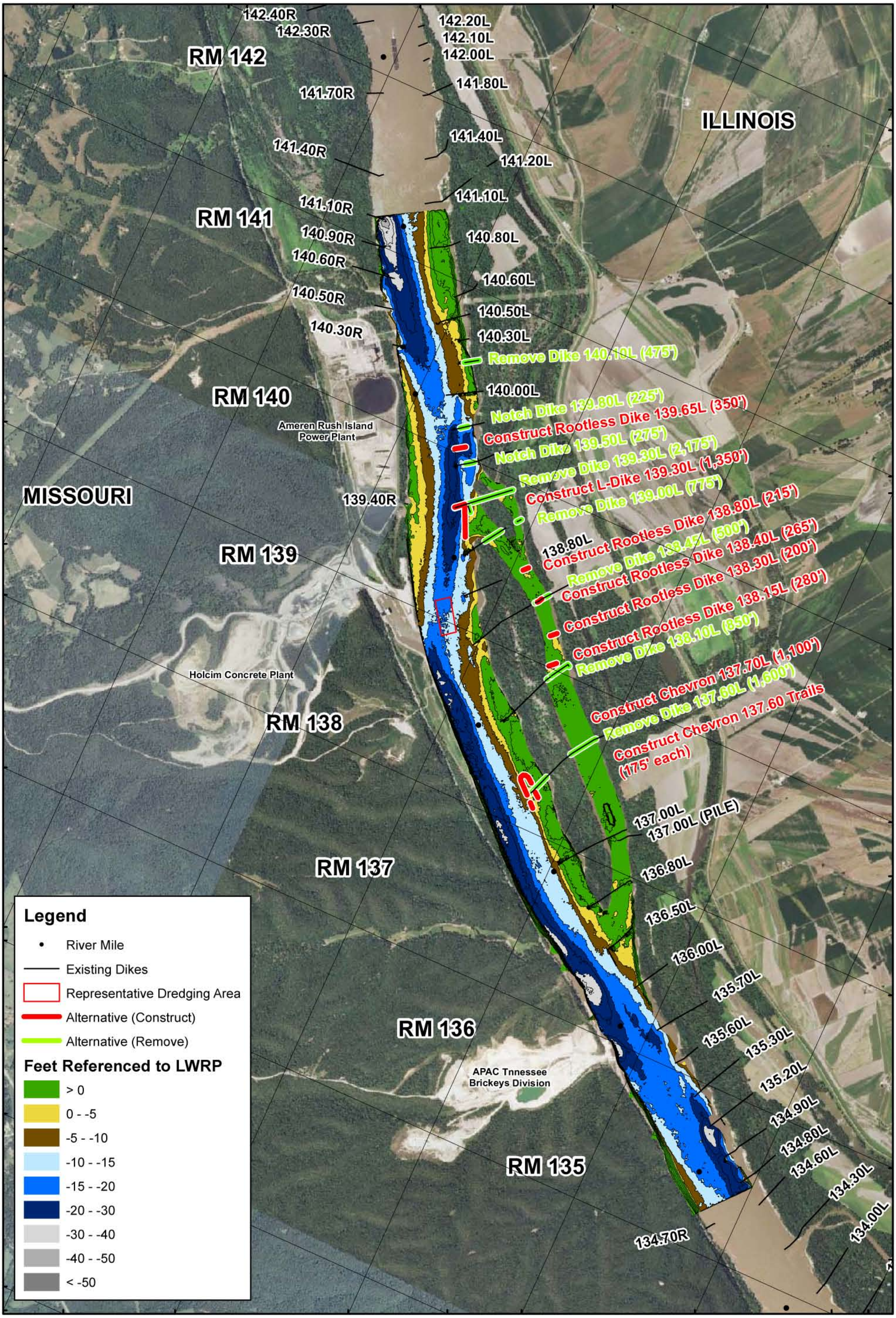

PLATE NUMBER 48

Alternative 18
2010 Aerial Photograph

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

Mississippi River Basin
St. Louis District
Salt Lake Chute
HSR Model

DESIGNED BY: B. Krischel	SURVEY DATE: 09/17/13	PLOT DATE: 01/31/2014
DRAWN BY: B. Krischel	REVIEWED BY: A. Cox	CHECKED BY: R. Davinroy, P.E.
SUBMITTED: B. Krischel	APPROVED: R. Davinroy, P.E.	
FILE NAME: L:\Salt Lake Chute HSR Model Study\Plates\		

APPLIED RIVER ENGINEERING CENTER

US Army Corps of Engineers St. Louis District

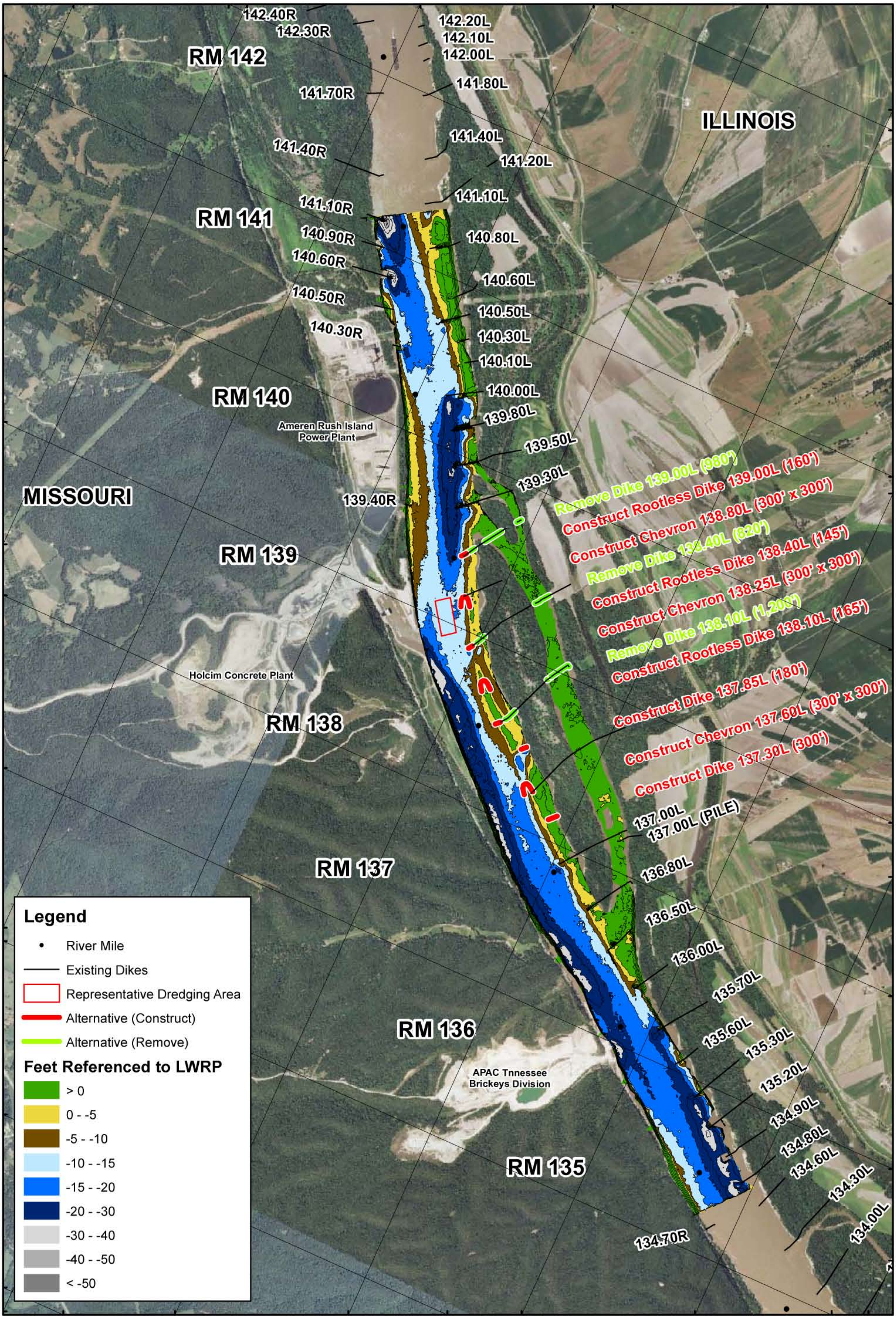

PLATE NUMBER 49

0 800 1,600 3,200 4,800 Feet

Alternative 19

2010 Aerial Photograph

U.S. ARMY ENGINEER DIVISION CORPS OF ENGINEERS ST. LOUIS, MISSOURI	DESIGNED BY: B. Krischel	SURVEY DATE: 09/23/13	PLOT DATE: 01/31/2014
	DRAWN BY: B. Krischel	REVIEWED BY: A. Cox	CHECKED BY: R. Davinroy, P.E.
Mississippi River Basin St. Louis District Salt Lake Chute HSR Model	SUBMITTED: B. Krischel	APPROVED: R. Davinroy, P.E.	
	FILE NAME: L:\Salt Lake Chute HSR Model Study\Plates\		

APPLIED RIVER ENGINEERING CENTER

US Army Corps of Engineers St. Louis District

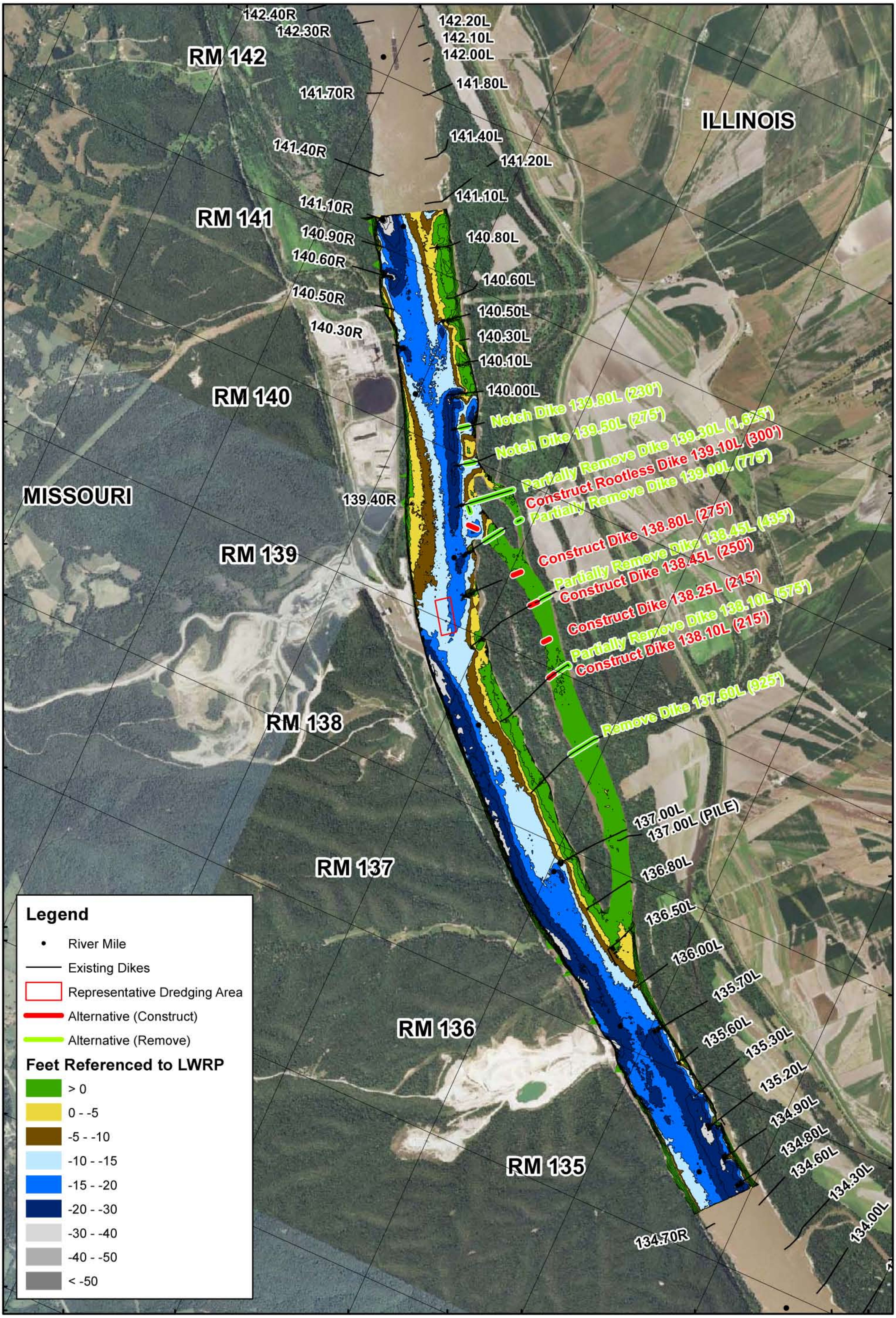

PLATE NUMBER 50

0 800 1,600 3,200 4,800 Feet

Alternative 20
2010 Aerial Photograph

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

Mississippi River Basin
St. Louis District
Salt Lake Chute
HSR Model

DESIGNED BY	SURVEY DATE	PLOT DATE
B. Krischel	10/23/13	01/31/2014
DRAWN BY: B. Krischel	REVIEWED BY: A. Cox	CHECKED BY: R. Davinroy, P.E.
SUBMITTED: B. Krischel	APPROVED: R. Davinroy, P.E.	

FILE NAME: L:\Salt Lake Chute HSR Model Study\Plates\

APPLIED RIVER ENGINEERING CENTER

US Army Corps of Engineers St. Louis District

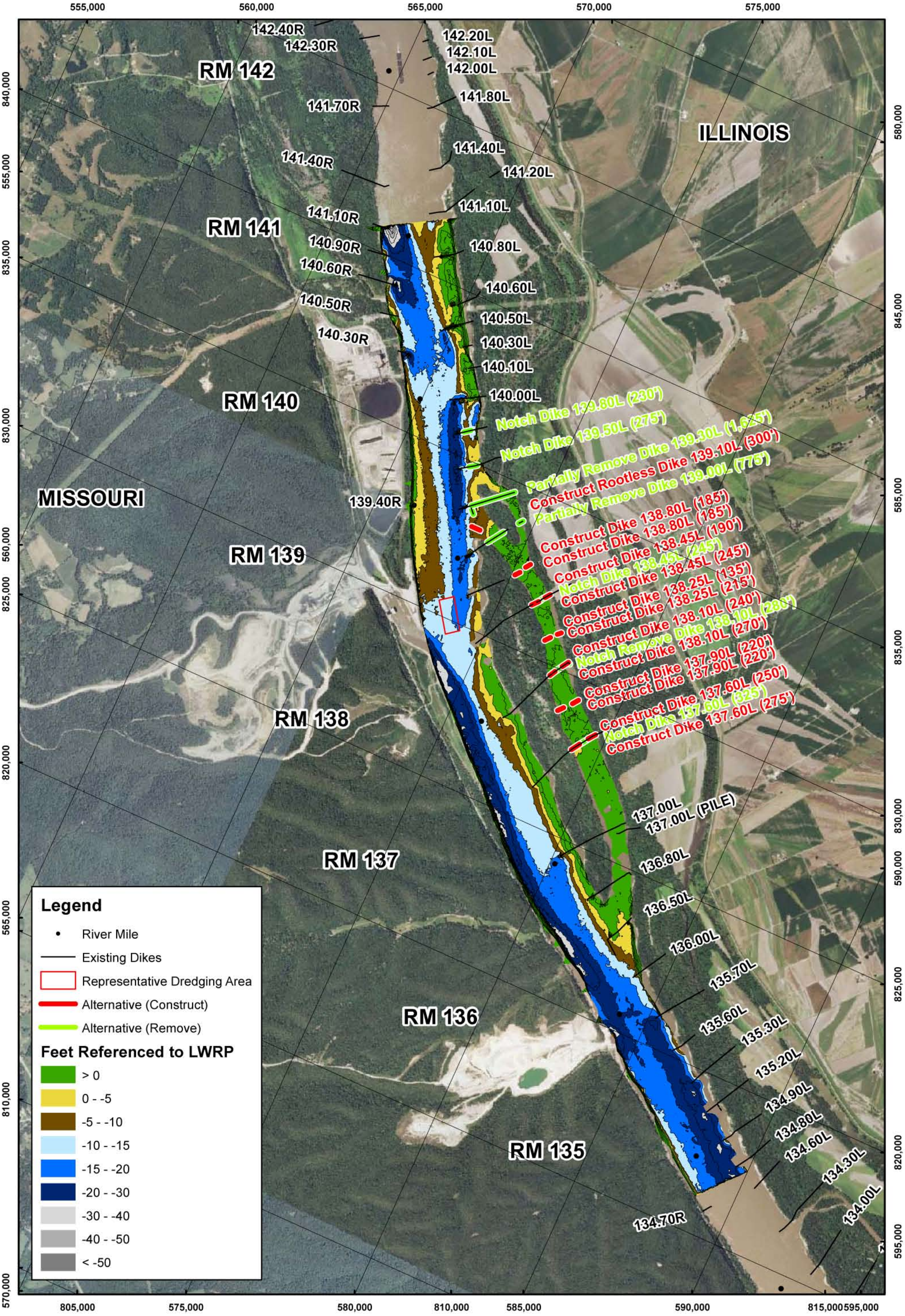

PLATE NUMBER 51

Alternative 21

2010 Aerial Photograph

U.S. ARMY ENGINEER DIVISION CORPS OF ENGINEERS ST. LOUIS, MISSOURI	DESIGNED BY: B. Krischel	SURVEY DATE: 10/25/13	PLOT DATE: 01/31/2014
	DRAWN BY: B. Krischel	REVIEWED BY: A. Cox	CHECKED BY: R. Davinroy, P.E.
Mississippi River Basin St. Louis District Salt Lake Chute HSR Model	SUBMITTED: B. Krischel	APPROVED: R. Davinroy, P.E.	
	FILE NAME: L:\Salt Lake Chute HSR Model Study\Plates\		

APPLIED RIVER ENGINEERING CENTER

US Army Corps of Engineers St. Louis District

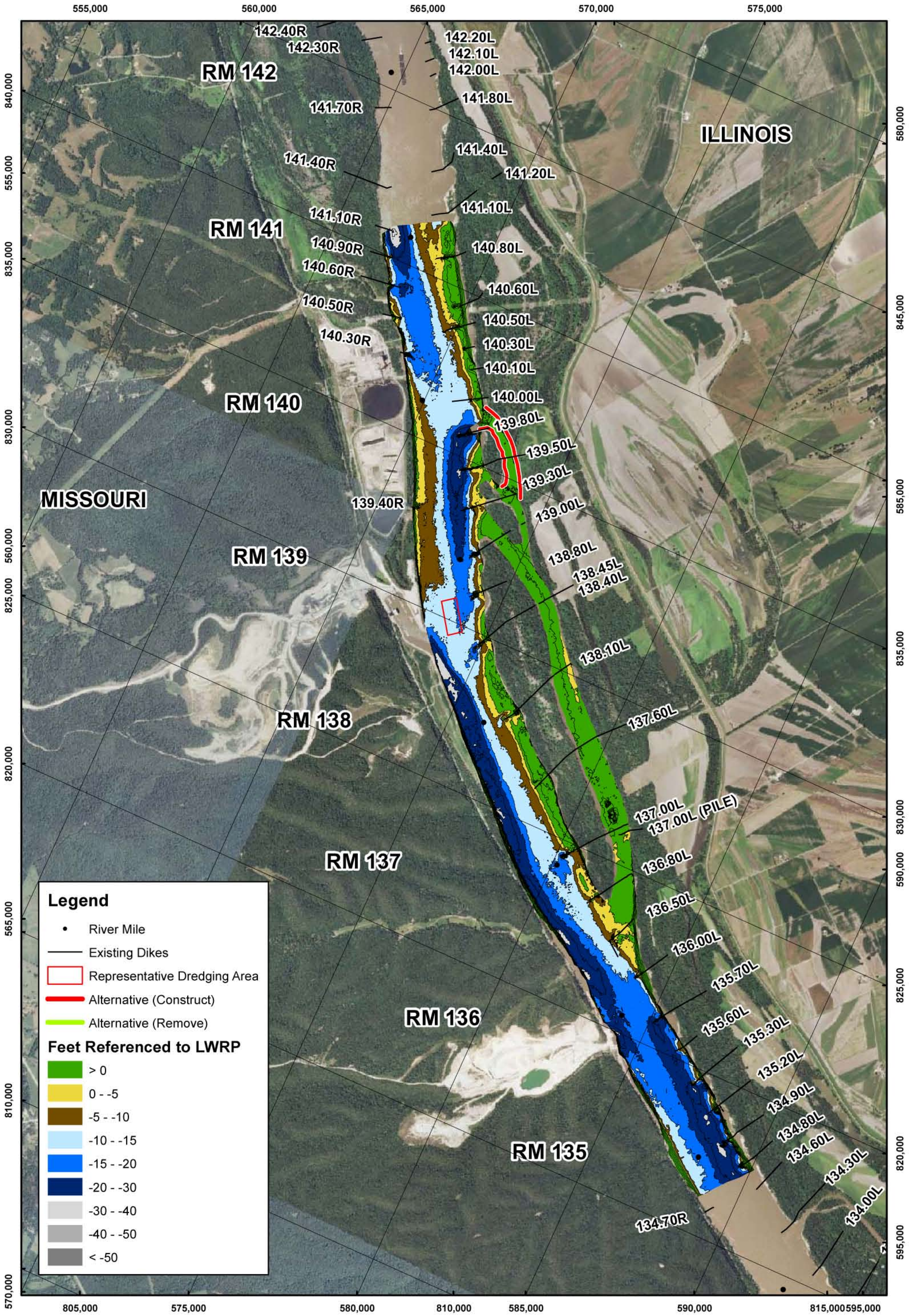

PLATE NUMBER 52

0 800 1,600 3,200 4,800
Feet

Alternative 22
2010 Aerial Photograph

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

Mississippi River Basin
St. Louis District
Salt Lake Chute
HSR Model

DESIGNED BY: B. Krischel	SURVEY DATE: 10/29/13	PLOT DATE: 01/31/14
DRAWN BY: B. Krischel	REVIEWED BY: A. Cox	CHECKED BY: R. Davinroy, P.E.
SUBMITTED: B. Krischel	APPROVED: R. Davinroy, P.E.	
FILE NAME: L:\Salt Lake Chute HSR Model Study\Plates\		

N E S W

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St. Louis District