



**US Army Corps  
of Engineers** ®  
Kansas City District

# **Evaluation of Reported Notch Problem Locations Below Rulo, Nebraska**

**April 2013**

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## **FINAL REPORT**



Table of Contents

1.0 Introduction..... 1

    1.1 History of the BSNP and Land Accretion..... 2

    1.2 Structure Notching ..... 4

    1.3 Bank Erosion ..... 10

    1.4 Reported Bank Erosion Problem Areas ..... 12

2.0 Erosion Analysis: Stated Cause is Notching..... 15

    2.1 Locations from River Mile 57 to River Mile 93 ..... 15

    2.2 Erosion Location at River Mile 93..... 46

    2.3 Notch Concerns at River Mile 137 – 140..... 48

    2.4 Concerns with Lowering Dikes From River Mile 146 to 150.5..... 52

    2.5 Erosion Concerns between River Mile 163 and River Mile 164 ..... 57

    2.6 Notch Concern at D190.7B between River Miles 182-183 ..... 61

    2.7 Notch Concern at River Mile 205 ..... 63

    2.8 Erosion Concerns Near River Mile 232 ..... 66

    2.9 Erosion concerns From River Mile 237 to River Mile 238..... 68

    2.10 Notch Concern from River Mile 278.2 to River Mile 291.2..... 70

3.0 Erosion Concerns: Stated Cause Other Than Notches..... 91

    3.1 Erosion Concerns near Natural Chute at River Mile 8..... 91

    3.2 Dike Maintenance Concerns at River Mile 290 and River Mile 296..... 93

    3.3 Erosion Concern at River Mile 466.5..... 94

4.0 Erosion Concerns: Stated Cause is Flooding..... 95

    4.1 Concerns at River Mile 320 from Flood Event ..... 95

    4.3 Concern near River Mile 435 from Flood Event..... 99

    4.4 Concern near River Mile 490 from Flood Event..... 101

5.0 Erosion Concerns: Stated Cause is Shallow Water Habitat..... 104

    5.1 Concern near River Mile 211 from Jameson Chute..... 104

    5.2 Erosion Concern at River Mile 500..... 107

6.0 Summary ..... 108

Table of Figures

Figure 1-1: Accretion process at Indian Cave Bend. .... 3

Figure 1-2: Typical Structure Layout. .... 3

Figure 1-3: Typical Cross Section of Notch ..... 4

Figure 1-4: Notches Constructed by KCD Since 1975 ..... 5

Figure 1-5: Width of Notches Constructed by Decade ..... 6

Figure 1-6: Size Classes For Various Width and Depths of Notches. .... 7

Figure 1-7: General Guideline for Distance of Notch to Bank ..... 7

Figure 1-8: Examples of Notch Size and Location: ..... 7

Figure 1-9: Bank Erosion on Federal Land for Increased Aquatic Habitat ..... 9

Figure 1-10: Two examples of erosion around structures with no notches. .... 10

Figure 1-11(a): Breakdown of Stated Cause by Category ..... 12

Figure 1-11(b): Breakdown of Locations With and Without Notch ..... 13

Figure 1-12: Number and Type of Location by Landowner ..... 13

Figure 2-1: Locations 1-5 for Dan Kuenzel ..... 15

Figure 2-2(a): Submitted Photos for Location 1 ..... 15

Figure 2-2(b): Submitted Photos for Location 2 ..... 16

Figure 2-2(c): Overview of Locations 1 and 2 ..... 16

Figure 2-2(d): Scour Hole from 1995 Flood ..... 17

Figure 2-2(e): Aerial Photo Comparison of Locations 1 and 2 over 10 years ..... 17

Figure 2-3(a): Submitted Photos for Location 3 ..... 19

Figure 2-3(b): Overview of Location 3 ..... 19

Figure 2-3(c): Aerial Photo Comparison of Location 3 over 17 years ..... 20

Figure 2-4(a): Submitted Photos for Location 4 ..... 21

Figure 2-4(b): Overview of Location 4 ..... 22

Figure 2-4(c): Aerial Photo Comparison of Location 4 over 17 years ..... 22

Figure 2-5(a): Submitted Photos for Location 5 ..... 23

Figure 2-5(b): Overview of Location 5 ..... 24

Figure 2-5(c): Aerial Photo Comparison of Location 5 over 17 years ..... 24

Figure 2-6: Locations 6-11 for Mr. Kuenzel’s Areas of Concern ..... 26

Figure 2-7(a): Submitted Photos for Location 6 ..... 27

Figure 2-7(b): Submitted Photos for Location 7 ..... 27

Figure 2-7(c): Overview of Locations 6 and 7 ..... 28

Figure 2-7(d): Aerial Photo Comparison near Location 6 and 7 over 17 year period ..... 28

Figure 2-8(a): Submitted Photos for Location 8 ..... 29

Figure 2-8(b): Overview of Location 8 ..... 29

Figure 2-8(c): Aerial Photo Comparison of Location 8 from 1995 to 2012 ..... 30

Figure 2-9(a): Submitted Photos for Location 9 ..... 31

Figure 2-9(b): Submitted Photos for Location 10 ..... 31

Figure 2-9(c): Overview of Locations 9 and 10 ..... 32

|  |    |
|--|----|
| Figure 2-9(d): Aerial Photo Comparison at Locations 9 and 10 from 1995 to 2012.....    | 33 |
| Figure 2-10(a): Submitted Photos for Location 11 .....                                 | 34 |
| Figure 2-10(b): Overview of Location 11.....   | 35 |
| Figure 2-10(c): Aerial Photo Comparison at Location 11 from 1996 to 2012 .....         | 36 |
| Figure 2-11: Locations 12-15 for Dan Kuenzel’s Areas of Concern.....                   | 37 |
| Figure 2-12(a): Submitted Photos for Location 12.....                                  | 38 |
| Figure 2-12(b): Overview of Location 12.....   | 38 |
| Figure 2-12(c): Aerial Photo Comparison for Location 12 from 1996 to 2012.....         | 39 |
| Figure 2-13(a): Submitted Photos for Location 13 .....                                 | 40 |
| Figure 2-13(b): Submitted Photos for Location 14.....                                  | 40 |
| Figure 2-13(c): Overview of Locations 13 and 14.....                                   | 41 |
| Figure 2-13(d): Aerial Photo Comparison of Locations 13 and 14 from 1996 to 2012 ..... | 41 |
| Figure 2-14(a): Submitted Photos for Location 15 .....                                 | 42 |
| Figure 2-14(b): Overview of Location 15.....   | 43 |
| Figure 2-14(c): Aerial Photo Comparison near Location 15 from 1996 to 2012 .....       | 44 |
| Figure 2-14(d): Aerial Photo Comparison near Hard Points from 2009 to 2012 .....       | 44 |
| Figure 2-15: Bryan Island Chute.....   | 45 |
| Figure 2-16(a): Submitted Photo by Dale Gloe .....                                     | 46 |
| Figure 2-16(b) Overview of Gloe’s Submittal Area .....                                 | 47 |
| Figure 2-16(c): Aerial Photo Comparison for Location 3 Near River Mile 94 .....        | 47 |
| Figure 2-17(a): Locations of Concern using Submitted GPS Coordinates.....              | 48 |
| Figure 2-17(b): Overview of Locations 1, 2, and 3 .....                                | 49 |
| Figure 2-17(c): Aerial Photo Comparison at Location 1 from 1995 to 2011 .....          | 49 |
| Figure 2-17(d): Aerial Photo Comparison at Locations 2 and 3.....                      | 50 |
| Figure 2-18(a): Structure Names and Locations of Concern near River Mile 145.....      | 52 |
| Figure 2-18(b): Overview of Location 1.....  | 53 |
| Figure 2-18(c): Aerial Photo Comparison Near Location 1 from 1991 to 2011 .....        | 54 |
| Figure 2-18(d): Overview of Locations 2-5.....   | 55 |
| Figure 2-18(e): Aerial Photo Comparison for Loaction 2-5 from 1995 to 2011 .....       | 56 |
| Figure 2-19(a): Submitted Photos of Area of Concern between RM 163 and RM 164.....     | 57 |
| Figure 2-19(b): Overview of Area of Concern .....                                      | 58 |
| Figure 2-19(c): Aerial Photo Comparison for Area of Concern from 1991 to 2011 .....    | 58 |
| Figure 2-19(d): Structure D171.5 Repair Details .....                                  | 59 |
| Figure 2-19(e): Flow Conditions Upstream of Stucture D171.5 in 2006 .....              | 59 |
| Figure 2-20 (a): Overview of Area of Concern .....                                     | 61 |
| Figure 2-20(b): Aerial Photo Comparison at Area of Concern from 1995 to 2001.....      | 62 |
| Figure 2-21(a): Submitted Photos of Area of Concern.....                               | 63 |
| Figure 2-21(b): Overview of Area of Concern .....                                      | 64 |
| Figure 2-21(c): Aerial Photo Comparison Near Area of Concern from 1995 to 2011 .....   | 64 |
| Figure 2-22(a): Submitted Photos for River Mile 232.3.....                             | 66 |

|  |     |
|--|-----|
| Figure 2-22(b): Overview of Area of Concern .....  | 66  |
| Figure 2-22(c): Aerial Photo Comparison of Area of Concern from 1991 to 2012 .....             | 67  |
| Figure 2-23(a): Overview of Area of Concern .....  | 68  |
| Figure 2-23(b): Aerial Photo Comparison for Area of Concern from 1994 to 2012 .....            | 68  |
| Figure 2-24(a): Overview of Locations 1 – 9 .....  | 70  |
| Figure 2-24(b): Overview of Locations 9 - 25 .....   | 71  |
| Figure 2-25: Overview of Location 1 .....  | 72  |
| Figure 2-26(a): Overview of Location 2 .....   | 73  |
| Figure 2-26(b): Aerial Photo Comparison at Location 2 from 1990 to 2012 .....                  | 74  |
| Figure 2-26(c): Change of Levee Location Near Location 2 .....                                 | 74  |
| Figure 2-27: Overview of Locations 3 - 6 .....   | 75  |
| Figure 2-28: Overview of Locations 7 - 9 .....   | 75  |
| Figure 2-29: Overview of Location 10 .....   | 75  |
| Figure 2-30(a): Overview of Locations 11 and 12 .....  | 76  |
| Figure 2-30(b): Aerial Photo Comparison at Locations 11 and 12 from 1995 to 2012 .....         | 77  |
| Figure 2-31(a): Overview of Locations 13 and 14 .....  | 78  |
| Figure 2-31(b): Aerial Photo Comparison at Locations 13 and 14 from 1995 to 2012 .....         | 79  |
| Figure 2-32(a): Overview of Location 15 .....  | 80  |
| Figure 2-32(b): Aerial Photo Progression near Location 15 from 1995 to 2012 .....              | 81  |
| Figure 2-33(a): Overview of Locations 16 – 19 .....  | 82  |
| Figure 2-33(b): Aerial Photo Comparison at Locations 16 – 19 from 1995 to 2012 .....           | 83  |
| Figure 2-34(a): Overview of Locations 20 – 22 .....  | 84  |
| Figure 2-34(b): Aerial Photo Comparison for Location 20-22 from March 1995 to March 1997 ..... | 85  |
| Figure 2-34(c): Aerial Photo Comparison for Location 20-22 from June 2006 and June 2007 .....  | 85  |
| Figure 2-34(d): Aerial Photo Comparison for Location 20-22 from July 2010 and Aug 2012 .....   | 86  |
| Figure 2-35(a): Overview of Locations 23 - 25 .....  | 87  |
| Figure 2-35(b): Aerial Photo Comparison at Locations 23 – 25 from 1995 to 2012 .....           | 88  |
| Figure 2-36: Locations 27 and 28 .....   | 89  |
| Figure 3-1(a): Overview of Location of Concern Near River Mile 8 .....                         | 91  |
| Figure 3-1(b): Aerial Photo Comparison from 1988 to 2011 .....                                 | 92  |
| Figure 3-2: Structure Names and Locations near River Mile 290 and River Mile 296 .....         | 93  |
| Figure 3-3: Overview of Area of Concern .....  | 94  |
| Figure 4-1(a): Photo Submitted by Larry Hicks near River Mile 320 .....                        | 95  |
| Figure 4-1(b): Overview of Area of Concern Near River Mile 320 .....                           | 96  |
| Figure 4-1(c): Aerial Photo Comparison near Area of Concern from 1996 to 2012 .....            | 96  |
| Figure 4-2(a): Submitted Photo by Larry Hicks between River Mile 324 – 325 .....               | 97  |
| Figure 4-2(b): Overview of Area of Concern Near River Mile 324 and 325 .....                   | 97  |
| Figure 4-2(c) Aerial Photo Comparison Near Area of Concern from 1996 to 2012 .....             | 98  |
| Figure 4-3(a): Overview of Area of Concern Near River Mile 435 .....                           | 99  |
| Figure 4-3(b): Aerial Photo Comparison Near Area of Concern from 1997 to 2012 .....            | 100 |

|  |     |
|--|-----|
| Figure 4-4(a): Overview of Location of concern near River Mile 490.....            | 101 |
| Figure 4-4(b): Submitted Pre-Flood Photo near Location of Concern .....            | 102 |
| Figure 4-4(c): Aerial Photo Comparison for Area of Concern from 1996 to 2009 ..... | 102 |
| Figure 4-4(d): Aerial Photos of Flood Damage Submitted by Mr. Derks .....          | 103 |
| Figure 5-1(a): Location of Concern near River Mile 211 .....                       | 104 |
| Figure 5-1(b): Bank Movement near RM 211 over a Period of 21 Years .....           | 105 |
| Figure 5-2: Flow Modeled at Jameson Island Chute .....                             | 106 |
| Figure 6-1: Comparison of notched and un-notched locations. ....                   | 108 |

# 1.0 Introduction

The Kansas City District (KCD) of the U.S. Army Corps of Engineers (Corps) operates and maintains the Missouri River Bank Stabilization and Navigation Project (BSNP) between Rulo, Nebraska and the mouth of the Missouri River located north of St. Louis, Missouri. The authorized purpose of the BSNP is to fix the river in one location while maintaining a reliable navigation channel. The BSNP provided an ancillary benefit of preventing most of the erosion that occurred prior to the project, but was not authorized or designed to prevent all erosion. As a result, erosion remains a constant threat to property and infrastructure located along the river.

Since 1975, the Corps has instituted a ‘notching’ program comprised of selectively removing portions of rock structures to increase flow conveyance and improve the aquatic habitat of the river. The notching program has always been a concern to landowners along the river due to the potential for erosion problems caused by notches located too close to the bank.

During an April 2012 Corps public meeting at Arrowrock, Missouri regarding a proposal to extend the Jameson Island Chute, landowners in attendance expressed concern about bank erosion caused by notching. In response, the Corps requested a list of problem notch locations so that the locations could be evaluated and the results reported back to stakeholders. The Missouri Department of Natural Resources facilitated the compilation of the list and forwarded the list to the KCD. A total of 18 individuals submitted a total of 82 locations. This report presents the evaluations of the 82 locations submitted.

## 1.1 History of the BSNP and Land Accretion

Prior to commencement of work on the BSNP, the Missouri River was a shallow, meandering river flowing through an alluvium filled valley. The river changed locations within the flood plain by continuously eroding the banks and by cutting new channels during flood events. Land lost in one place was ultimately accreted in another place with no net increase or decrease in river surface.

Congress authorized the development of a 6-foot navigation channel from Kansas City to the mouth on July 25, 1912 and in 1927, extended the Project upstream to Sioux City, Iowa. A Project designed to secure a 9-foot navigation channel from Sioux City to the mouth of the Missouri River was authorized in 1945 by the Rivers and Harbors Act, as set forth in House Document 274, 76<sup>th</sup> Congress. This is the current authorization of the BSNP.

Paragraph 58, on page 19 of House Document 274 recommends the adoption of a project for the improvement of the Missouri River between Sioux City and the mouth of the Missouri River by “means of bank revetment, permeable dikes to contract and stabilize the waterway, cut-offs to eliminate long bends, dams for closing minor channels, removal of snags, and dredging for improvement and maintenance as required, with a view to securing a navigable channel of 9-foot depth and a minimum width of not less than 300 feet....”

Numerous previously published reports were reviewed during the development of House Document 274 including House Document 238, 73<sup>rd</sup> Congress, commonly known as the 308 Report. The 308 Report, on page 195, discusses the method of improvement used up to that point and says “...this method consisted of 2 stages: Namely, stabilization and regulation”. The report goes on to define stabilization as “confining the river to a smoothly curved discharge channel of a uniform width ...by the use of permeable dikes and bank revetment” and defines regulation as “shaping the low-water channel properly in order to obtain the most effective depth.”

Stabilization and regulation resulted in fixed outer banks and inner banks that moved riverward as deposition and ensuing land formation occurred between the dikes. As a result of this work, the river no longer changed its location within the floodplain, a reliable 9 feet by 300 feet navigation channel was established, and 188,000 acres of the river downstream of Sioux City were converted from river surface to accreted land. The land accretion process that occurred at Indian Cave Bend can be seen in Figure 1-1.

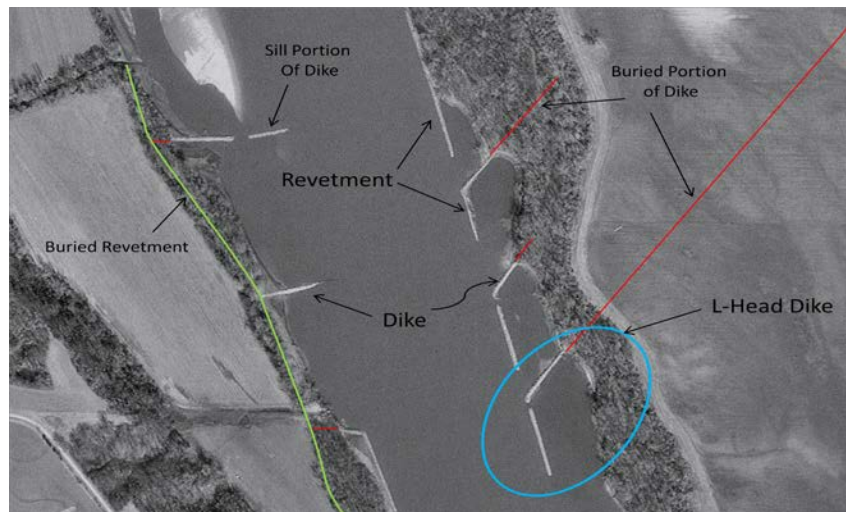




**Figure 1-1: Accretion process at Indian Cave Bend.**

During the construction phase of the BSNP there was no specific location where the bank was designed to accrete. Rather, as structures were constructed and existing structures extended, the trend was accretion and riverward movement of the bank lines. This process was greatly enhanced by the relatively high sediment loads in the river during this time period. The accretion that took place was a desired benefit of construction but was not an authorized purpose and did not materially affect the performance of the BSNP either positively or negatively.

In 1980, the Project was declared officially complete and entered its operational phase, which consists primarily of maintaining the existing dikes and revetments and the occasional construction of new structures. The rock structures are maintained to criteria established in 1974. Structure types can be seen in Figure 1-2.



**Figure 1-2: Typical Structure Layout.**

After the completion of the Project in 1980, the amount of additional accretion was minor as the river adjusted to the full complement of structures. It is likely that the maximum amount of accretion was occurred during the years immediately prior to the 1993 flood. Since the 1993 flood, banklines have either remained in place or experienced gradual landward movement.

## 1.2 Structure Notching

### 1.2.1 History

In 1975, under the authority and funding of the BSNP, the Corps developed what was called the “Riverine Habitat and Floodway Restoration Program” on the river. The objective of the program was to arrest further loss of water surface area and therefore maintain or improve the aquatic habitat of the river and maintain or improve the flow conveyance capacity of the river. Structure notching was a component of that Program. Recently, structure notching has also been used to meet the objectives of the Corps’ Missouri River Fish and Wildlife Mitigation Project and to meet the requirements of the 2003 Fish and Wildlife Service’s Biological Opinion on the operation and maintenance of the BSNP.

A notch is the removal of a portion of a dike or revetment riverward of the high bank. Depending on the material used in construction of the structure, the removed portion is comprised of wood piling, stone fill, or wood piling with stone fill. The notch will have a width and depth measured from an imaginary sloping plane called the Construction Reference Plane (CRP). The CRP is a water surface elevation that is exceeded 75% of the time during the eight month navigation season and is generally within a few feet of the elevation of full service navigation flow. Figure 1-3 illustrates a cross section profile of a dike structure with a notch in the sill and a notch in the dike itself.

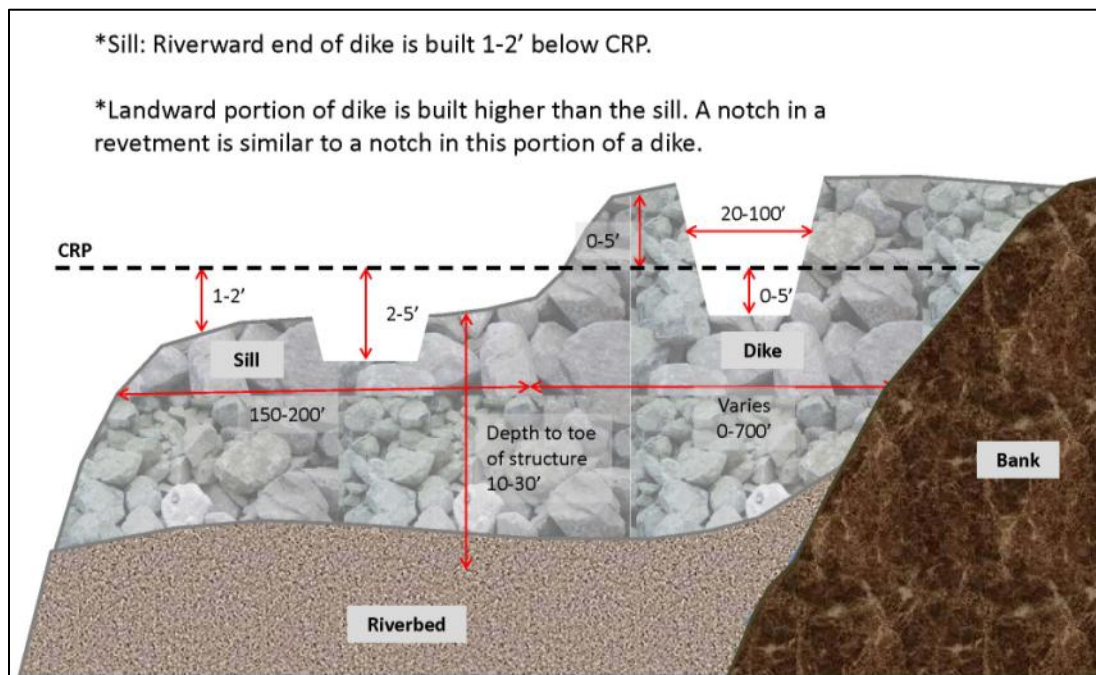
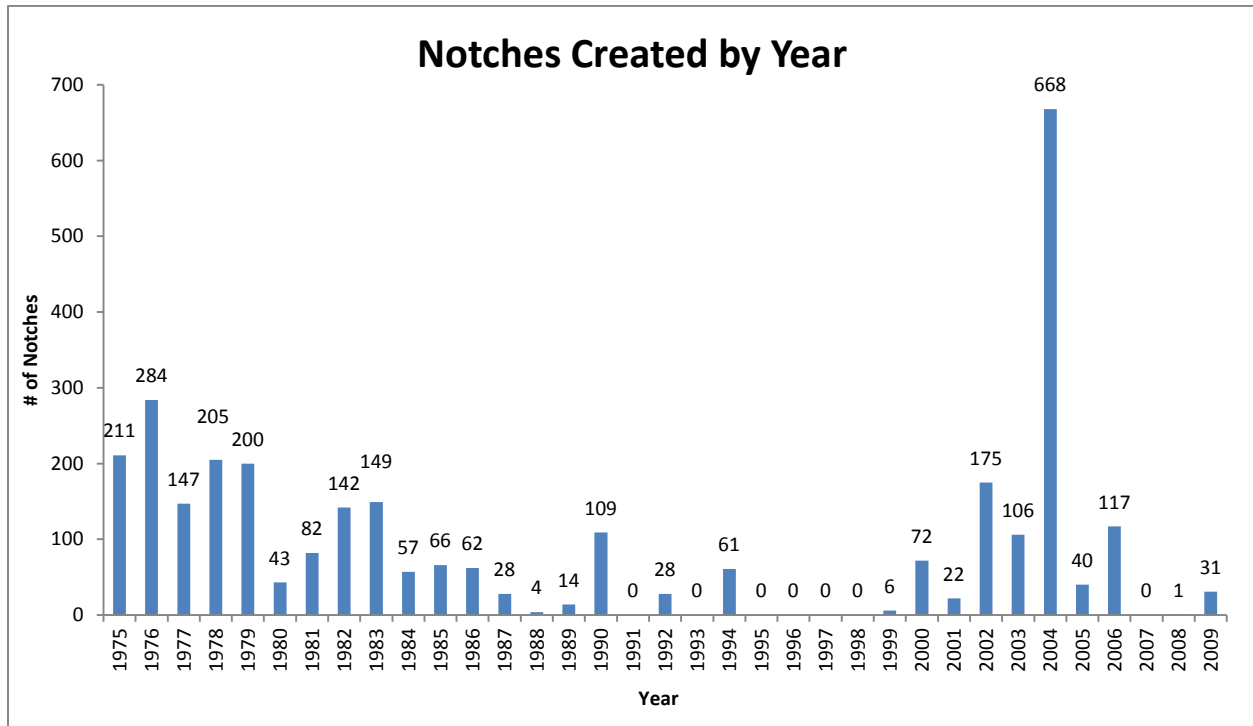


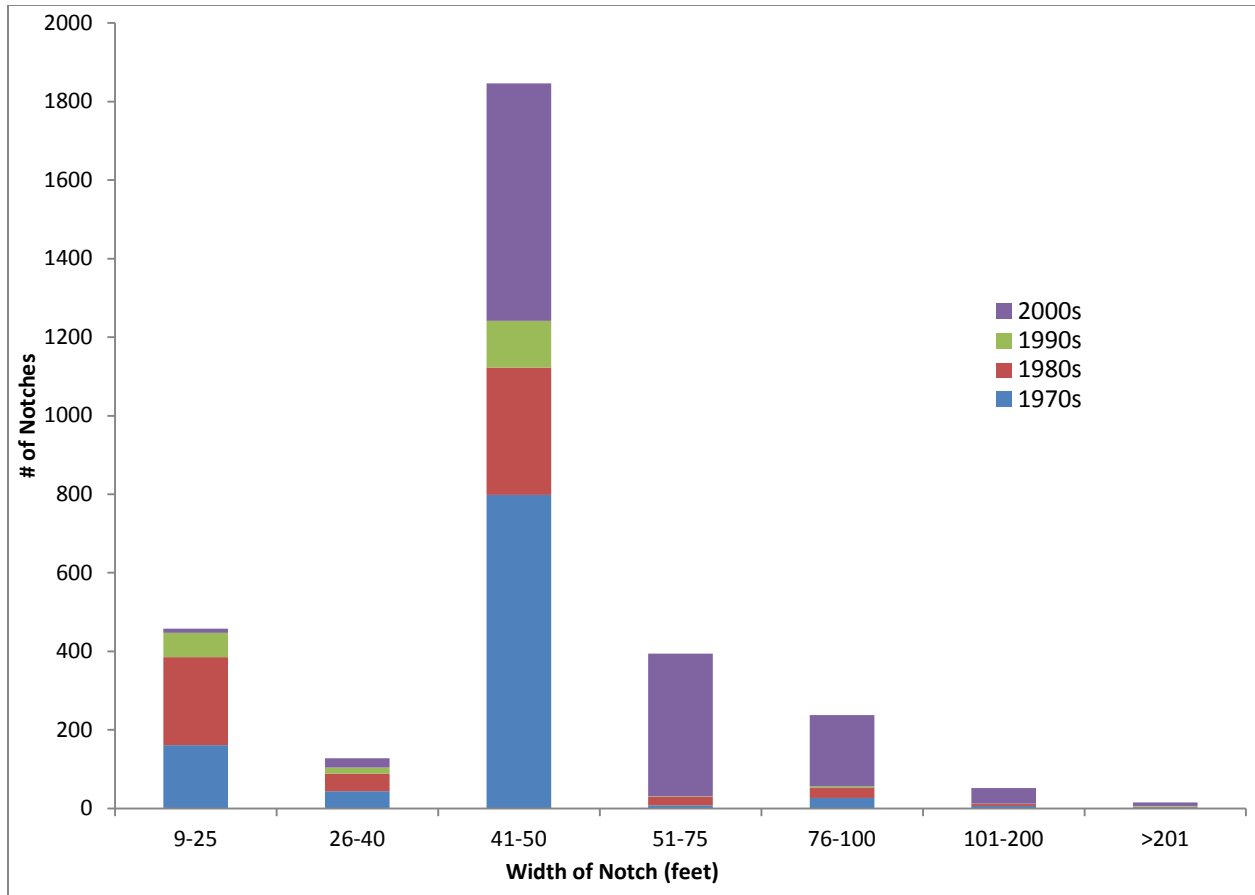
Figure 1-3: Typical Cross Section of Notch

Between 1975 and 2000, the KCD constructed approximately 1,900 notches. Since 2000, an additional 1,300 notches have been constructed. Notches constructed by the KCD per year are illustrated in Figure 1-4. The high number of notches in 2004 were constructed to off-set the additional acres of shallow water habitat that would have been realized had a low summer flow regime been implemented as required in the 2003 Biological Opinion.



**Figure 1-4: Notches Constructed by KCD Since 1975**

The number of notches constructed by width of notch and by decade is shown in Figure 1-5 below. The majority of notches are between 41- and 50-foot wide.



**Figure 1-5: Width of Notches Constructed by Decade**

### ***1.2.2. Notch Design Considerations Relative to Bank Erosion***

The width, depth, and location of each notch is based on the intent of the notch. Most notches are intended to provide flow diversity and connectivity for the aquatic areas upstream and downstream of a structure. These notches are smaller and located away from the bank to prevent adverse impacts to the bank. Larger notches, located next to the bank, provide flow diversity and connectivity, and are also intended to erode the bank and increase the surface area of the river. Large notches are *always adjacent to public property*. Figure 1-6 below classifies notches as either small, medium, or large based on notch width and depth.

| Depth Below CRP (feet) | Width (feet) |    |        |    |       |  |
|------------------------|--------------|----|--------|----|-------|--|
| 0                      | 20           | 40 | 60     | 80 | 100   |  |
| 2                      | 20           | 40 | 60     | 80 | 100   |  |
| 3                      | 20           | 40 | 60     | 80 | 100   |  |
| 4                      | 20           | 40 | 60     | 80 | 100   |  |
| 5                      | 20           | 40 | 60     | 80 | 100   |  |
| 6                      | 20           | 40 | 60     | 80 | 100   |  |
|                        | Small        |    | Medium |    | Large |  |

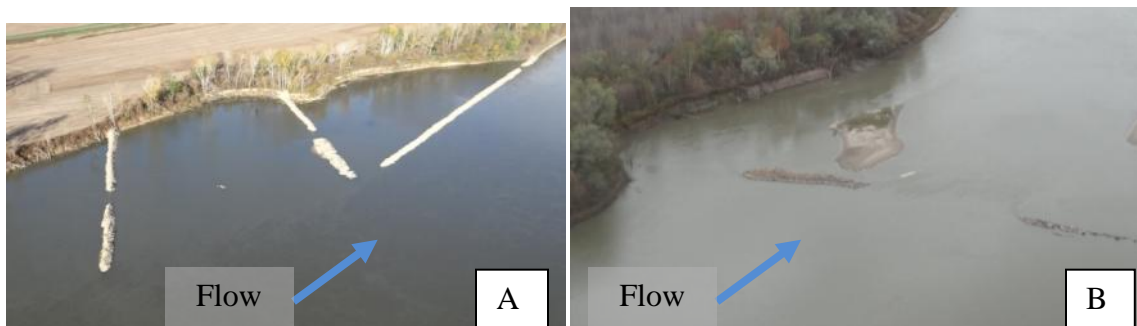
**Figure 1-6: Size Classes For Various Width and Depths of Notches.**

To avoid undesired bank erosion, a notch must be located an appropriate distance from the bank line. The larger the notch, the further the distance required. Considerations such as whether the notch is located on the inside or outside of a bend, orientation of the structure relative to the bank, and spacing of adjacent structures prevent promulgation of a minimum distance from the bank. A notch study published by the Corps in 1982 recommended the minimum distance between a notch and the bank of 25 feet (USACE 1982: 68). The distances in Figure 1-7 provide a general guideline for notch placement where erosion of the bank cannot be tolerated. Figure 1-8 illustrates two examples of notches with variation in size and location.

| Size   | Distance From Bank (feet) |    |    |    |     |     |
|--------|---------------------------|----|----|----|-----|-----|
| Small  | 20                        | 40 | 60 | 80 | 100 | 120 |
| Medium | 20                        | 40 | 60 | 80 | 100 | 120 |
| Large  | 20                        | 40 | 60 | 80 | 100 | 120 |

Red: Likely to have impact.  
Yellow: Could have impact.  
Green: Unlikely to have impact.

**Figure 1-7: General Guideline for Distance of Notch to Bank**



**Figure 1-8: Examples of Notch Size and Location:**

*Photo A is example of medium sized notches intended to diversify the aquatic habitat around the structures: notches are smaller and located away from the bank. Photo B shows one dike with two large notches: notch next to the bank is intended to erode the bank; riverward notch is intended to diversify habitat. In the second example, due to the large size of both notches, the dike was extended riverward to compensate for flow through the notches.*

### ***1.2.3 Design Considerations Relative to Navigation***

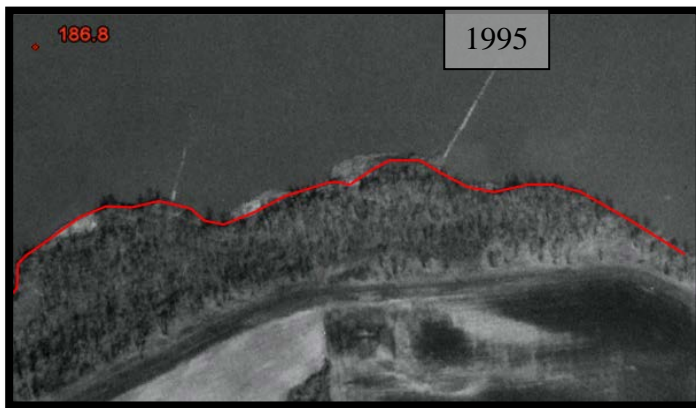
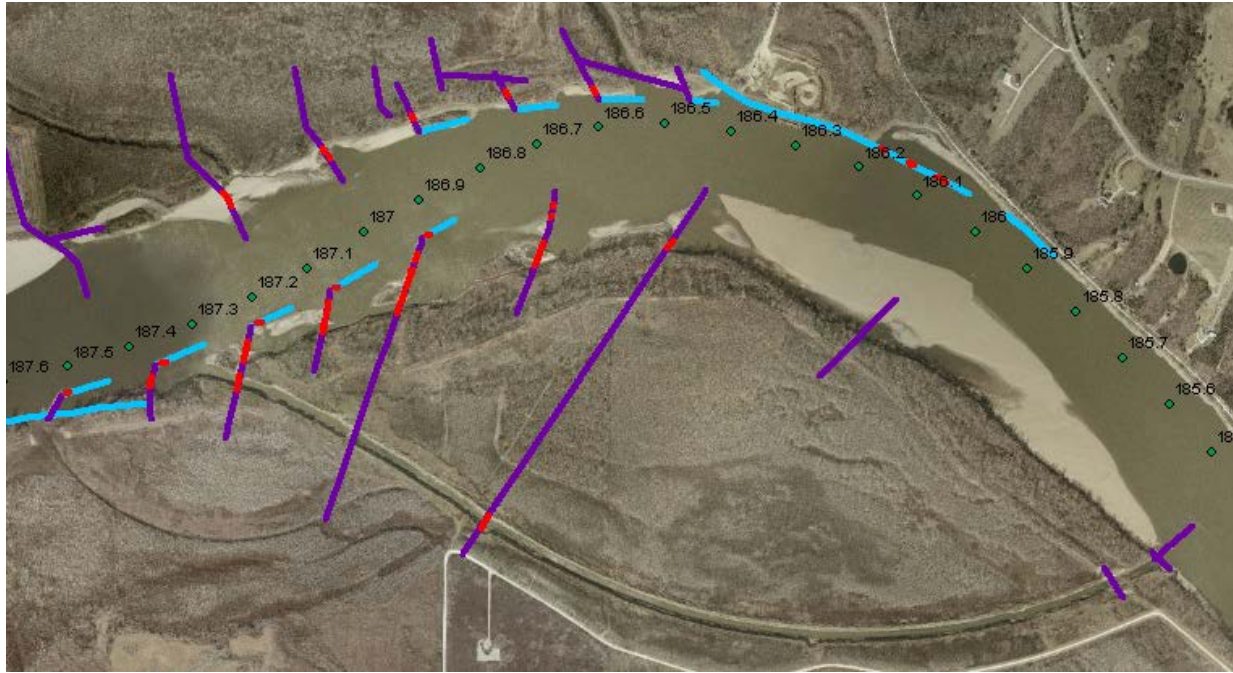
The width, depth, and location of a notch influence the amount of flow through the notch. Larger notches carry more flow than smaller notches, and notches in structures oriented perpendicular to flow (dikes) convey more flow than similar sized notches in structures oriented parallel to flow (revetments). During low navigation flows, the flow through a notch is generally less than 1% of total river flow thus preserving flow needed in the navigation channel. As flows increase, and channel flows are not as critical, the percent of total river flow through the notch can increase up to about 3%, peaking when the river stage is at the top of the dike. As structures are overtopped, the percentage of flow through the notch decreases due to the declining cross sectional area of the notch relative to the cross sectional area of the river. In almost all cases, the flow conveyed through a notch returns back to the channel within one mile downstream.

### ***1.2.4 Notches and Aquatic Habitat Improvement***

Smaller notches, when flow is below the top of the structure, provide connection between the aquatic areas upstream and downstream of the structure and also improve the habitat in these same areas by creating velocity diversity. Larger notches also improve the habitat through velocity diversity, but also create depth diversity due to the scouring action of the higher flow through the larger notch. Depth and velocity diversity are desirable aquatic habitat attributes. In addition, the scour action of larger notches prevents deposition which can lead to the establishment of woody growth and encroachment of the bank reducing the width of the river channel. Thus, larger notches help to maintain the flow conveyance capacity of the river by maintaining the river's cross sectional area.

Larger notches, along public property and designed to erode the bank, direct water at the base of the bank, eroding away the bank which leads to increased acreage of open river and increased area of aquatic habitat. These notches are moved toward the bank in an iterative process as the bank slowly erodes away. An example of this erosion on federal land at Overton Bottoms North near River Mile 186 can be seen in Figure 1-9 below.





**Figure 1-9: Bank Erosion on Federal Land for Increased Aquatic Habitat**

## 1.3 Bank Erosion

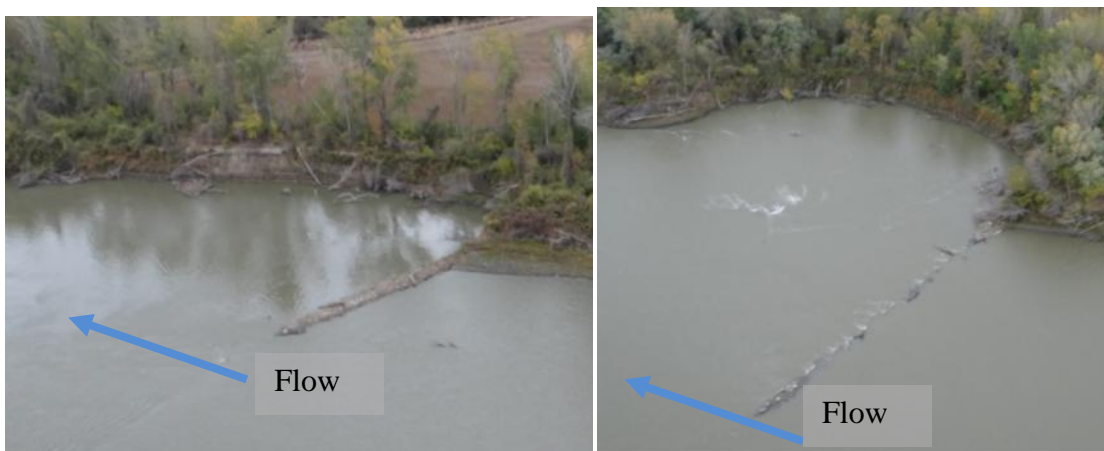
Due to the non-cohesive nature of the bank material found along the Missouri River, bank erosion has always been a constant threat to land and infrastructure located along the river. Increased discharge in the river over time, abnormally prolonged periods of bank-full flow, and low sediment loads in the river can exacerbate the erosion threat. Observation over time indicates that the general trend along the river is eroding banks and widening of the top-width of the river. This trend is especially pronounced in certain reaches of the river such as between Sugar Creek and Glasgow, Missouri and downstream of Hermann, Missouri.

### *1.3.1 Bank Erosion Caused by Notches*

If a notch is found to be the causing or contributing to an erosion problem, the notch will be filled. Since 2000, less than 10 notches have been filled because they caused or contributed to undesired bank erosion.

### *1.3.2 Bank Erosion Not Caused by Notches*

The banks above revetments and upstream and downstream of the dikes are not armored with rock and are subjected to the erosive action of the river's flow under the right conditions. Two examples of erosion behind dikes with no notches are shown in Figure 1-10.



**Figure 1-10: Two examples of erosion around structures with no notches.**

BSNP funds may only be spent on expenditures which expressly authorized or are reasonably necessary for operation and maintenance of the project. Erosion protection is not expressly authorized and therefore expending BSNP funds for erosion protection must be analyzed under the necessary expense test. This test requires the expense to be reasonably necessary in carrying out an authorized function or materially contribute to the effective accomplishment of that

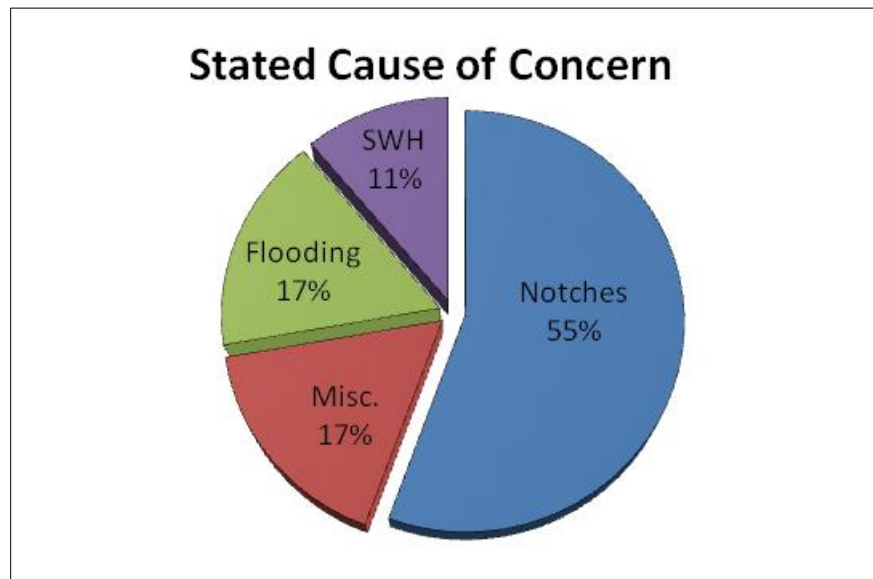


function. As the performance of the BSNP is generally independent of the location of the bank line, expending funds to prevent erosion is usually not a necessary expense.

For these reasons, erosion protection of the bank above revetments or between the dikes is rarely an authorized expenditure. Some exceptions are when erosion is removing bank material behind a revetment and the revetment's stability is dependent on the bank or when the erosion threatens to detach a dike from the bank allowing water to flow between the dike and the bank.

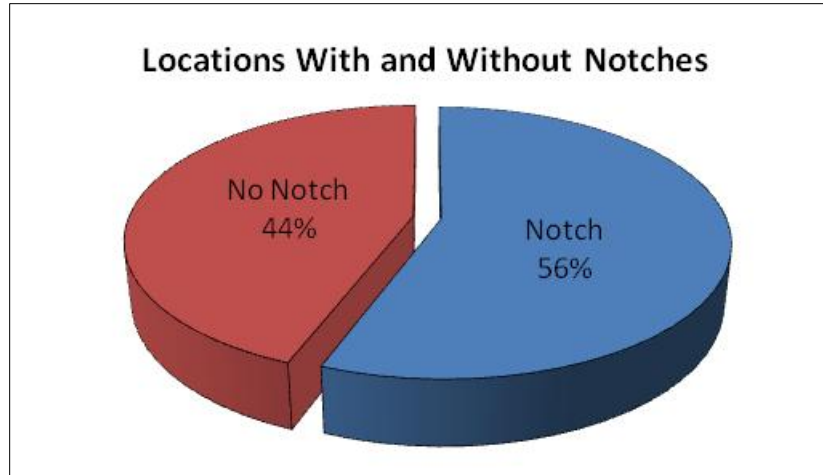
## 1.4 Reported Bank Erosion Problem Areas

A total of 18 individuals submitted locations of bank erosion concern. Of the 18 individuals, 10 stated notches as the cause of the bank erosion, two stated shallow water habitat (SWH)/mitigation as the cause of the bank erosion, three stated the 2011 flood as the cause of the bank erosion and three stated miscellaneous reasons for the bank erosion such as high water and insufficient structure height. The breakdown of the stated cause of bank erosion by the 18 individuals can be seen in Figure 1-11(a).



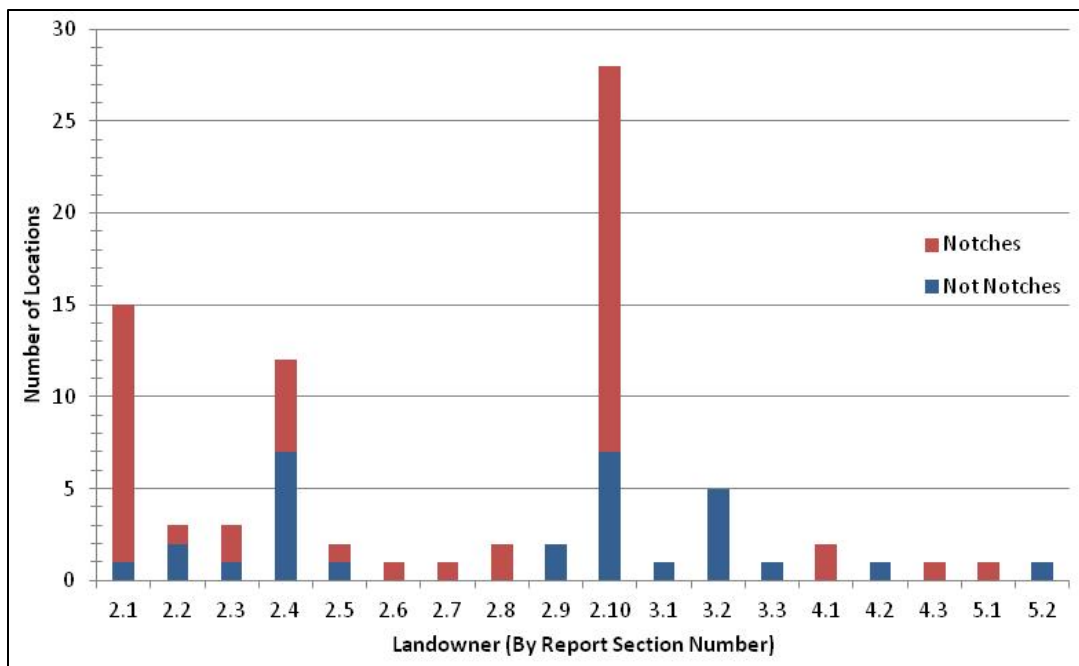
**Figure 1-11(a): Breakdown of Stated Cause by Category**

The 18 individuals submitted a total of 82 locations. Of the 82 locations, 52 locations have a notch on a structure in the immediate area. The breakdown of locations with and without notches is presented in Figure 1-11(b). Of the ten landowners who stated notches as the cause of bank erosion, a total of 59 individual locations were identified. Of these, 48 locations have notches and 11 locations do not have notches.



**Figure 1-11(b): Breakdown of Locations With and Without Notch**

Many of the landowners submitted only one or two specific locations. However, some landowners submitted multiple locations. Three landowners submitted over 67% of all locations. A breakdown of locations by landowner can be seen in Figure 1-12.



**Figure 1-12: Number and Type of Location by Landowner**

A standard evaluation process was followed for all 82 locations reported. The evaluation process consisted of the following steps:

1. Review of all submitted photos, descriptions and maps
2. Investigate nearby structure history including notches and structure repairs
3. Establish extent of bank line location change using dated aerial photos

4. Determine if the submitted location is on Federal or State property
5. Contact landowner for more information (if needed)
6. Conduct site visit to collect additional information (if needed)

Each location evaluation consists of the following sections:

1. A statement of problem as submitted by stakeholder including copies of photos submitted by stakeholder (if any)
2. An analysis of the problem area comprised of overview photo including a table of structure maintenance and/or notching records and aerial photo comparison
3. A conclusion

Aerial photo comparison is the best tool for determining bank movement over time. However, differing water levels in the photo series will show different bank line locations, especially on gently sloping banks. The visibility of the rock structures in the aerial photo is a good indicator of relative water level. In the overview photos, the green lines denote revetments, the blue lines denote dike structure, red lines denote notches, and the purple lines represent levees. Pink or purple shaded areas signify Federal or State owned land. Water flows downstream from higher river mile to lower river mile.

## 2.0 Erosion Analysis: Stated Cause is Notching

### 2.1 Locations from River Mile 57 to River Mile 93

A total of 15 different locations were submitted by Dan Kuenzel between river mile 57 and river mile 93. The first five locations submitted can be seen in Figure 2-1. All five of these locations contain notches.

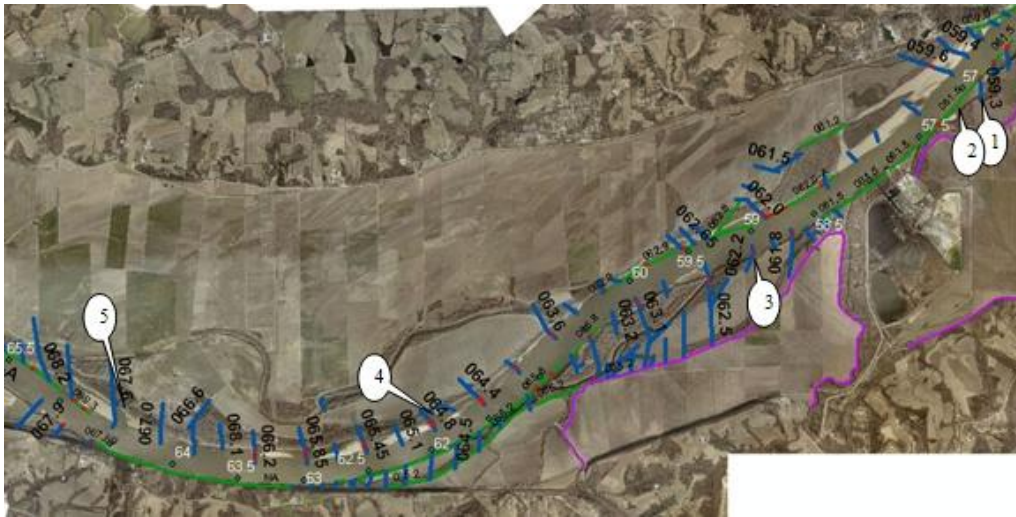


Figure 2-1: Locations 1-5 for Dan Kuenzel

#### 2.1.1 Location 1 and Location 2

##### Submitted Statement:

At Location 1, Mr. Kuenzel stated, “200 yards below MM 57 dike repair done this winter but still has notch in it should be closed up. This is in Labadie bottoms. Right bank.” His pictures of this area can be seen in Figure 2-2(a).



Figure 2-2(a): Submitted Photos for Location 1

At Location 2, Mr. Kuenzel stated, “Rock revetment in same location in major need of repair. 200 yards below MM 57 right bank.” Photos of this location can be seen in Figure 2-2(b).



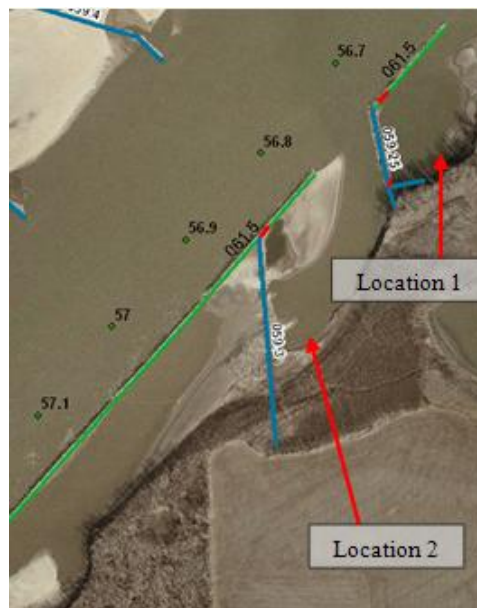
**Figure 2-2(b): Submitted Photos for Location 2**

**Analysis:**

Locations 1 and 2 are located near dikes D059.3 and D059.25 and revetment R061.5. There are a total of three notches at these locations. Table 2.1 below shows notch details, including width, depth, and the year the notches were constructed.

**Table 2.1: Notching near Locations 1 and 2**  
*(Refer to Figure 2-2(c) for Structure Locations)*

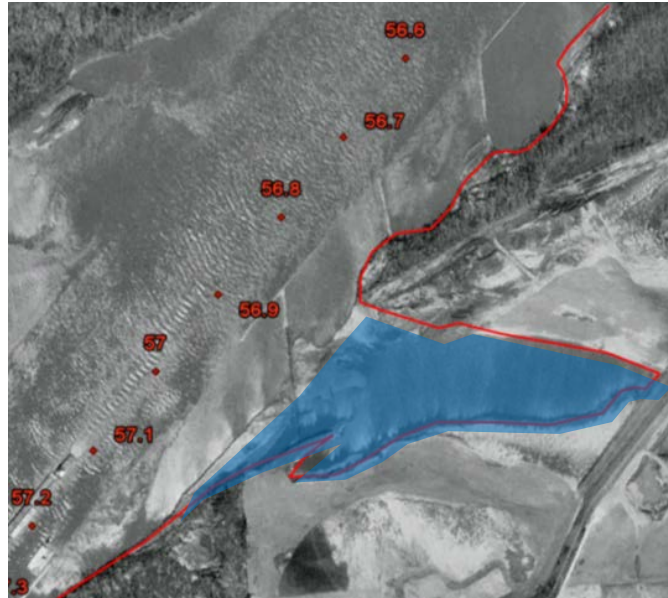
| <i>Structure</i> | <i>Station</i> | <i>CRP Elev (ft)</i> | <i>Width (ft)</i> | <i>Year</i> | <i>Distance from Bank</i> |
|------------------|----------------|----------------------|-------------------|-------------|---------------------------|
| R061.5           | 85+18 to 85+68 | 0                    | 50                | 1976        | 635                       |
| R061.5           | 93+52 to 94+02 | 0                    | 50                | 1979        | 500                       |
| D059.25          | 24+00 to 24+60 | -3                   | 60                | 2004        | 130                       |



**Figure 2-2(c): Overview of Locations 1 and 2**

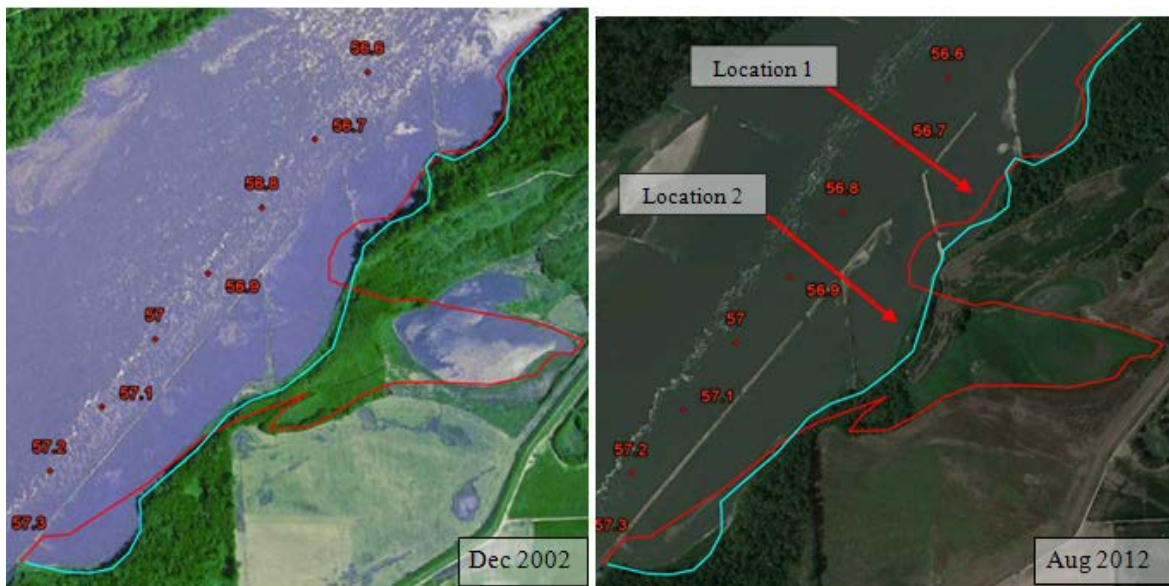


After the 1995 flood event, a large scour hole developed at this location. The area affected by the scour hole is highlighted in blue in Figure 2-2(d). The revetment was repaired with 21,585 tons of stone fill immediately after the flood.



**Figure 2-2(d): Scour Hole from 1995 Flood**

The most recent aerial photo available after the 1995 flood event was taken in 2002. Aerial photos from 2002 and 2012 were compared. The 2002 photo predates the notch in D059.25 but is after the notches in R61.5 were constructed. The red line represents the bank line in 1995 as shown in figure 2-2(d) above and the blue line indicates the bank line in 2002. These photos are shown in Figure 2-2(e) below.



**Figure 2-2(e): Aerial Photo Comparison of Locations 1 and 2 over 10 years**

**Conclusion:**

The large scour hole from the 1993 flood has almost completely filled in. Between 1995 and 2002, one bank location experienced erosion but it is upstream of all three notches and therefore not caused by the notches. This area appears to have partially filled in between 2002 and 2012. The notches do not appear to be causing bank erosion.



### 2.1.2 Location 3

#### Submitted Statement:

Mr. Kuenzel stated, “Boles bottom at MM 59 shows heavy bank erosion some rock was added in last years but more is needed right bank.” His photos taken at Location 3 can be seen below in Figure 2-3(a).



**Figure 2-3(a): Submitted Photos for Location 3**

#### Analysis:

Location 3 is located downstream of structure D062.2 near the Labadie Power Plant intake. A notch was constructed at this location in 1985 and the structure repaired in 2009 with nearly 1,000 tons of rock. Notch details can be seen in Table 2.2.

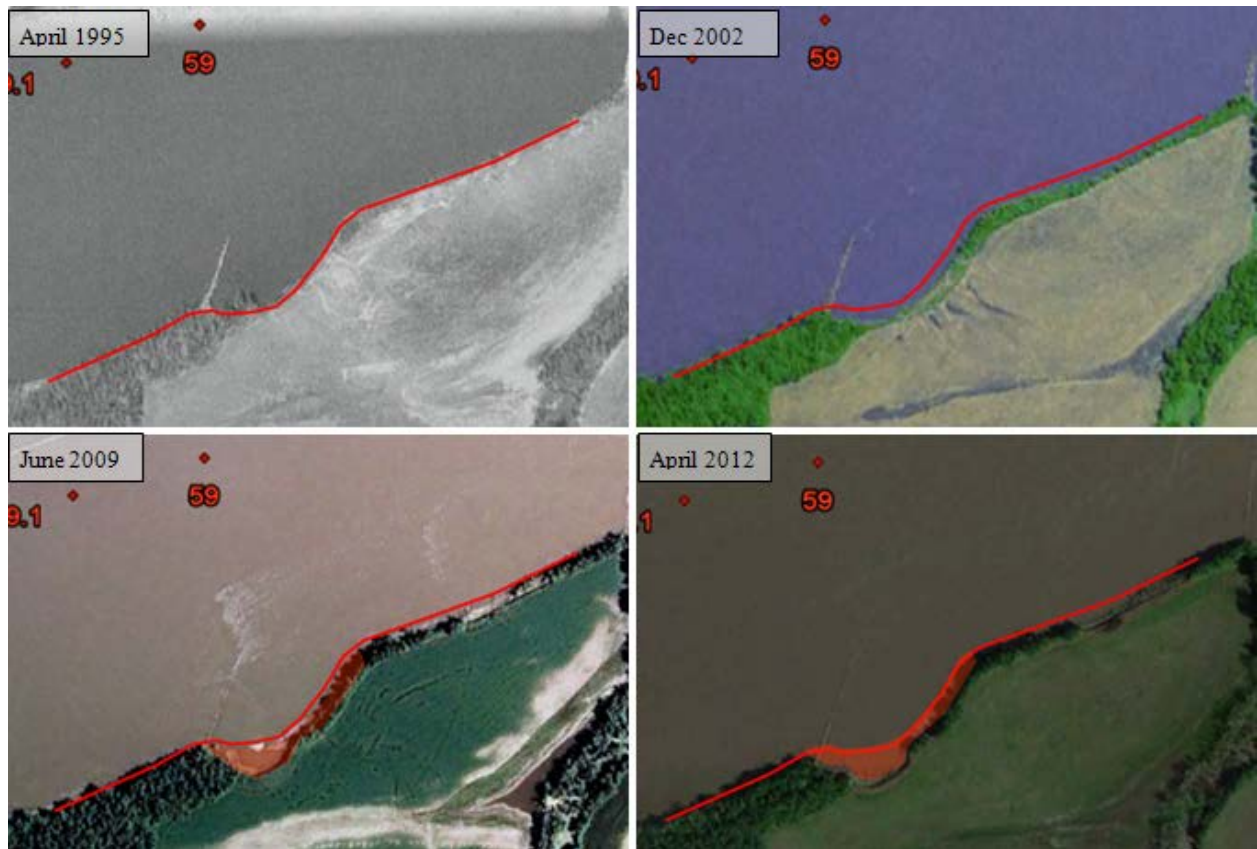
Table 2.2: Notching near Locations 3  
(Refer to Figure 2-3(b) for Structure Locations)

| Structure | CRP Elev (ft) | Width (ft) | Year | Distance from Bank (ft) |
|-----------|---------------|------------|------|-------------------------|
| D062.2    | -2            | 20         | 1985 | 250                     |



**Figure 2-3(b): Overview of Location 3**

Aerial photos between 1995 and 2012 were compared. The photos in Figure 2-3(c) indicate the bank has eroded near the root of D062.2.



**Figure 2-3(c): Aerial Photo Comparison of Location 3 over 17 years**

The bank near the root of the dike shows some erosion in the 2002 photo. By 2009, the bank had moved 120 feet from the bank location of April 1995. The bank location does not appear to have moved since 2009 when the dike was repaired. Over the period of 17 years shown in the aerial photos, the bank line moved as indicated by the red shaded area in Figure 2-3(c).

**Conclusion:**

There is erosion at this location near the root of the dike structure. The dike contains a notch that is 20 feet wide with a bottom elevation one foot below the top of the adjacent dike height, and is at least 250 feet from the bankline. Since the notch is only 20 feet wide and 1 foot deep, located out on the dike and slightly downstream of most of the erosion, and has been in place since 1985, it is unlikely the cause of the erosion that has occurred near the root of the dike. The dike repair completed in 2009 should help prevent further erosion.

### 2.1.3 Location 4

#### Submitted Statement:

For Location 4, Mr. Kuenzel stated, “Augusta bottom 200 yards below MM 62 left bank showing hard points that have been put in along with additional rock laid against the toe of the levee. Notice the farmer moving hay bales on the top of the levee the bank of the river is less than 50 feet. There is no excuse for this.” His submitted photos of Location 4 can be seen in Figure 2-4(a).



**Figure 2-4(a): Submitted Photos for Location 4**

#### Analysis:

Location 4 is located at the root of structure D064.8 which contains a notch. Three hard points were added at this location in 2002. Notch details can be seen in Table 2.3.

Table 2.3: Notching Performed near Location 4  
(Refer to Figure 2-4(b) for Structure Locations)

| Structure | CRP Elev (ft) | Width (ft) | Year | Distance from Bank (ft) |
|-----------|---------------|------------|------|-------------------------|
| D064.8    | -3            | 50         | 1990 | 425                     |



**Figure 2-4(b): Overview of Location 4**

Aerial photos were compared over the past 17 years. The photos in Figure 2-4(c) indicate the bank eroded between 1995 and 2002 near the root of D064.8.



**Figure 2-4(c): Aerial Photo Comparison of Location 4 over 17 years**

**Conclusion:**

Since the notch is a small/medium notch, located 400 feet away from the bank, and not aligned so as to direct water toward the bank, it is unlikely the notch is the cause of the bank erosion that occurred near the root of the dike. Hard points were added in 2002 and the bank line has not changed since that time.



### 2.1.4 Location 5

**Submitted Statement:**

Mr. Kuenzel stated, “Pictures...show rock revetment needing major repair this is MM 65 left bank.” His submitted photos can be seen below in Figure 2-5(a).



**Figure 2-5(a): Submitted Photos for Location 5**

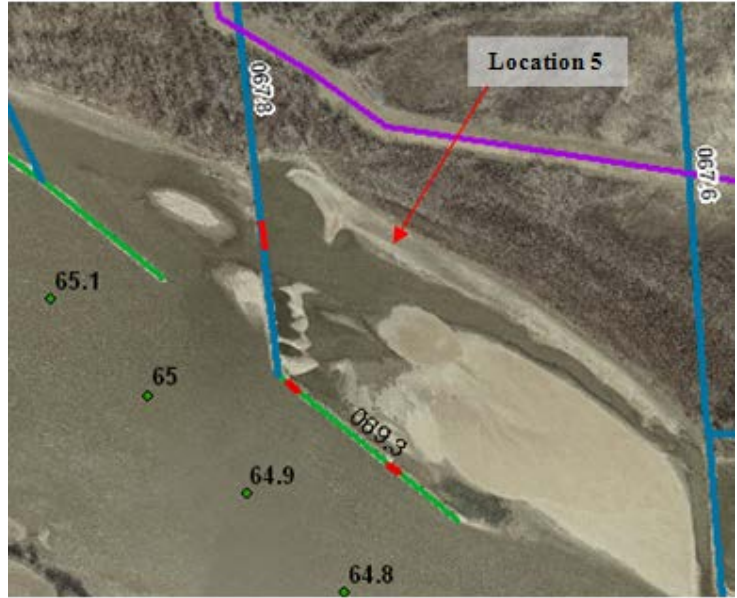
**Analysis:**

Location 5 is located near two notches in revetment R069.3 and one notch in dike D067.8. Details can be seen in Table 2.4. In 2002 the revetment was repaired with almost 3,500 tons of stone fill to the design elevation of +5 CRP.

**Table 2.4: Notching Performed near Location 5**

*(Refer to Figure 2-5(b) for Structure Locations)*

| <i>Structure</i> | <i>Station (ft)</i> | <i>CRP Elev (ft)</i> | <i>Width (ft)</i> | <i>Year</i> | <i>Distance from Bank (ft)</i> |
|------------------|---------------------|----------------------|-------------------|-------------|--------------------------------|
| R069.3           | 74+15 to 74+65      | -2                   | 50                | 1979        | 750                            |
| R069.3           | 79+15 to 79+65      | -2                   | 50                | 1979        | 750                            |
| D067.8           |                     | -4                   | 60                | 1995        | 400                            |



**Figure 2-5(b): Overview of Location 5**

Aerial photos between 1995 and 2012 are shown in Figure 2-5(c) and indicate very little change in the bank line. This location experienced significant scour from the 1993 flood. Bank movement that has occurred since 1995 is represented by the red shaded area in the 2012 photo.



**Figure 2-5(c): Aerial Photo Comparison of Location 5 over 17 years**

**Conclusion:**

The notches in the revetment are small and between 750 – 800 feet from the bank. The notch in the dike is medium size and almost 400 feet from the bank. Most of the bank erosion is near the root of the dike which is upstream of all three notches and not affected by flow through the notches. Therefore, it is unlikely the notches are the cause of the bank erosion. The dike structure, D067.8, is currently on the deficiency list as being 3 feet low and will be repaired at the next opportunity. The erosion could be caused due to the deficient elevation of the dike structure next to bank.

The next 6 locations submitted by Mr. Kuenzel can be seen in Figure 2-6. Of these locations, five have notches nearby.



**Figure 2-6: Locations 6-11 for Mr. Kuenzel’s Areas of Concern**



### 2.1.5 Location 6 and Location 7

#### Submitted Statement:

Mr. Kuenzel stated, “Pictures... show revetment being cut this is at MM 70.7 left bank. There is no excuse for this at all.” He also notes an issue on the other side of the river and stated, “MM 70.7 right bank this is less than 100 feet from the toe of St Johns Island levee.” His submitted photos are shown in Figure 2-7(a).



**Figure 2-7(a): Submitted Photos for Location 6**

For location 7, Mr. Kuenzel stated, “Pictures... show heavy bank erosion from dike being notched at mm 71.5 right bank.” These photos are shown in Figure 2-7(b).



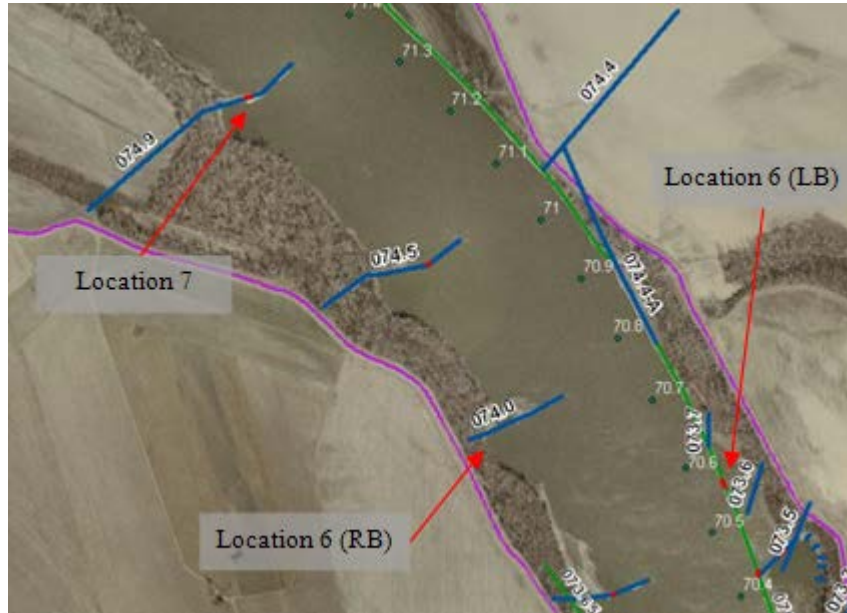
**Figure 2-7(b): Submitted Photos for Location 7**

#### Analysis:

Location 6 is near structure R078.1 on the left bank (contains a notch created in 2006) and near D074.0 on the right bank (does not contain a notch). D074.0 was repaired in 1990 and again in 2000 with a total of 9,178 tons of stone fill. The notch in D074.9 at Location 7 was constructed in 2005. Notch details are shown in Table 2.5.

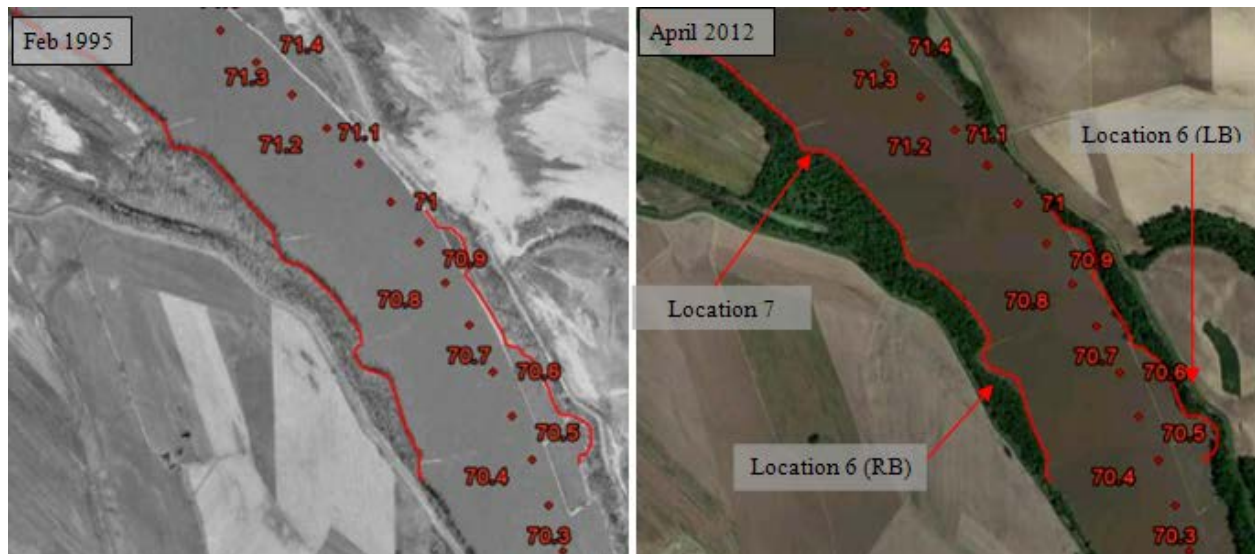
Table 2.5: Notching and Maintenance Performed near Locations 6 and 7  
(Refer to Figure 2-7(c) for Structure Locations)

| Structure | CRP Elev (ft) | Width (ft) | Year | Distance from Bank (ft) |
|-----------|---------------|------------|------|-------------------------|
| R078.1    | -5            | 56         | 2006 | 175                     |
| D074.9    | -4            | 50         | 2005 | 190                     |



**Figure 2-7(c): Overview of Locations 6 and 7**

Aerial photos from 1995 to 2012 were analyzed for Location 6 and 7 and are shown in Figure 2-7(d). The red line indicates the bank line location in February 1995.



**Figure 2-7(d): Aerial Photo Comparison near Location 6 and 7 over 17 year period**

**Conclusion:**

The left bank line and the right bank line areas for Location 6 and Location 7 have shown no movement since 1995, therefore, the notches have not caused any bank erosion.

## 2.1.6 Location 8

### Submitted Statement:

At Location 8, Mr. Kuenzel stated, “Pictures...shows dike notch at right bank MM 72 cut is very bad into bar ground that we farm.” His submitted photos of the location are shown in Figure 2-8(a).



**Figure 2-8(a): Submitted Photos for Location 8**

### Analysis:

Location 8 is near two notches in D076.5-A. Notch details can be seen in Table 2.6.

**Table 2.6: Notching near Location 8**

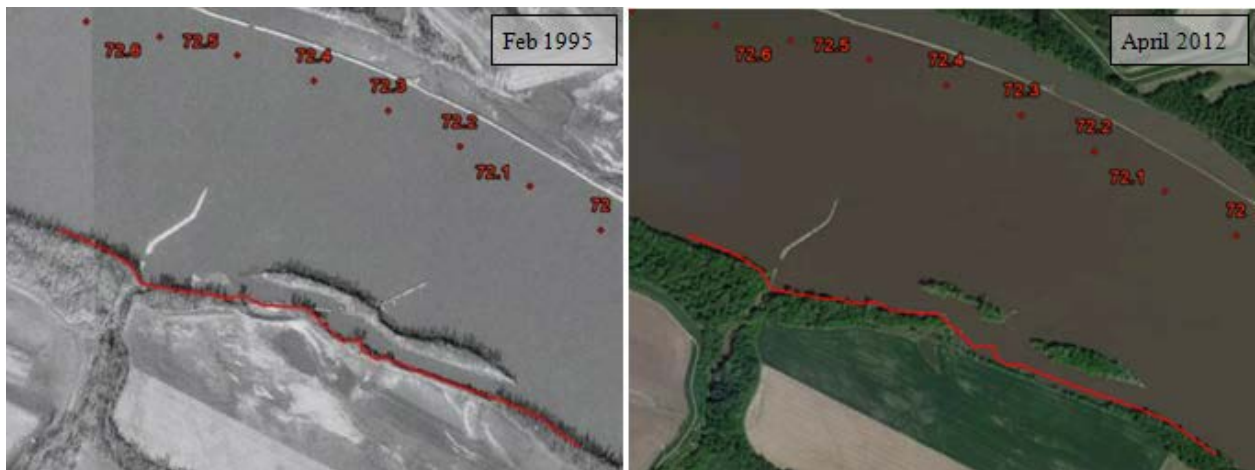
*(Refer to Figure 2-8(b) for Structure Locations)*

| Structure | CRP Elev (ft) | Width (ft) | Year | Distance from Bank (ft) |
|-----------|---------------|------------|------|-------------------------|
| D076.5-A  | -2            | 50         | 1975 | 100                     |
| D076.5-A  | 0             | 20         | 1990 | 650                     |



**Figure 2-8(b): Overview of Location 8**

Aerial photos from 1995 to 2012 were compared and are shown in Figure 2-8(c). The red line indicates the bank line location from 1995.



**Figure 2-8(c): Aerial Photo Comparison of Location 8 from 1995 to 2012**

**Conclusion:**

The bank line shows no movement over the 17 year period in the photos. Therefore, the notches have not caused bank erosion.



### 2.1.7 Location 9 and Location 10

#### Submitted Statement:

At Location 9, Mr. Kuenzel stated, “Dike at MM 73 right bank notice how the dike has been notched.” In addition, “Pictures... show hard points put in at MM 73 right bank this would not be like this had the dike not been notched.” His submitted photos of Location 9 can be seen in Figure 2-9(a).



**Figure 2-9(a): Submitted Photos for Location 9**

At Location 10, Mr. Kuenzel states, “Pictures... show bank ate away from dike is at MM 73.5 right bank. MM 73.5 right bank very heavy bank erosion. Notched dike at MM 73.5 right bank this has been a problem since this has been notched. We have lost about 7-10 acres of land since the cut was made and the first rock they put in here in the late 90s was 78 foot deep at the river bank. Take note to this problem. This is your fault and no one else. I would still have my land if not for your notch!!!!” His submitted photos can be seen in Figure 2-9(b).



**Figure 2-9(b): Submitted Photos for Location 10**

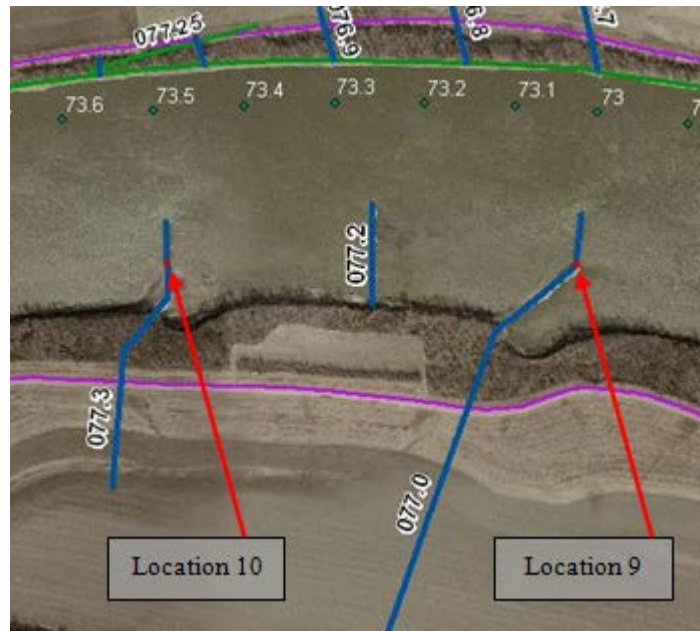
**Analysis:**

There is one notch at Location 9 in structure D077.0 and one notch at Location 10 in structure D077.3. Almost 700 tons of rock was added to D077.0 in 2009 to raise it to an elevation of +3 CRP. Notch details can be seen in Table 2.7.

**Table 2.7: Notching near Location 9 and 10**

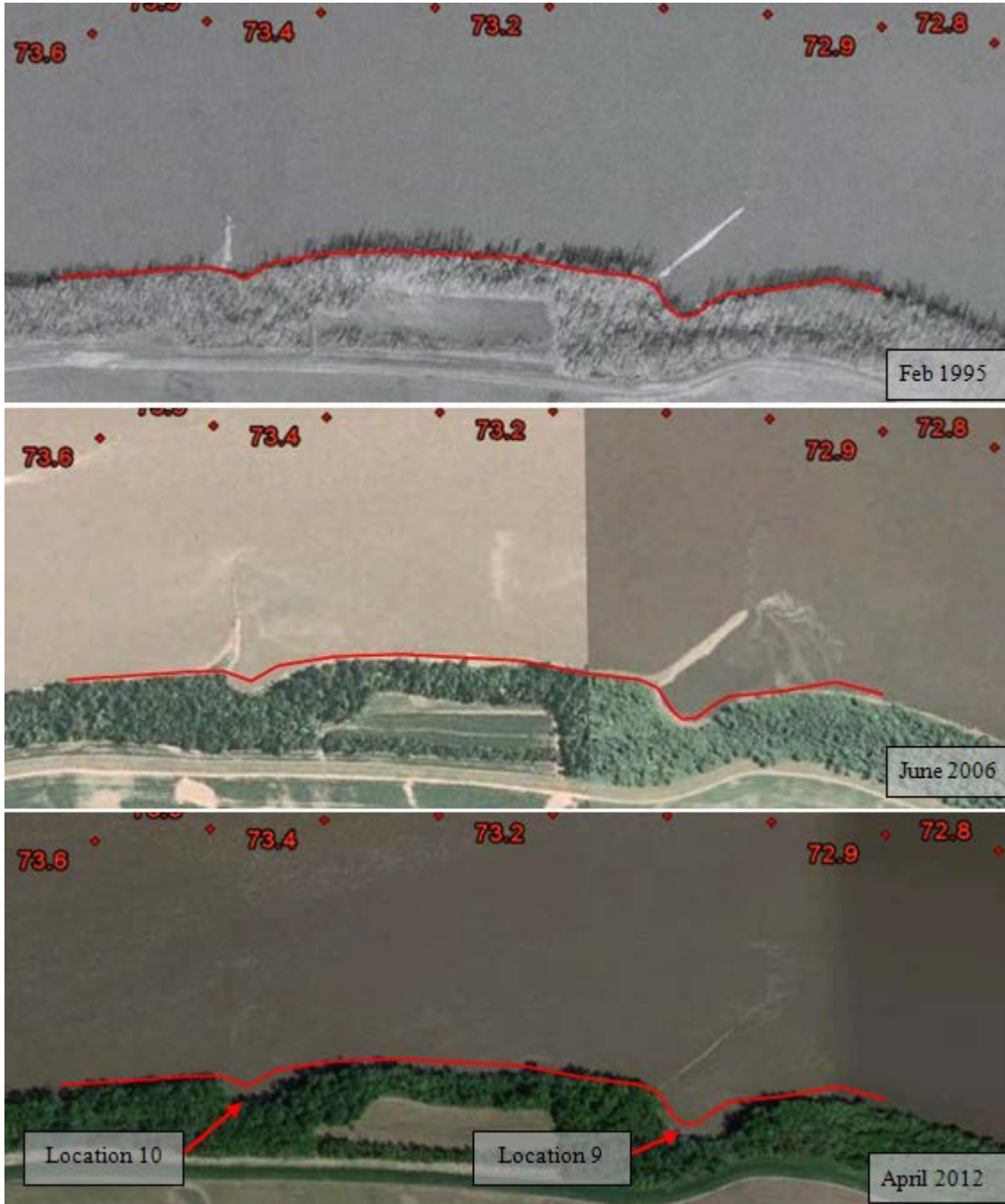
*(Refer to Figure 2-9(c) for Structure Locations)*

| Structure | CRP Elev (ft) | Width (ft) | Year | Distance from Bank (ft) |
|-----------|---------------|------------|------|-------------------------|
| D077.0    | 0             | 20         | 1990 | 400                     |
| D077.3    | 0             | 20         | 1990 | 300                     |



**Figure 2-9(c): Overview of Locations 9 and 10**

Photos from 1995 to 2012 were analyzed to determine movement of the bank line. The red line indicates the bank location during February 1995. These photos are shown in Figure 2-9(d).



**Figure 2-9(d): Aerial Photo Comparison at Locations 9 and 10 from 1995 to 2012**

**Conclusion:**

Erosion over the 17 year period is apparent near the root of each dike at both locations. Since the notches are small (20 ft wide), located 300 to 400 ft away from the bank, and the erosion is near the root of the structures, it is unlikely the notches are the cause of the bank erosion. The worst erosion occurred at Location 9 which was repaired in 2009. The repair should help prevent additional erosion.



### 2.1.8 Location 11

#### Submitted Statement:

At Location 11, Mr. Kuenzel stated, “MM 78 right bank very heavy erosion. In same area MM78 right bank Railroad tracks is real close here.” His submitted photos can be seen in Figure 2-10(a).



**Figure 2-10(a): Submitted Photos for Location 11**

#### Analysis:

There is one notch in D082.3 which was constructed in 1979 and one notch in R082.84 at the end of D082.3 that was created 1978. In 2002, 2,922 tons of rock was added to R082.84 to raise the deficient areas to an elevation of +5 CRP. Additional notch details can be seen in Table 2.8.

**Table 2.8: Notching near Location 11**  
(Refer to Figure 2-10(b) for Structure Locations)

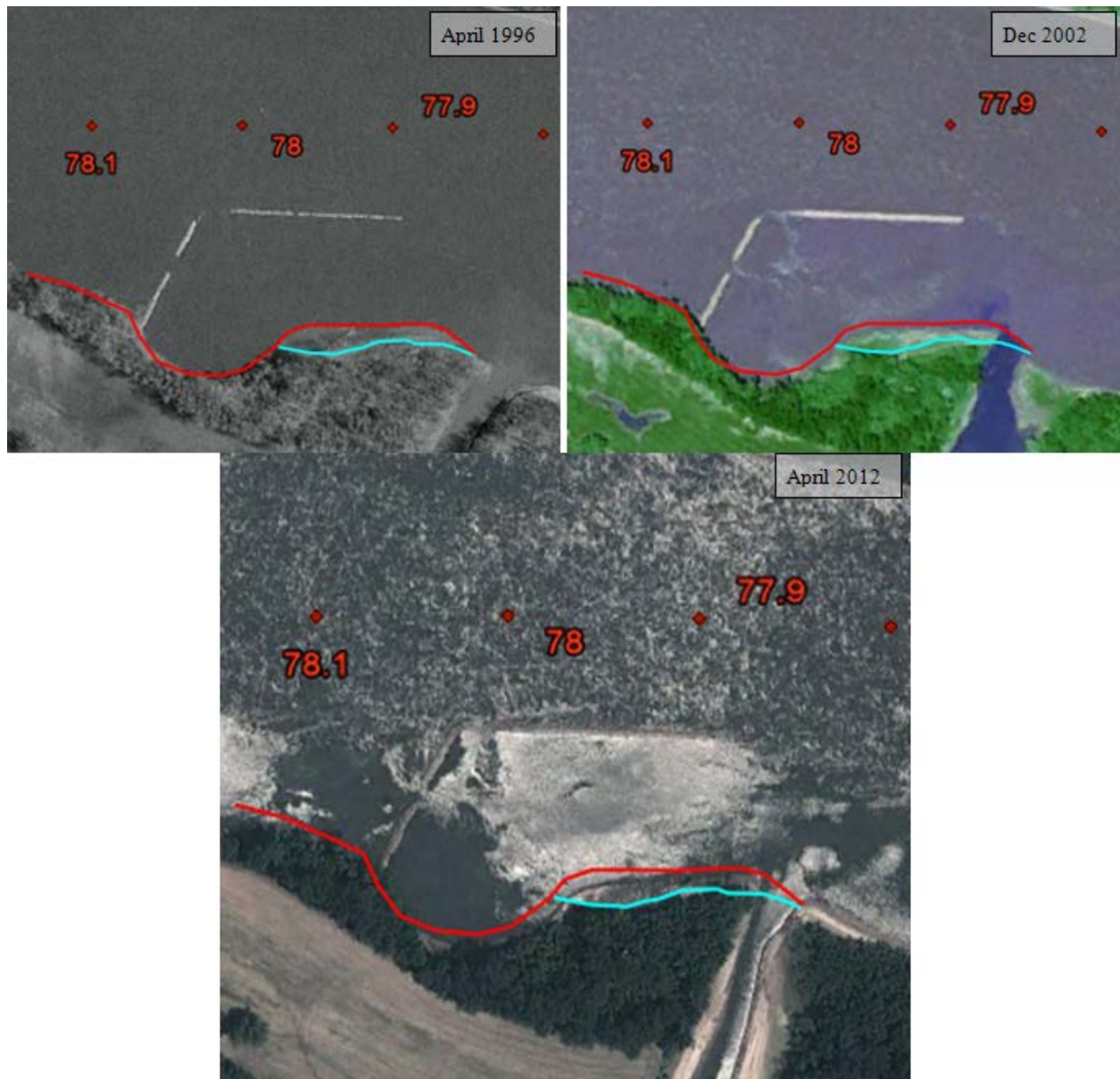
| <i>Structure</i> | <i>CRP Elev (ft)</i> | <i>Width (ft)</i> | <i>Year</i> | <i>Distance from Bank (ft)</i> |
|------------------|----------------------|-------------------|-------------|--------------------------------|
| D082.3           | -3                   | 50                | 1979        | 250                            |
| R082.84          | -5                   | 20                | 1978        | 650                            |





**Figure 2-10(b): Overview of Location 11**

Photos from 1996 to 2012 were analyzed to determine movement of the bank line. The red line indicates the bank location from April 1996. The bank line downstream of the dike is a sloping bank and therefore water's edge will vary greatly depending on water level. The blue line indicates the tree line, which is a better visual reference for fluctuating water levels. These photos are shown in Figure 2-10(c).



**Figure 2-10(c): Aerial Photo Comparison at Location 11 from 1996 to 2012**

**Conclusion:**

The bank has moved less than 50 feet at its greatest point over the 16 year period and the bank is over 650 feet from the railroad tracks at this location. The notch in the dike is a medium notch and located approximately 250' from the bank. The notch in the revetment small and located over 600 feet from the bank. Both notches were constructed in the late 1970's. Due to the size and locations of the notches, they are unlikely the cause of the bank erosion. The bank will be monitored for additional bank movement and the notch filled or moved riverward if determined to be the cause of erosion.

The last four locations of concern can be seen in Figure 2-11. Of these four locations, three contain notches.

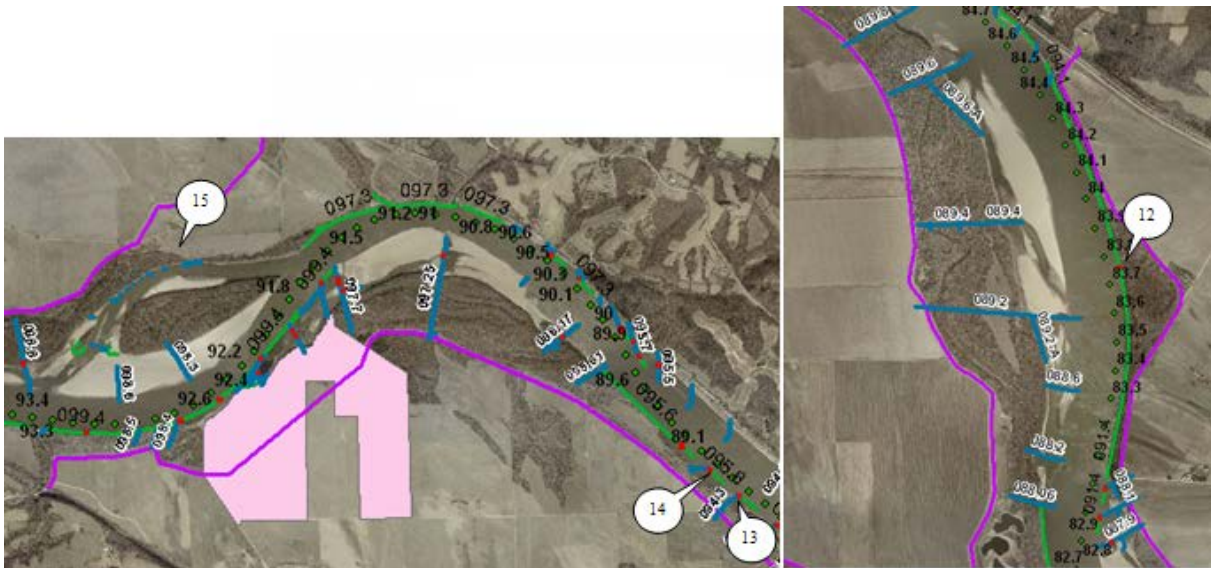


Figure 2-11: Locations 12-15 for Dan Kuenzel's Areas of Concern

## 2.1.9 Location 12

### Submitted Statement:

Mr. Kuenzel stated, “Pictures... are of a notched revetment at MM 83.8 left bank. this was only done so it would cut the bank out to make a major erosion problem.” His submitted photos can be seen in Figure 2-12(a).



**Figure 2-12(a): Submitted Photos for Location 12**

### Analysis:

The structure of concern is R091.4. The notch was constructed in 1987 and deepened in 2006. Work performed in the area since the notch was created can be seen in Table 2.9.

**Table 2.9: Notching near Location 12**

*(Refer to Figure 2-12(b) for Structure Locations)*

| Structure | CRP Elev (ft) | Width (ft) | Year | Distance from Bank (ft) |
|-----------|---------------|------------|------|-------------------------|
| R091.4    | 0             | 50         | 1987 | 0                       |
| R091.4*   | -5            | 50         | 2006 | 35                      |

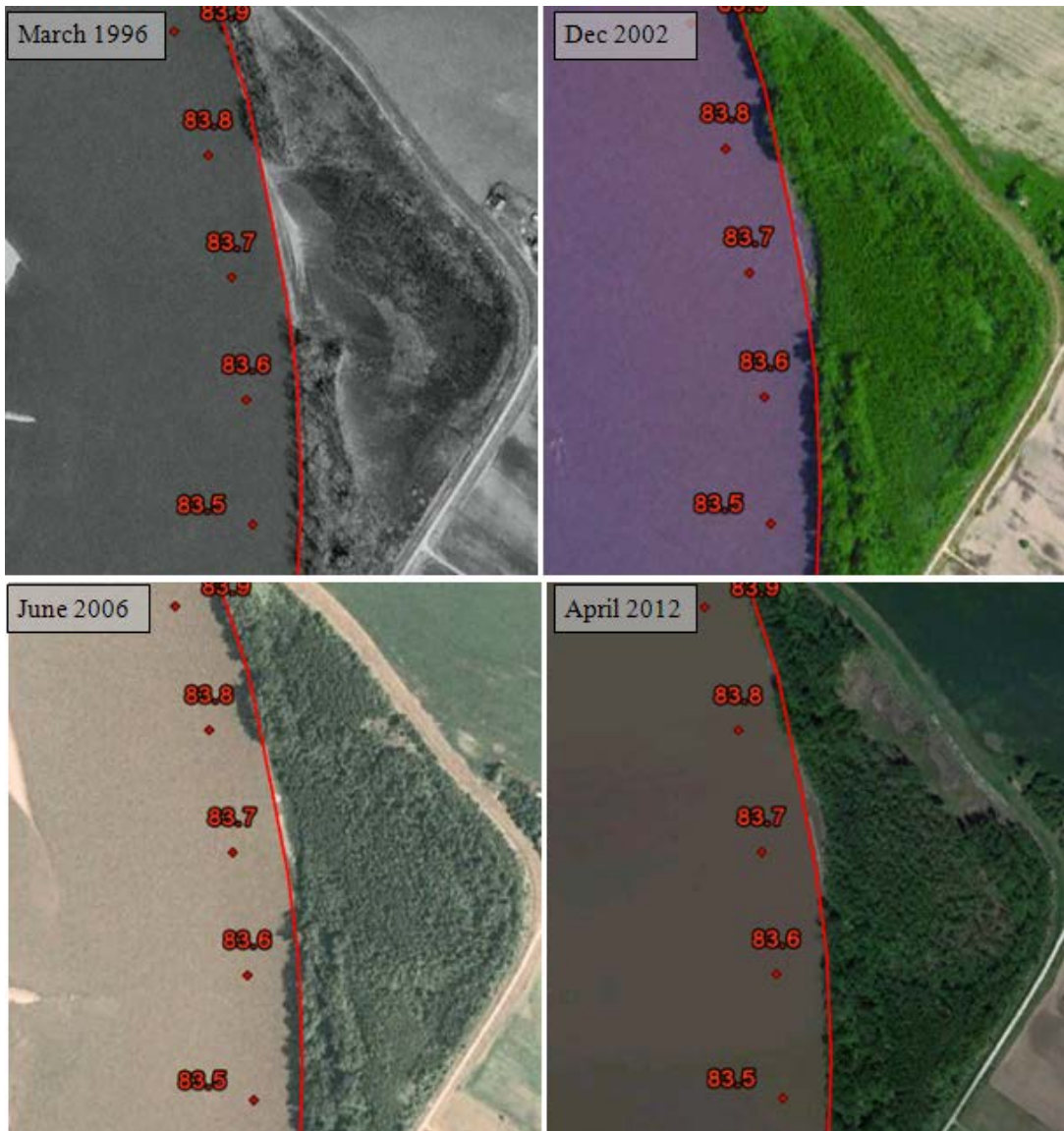
*Notch made deeper in 2006*



**Figure 2-12(b): Overview of Location 12**



Photos from 1996 to 2012 were analyzed to determine movement of the bank line where the notch is located. The red line indicates the bank location during March 1996. In the 1996 photo, it appears that a scour hole developed during the 1993 or 1995 floods and the levee was relocated around the scour hole. The exact aerial extent of the scour hole is unclear in the 1996 photo. These photos are shown in Figure 2-12(c).



**Figure 2-12(c): Aerial Photo Comparison for Location 12 from 1996 to 2012**

**Conclusion:**

The scour hole from the 1993 or 1995 flood has almost completely filled in. It does not appear that the notch has caused any erosion. The notch was created to connect the aquatic area landward of the revetment to the river. Since the notch was placed for aquatic connectivity and not bank erosion, only one 50 foot wide notch was placed in the location

### 2.1.10 Location 13 and Location 14

#### Submitted Statement:

At Location 13, Mr. Kuenzel stated, “Heavy bank erosion at MM 88.9 right bank most of this due to a dike notch.” His submitted pictures can be seen in Figure 2-13(a).



**Figure 2-13(a): Submitted Photos for Location 13**

At Location 14, Mr. Kuenzel stated, “MM 89 right bank heavy bank erosion due to dike notching this also within 100 ft of the toe of the berger levee. I have lost about 3-5 acres of land due to this.” His submitted photos for this location are in Figure 2-13(b).



**Figure 2-13(b): Submitted Photos for Location 14**

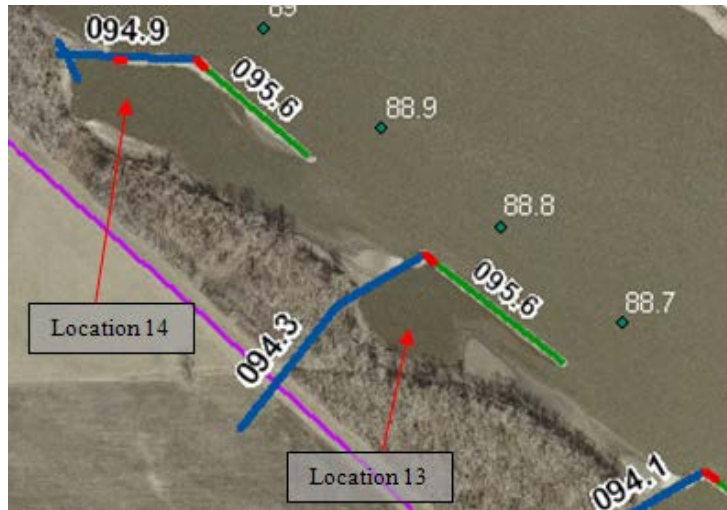
#### Analysis:

There are two notches on structure R095.6 which were constructed in 1976. Structure D094.9 has a 50’ notch and had 3,778 tons of rock added in 2002. Notch details are shown in Table 2.10.

**Table 2.10: Notching near Location 13 and 14**

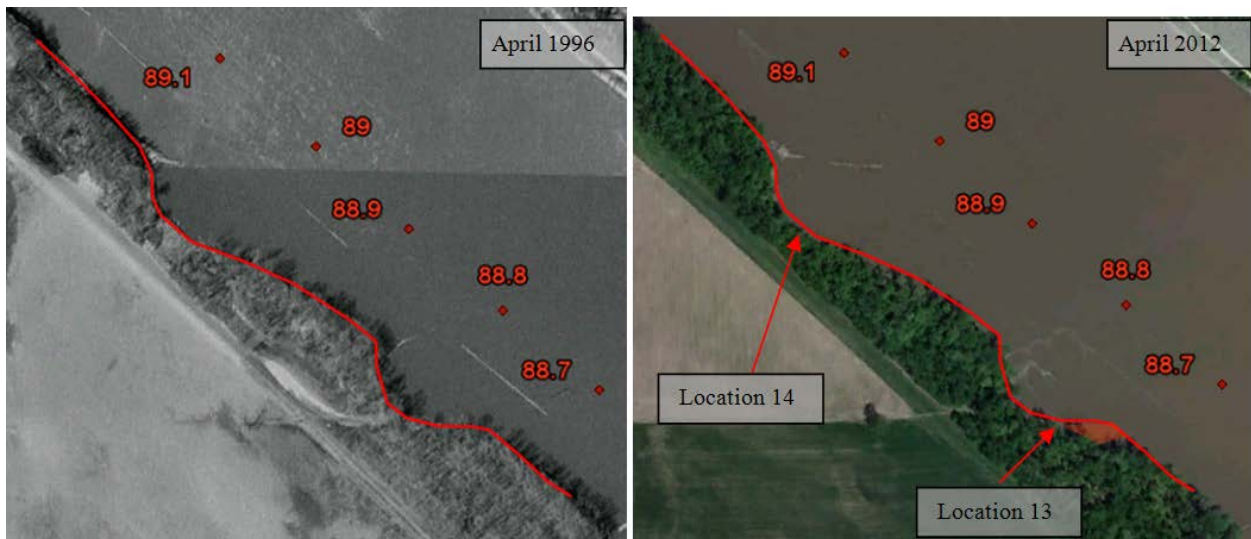
*(Refer to Figure 2-13(c) for Structure Locations)*

| Structure | Station (ft)   | CRP Elev (ft) | Width (ft) | Year | Distance from Bank (ft) |
|-----------|----------------|---------------|------------|------|-------------------------|
| R095.6    | 38+13 to 38+63 | -2            | 50         | 1976 | 230                     |
| R095.6    | 48+16 to 48+66 | -2            | 50         | 1976 | 230                     |
| D094.9    |                | -3            | 50         | 1994 | 200                     |



**Figure 2-13(c): Overview of Locations 13 and 14**

Photos from 1996 to 2012 were analyzed to determine movement of the bank line near the area of concern. The red line indicates the bank location from April 1996. These photos are shown in Figure 2-13(d).



**Figure 2-13(d): Aerial Photo Comparison of Locations 13 and 14 from 1996 to 2012**

**Conclusion:**

Location 13, with one notch at the juncture of the dike and revetment shows bank erosion as indicated by the red shaded area in the 2012 photo above. Location 14, with a notch at the juncture of the dike and revetment and a notch in the dike, shows no bank erosion. It is unlikely the notch at location 13 caused the erosion noted in the photo since it is small and located 230 feet from the bank. Structure D094.3 is on the structure deficiency list and will be repaired as soon as possible. The notch in D094.9 has widened slightly over time and will be evaluated and repaired if necessary. Overall, the notches do not appear to be the cause of bank erosion.



### ***2.1.11 Location 15***

#### **Submitted Statement:**

At Location 15, Mr. Kuenzel stated, “Left bank looking upstream devils elbow this side channel is about 75 to 100 yards wide and about 7-11 feet deep on 2/3s of the lower end. River reading at Hermann Mo on the day of these pictures were taken was 7.7 ft. Left bank shows pictures of hard points put in but not doing a very good job. Notice... how there are no trees on the bank just bare ground. There is a private levee about 50 feet from the river bank. This private levee has already been moved twice by the land owner because the CORPS will not fix this problem right.”

Kuenzel also stated, “MM 93 left bank show more pictures of the hard points that have been put in but still not working right because bank erosion down stream is very bad. MM 93 left bank side channel about 75-100 yards long and about any where from 2-5 feet deep for about 1/3 of the distance from the main river channel.” Lastly, Mr. Kuenzel stated, “Please note Dan Kuenzel farms a 60 mile stretch of the Mo river and the pictures here on only on about 35 miles of river. Another note to point out that mile marker 93 has been a big problem for 20 years and the CORP has done very little to fix this. All that has been done is put a dike at the top of the side channel that was there originally to stop the water from going through. But this would to easy and this is not what they want.” His submitted photos can all be seen in Figure 2-14(a).



**Figure 2-14(a): Submitted Photos for Location 15**



**Analysis:**

This is a natural chute. There are no notches in the location of concern. Fifteen hardpoints have been constructed on the left bank of the chute and two chevrons constructed since 1999. Structure work in the area of concern over the past 25 years can be seen in Table 2.11.

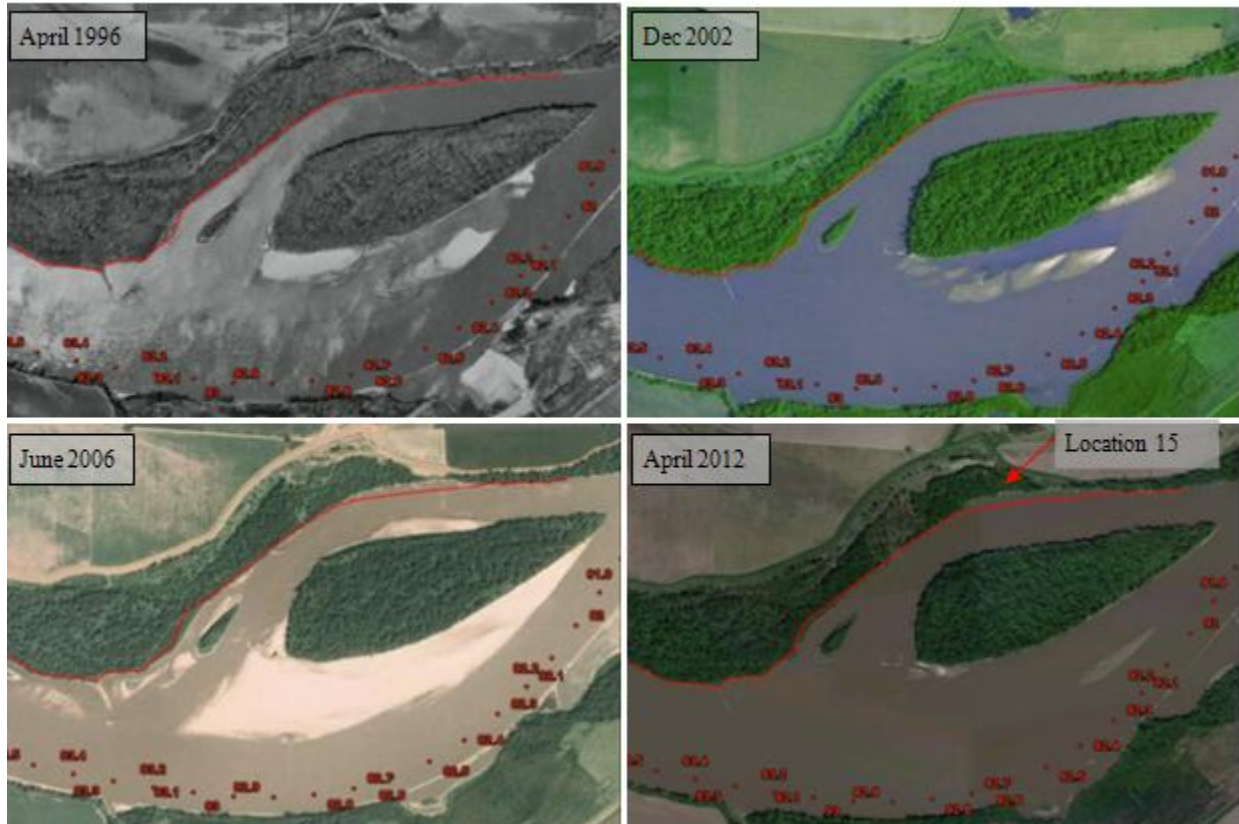
**Table 2.11: Maintenance Performed near Location 15  
(Refer to Figure 2-14(b) for Structure Locations)**

| <i>Structure</i> | <i>Type of Work</i> | <i>Rock Qty (tons)</i> | <i>CRP Elev (ft)</i> | <i>Width (ft)</i> | <i>Year</i> |
|------------------|---------------------|------------------------|----------------------|-------------------|-------------|
| D097.91          | Hard Point          | 1141                   | 15                   | 50                | 1999        |
| D097.92          | Hard Point          | 1787                   | 15                   | 50                | 1999        |
| D097.93          | Hard Point          | 1194                   | 15                   | 50                | 1999        |
| D097.94          | Hard Point          | 1227                   | 15                   | 50                | 1999        |
| D097.95          | Hard Point          | 1246                   | 15                   | 50                | 1999        |
| D097.96          | Hard Point          | 884                    | 1                    | 75                | 2004        |
| D098.0           | Hard Point          | 3230                   | 3                    | 125               | 2004        |
| D098.01          | Hard Point          | 871                    | 0                    | 75                | 2004        |
| D098.02          | Hard Point          |                        | 4                    | 76                | 2004        |
| D098.8-10        | Hard Point          | 300                    |                      | 15                | 2009        |
| D098.8-5         | Hard Point          | 295                    | 10                   | 15                | 2009        |
| D098.8-6         | Hard Point          | 633                    | 10                   | 15                | 2009        |
| D098.8-7         | Hard Point          | 618.2                  | 10                   | 15                | 2009        |
| D098.8-8         | Hard Point          | 647.26                 | 10                   | 15                | 2009        |
| D098.8-9         | Hard Point          | 643                    | 10                   | 15                | 2009        |



**Figure 2-14(b): Overview of Location 15**

Photos from 1996 to 2012 were analyzed to determine movement of the bank line near the area of concern. The red line indicates the bank from April 1996. These photos are shown in Figure 2-14(c).



**Figure 2-14(c): Aerial Photo Comparison near Location 15 from 1996 to 2012**

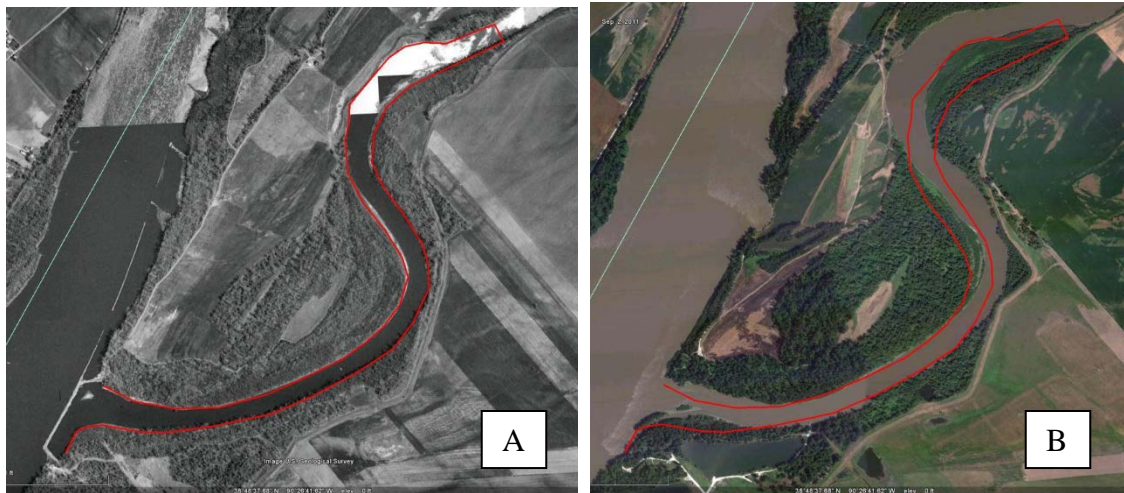
The red arrow in the April 2012 photo above indicates the bank line that experienced the most erosion during this timeframe. A closer look at this area between June 2009 (addition of the last set of hard points) and April 2012 is shown in Figure 2-14(d).



**Figure 2-14(d): Aerial Photo Comparison near Hard Points from 2009 to 2012**

## Conclusion:

This natural chute has deepened and eroded the landside bank as indicated in the photos above. Hard points were added in 1999, 2004 and 2009 to prevent meander of the chute and appear to be working as designed. Closing off the chute with a rock structure will not improve the situation over what currently exists as other natural chutes on the lower river are completely closed off and have experienced erosion and meander even more significant. An example of this is shown in Figure 2-15, which shows the meander of the natural Bryan Island Chute at river mile 23 near St. Charles, Missouri .



**Figure 2-15: Bryan Island Chute**

*Picture A is Bryan Island chute in 1990. Picture B is the same chute in 2011. The red lines indicate the 1990 bankline. The chute is completely closed off from the river at the entrance by a rock revetment until stages reach +7 CRP. The chute is a naturally occurring chute.*

### ***2.1.12 Overall Summary for Areas Submitted by Dan Kuenzel:***

Corps staff have meet with Mr. Kuenzel numerous times over the last five years. As a result of these meetings, numerous rock structures have been put on the structure deficiency list and repaired.

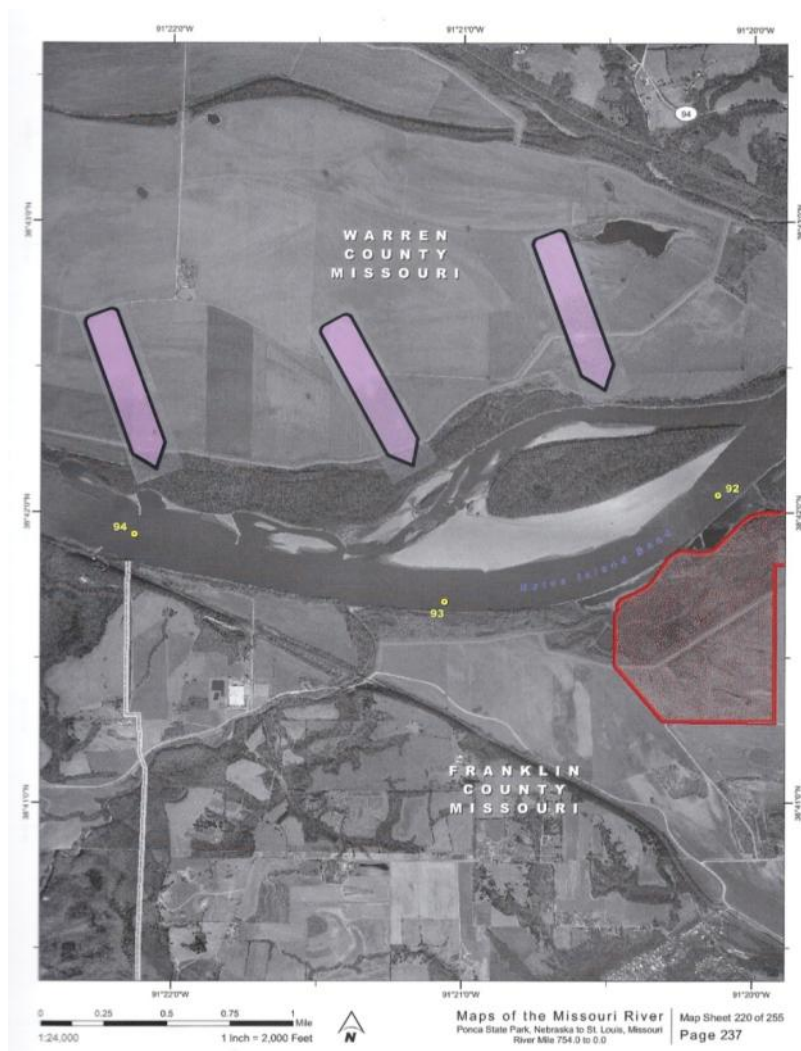
Mr. Kuenzel submitted 15 locations of concern between river mile 57 and river mile 93. Of these 15 locations, 14 contained notches. None of the notches appear to be causing bank erosion. Two of the locations have structures on the deficiency list and the structure will be repaired to design grade as soon as possible.



## 2.2 Erosion Location at River Mile 93

### Submitted Statement:

Dale Gloe submitted concerns about erosion around river mile 93. He believes the area needs immediate attention by building dikes to a higher level and directing water toward the main channel to at least slow the erosion and land loss along the north bank of the river and chute. He believes further erosion will jeopardize the Tri-County Levee. He indicated three areas of concern as shown below in Figure 2-16(a).



**Figure 2-16(a): Submitted Photo by Dale Gloe**

### Analysis:

The two downstream most locations were analyzed in Mr. Kuenzel's Location 15 above. Therefore, only the upstream location at Location 3 in Figure 2-16(b) will be analyzed here.

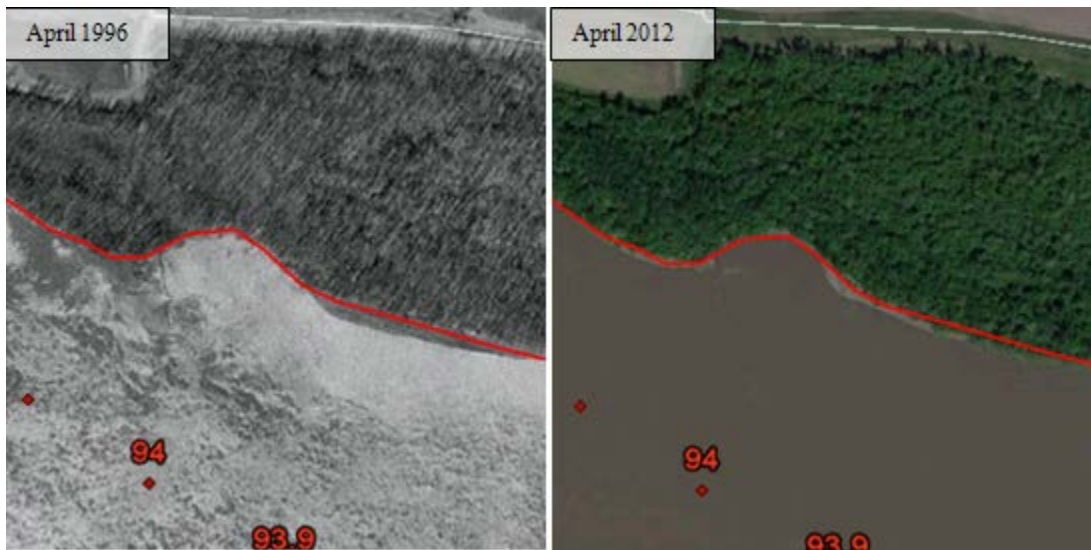


**Figure 2-16(b) Overview of Gloe's Submittal Area**

As seen in Figure 2-16(b), there is one notch at Location 3. Notch details can be seen in Table 2.13. Aerial photos were compared from 1996 and 2012 to determine bank movement at Location 3. These photos are shown in Figure 2-16(c),

**Table 2.13: Notching near Location 3**

| <i>Structure</i> | <i>CRP Elev (ft)</i> | <i>Width (ft)</i> | <i>Year</i> | <i>Distance from Bank (ft)</i> |
|------------------|----------------------|-------------------|-------------|--------------------------------|
| D099.5           | 0                    | 50                | 1978        | 200                            |



**Figure 2-16(c): Aerial Photo Comparison for Location 3 Near River Mile 94**

**Conclusion:**

This location showed no bank movement over the 16 year period and therefore the notch has not caused any bank erosion.

## 2.3 Notch Concerns at River Mile 137 – 140

### Submitted Statement:

There were three locations of concern between river mile 137 and river mile 140 submitted by Clarence Trachsel. The locations were determined by coordinates submitted by Mr. Trachsel and can be seen in Figure 2-17(a).



Figure 2-17(a): Locations of Concern using Submitted GPS Coordinates

### Analysis:

Overviews of structure locations for all three areas of concern are shown in Figure 2-17(b).





**Figure 2-17(b): Overview of Locations 1, 2, and 3**

At Location 1, there is one notch in R145.95. Details can be seen in Table 2.14. Bank line movement was determined by comparing aerial photos from 1995 to 2011. These photos are shown in Figure 2-17(c). The red line indicates the bank line location in 1995. The bank moved landward in the 16 years as indicated by the red shaded area in the June 2011 photo.

**Table 2.14: Notching near Location 1**  
*(Refer to Figure 2-16(b) for Structure Locations)*

| Structure | CRP Elev (ft) | Width (ft) | Year | Distance from Bank (ft) |
|-----------|---------------|------------|------|-------------------------|
| R145.95   | -1            | 40         | 1978 | 350                     |



**Figure 2-17(c): Aerial Photo Comparison at Location 1 from 1995 to 2011**



At Location 2, there is one notch in structure D146.4. There is no notch in structure D146.6 at Location 3 and the structure was repaired in 2002 with 1,170 tons of stone fill. Notch details can be seen in Table 2.15.

Table 2.15: Notching near Locations 2 and 3  
*(Refer to Figure 2-17(b) for Structure Locations)*

| Structure | CRP Elev (ft) | Width (ft) | Year | Distance from Bank (ft) |
|-----------|---------------|------------|------|-------------------------|
| D146.4    | 4             | 20         | 1986 | 150                     |

The change in the bank line for Location 2 and 3 was analyzed by comparing aerial photos from 1995 to 2011 as seen in Figure 2-17(d). The red line represents the bank line location in 1995. Location 2 shows no bank movement and Location 3 shows bank movement near the root of the dike as indicated by the red shaded area in the June 2011 photo.



Figure 2-17(d): Aerial Photo Comparison at Locations 2 and 3

**Conclusion:**

Location 3 does not contain a notch and shows bank erosion near the root of the structure. Location 2 contains a small notch out on the structure and shows no bank erosion. Location 1 contains a notch at the juncture of the dike and revetment and shows bank erosion near the root of the dike. It is unlikely the notch at Location 1 is the cause of the erosion near the root of the dike since the notch is small, located away from the bank, and slightly downstream of the erosion. The revetment (portion of the structure parallel to river flow) at location 3 is approximately 3 feet low and will be repaired when the next repair contract is in the area. All other structures in the area are up to grade.

## 2.4 Concerns with Lowering Dikes From River Mile 146 to 150.5

### Submitted Statement:

Bill Lepage expressed concern that the Corps has lowered dikes around river mile 145. He indicated the following structures were of concern: D154.2, D154.4, D154.5, D 154.75, D155, D155.15, D155.6, D155.95, D157.3, D157.6, D157.7, and D157.8. These structures are circled below in Figure 2-18(a).

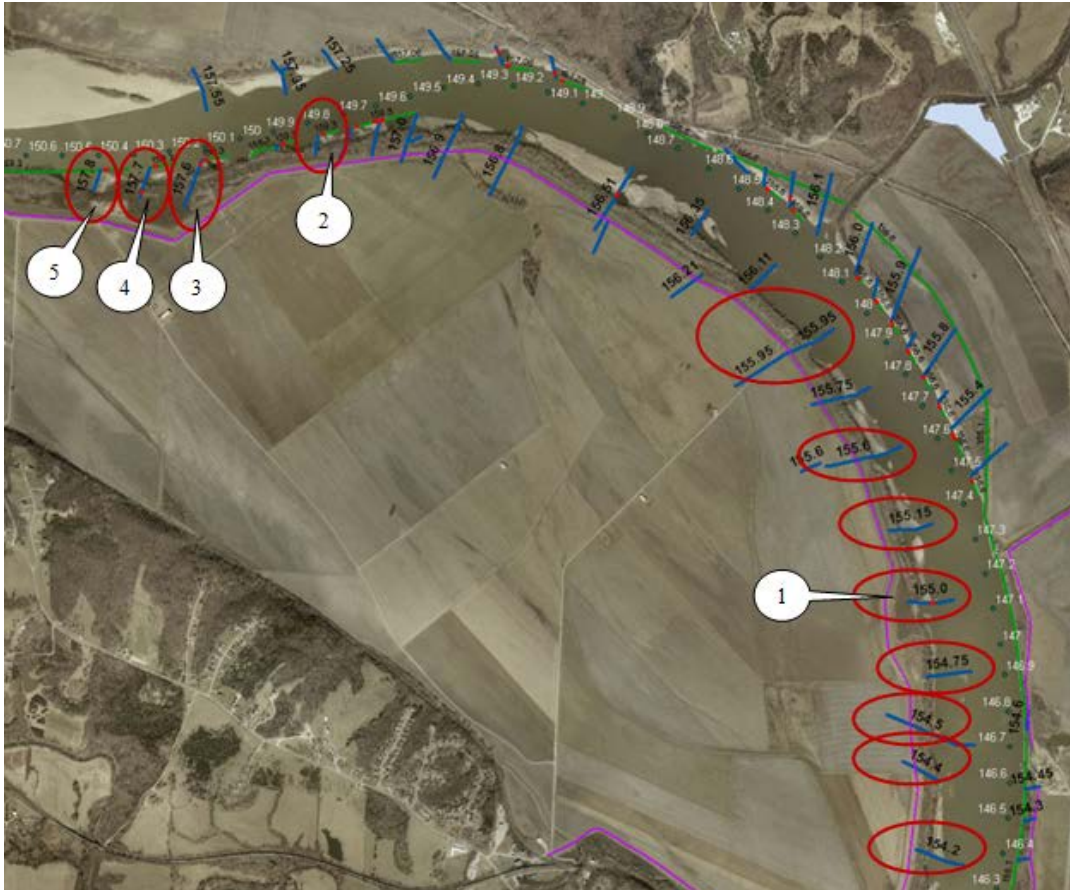


Figure 2-18(a): Structure Names and Locations of Concern near River Mile 145

### Analysis:

There were twelve structures identified by Mr. Lepage. All structures in this reach of river are maintained to design standards in place since 1974 and none have been lowered. In 1994, 5,751 tons of rock was added to D157.8 to raise the elevation to +6 CRP and 675 tons of rock was added to R159.3 to raise the elevation to +5 CRP. Five of the locations contain notches and will be analyzed. The other locations will not be analyzed since they do not contain notches and have not been lowered.

### 2.4.1 Location 1:

Location 1 is located near a notch in structure D155.0. Notch details can be seen in Table 2.16.

Table 2.16: Notching near Location 1  
(Refer to Figure 2-18(b) for Structure Locations)

| Structure | CRP Elev (ft) | Width (ft) | Year | Distance from Bank (ft) |
|-----------|---------------|------------|------|-------------------------|
| D155.0    | -4            | 50         | 2004 | 150                     |



Figure 2-18(b): Overview of Location 1

Aerial photos were compared from 1991 to 2011. As seen in Figure 2-18(c) it is evident that the bank line movement was caused by the scour hole which formed during the 1993 flood event. The red line indicates the bank line location in 1991 and the blue line indicates the bank line location in 1995.

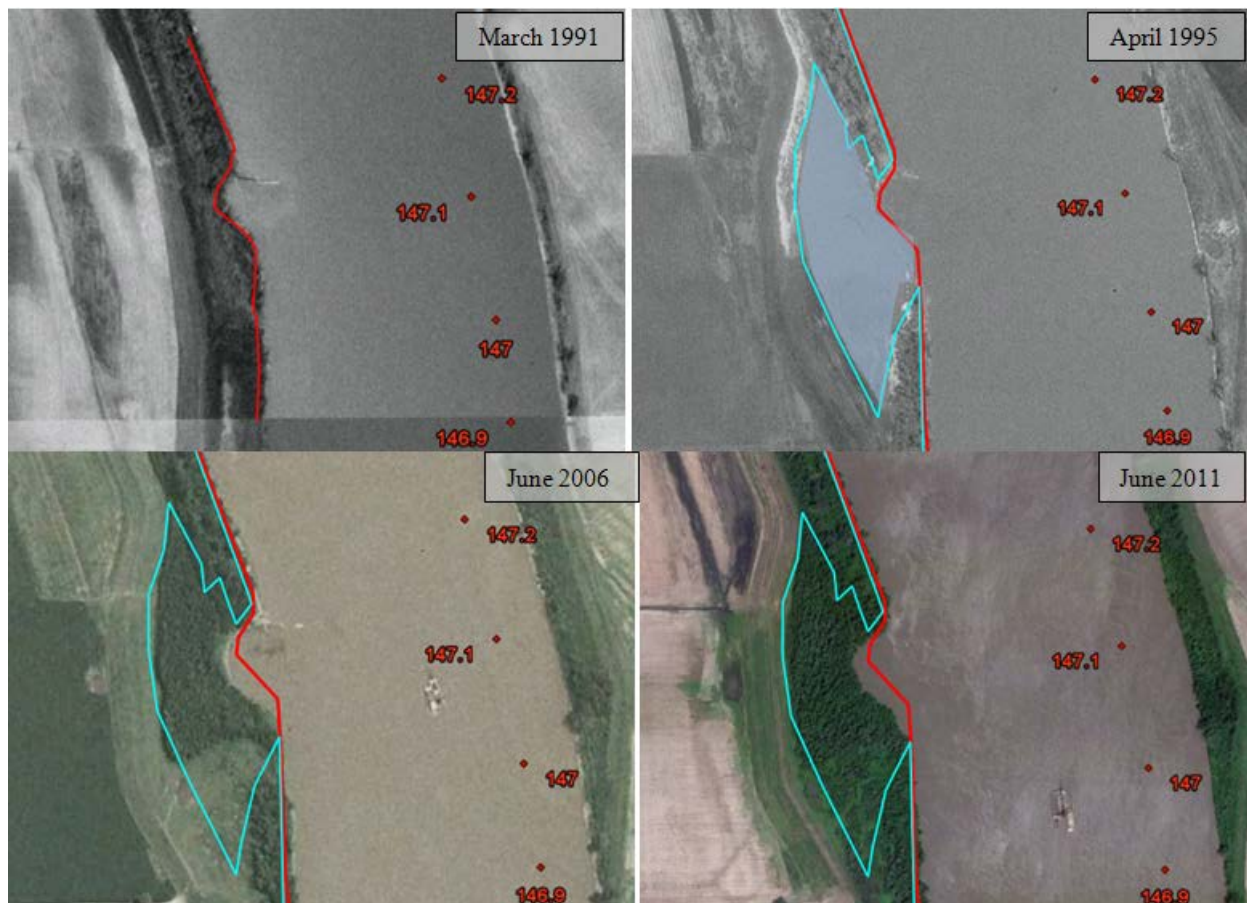


Figure 2-18(c): Aerial Photo Comparison Near Location 1 from 1991 to 2011

### 2.4.2 Location 2 through Location 5:

A total of six notches are in place at Location 2 through Location 5. There is one notch at Location 2 in structure D157.3 and two notches at Location 3 in Structures R159.3 and D157.6. There are two notches at Location 4 in structure R159.3 and in structure D157.7. There is one notch at Location 5 in structure R159.3. A summary of the notches is located in Table 2.17.

Table 2.17: Notching near Locations 2 - 5

(Refer to Figure 2-18(d) for Structure Locations)

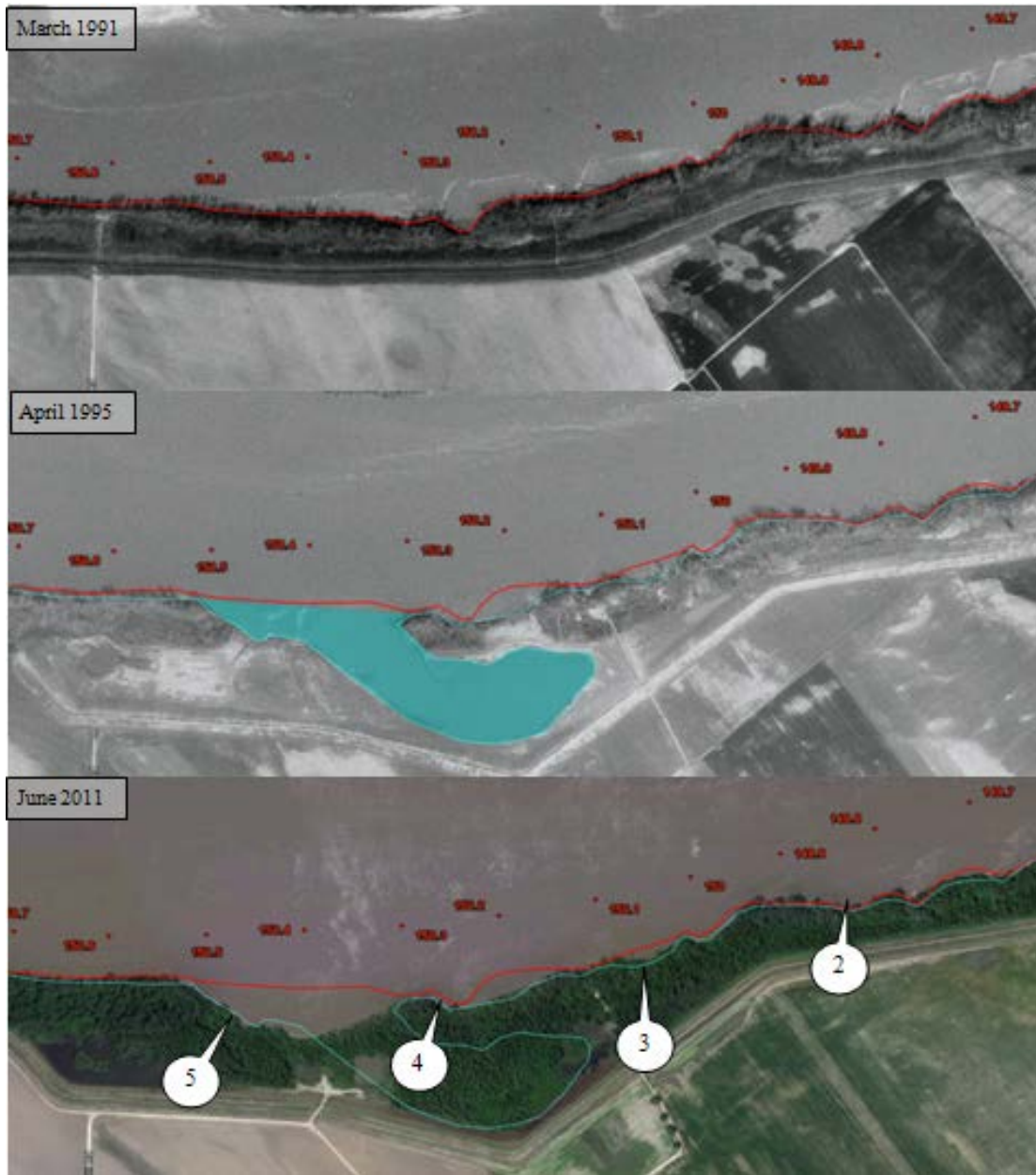
| Structure | CRP Elev (ft) | Width (ft) | Year | Distance from Bank (ft) |
|-----------|---------------|------------|------|-------------------------|
| D157.3    | -2            | 50         | 1977 | 150                     |
| R159.3    | -2            | 50         | 1977 | 150                     |
| D157.6    | -4            | 50         | 2004 | 75                      |
| R159.3    | -2            | 50         | 1977 | 250                     |
| D157.7    | -4            | 50         | 2004 | 75                      |
| R159.3    | -2            | 50         | 1977 | 300                     |





**Figure 2-18(d): Overview of Locations 2-5**

As shown by the aerial photos in Figure 2-18(e), a scour hole formed at this location during the 1993 flood which resulted in significant bank erosion. The eroded area is shaded blue. Since the flood, the scour hole has partially filled and the bank has otherwise shown no movement.



**Figure 2-18(e): Aerial Photo Comparison for Loaction 2-5 from 1995 to 2011**

**Conclusion:**

Corps staff met on-site with Mr. Lepage approximately ten years ago. The analysis of all five locations shows no bank erosion since the formation of the scour holes during the 1993 flood. The scour holes have almost completely filled in. Since the bank erosion was due to the scour holes and the scour holes were due to flood events, the notches are not the cause of any bank erosion. Structure D157.5 is listed as deficient and will be repaired to design criteria. In addition, no other dikes in any of the areas identified have been lowered and are all maintained to design standards in place since 1974.



## 2.5 Erosion Concerns between River Mile 163 and River Mile 164

### Submitted Statement:

Stephen Diedrich submitted photos concerning the bank between river miles 163 and 164. He did not provide any specific location or contact information for further inquiry. However, based on Corps records and Mr. Diedrich's submitted photos, the area of concern has been determined to be the left descending bank, upstream of structure D171.5. Mr. Diedrich's submitted photos are shown in Figure 2.19(a).



**Figure 2-19(a): Submitted Photos of Area of Concern between RM 163 and RM 164**

### Analysis:

The structures between river miles 163 and 164 are shown in Figure 2-19(b). The right descending bank is State owned land as indicated by the pink shaded area. There are three notches on the left bank. Notch details can be seen below in Table 2.18.

Table 2.18: Notching Performed on Structure D171.5

(Refer to Figure 2-19(b) for Structure Locations)

| Structure | Type of Work | Stationing   | CRP Elev (ft) | Width (ft) | Year | Distance from Bank (ft) |
|-----------|--------------|--------------|---------------|------------|------|-------------------------|
| D171.5    | Notching     | 2+75 to 3+25 | -2            | 50         | 1980 | 175                     |
| D171.5    | Notching     | 7+05 to 7+25 | -5            | 20         | 1986 | 250                     |
| D171.5    | Notching     | 3+50 to 4+00 | -2            | 50         | 2001 | 625                     |
| D171.5*   | SFD          | 1+50 to 3+50 | 3             | 200        | 2001 |                         |

\*Rock added to fill in notch created in 1980 in order to move notch riverward.



Figure 2-19(b): Overview of Area of Concern

Aerial photos of the area were compared. The red line is the location of the bank in 1991 and the blue line is the location of the bank in 2003. Significant erosion occurred between 1995 and 2003. Additional erosion has occurred since 2003 as is evident in the 2011 photo near the downstream end of the blue line. The photos are shown in Figure 2-19(c).

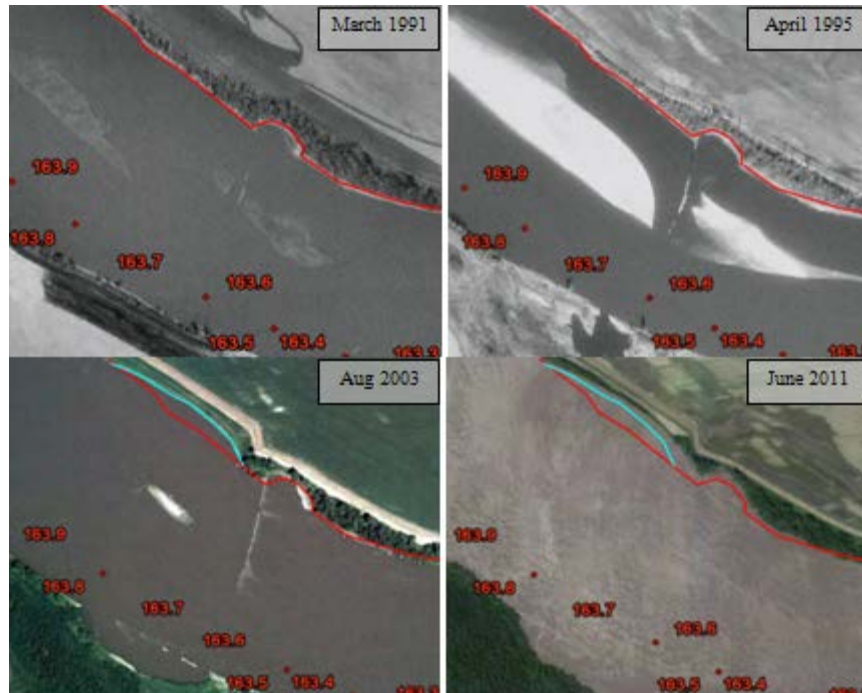
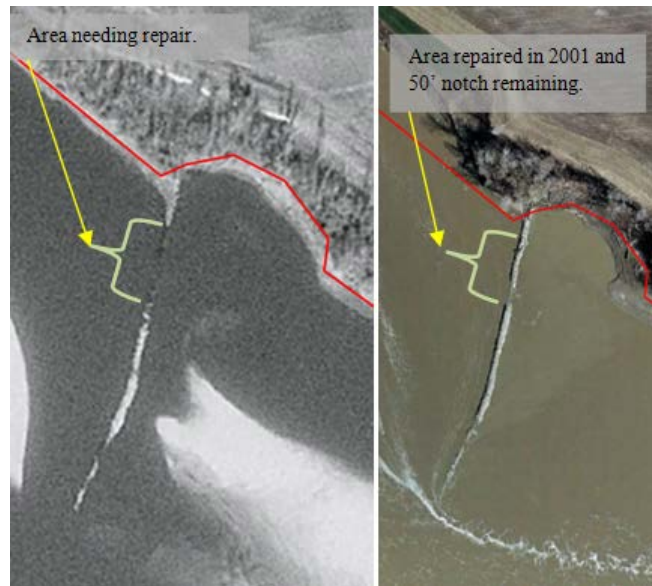


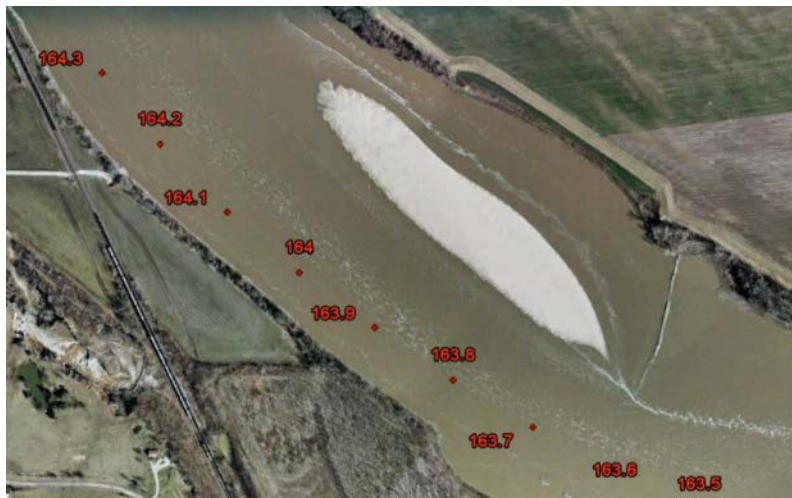
Figure 2-19(c): Aerial Photo Comparison for Area of Concern from 1991 to 2011

The notch closest to the bank was filled and moved riverward as part of the 2001 structure repair work. In Figure 2-19(d), the 1995 photo on the left shows the degraded portion of the structure and the 2006 photo on the right shows the repaired structure with the notch left at the current riverward location.



**Figure 2-19(d): Structure D171.5 Repair Details**

The repair work in 2001 reduced the flow landward of the sandbar, however, as apparent in the 2006 photo shown in Figure 2-19(e) below, there is still significant flow in this area. This flow is likely the cause of the erosion since 2003 as the 2006 photo shows the flow going around the riverward end of the dike.



**Figure 2-19(e): Flow Conditions Upstream of Structure D171.5 in 2006**

**Conclusion:**

Corps staff met on-site with representatives of the Levee District in 2001 to examine the area. The repairs of 2001 were accomplished shortly after that meeting. This area has shown significant erosion between 1995 and 2003 and the erosion has continued since 2003, but at a slower rate. The erosion appears to be caused by flow between the sandbar and the bank as seen in Figure 2-19(e). It is evident that even at river levels below the top of the dike, a portion of the river's flow is diverting behind the sand bar next to the bank. The dike is effective at channeling the flow back out into the river. The dike repair completed in 2001 has likely slowed the erosion rate. Due to the size and location of the notch and the obvious flow around the sandbar, the flow around the sandbar is the cause of the erosion and not the notch. The area will continue to be monitored and additional action taken if the integrity of the dike is threatened.



## 2.6 Notch Concern at D190.7B between River Miles 182-183

### Submitted Statement:

Adam Schuttler has a concern with a notched dike causing bank erosion near a high-voltage transmission line owned by the City of Columbia Water and Light Department. The dike is located at river mile 183.6, right bank. He wants to ensure the erosion will not affect the tower.

### Analysis:

The location of concern is near structure D191.2 and is shown in Figure 2-20(a). The light purple shaded area is land owned by the Corps of Engineers and managed by the Fish and Wildlife Service (FWS) as a component of the FWS Big Muddy National Wildlife Refuge. Structure D191.2, has three notches which were constructed in 1990, 2002, and 2003. The 2002 and 2003 notches were located and sized for the purpose of eroding the bank. Revetment R192.65 (green line in photo) contains a notch constructed in 1975. Notching details are shown in Table 2.19.

Table 2.19: Notching Performed on Structure D171.5

(Refer to Figure 2-20(a) for Structure Locations)

| Structure | CRP Elev (ft) | Width (ft) | Year | Distance from Bank (ft) |
|-----------|---------------|------------|------|-------------------------|
| R192.65   | -1            | 50         | 1975 | 400                     |
| D191.2    | -2            | 20         | 1990 | 230                     |
| D191.2    | -4            | 70         | 2002 | 140                     |
| D191.2    | -5            | 50         | 2003 | 60                      |

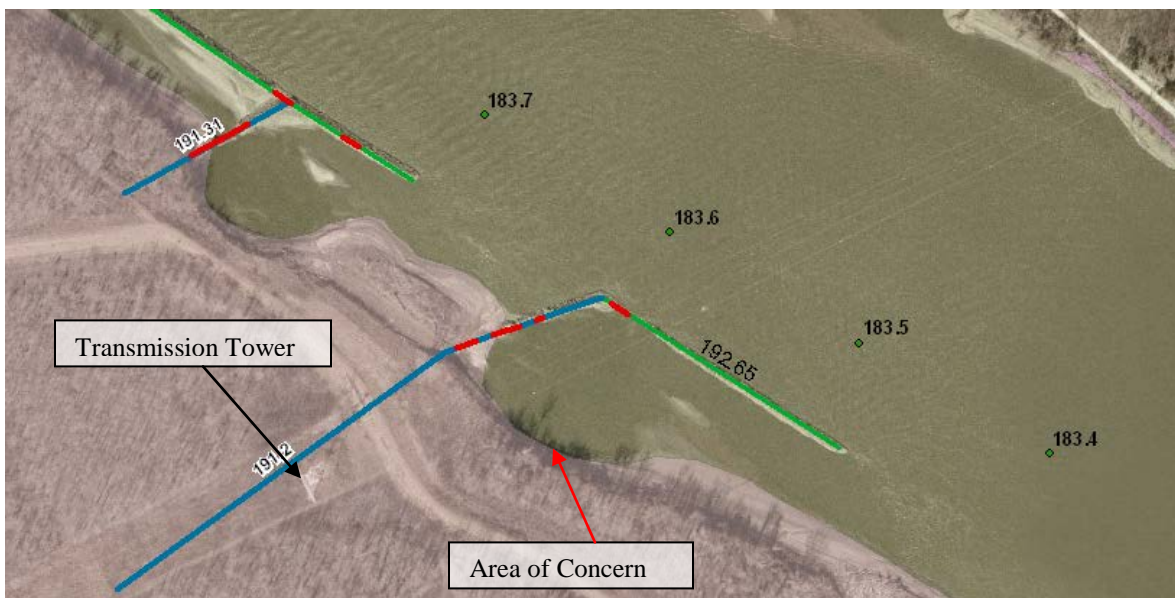
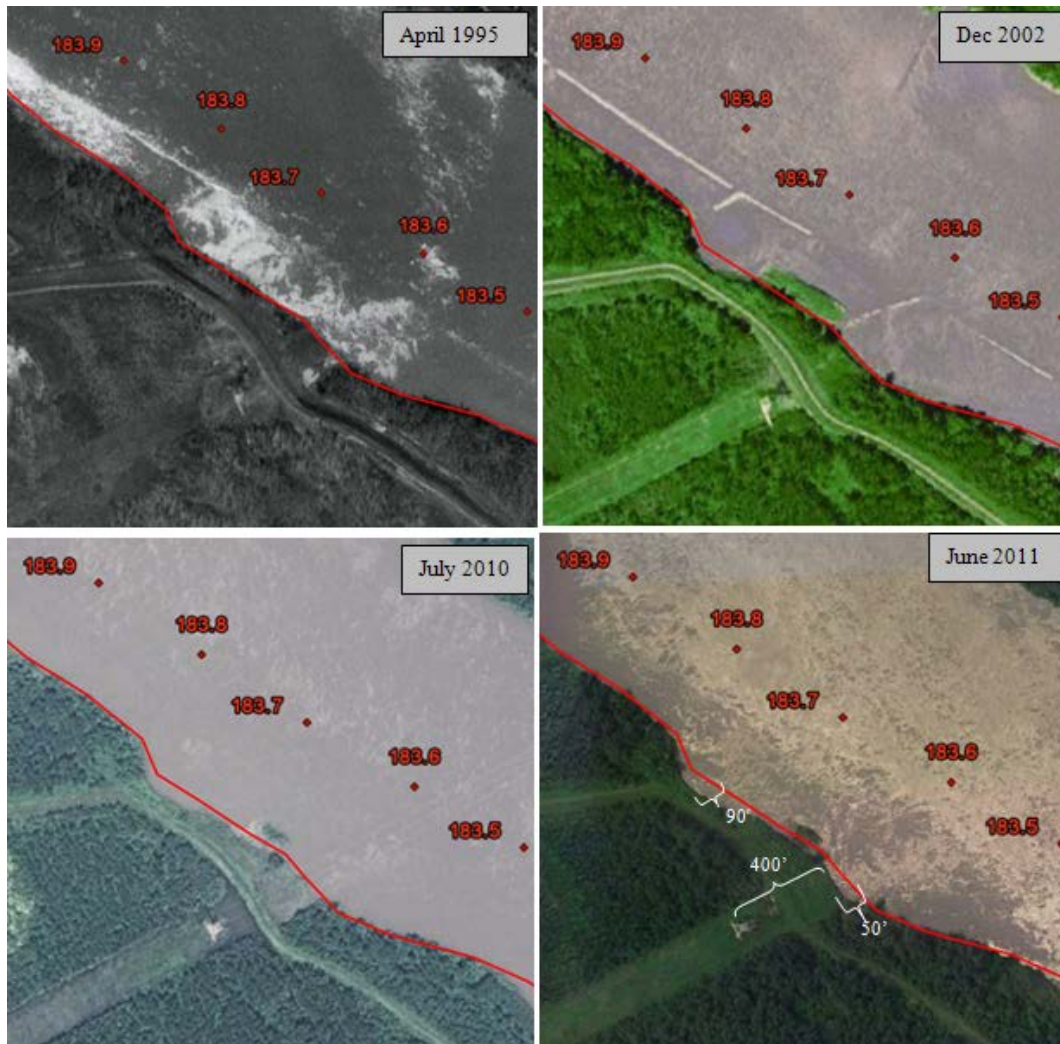


Figure 2-20 (a): Overview of Area of Concern

Aerial photos from 1995 and 2011 are shown in Figure 2-20(b). The red line indicates the bank line location from April 1995. In places, the bank has eroded approximately 90 feet in 16 years. The transmission tower is still over 400 feet from the bank line.



**Figure 2-20(b): Aerial Photo Comparison at Area of Concern from 1995 to 2011**

**Conclusion:**

The bank has eroded up to 90 feet since the last two notches were constructed in 2002 and 2003. As the bank erodes, the distance between the bank and the notch increases, resulting in reduced effects on the bank from the notch. The erosion from the notch will stop once it is over 100 feet from the bank, leaving over 300 feet between the transmission tower and the bank line. In addition, the buried portion of structure D191.2 is upstream of the transmission tower (see Figure 2-20(a)) and will protect the bank around the tower. This area is actively monitored and the notches will be reduced in size or filled completely if the erosion continues to the point of endangering the tower.



## 2.7 Notch Concern at River Mile 205

### Submitted Statement:

Doris Linneman stated, “The experiment of the notching of dikes should end. The dikes should be filled back to the original height. Equal money should be available for repairs as needed to dikes and bank stabilization instead of spending all the funds for birds, fish, etc.” She also believes the bank erosion is caused by notched dikes and abnormal high river flow over the last 15 years. Her area of concern is near river mile 205, on the right descending bank. Her submitted photos are shown below in Figure 2-21(a).



**Figure 2-21(a): Submitted Photos of Area of Concern**

### Analysis:

There are two notches near river mile 205 located in structures D214.45 and R212.3. Notch details are shown in Table 2.20. Four hard points were added to this location in 1997 as well as 536 tons of rock added to D214.55 to raise the structure to an elevation of +5 CRP.

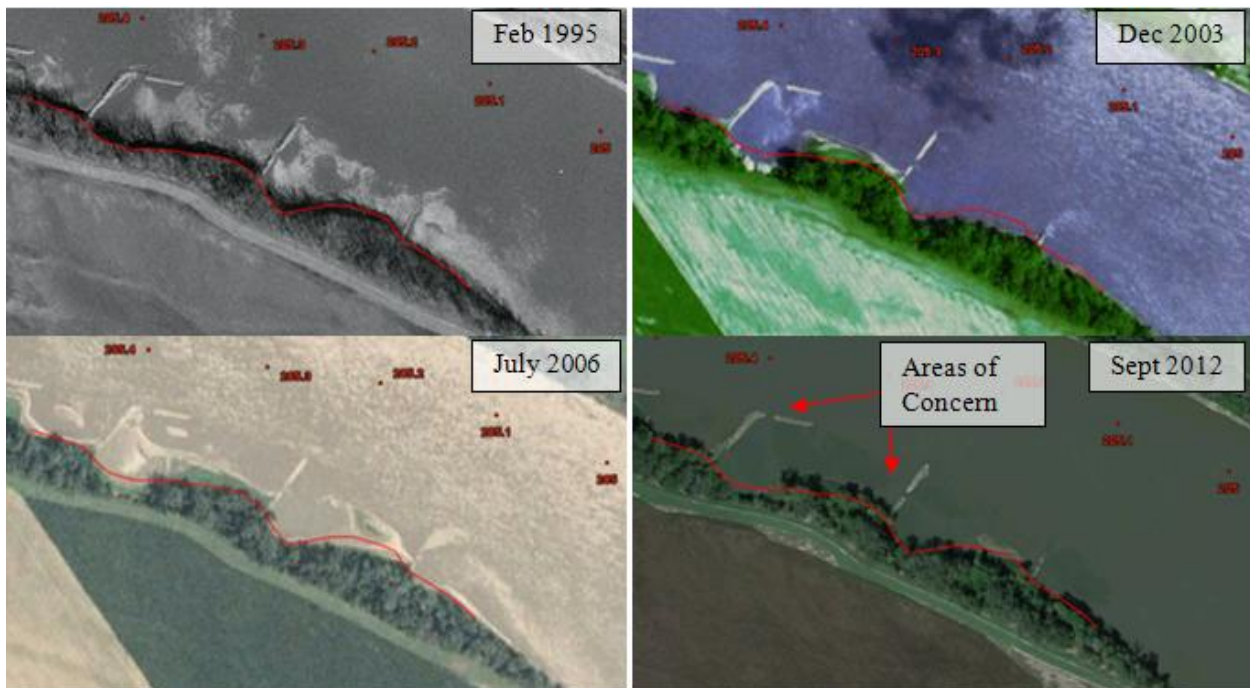
Table 2.20: Notching Performed Near Linneman’s Area of Concern  
(Refer to Figure 2-21(b) for Structure Locations)

| Structure | CRP Elev (ft) | Width (ft) | Year | Distance from Bank (ft) |
|-----------|---------------|------------|------|-------------------------|
| D214.45   | 0             | 50         | 1983 | 90                      |
| R212.3    | 0             | 50         | 1975 | 300                     |



**Figure 2-21(b): Overview of Area of Concern**

Aerial photography from February 1995 to September 2012 was compared to determine bank movement. The bank line eroded approximately 30 feet near the root of D214.55 and slightly eroded downstream of D214.45. Hard points were added near the root of D214.55 in 1997 and appear to have prevented any additional erosion. The aerial photos are shown in Figure 2-21(c).



**Figure 2-21(c): Aerial Photo Comparison Near Area of Concern from 1995 to 2011**

**Conclusion:**

Corps representatives met with the Linneman family in 1997, 2000, and 2005. As a result of those meetings hardpoints were constructed, one rootless dike was tied into the bank, a revetment was repaired, and a flanked dike was repaired by trucking rock into the area. The area was inspected during the summer of 2012 and the elevations of the structures are consistent with design elevations. The erosion occurred between 1995 and 2003. The 2012 photo shows that the bank line has almost returned to the 1995 location. It is unlikely the notches caused the erosion due to the small size of the notches and distance between the notches and the erosion.

## 2.8 Erosion Concerns Near River Mile 232

### Submitted Statement:

Carol Stundebeck and Jeffrey Gebhardt have concerns at river mile 232 about erosion occurring near the root of two dikes. Photos submitted by Ms. Stundebeck are shown below in Figure 2-22(a).



Figure 2-22(a): Submitted Photos for River Mile 232.3

### Analysis:

The picture on the left in Figure 2-22(b) was submitted by Ms. Stundenbeck. The picture on the right in Figure 2-22(b) shows the structure details.



Figure 2-22(b): Overview of Area of Concern



There are three notches at this location. One notch is located in structure D244.15, one notch is located at the end of D244.15 in structure R245.93, and one notch is located on structure D244.09. Notch details are shown in Table 2.21.

Table 2.21: Notching Performed Near Area of Concern

(Refer to Figure 2-22(b) for Structure Locations)

| Structure | CRP Elev (ft) | Width (ft) | Year | Distance from Bank (ft) |
|-----------|---------------|------------|------|-------------------------|
| D244.15   | 0             | 25         | 1981 | 100                     |
| R245.93   | 0             | 50         | 1984 | 250                     |
| D244.09   | 0             | 20         | 1978 | 300                     |

Aerial photos were analyzed to compare bank line movement from March 1991 to September 2012. These images are shown below in Figure 2-22(c).

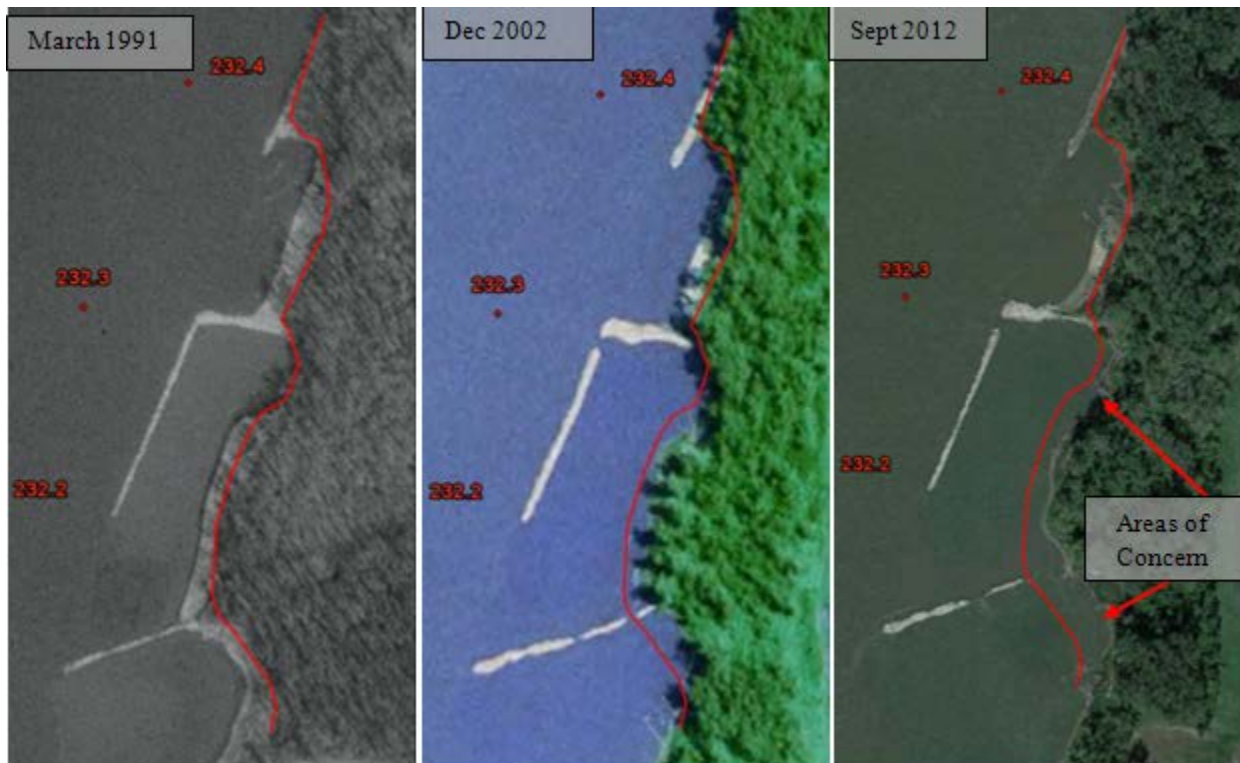


Figure 2-22(c): Aerial Photo Comparison of Area of Concern from 1991 to 2012

### Conclusion:

There has been considerable erosion at this location, especially around and downstream of structure D244.09. Most of the erosion appears to have occurred between 2002 and 2012. Due to the small size of the notches and their distance from the bank, it is unlikely the notches were the cause of the bank erosion. It appears from the 2012 photo that the root of D244.09 is in need of repair and has been added to the deficient structure list.



## 2.9 Erosion concerns From River Mile 237 to River Mile 238

### Submitted Statement:

Jeffrey Gebhardt and Carol Studenbeck have a concern with erosion occurring between river mile 237 and river mile 238. Mr. Gebhardt believes it is relatively close to the Lower Chariton River Levee and may result in severe damage to the levee in a few years.

### Analysis:

The picture on the left in Figure 2-23(a) was submitted by Ms. Studenbeck. The structures are D248.8, D248.9 and R250.0 as shown in the picture on the right. None of these structures contain a notch.



Figure 2-23(a): Overview of Area of Concern

Aerial photos were compared from February 1995 to September 2012 to determine bank movement. The photos are shown in Figure 2-23(b).



Figure 2-23(b): Aerial Photo Comparison for Area of Concern from 1994 to 2012

**Conclusion:**

Representatives from the Corps have met numerous times on-site with Levee District representatives over the past 15 years. Hardpoints (not visible in the photos) were constructed in 2002 as a result of one of those meetings. There are no notches in the location identified and therefore notches are not the cause of the bank erosion. The last on-site inspection showed the hardpoints are in need of repair and will be repaired when the next river contract is in the area. The area will continue to be inspected at least twice a year until the repair is completed.

## 2.10 Notch Concern from River Mile 278.2 to River Mile 291.2

### Submitted Statement:

Kelly and Tim Thorp submitted 28 different locations of concern between river miles 278.2 and 291.2. Tim Thorp stated the issue was “99% notches in dikes or revetments. One time, dike across river made longer and higher shooting water across.”

Of the 28 submitted locations, 21 have notches. The exact locations are shown in Figure 2-24(a) and Figure 2-24(b). Purple shaded areas is land owned by either the Corps of Engineers or the Fish and Wildlife Service. A more detailed look at each location follows.

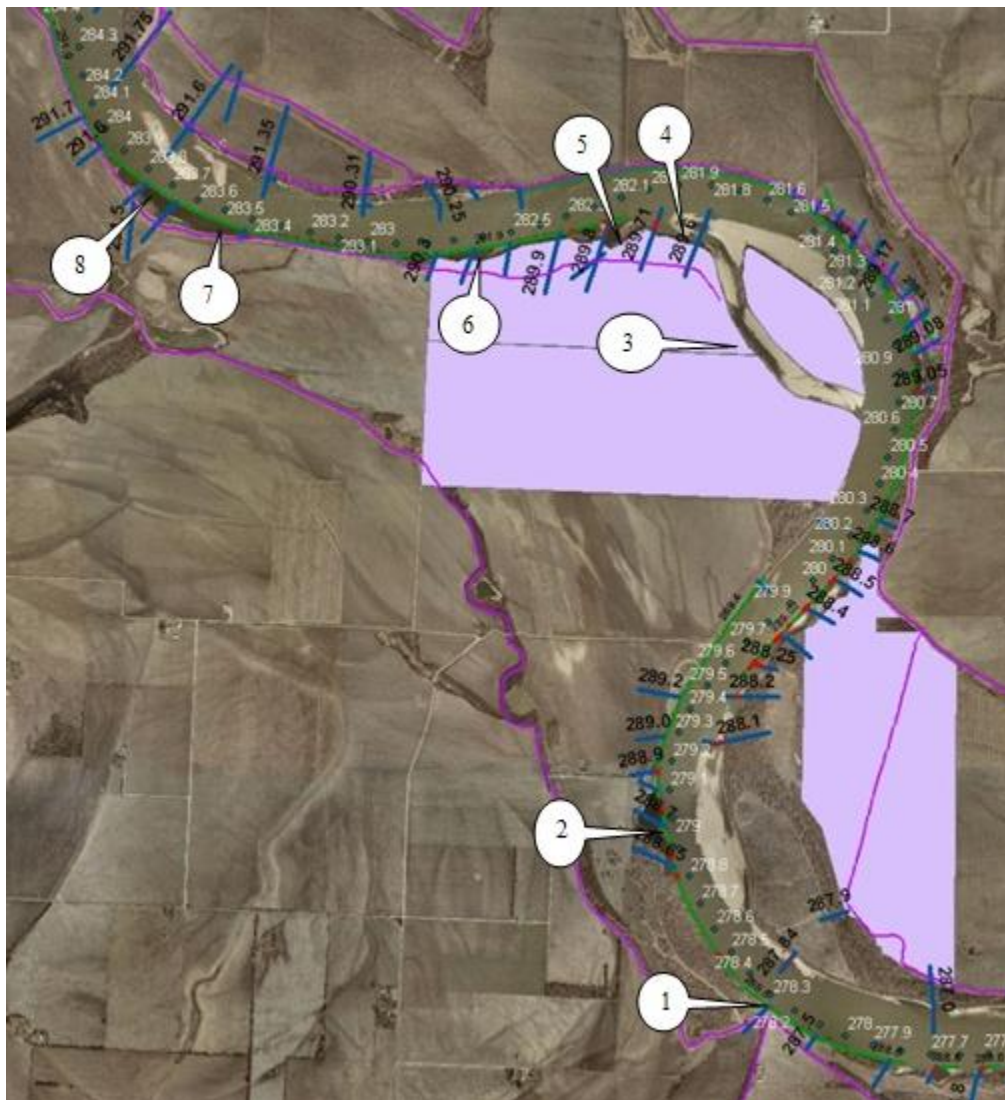


Figure 2-24(a): Overview of Locations 1 – 9



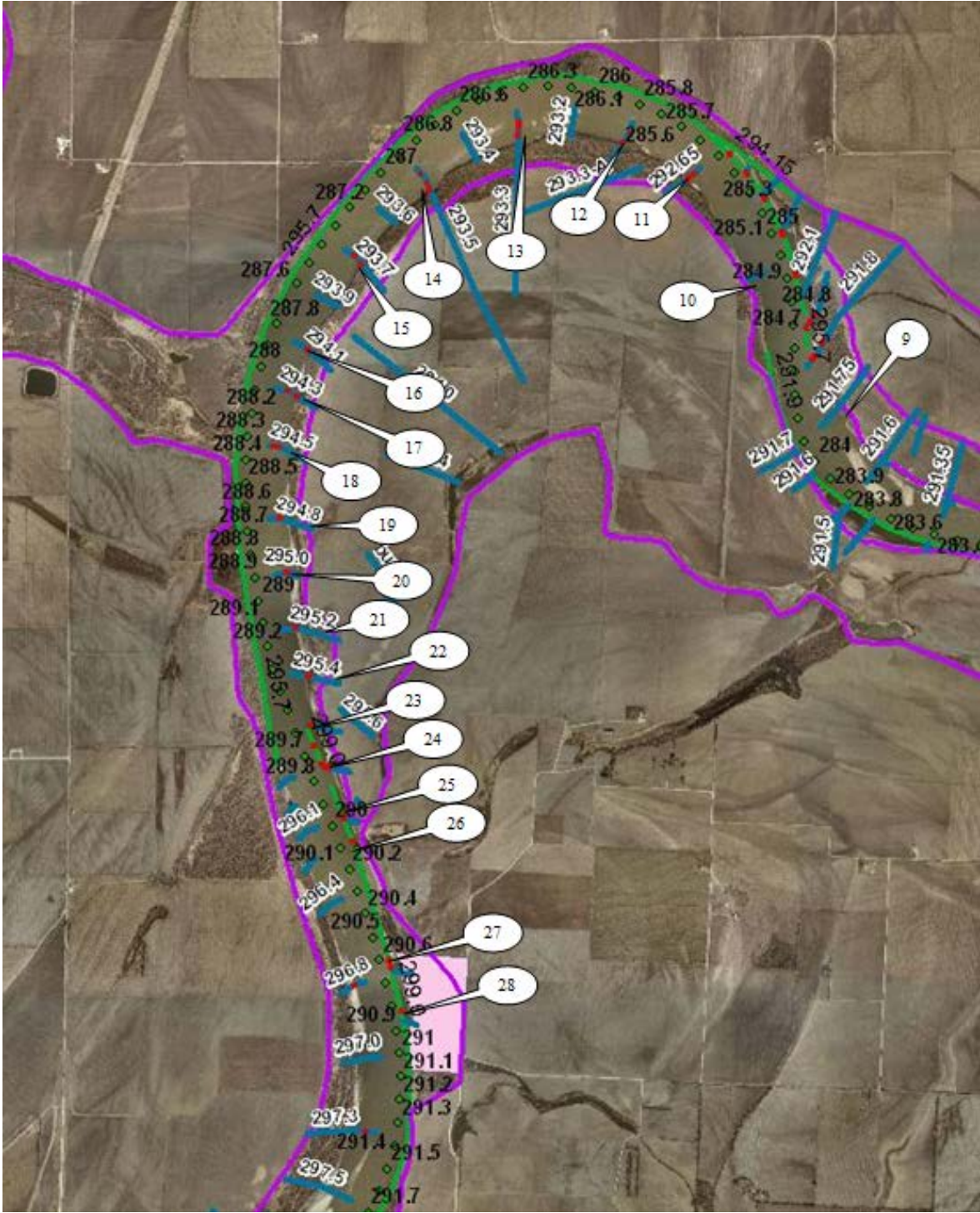


Figure 2-24(b): Overview of Locations 9 - 25

### ***2.10.1 Location 1:***

#### **Analysis:**

As shown in Figure 2-25, there are no notches at structure D287.85. The structure has not been modified since 1956.



**Figure 2-25: Overview of Location 1**



## 2.10.2 Location 2:

### Analysis:

There is no notch in structure D288.7, however, there are three notches in structure R289.4. The notches at this location were constructed to connect the aquatic area landward of the revetment with the main channel. They do not convey flow since there is only one notch between dikes. Table 2.22 contains details on notching at this location. Multiple entries are due to the notches being made deeper in 2004.

Table 2.22: Notching Performed Near Location 2

(Refer to Figure 2-26(a) for Structure Locations)

| Structure | Station (ft)   | CRP Elev (ft) | Width (ft) | Year | Distance from Bank (ft) |
|-----------|----------------|---------------|------------|------|-------------------------|
| R289.4    | 41+57 to 42+27 | -1            | 70         | 1985 | 120                     |
| R289.4    | 41+70 to 42+20 | -3            | 50         | 2004 |                         |
| R289.4    | 42+27 to 42+47 | -1            | 20         | 1986 |                         |
| R289.4    | 42+40 to 42+90 | -3            | 50         | 2004 |                         |
| R289.4    | 49+20 to 49+70 | -3            | 50         | 1983 | 120                     |
| R289.4    | 49+20 to 49+70 | -4            | 50         | 2004 |                         |
| R289.4    | 49+77 to 50+25 | -1            | 48         | 1985 | 120                     |
| R289.4    | 49+90 to 50+40 | -3            | 50         | 2004 |                         |

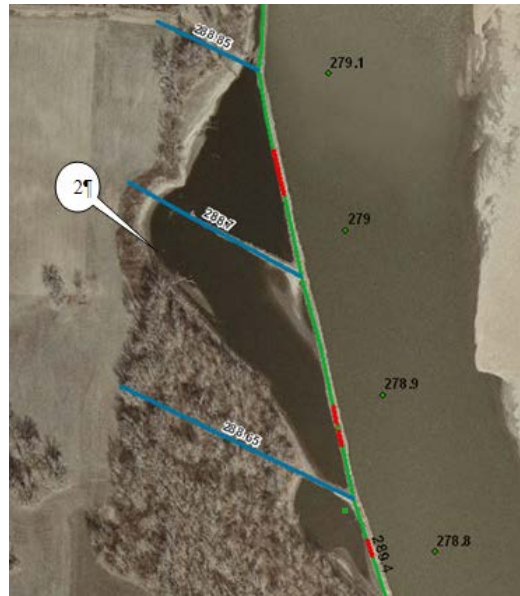
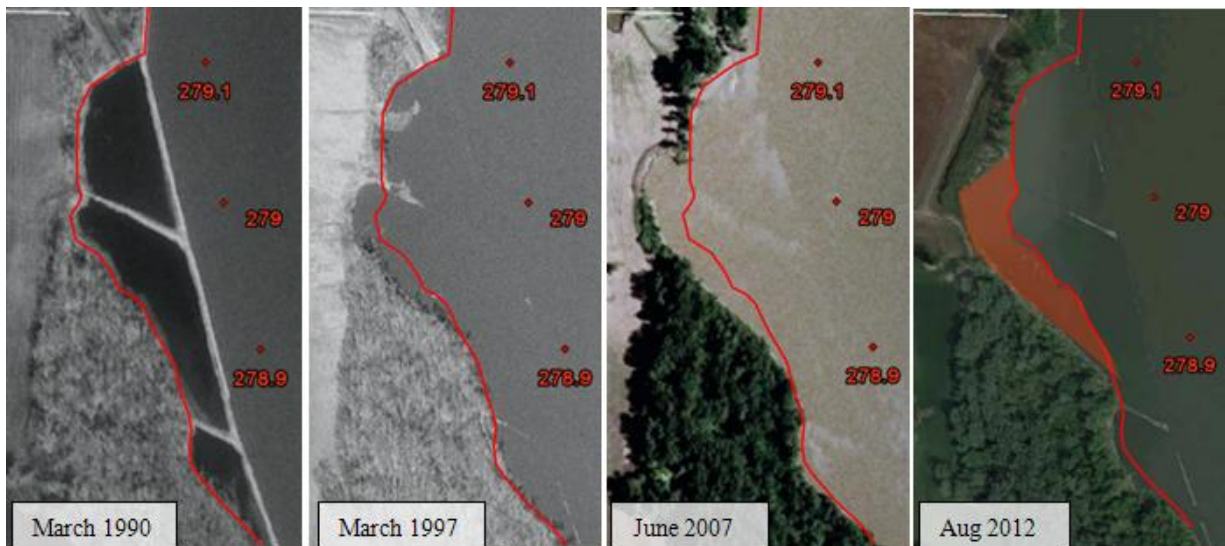


Figure 2-26(a): Overview of Location 2

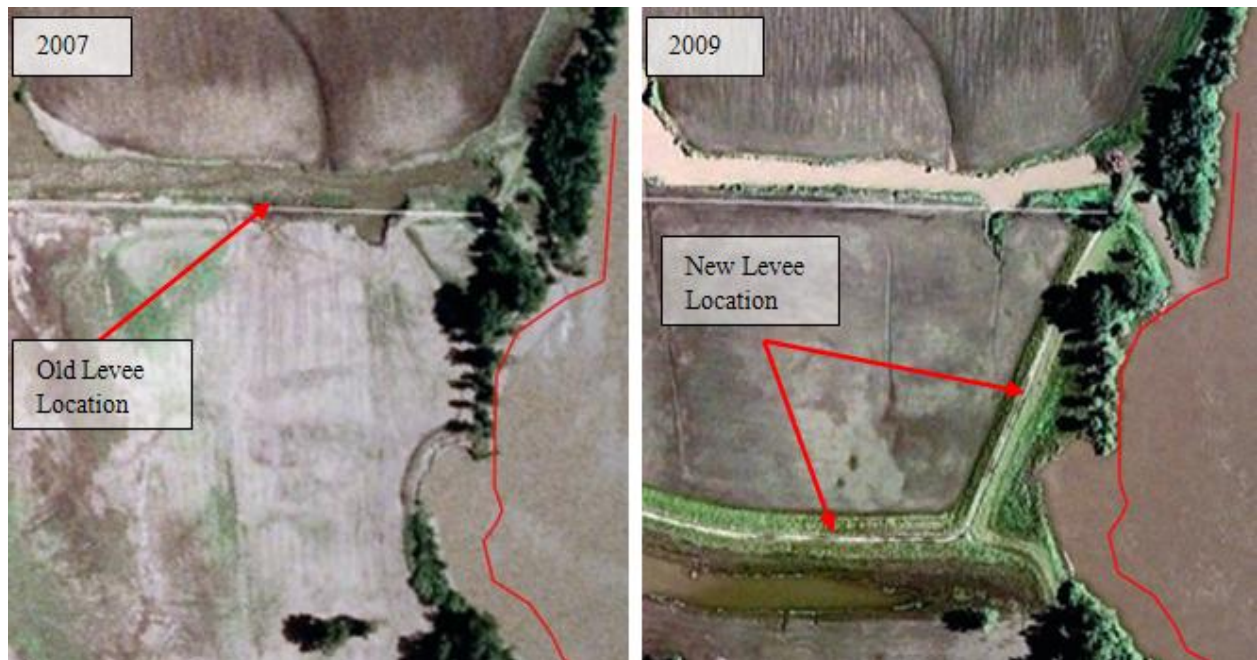
Aerial photos from 1990 to 2012 were reviewed and shown in Figure 2-26(b). There was significant bank movement between March 1990, March 1997 and June 2007. The red shaded area indicates the bank erosion that has occurred since 1990.



**Figure 2-26(b): Aerial Photo Comparison at Location 2 from 1990 to 2012**

**Conclusion:**

This area has shown significant erosion and the eroding bank is close to a levee. The levee was moved closer to the erosion location sometime between 2007 and 2009 (Figure 2-26(c)). A recent on-site inspection showed that the middle dike is no longer tied into the bank. This ‘flanked’ dike is likely the cause of the bank erosion as it allows water to flow between the dike and the bank during high flows resulting in bank erosion. The revetment and the middle dike are on the structure deficiency list and will be repaired as soon as possible.



**Figure 2-26(c): Change of Levee Location Near Location 2**

### 2.10.3 Locations 3, 4, 5 and 6:

There are notches at two of the four locations. However, the locations are on public land owned by the Corps of Engineers. Public land is indicated by the pink shaded area in Figure 2-27.



**Figure 2-27: Overview of Locations 3 - 6**

### 2.10.4 Location 7, 8 and 9:

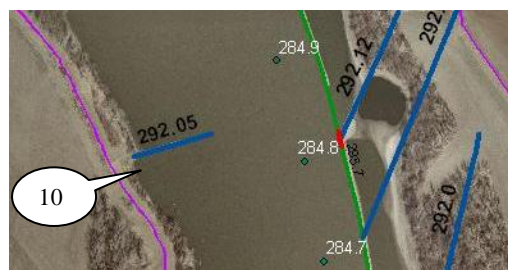
There are no notches in the structures around Location 7, 8, and 9, as shown in Figure 2-28. The revetment at this location was repaired in 2001 and D291.40 was constructed in 2006. The revetment is in need of additional repair and is currently on the structure deficiency list and will be repaired at the next opportunity.



**Figure 2-28: Overview of Locations 7 - 9**

### 2.10.5 Location 10:

There is no notch at Location 10 as shown in Figure 2-29.



**Figure 2-29: Overview of Location 10**



## 2.10.6 Location 11 and 12

### Analysis:

There are two notches at Location 11 on structure D292.65 and two notches at Location 12 on structure D293.0. In 1992, 1,030 tons of rock was added to D292.65 and 1,950 tons of rock was added to D293.0. An additional 1,695 tons was added to D293.0 in 1998. Notch details can be seen in Table 2.23.

Table 2.23: Notching Performed Near Locations 11 and 12

(Refer to Figure 2-30(a) for Structure Locations)

| Structure | Station (ft)   | CRP Elev (ft) | Width (ft) | Year | Distance from Bank (ft) |
|-----------|----------------|---------------|------------|------|-------------------------|
| D292.65   | 7+05 to 7+50   | -5            | 45         | 1978 | 200                     |
| D292.65*  | 7+50 to 8+00   | -4            | 50         | 1985 | 200                     |
| D292.65   | 5+75 to 6+25   | -4            | 50         | 2004 | 65                      |
| D293.0    | 11+05 to 11+25 | -4            | 20         | 1985 | 325                     |
| D293.0    | 8+15 to 8+65   | -4            | 50         | 2004 | 50                      |

\*Notch was made wider in 1985 to a total width of 95 feet.

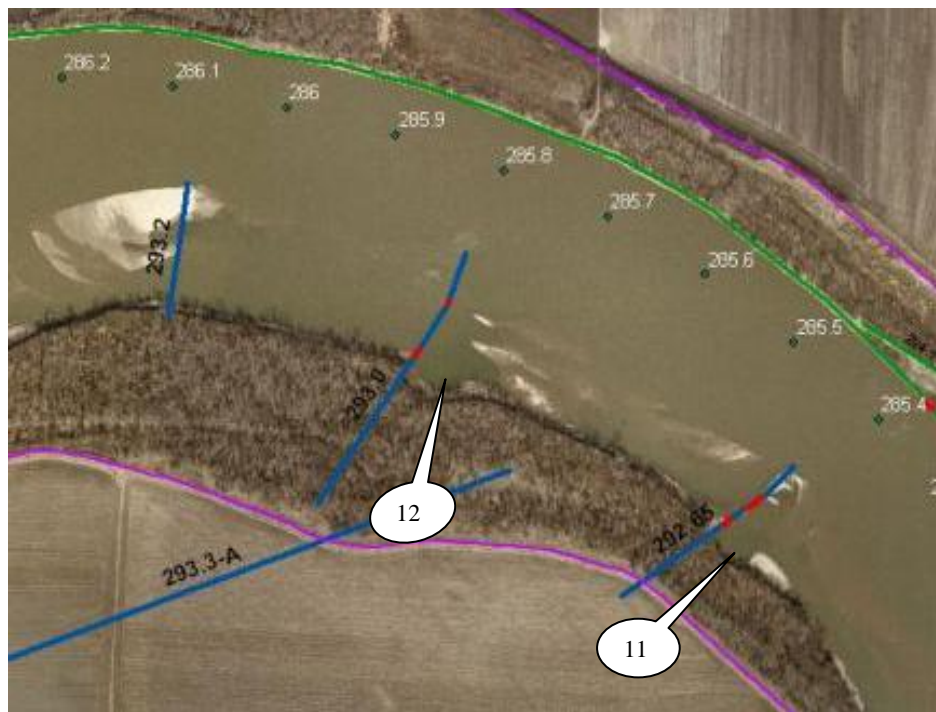
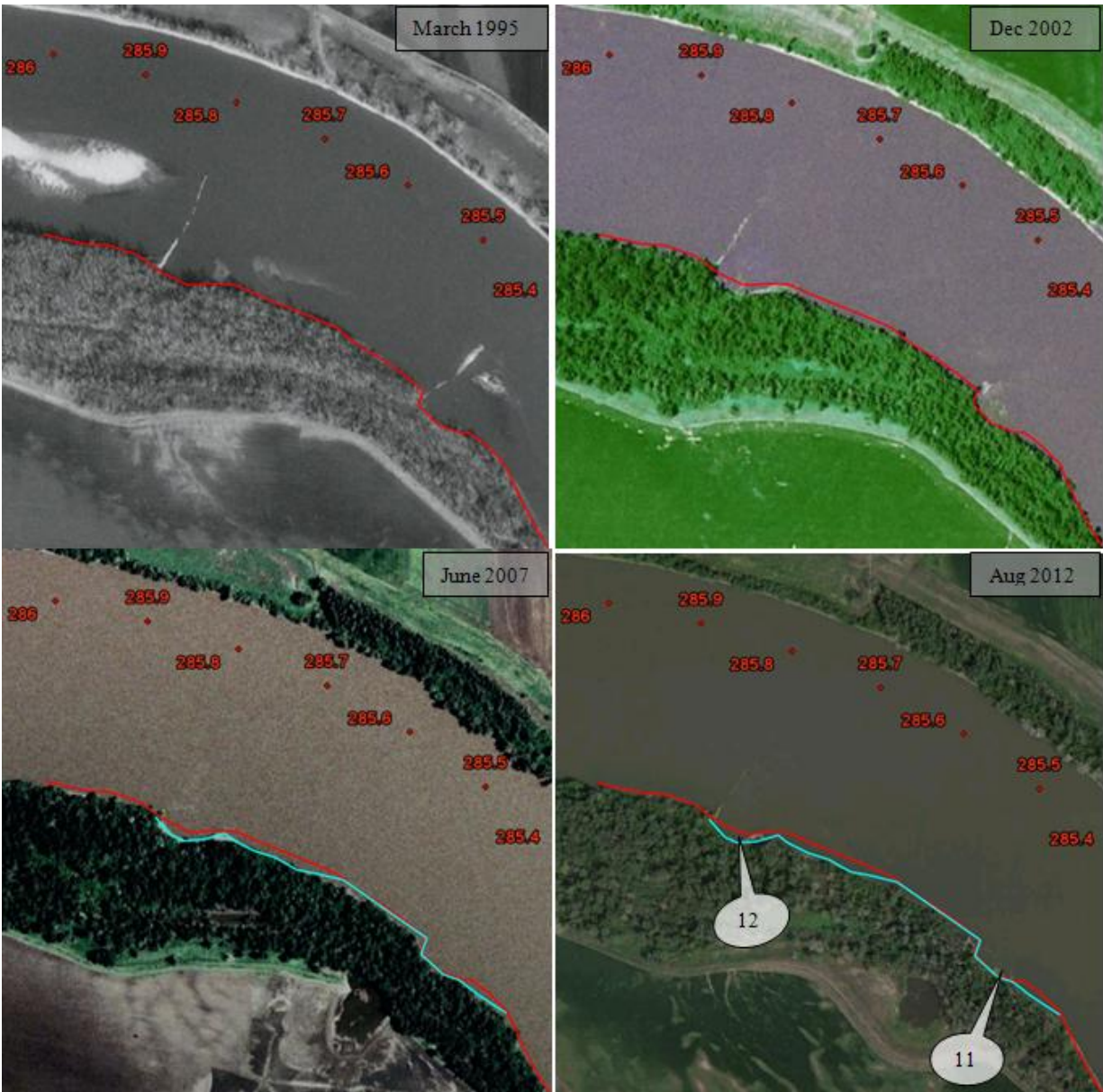


Figure 2-30(a): Overview of Locations 11 and 12

Aerial photos from March 1995 and August 2012 were compared and shown in Figure 2-30(b). The red line indicates the 1995 bank line location and the blue line indicates the bank line location in 2003 prior to the construction of the last two notches.



**Figure 2-30(b): Aerial Photo Comparison at Locations 11 and 12 from 1995 to 2012**

**Conclusion:**

Since the last two notches were added in 2004, the bank line has not moved. Note the breach in the levee in 2007 from a high water event (seen in bottom, left photo).



### 2.10.7 Location 13 and 14

At Location 13, there are three notches in structure D293.3. At Location 14, there are three notches on structure D293.5. Notch details can be seen in Table 2.24.

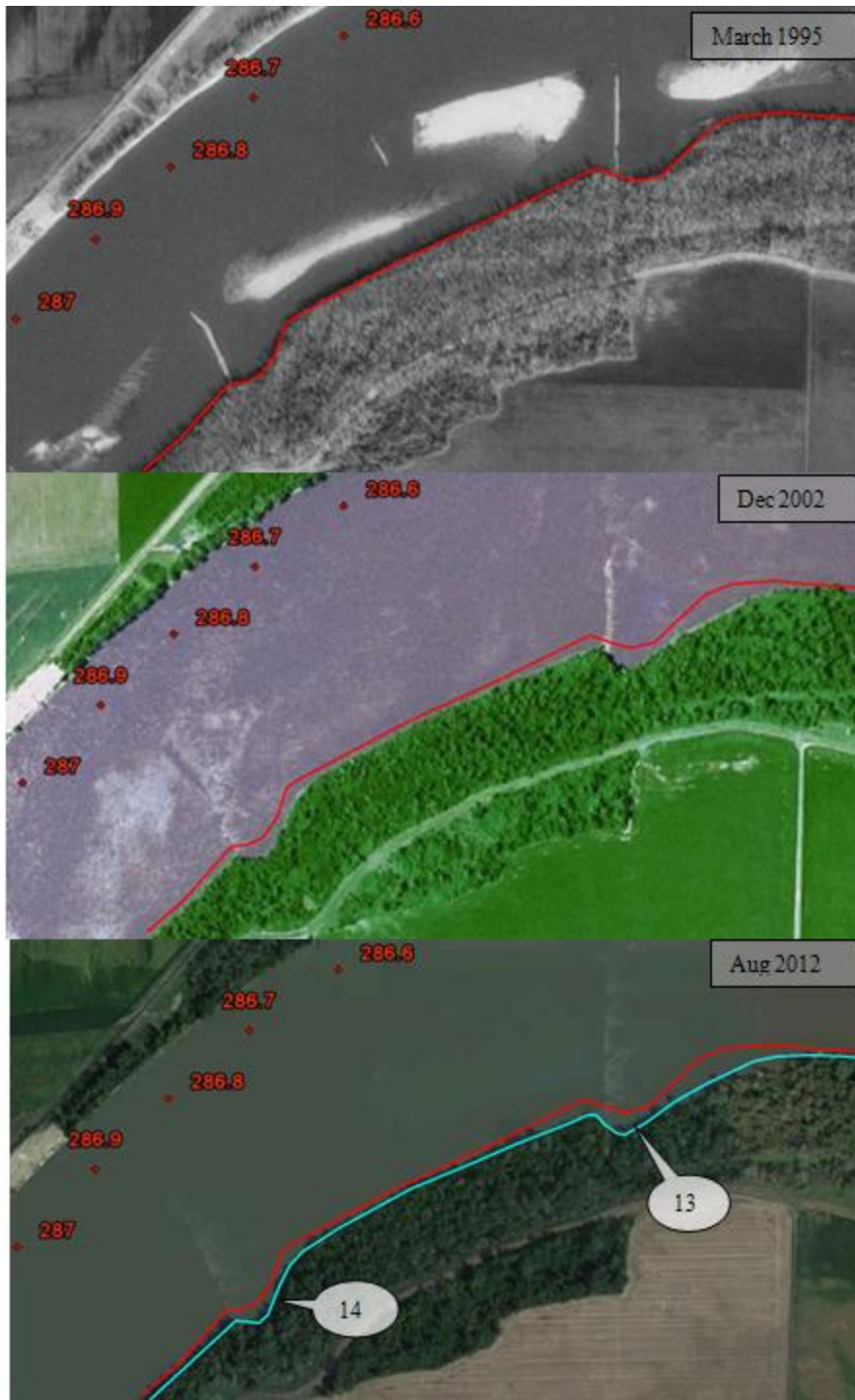
Table 2.24: Notching Performed Near Locations 13 and 14  
(Refer to Figure 2-31(a) for Structure Locations)

| Structure | Station (ft)   | CRP Elev (ft) | Width (ft) | Year | Distance from Bank (ft) |
|-----------|----------------|---------------|------------|------|-------------------------|
| D293.3    | 38+25 to 38+52 | -5            | 27         | 1985 | 575                     |
| D293.3    | 37+40 to 37+90 | -4            | 50         | 2004 | 500                     |
| D293.3    | 35+40 to 35+90 | -4            | 50         | 2004 | 285                     |
| D293.5    | 29+55 to 29+75 | -5            | 1986       | 500  |                         |
| D293.5    | 26+96 to 27+16 | -5            | 20         | 1986 | 250                     |
| D293.5    | 25+30 to 25+80 | -4            | 50         | 2004 | 75                      |



Figure 2-31(a): Overview of Locations 13 and 14

Aerial photos from March 1995 to August 2012 were compared as shown in Figure 2-31(b). The red line indicates the bank line location in 1995 and the blue line indicates the bank line location in 2002.



**Figure 2-31(b): Aerial Photo Comparison at Locations 13 and 14 from 1995 to 2012**

**Conclusion:**

The aerial photos indicate the bank erosion occurred prior to the creation of the 2004 notches and shows no movement since that time. It is unlikely the pre-2004 notches caused the bank erosion between 1995 and 2002 due to the small size of the notches and distance from the bank line.

### 2.10.8 Location 15

#### Analysis:

There are two notches at Location 15 on structure D293.7. The riverward notch is 20 feet wide and the notch closest to the bank is 50 feet wide. Notch details are shown in Table 2.25

Table 2.25: Notching Performed Near Location 15

(Refer to Figure 2-32(a) for Structure Locations)

| Structure | CRP Elev (ft) | Width (ft) | Year | Distance from Bank (ft) |
|-----------|---------------|------------|------|-------------------------|
| D293.7    | -2            | 20         | 1983 | 275                     |
| D293.7    | -5            | 50         | 2004 | 50                      |

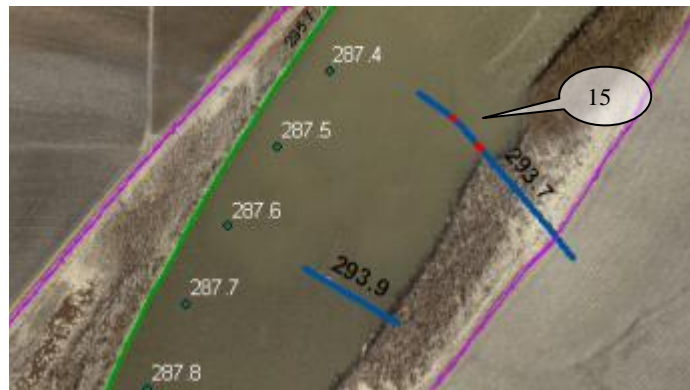
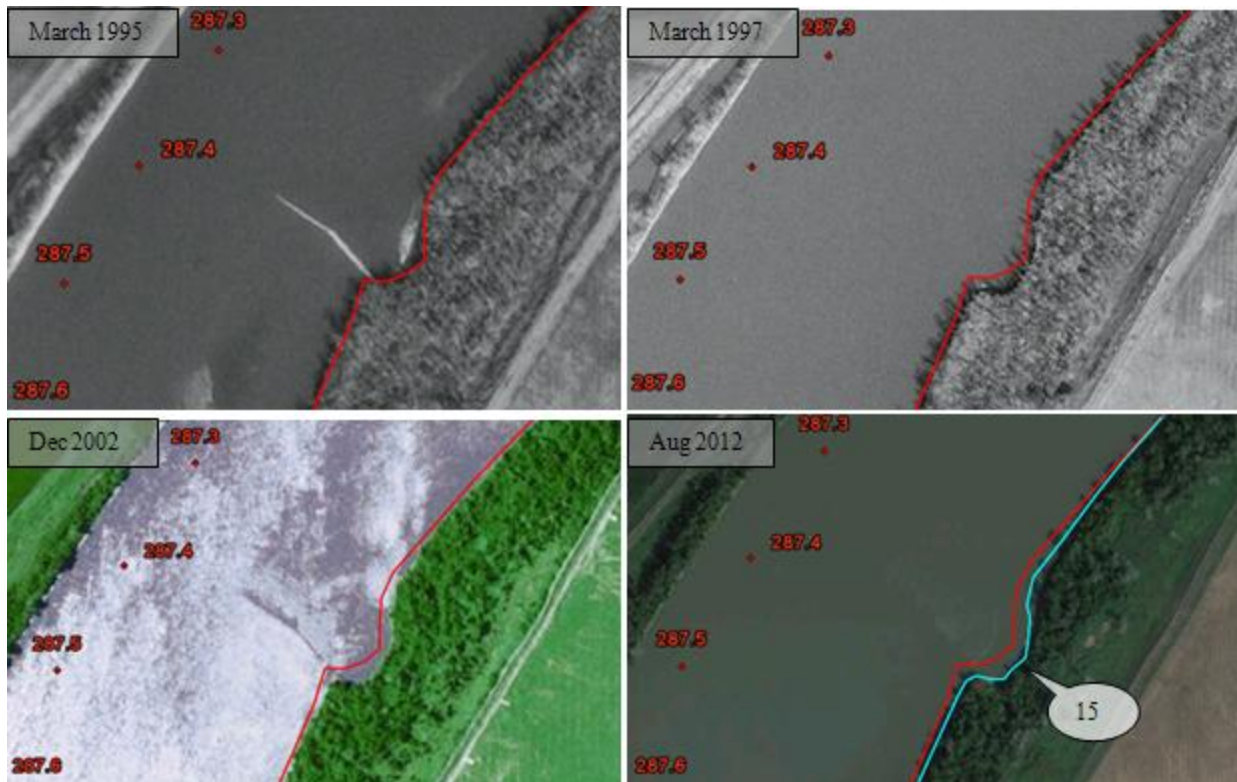


Figure 2-32(a): Overview of Location 15

Aerial photos from March 1995 and August 2012 were compared. The red line indicates the bank line location in 1995 and the blue line indicates the bank line location in 2002. The photos are shown in Figure 2-32(b).



**Figure 2-32(b): Aerial Photo Progression near Location 15 from 1995 to 2012**

**Conclusion:**

Bank movement began as early as 1997 and continued until 2002, as indicated by the aerial photos. It is unlikely the 1983 notch is the cause of the bank erosion due to the small size of the notch and the distance from the bank. The bank shows no erosion over the last 10 years, therefore, the 2004 notch has not caused any bank erosion.



## 2.10.9 Location 16, 17, 18 and 19

### Analysis:

There are a total of 6 notches at these four locations. There is one notch at Location 16 in structure D294.1. There are two notches at Location 17 in structure 294.3. The riverward notch is 20 feet wide and the notch closer to the bank is 50 feet wide. There are two notches at Location 18 in structure D294.5; both notches are 20 feet wide. Location 19 has one notch in structure D294.8. Table 2.26 contains notch details.

Table 2.26: Notch Details for Locations 16-19

(Refer to Figure 2-33(a) for Structure Locations)

| Structure | CRP Elev (ft) | Width (ft) | Year | Distance from Bank (ft) |
|-----------|---------------|------------|------|-------------------------|
| D294.1    | -4            | 50         | 2004 | 85                      |
| D294.3    | -5            | 20         | 1989 | 350                     |
| D294.3    | -4            | 50         | 2004 | 100                     |
| D294.5    | -3            | 20         | 1983 | 450                     |
| D294.5    | 0             | 20         | 1989 | 325                     |
| D294.8    | 0             | 33         | 1989 | 250                     |

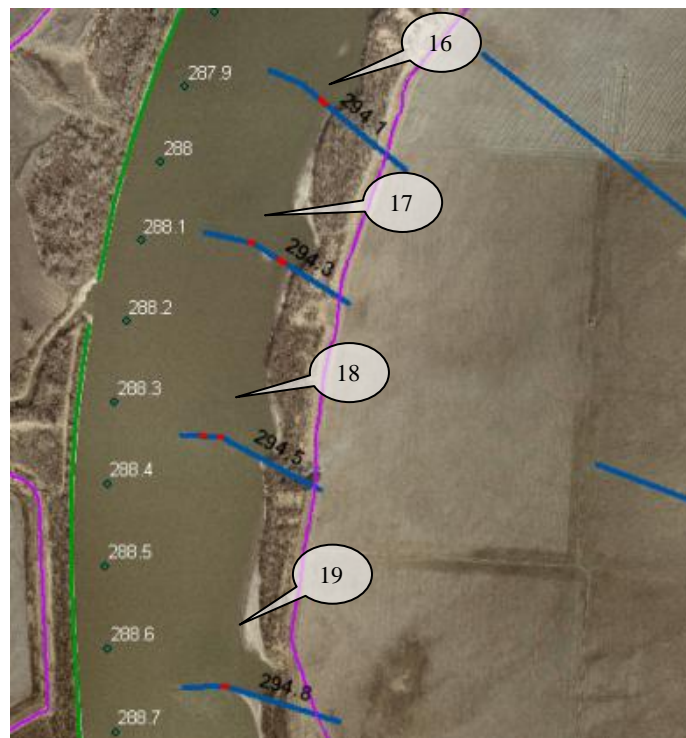
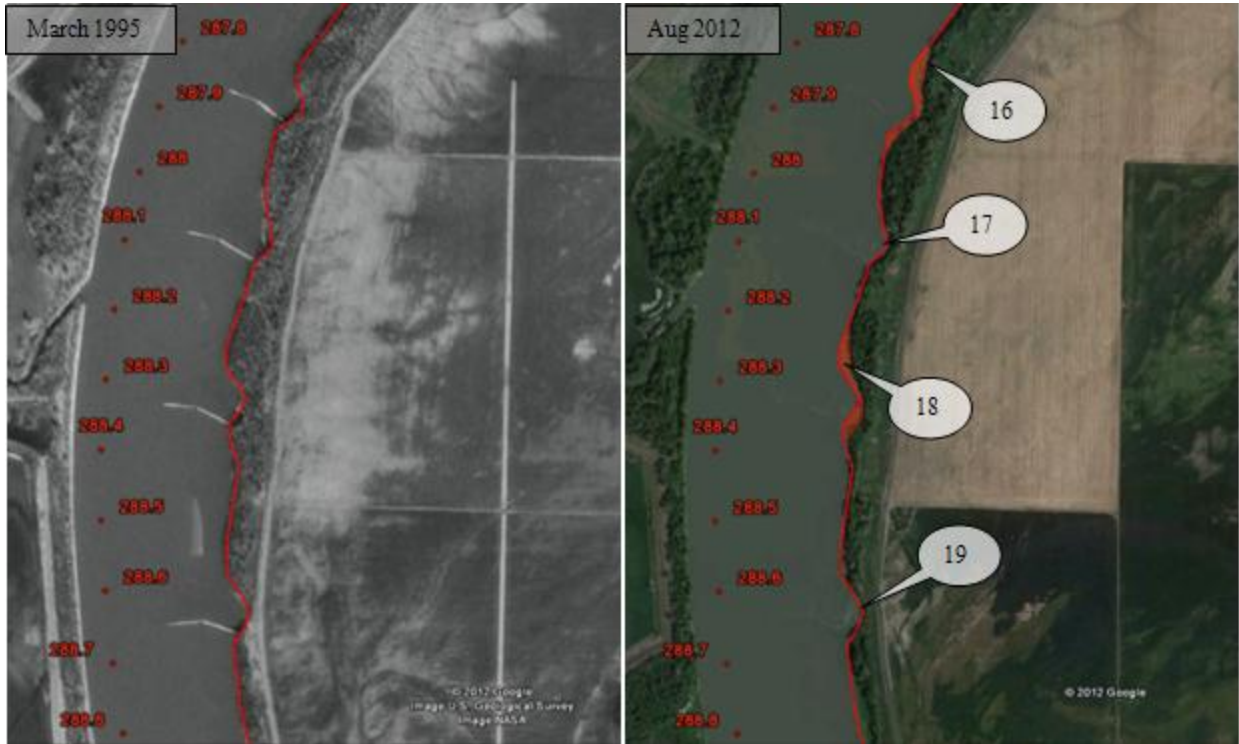


Figure 2-33(a): Overview of Locations 16 – 19

Aerial photos from March 1995 and August 2012 were compared to determine bank line movement. The bank movement can be seen by the red shaded areas in Figure 2-33(b).



**Figure 2-33(b): Aerial Photo Comparison at Locations 16 – 19 from 1995 to 2012**

**Conclusion:**

There has been bank movement at Location 16 and 18. Locations 16 and 17 have more recent constructed notches closer to the bank than Locations 18 and 19. The notches at Location 18 are small and located far from the bank and unlikely the cause of the bank erosion. Since Location 16 and 17 have similar notches constructed at the same time, but only Location 16 shows bank erosion, the notch at Location 16 is unlikely the cause of the bank erosion.

### 2.10.10 Location 20, 21 and 22

#### Analysis:

There is one notch on each structure at Locations 20, 21 and 22 which were created in 1977. In addition to the notching, stone was added to the structures to bring them up to grade in 1981, 1982 and 1996. Notch details can be seen in Table 2.27.

Table 2.27: Notch Details for Locations 20-22  
(Refer to Figure 2-34(a) for Structure Locations)

| Structure | CRP Elev (ft) | Width (ft) | Year | Distance from Bank (ft) |
|-----------|---------------|------------|------|-------------------------|
| D295.0    | -3            | 50         | 1977 | 225                     |
| D295.2    | -3            | 50         | 1977 | 150                     |
| D295.4    | -3            | 50         | 1977 | 90                      |

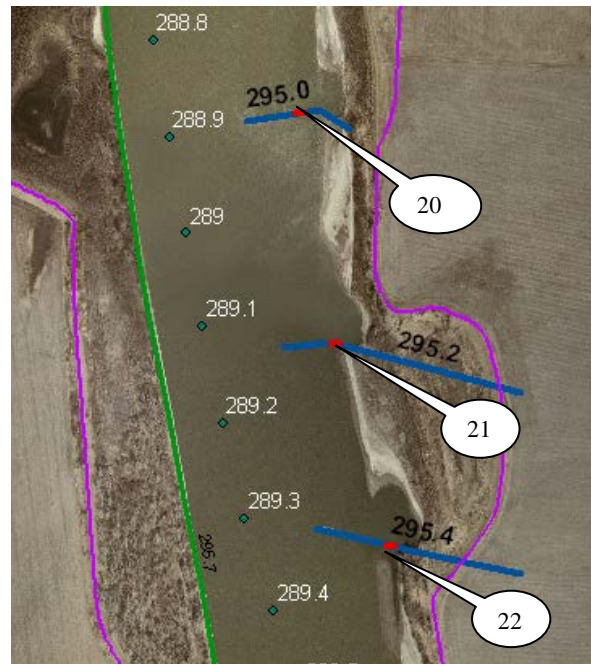
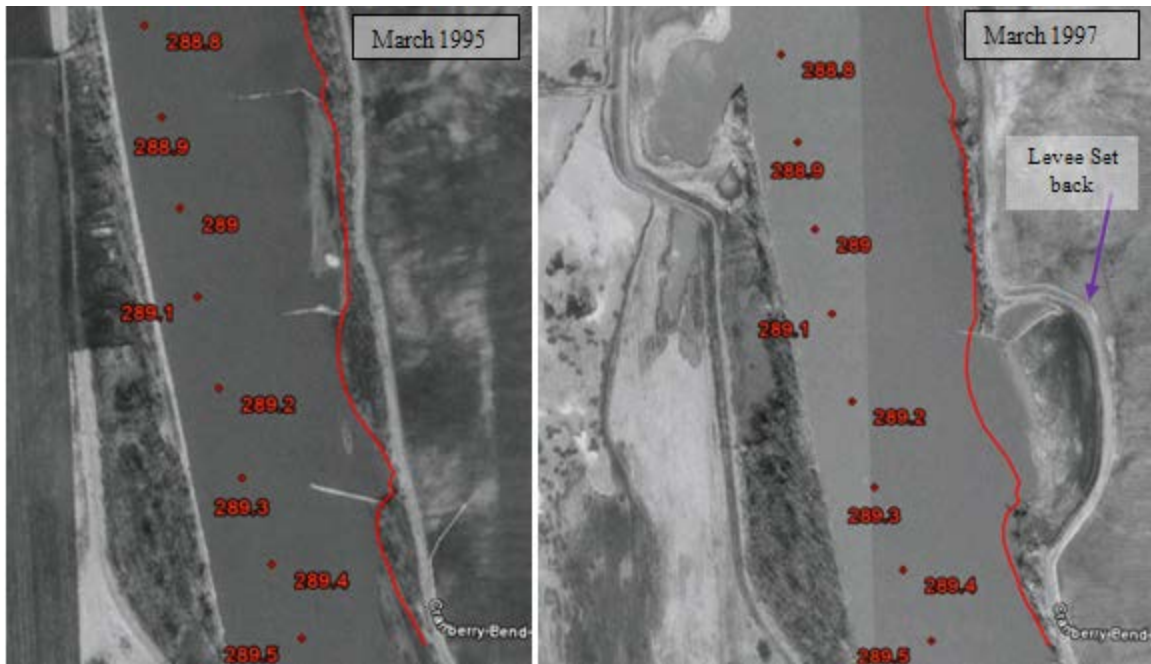


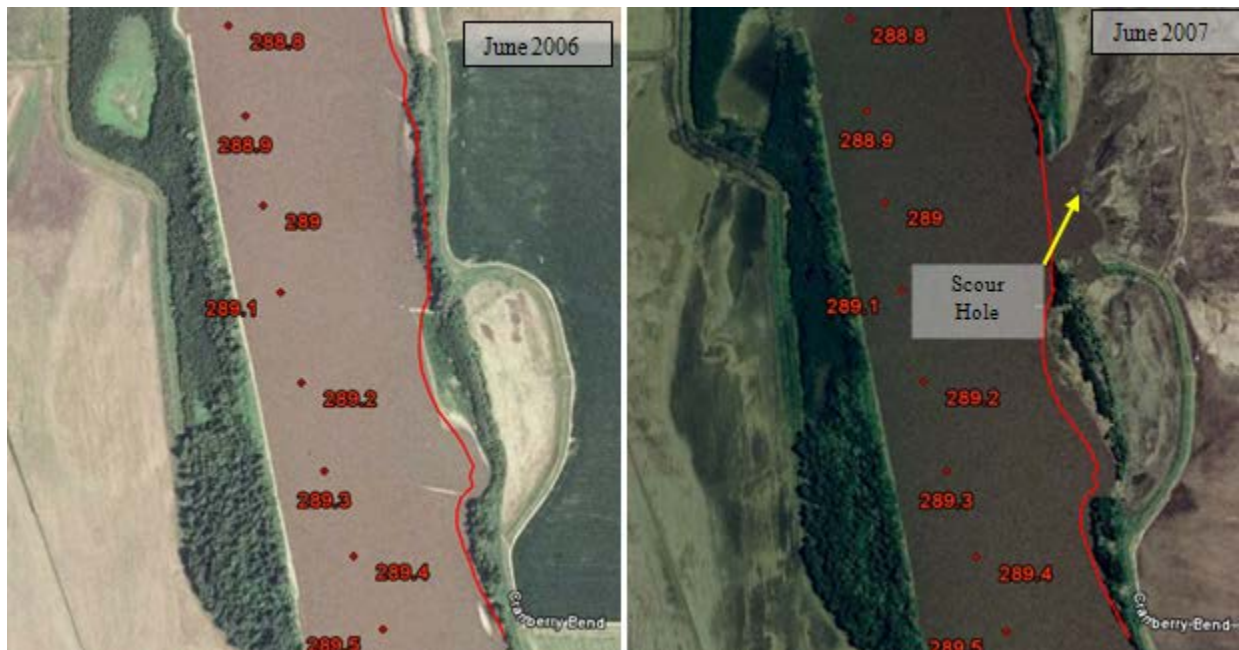
Figure 2-34(a): Overview of Locations 20 – 22

Aerial photos were reviewed to determine bank line movement near Locations 20, 21 and 22. The red line indicates the bank line location in March 1995. Between March 1995 and March 1997, a scour hole formed near river mile 289.2 and the levee was set back. The scour hole is seen in Figure 2-34(b).



**Figure 2-34(b): Aerial Photo Comparison for Location 20-22 from March 1995 to March 1997**

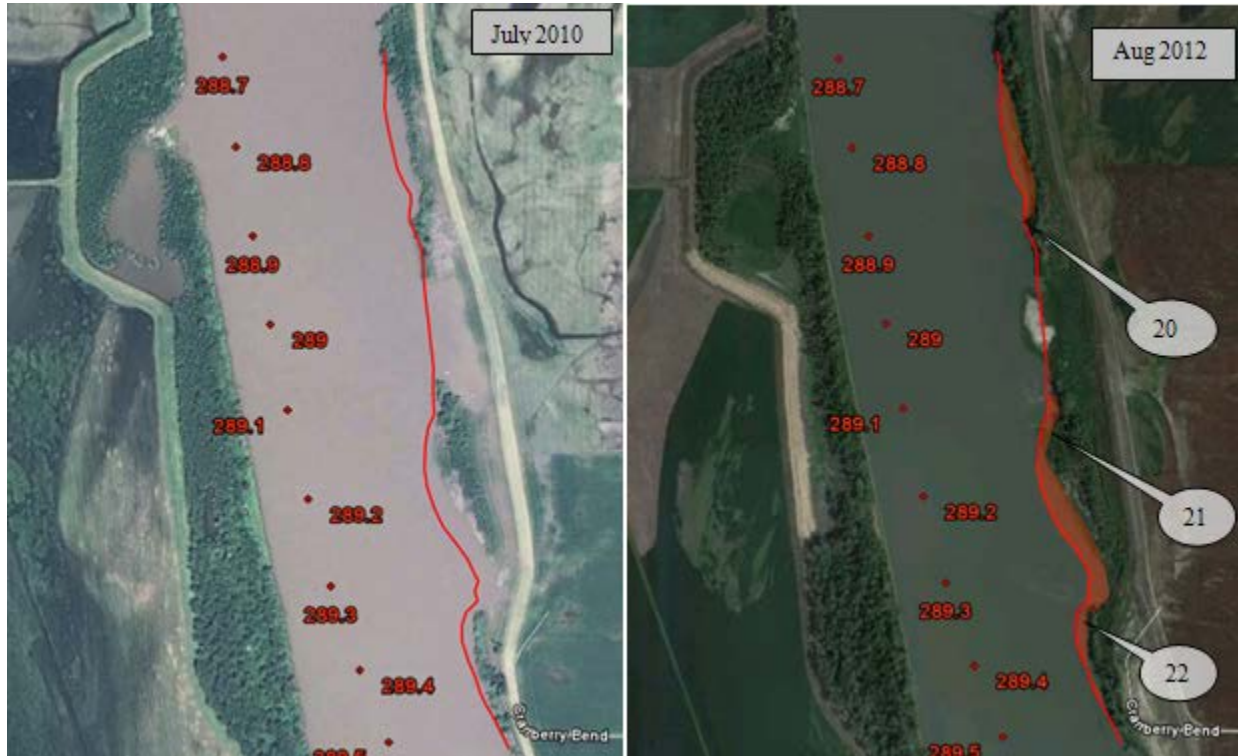
The next set of photos (Figure 2-34(c)) are from June 2006 and June 2007. The red line indicates the bank line location from March 1995. The June 2007 photo indicates another scour hole formed immediately upstream of the previous scour hole. The newer scour hole can be seen in Figure 2-34(c).



**Figure 2-34(c): Aerial Photo Comparison for Location 20-22 from June 2006 and June 2007**



The last set of photos (Figure 2-34(d)) are from July 2010 and August 2012. The levee had been set back to its original location (from March 1995 photo) by July 2010. High water is apparent in the June 2010 photo. The August 2012 photo shows the scour holes have mostly filled in.



**Figure 2-34(d): Aerial Photo Comparison for Location 20-22 from July 2010 and Aug 2012**

**Conclusion:**

Most of the bank erosion at these locations is due to the two scour holes that formed during flood events. There is erosion downstream of structure D295.0 that occurred between 1995 and 1997 that does not appear to be directly related to scour hole formation. However, the notch in structure D295.0 has been in place since 1977, is only 1 foot below the top of the adjacent structure, and is a considerable distance from the bank. It is unlikely the erosion was caused by the notch.

### 2.10.11 Locations 23, 24, 25 and 26

#### Analysis:

There are five notches near Locations 23, 24, 25 and 26. The most recent maintenance in the area was performed on structure D295.8 in 1998. Table 2.28 contains notch details.

Table 2.28: Notch Details for Locations 23-26  
(Refer to Figure 2-35(a) for Structure Locations)

| Structure | Stationing (ft)  | Location | CRP Elev (ft) | Width (ft) | Year | Distance from Bank (ft) |
|-----------|------------------|----------|---------------|------------|------|-------------------------|
| D295.65   | 7+00 to 7+50     | 23       | -2            | 50         | 1983 | 235                     |
| R299.0    | 189+30 to 189+80 | 24       | 0             | 50         | 1985 | 250                     |
| R299.0*   | 189+30 to 189+80 |          | -3            | 50         | 1994 | 250                     |
| R299.0    | 184+80 to 185+30 | 24       | 0             | 50         | 1976 | 350                     |
| R299.0*   | 184+80 to 185+30 |          | -3            | 50         | 1994 | 350                     |
| R299.0    | 171+50 to 172+50 | 25       | -1            | 100        | 1982 | 200                     |
| R299.0*   | 171+50 to 172+00 |          | -3            | 50         | 1994 | 200                     |
| R299.0*   | 172+25 to 172+50 |          | -3            | 25         | 1994 | 200                     |
| R299.0    | 166+00 to 166+25 | 26       | -3            | 25         | 1994 | 150                     |

\*Existing notch made lower

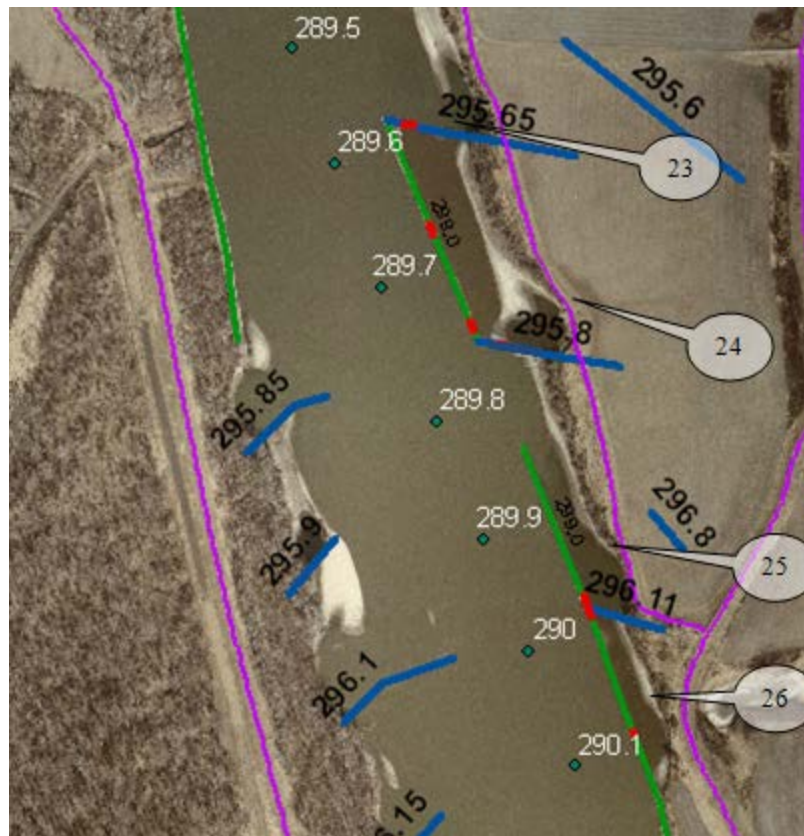
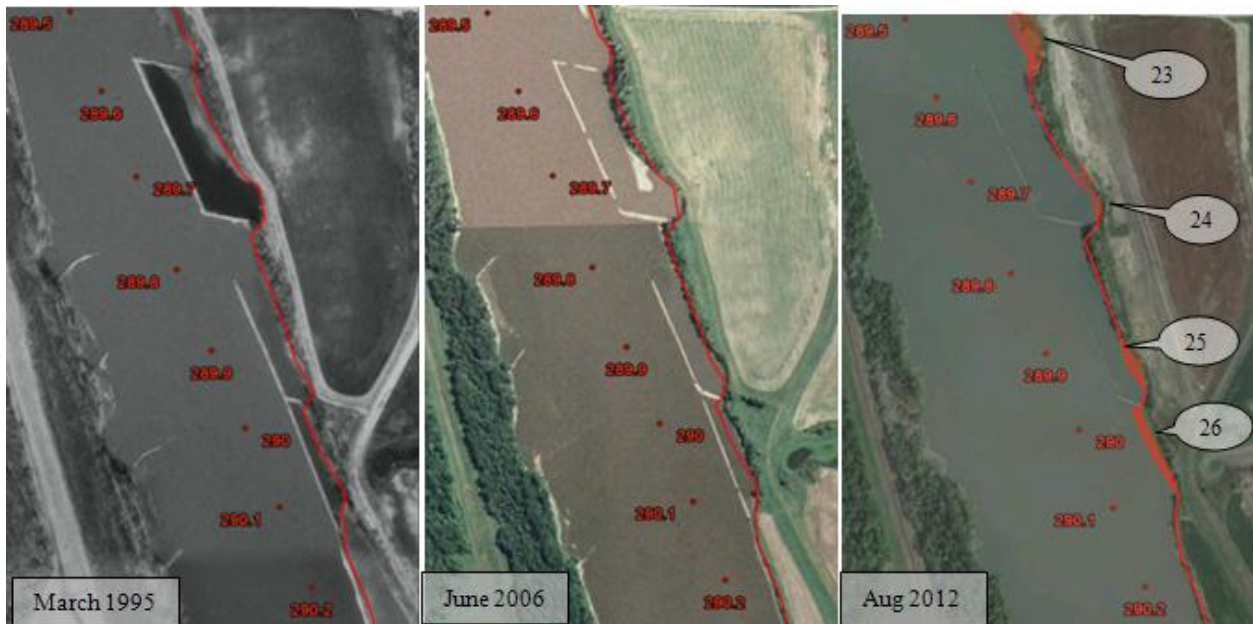


Figure 2-35(a): Overview of Locations 23 - 25.

Aerial photos from March 1995, June 2006, and August 2012 were compared as seen in Figure 2-35(b). Bank movement over the 17 years is indicated by the red shaded areas.



**Figure 2-35(b): Aerial Photo Comparison at Locations 23 – 25 from 1995 to 2012**

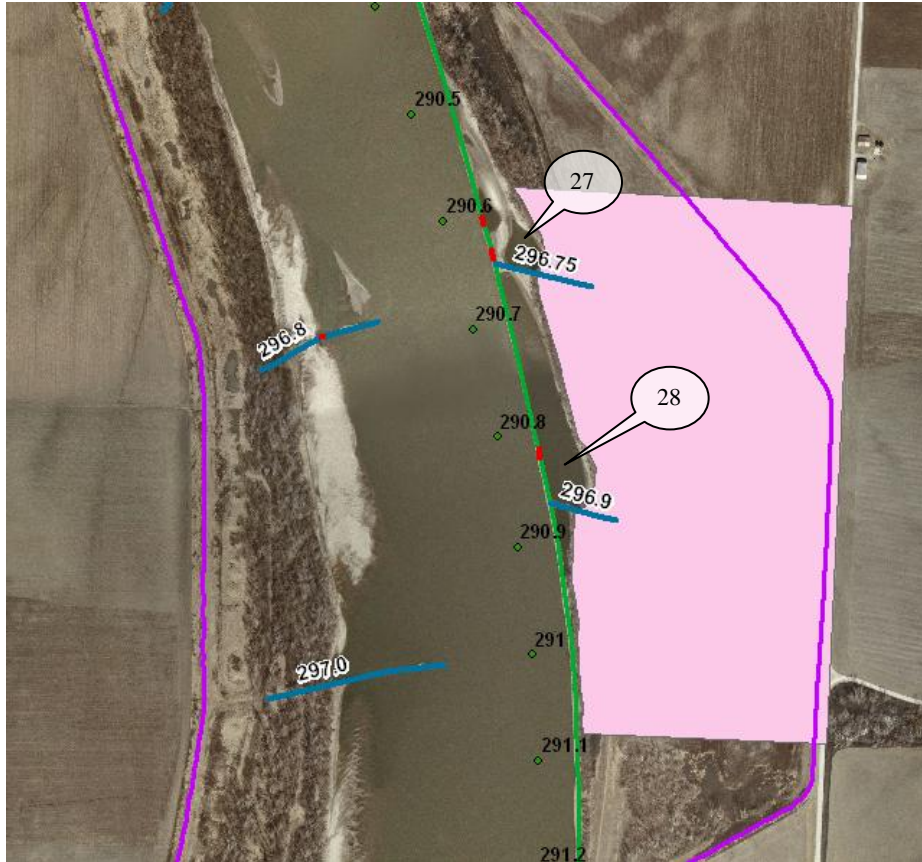
**Conclusion:**

This area has been a concern for at least the last 10 years. The notches are all small and located away from the bank. Corps staff have meet on-site with Levee District representatives at least three times to inspect the area. During those inspections all structures were determined to be up to design elevation and notches were not identified as the cause of the erosion. Based on the notch and erosion locations shown above, the bank erosion does not appear to be caused by the notches. The area will continue to be monitored

### ***2.10.12 Locations 27 and 28***

#### **Analysis:**

Locations 27 and 28 are located on Federal land owned by the Big Muddy National Fish and Wildlife Refuge. This area is indicated by the pink shaded area in Figure 2-36.



**Figure 2-36: Locations 27 and 28**

#### **Conclusion:**

There are notches at these locations, but the areas of concern are located on Federally owned land and the levee is set back from the river.

### ***2.10.13 Overall Recommendation***

Only three locations, Location 2, Location 22 and Location 23 showed even minimal areas of concern. These areas will be monitored. A summary of each location is in the table below.



| <b>Location</b> | <b>Recommendation</b>   |
|-----------------|---|
| 1               | There is no notch at this location  |
| 2               | This area will be monitored. In addition, the structure is noted on the deficiency list as needed additional rock due to the revetment being 4' low in some areas |
| 3               | There is no notch at this location and it is on federal land.   |
| 4               | Erosion is on federal land.   |
| 5               | Erosion is on federal land.   |
| 6               | There is no notch at this location and it is on federal land.   |
| 7               | There is no notch at this location  |
| 8               | There is no notch at this location  |
| 9               | There is no notch at this location  |
| 10              | There is no notch at this location  |
| 11              | Bank movement is minimal and notches are working as designed.   |
| 12              | Bank movement is minimal and notches are working as designed.   |
| 13              | Bank movement is minimal and notches are working as designed.   |
| 14              | Bank movement is minimal and notches are working as designed.   |
| 15              | Bank movement is minimal and notches are working as designed.   |
| 16              | Bank movement is minimal and notches are working as designed.   |
| 17              | There has been no bank movement. Notch is working as designed.  |
| 18              | Bank movement is minimal and notches are working as designed.   |
| 19              | There has been no bank movement. Notch is working as designed.  |
| 20              | Bank movement is minimal and notches are working as designed.   |
| 21              | Bank movement is minimal and notches are working as designed.   |
| 22              | Bank movement is moderate and will be monitored.  |
| 23              | Bank movement is moderate and will be monitored.  |
| 24              | Bank movement is minimal and notches are working as designed.   |
| 25              | Bank movement is minimal and notches are working as designed.   |
| 26              | Bank movement is minimal and notches are working as designed.   |
| 27              | This area is located on federal land.   |
| 28              | This area is located on federal land.   |

## 3.0 Erosion Concerns: Stated Cause Other Than Notches

### 3.1 Erosion Concerns near Natural Chute at River Mile 8

#### Submitted Statement:

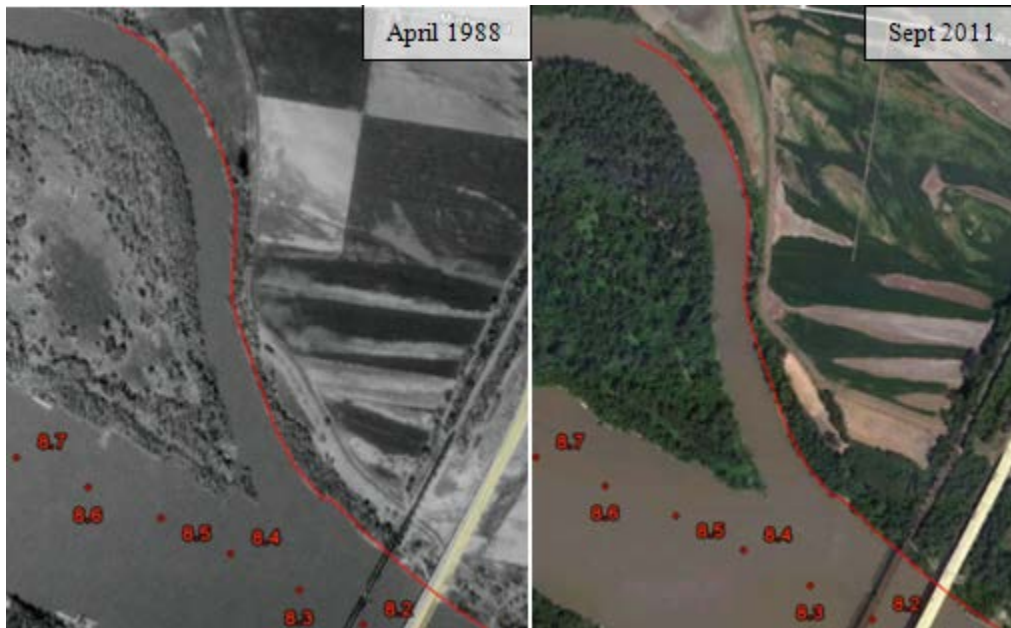
Mike Farley has a concern around River Mile 7 involving bank erosion on the lower part of a natural chute upstream of the US 67 bridge. Mr. Farley stated “The Kansas City Corps is aware of the problem and have been working to solve the issue, but as yet, it is still eroding.” He believes the problem is caused by high water through the chute. The area can be seen in Figure 3-1(a).



**Figure 3-1(a): Overview of Location of Concern Near River Mile 8**

#### Analysis:

Aerial photos from April 1988 and September 2011 were compared as shown in Figure 3-1(b). These photos indicate minimal bank movement.



**Figure 3-1(b): Aerial Photo Comparison from 1988 to 2011**

**Conclusion:**

This location, in a natural chute, does not contain any notches and shows minimal bank movement since 1988. Corps staff has met on-site with representatives of the Levee District numerous times over the last 5 years. As a result of those meetings, existing hard points were repaired and new hard points constructed downstream of the existing ones. No further repairs are scheduled at this time.

## 3.2 Dike Maintenance Concerns at River Mile 290 and River Mile 296

### Submitted Statement:

Kevin Casner has erosion concerns which he believes is caused by dike notches and lack of maintenance near river mile 290, caused specifically by structures D295.85 and D296.1. He also has concerns near river mile 296, specifically with structures D301.7, D301.8, and D302.55.

### Analysis:

There are no notches at any of these locations. Structure locations are circled and can be seen in Figure 3-2.



Figure 3-2: Structure Names and Locations near River Mile 290 and River Mile 296

### Conclusion:

Corps staff meet on-site with Mr. Casner in 1998 to inspect the dikes at river mile 296. The dikes at this location were repaired soon after that meeting. There are no notches at either of these two locations and recent inspections show that all structures are up to design elevation.



### 3.3 Erosion Concern at River Mile 466.5

#### Submitted Statement:

David Banks stated “The area parallel to the river and just downstream of Forbes Creek needs stabilization. It was rocked several years ago and needs rock added to stabilize the bank or they may lose the riverfront property.” This area is shown in Figure 3-3.



Figure 3-3: Overview of Area of Concern

#### Conclusion:

There are no notches in this area.

## 4.0 Erosion Concerns: Stated Cause is Flooding

### 4.1 Concerns at River Mile 320 from Flood Event

#### Submitted Statement:

Larry Hicks has concerns around river mile 320 and between river miles 324-325. Mr. Hicks submitted a letter stating, “Enclosed please find pictures of two areas of concern to our district. The bank cut down at mile 320 is very dangerous to our levy. Both occurred during 2011 event.”

#### *4.1.1 Location 1*

The photo submitted for river mile 320 is shown in Figure 4-1(a).



**Figure 4-1(a): Photo Submitted by Larry Hicks near River Mile 320**

#### Analysis:

There is no notch at this location, as seen in Figure 4-1(b). Table 4.1 contains maintenance that has been performed on structure R326.8 in the location of concern.

Table 4.1: Maintenance at structure R326.8 since 1980 in Area of Concern

| Structure | Type of Work | Station (ft)   | CRP Elev (ft) | Width (ft) | Year |
|-----------|--------------|----------------|---------------|------------|------|
| R326.8    | TTR Repair   | 28+00 to 45+50 | 13            | 1750       | 1980 |
| R326.8    | TTR Repair   | 31+50 to 37+50 | 14            | 600        | 1986 |
| R326.8    | TTR Repair   | 34+00 to 36+00 | 14            | 200        | 1987 |



Figure 4-1(b): Overview of Area of Concern Near River Mile 320

Figure 4-1(c) shows aerial photos from March 1996 and August 2012, indicating where the area of concern is located.

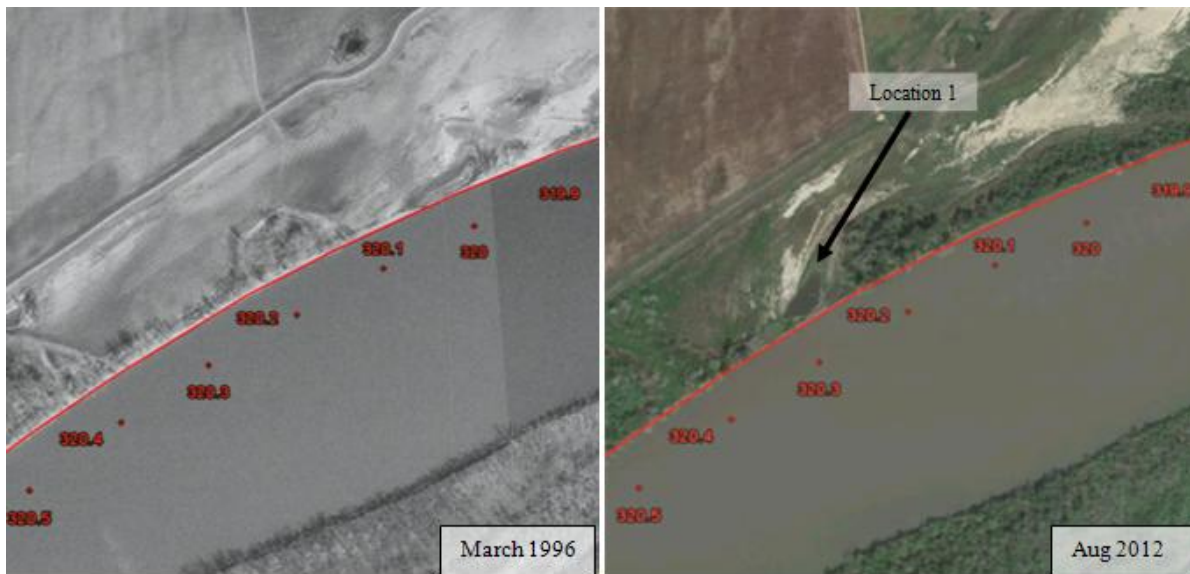


Figure 4-1(c): Aerial Photo Comparison near Area of Concern from 1996 to 2012

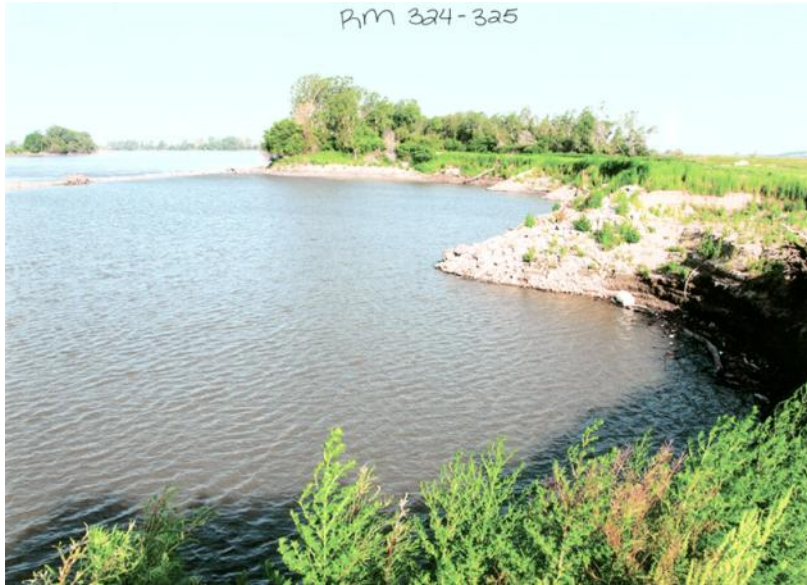
**Conclusion:**

The concerns at this location are due to the high flow events of 2011. There are no notches at this location and recent inspections show that the revetment is to design elevation. It is likely the scour hole will accrete in over the next few years.

## 4.1.2 Location 2

### Analysis:

The photo submitted for the concern between river mile 324 and 325 is shown in Figure 4-2(a).



**Figure 4-2(a): Submitted Photo by Larry Hicks between River Mile 324 – 325**

The structures in the area can be seen in Figure 4-2(b). The first notch in structure R337.5 was constructed in 1976 and the second notch was constructed in 1983. In 2008, 5 hard points were constructed upstream of D331.0 and the revetment repaired with nearly 3,000 tons of rock. Details of the notches can be seen in Table 4.2.



**Figure 4-2(b): Overview of Area of Concern Near River Mile 324 and 325**

Table 4.2: Notching at Structure R337.5

| Structure | Station (ft)   | CRP Elev (ft) | Width (ft) | Year | Distance from Bank (ft) |
|-----------|----------------|---------------|------------|------|-------------------------|
| R337.5    | 58+50 to 59+00 | -3            | 50         | 1976 | 375                     |
| R337.5    | 66+99 to 67+48 | 1             | 49         | 1983 | 225                     |



Aerial photos from March 1996 to August 2012 were compared to determine bank movement. Bank erosion first started to occur sometime between 1996 and 2002. Erosion was more noticeable in 2007. The most significant bank movement occurred between 2007 and 2012, probably during the high flow event of 2011. The red shaded area in Figure 4-2(c) indicates bank movement over 16 years from March 1996 to August 2012.

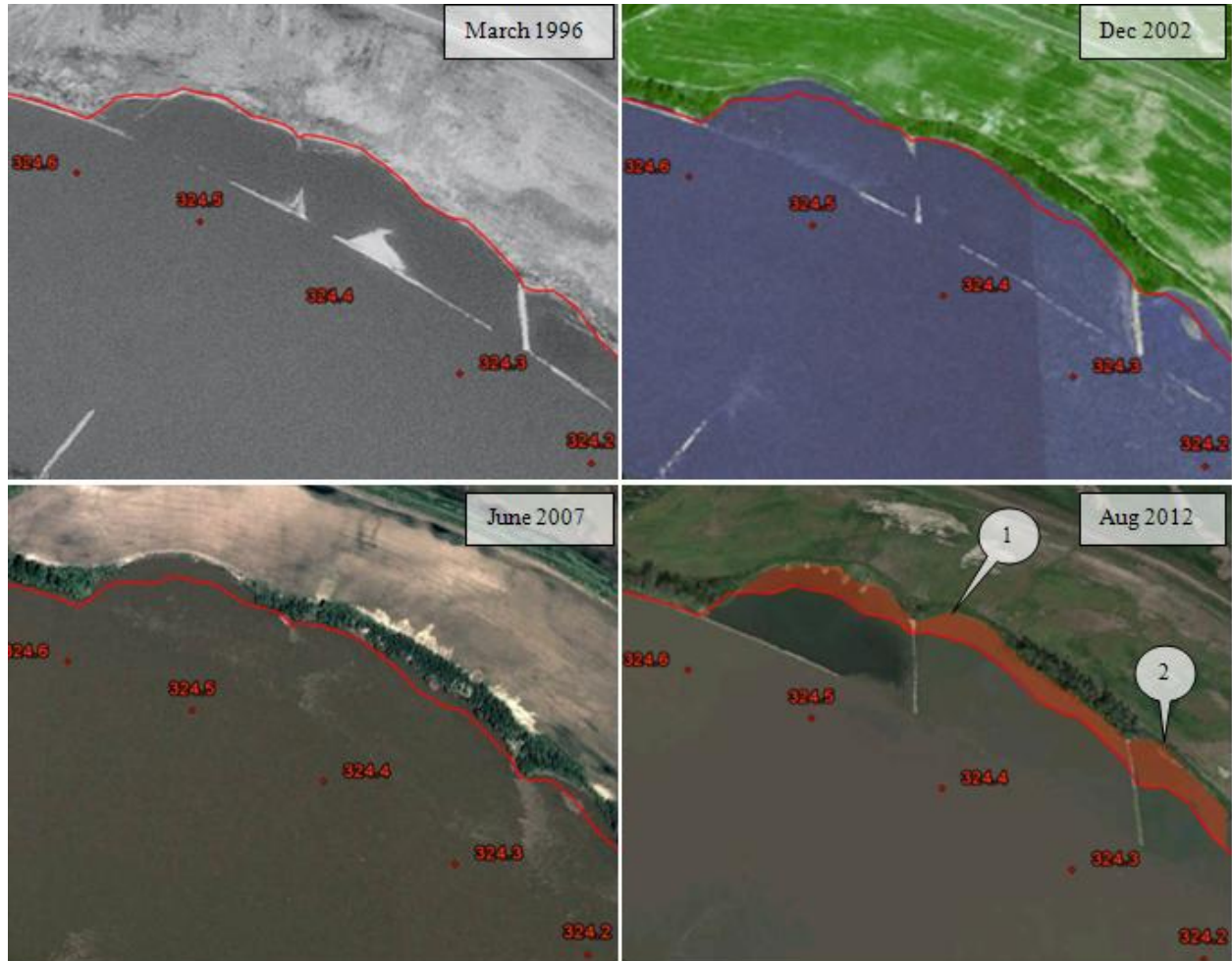


Figure 4-2(c) Aerial Photo Comparison Near Area of Concern from 1996 to 2012

**Conclusion:**

The bank has experienced significant erosion. Due to the widespread nature of the erosion, small size of the notches, and distance from the bank, it is unlikely the erosion is caused by the notches. Structure D330.7 is listed as a deficient structure and will be repaired as soon as possible. This rock should aid in protecting the bank from additional erosion.

### 4.3 Concern near River Mile 435 from Flood Event

#### Submitted Statement:

Jeffrey Gaskill has concerns with river mile 435. He believes the problem began during the 1993 flood and got worse during the 2011 flood where it almost cut into his private levee. He also believes rock has been added for fish habitat. Figure 4-3(a) indicates the area of concern.



Figure 4-3(a): Overview of Area of Concern Near River Mile 435

#### Analysis:

Aerial photos were compared from September 1991 to September 2012 as seen in Figure 4-3(b). The red line indicates the bank line from 1991. The bank moved significantly due to the high water events in 1993 and 1995. The blue line indicates the bank line from 1997. There was minimal bank movement from 1997 to 2010. However, since 2010, the bank has moved approximately 100 feet.

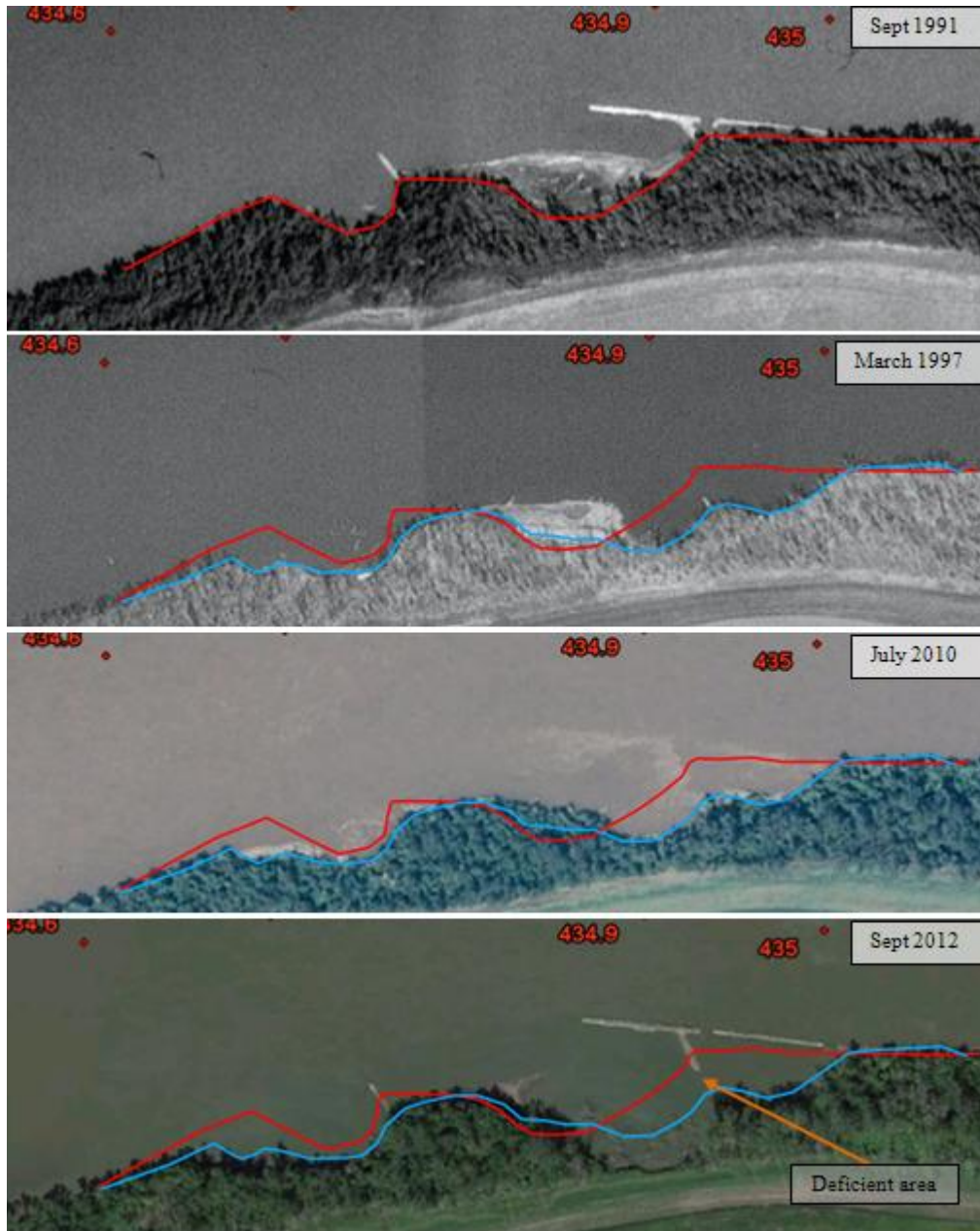


Figure 4-3(b): Aerial Photo Comparison Near Area of Concern from 1997 to 2012

**Conclusion:**

Bank movement in this area has been significant. Corps staff have met on-site with representatives of the Levee District to inspect the site. Structure D467.2-G was heavily damaged during the 2011 flood and is scheduled to be repaired in early 2013. The orange arrow in Figure 4-3(b), indicates the area where repair rock will be placed.

## 4.4 Concern near River Mile 490 from Flood Event

### Submitted Statement:

Paul Derks a concern at River Mile 490 which he states was caused by the 2011 flood.

### Analysis:

There is one notch in this location that was constructed in 1982. Details are located in Table 4.3.

Table 4.3: Notching at Structure R337.5

| Structure | CRP Elev (ft) | Width (ft) | Year | Distance from Bank (ft) |
|-----------|---------------|------------|------|-------------------------|
| R528.6    | 0             | 50         | 1982 | 45                      |

It is 50 feet wide and set to an elevation of 0 CRP. The structure names and locations are seen in Figure 4-4(a).



Figure 4-4(a): Overview of Location of concern near River Mile 490

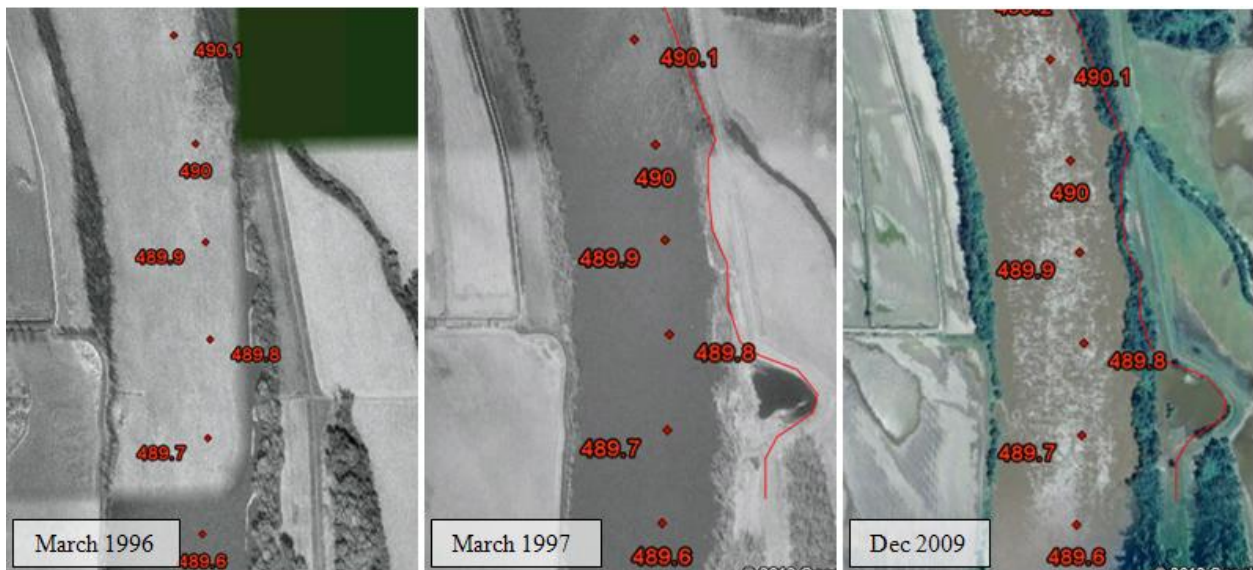
Mr. Derks submitted an aerial photo of the location taken before the flood event, as seen in Figure 4-4(b).





**Figure 4-4(b): Submitted Pre-Flood Photo near Location of Concern**

The levee was relocated between 1996 and 1997, as seen in the aerial photos in figure 4-4(c). There is no aerial photography available since 2009.



**Figure 4-4(c): Aerial Photo Comparison for Area of Concern from 1996 to 2009**

Mr. Derks submitted aerial photos of the damage caused from the 2011 flood. These can be seen in Figure 4-4(d).



**Figure 4-4(d): Aerial Photos of Flood Damage Submitted by Mr. Derks**

**Conclusion:**

The one notch in this location has been in place since 1982. It is apparent the high water of 1997 and the 2011 flood caused the damage in the area. Structure R528.6 is listed on the deficiency list and will be repaired in 2013.

## 5.0 Erosion Concerns: Stated Cause is Shallow Water Habitat

### 5.1 Concern near River Mile 211 from Jameson Chute

#### Submitted Statement:

Mark Schupp has a concern at River Mile 211 and believes it is caused by the Jameson Island chute. Structure names and locations in the area are seen below in Figure 5-1(a).

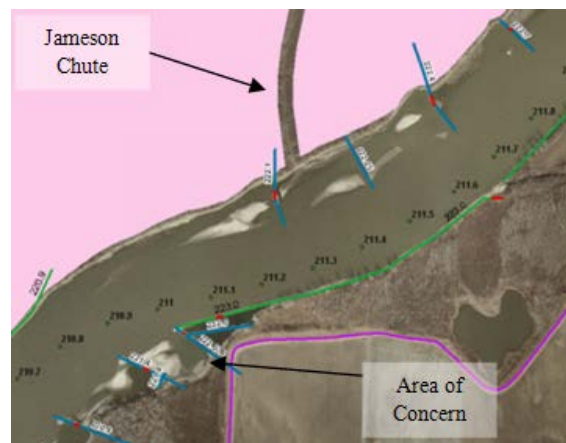


Figure 5-1(a): Location of Concern near River Mile 211

#### Analysis:

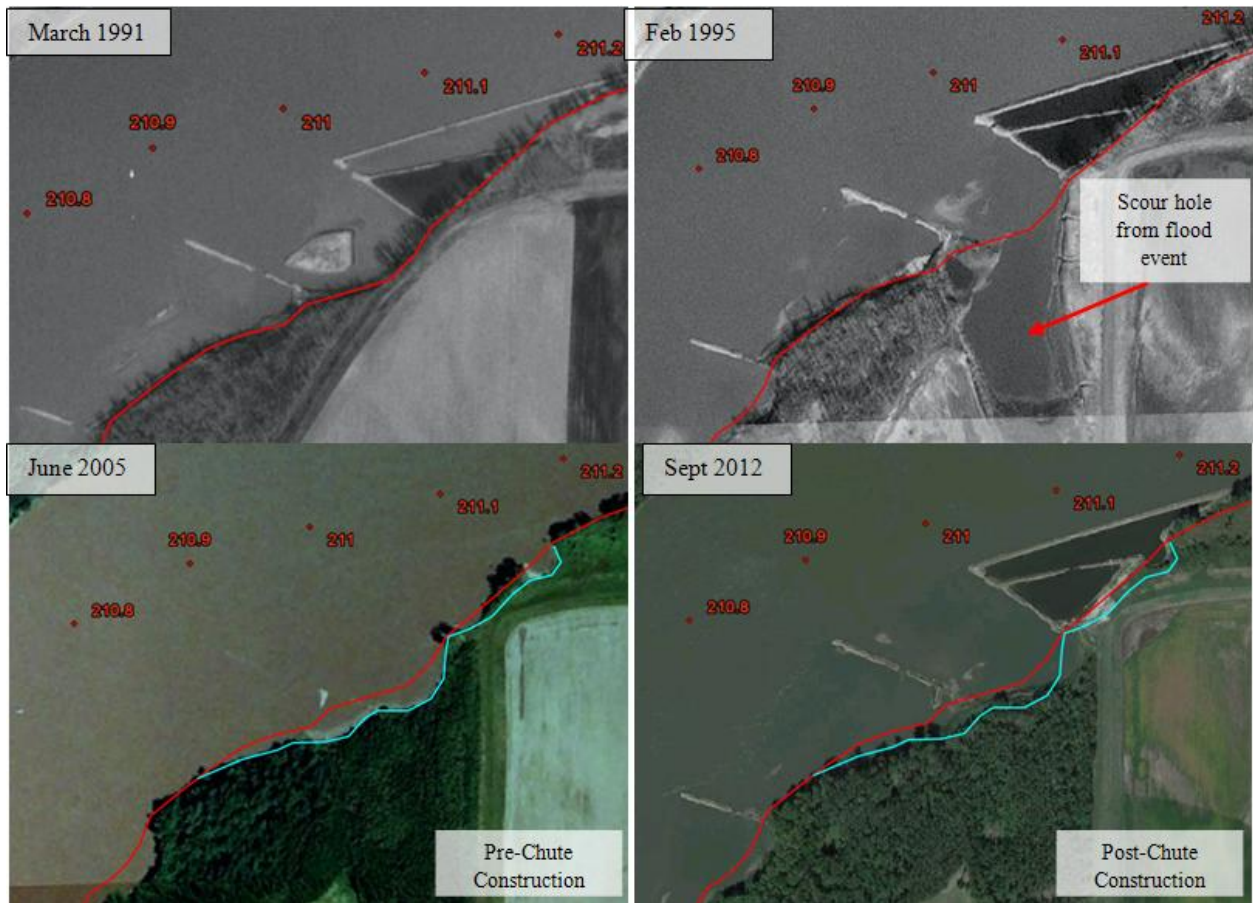
There are four notches near the area of concern. Notch details can be found in Table 5.1. Three of the notches were constructed in 1983 and one notch was constructed in 1994. Jameson chute was constructed in 2007.

Table 5.1: Notch Details Near River Mile 211

(Refer to Figure 5-1(a) for Structure Locations)

| Structure | CRP Elev (ft) | Width (ft) | Year | Distance from Bank (ft) |
|-----------|---------------|------------|------|-------------------------|
| D221.0-A  | -4            | 50         | 1994 | 350                     |
| D221.4    | 0             | 50         | 1983 | 200                     |
| D220.8    | 0             | 50         | 1983 | 85                      |
| D220.5    | 0             | 50         | 1983 | 175                     |

Aerial photos were compared near river mile 211 and are shown in Figure 5-1(b). The first photo was taken in March 1991. The next photo, taken in February 1995, shows a scour hole near river mile 211 which occurred during the high water events of 1993/1995. The September 2012 photo, shows the current bank line location relative to the March 1991 bank line (shown in red) and the June 2005 bank line (shown in blue).

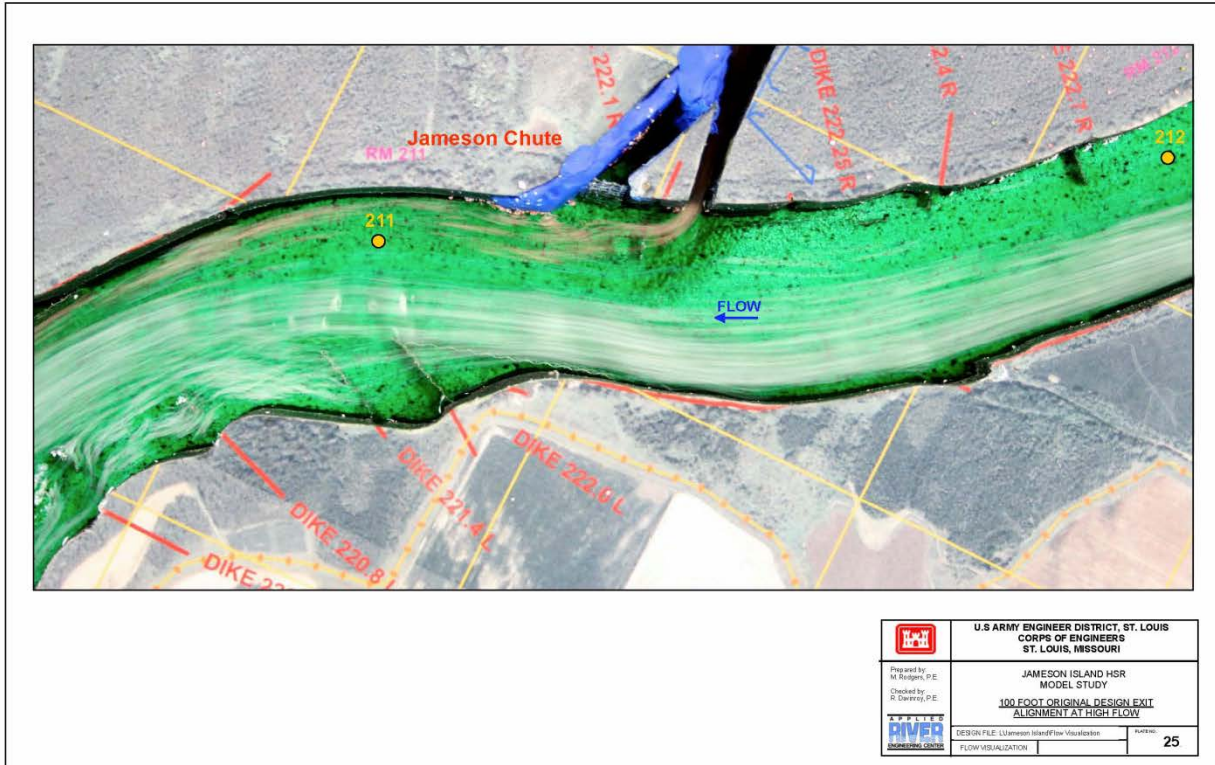


**Figure 5-1(b): Bank Movement near RM 211 over a Period of 21 Years**

**Conclusion:**

The bank has shown no movement since construction of the chute. A model of the location was constructed by the Corps to determine if flow out of the chute can affect flow patterns at the area of concern. The model, seen in Figure 5-2, showed that flow out of the chute quickly turns downstream and does not impact the area of concern. The model results are supported by photos taken during recent flood events. The chute exit is scheduled to be moved downstream sometime in 2013.





**Figure 5-2: Flow Modeled at Jameson Island Chute**

## **5.2 Erosion Concern at River Mile 500**

### **Submitted Statement:**

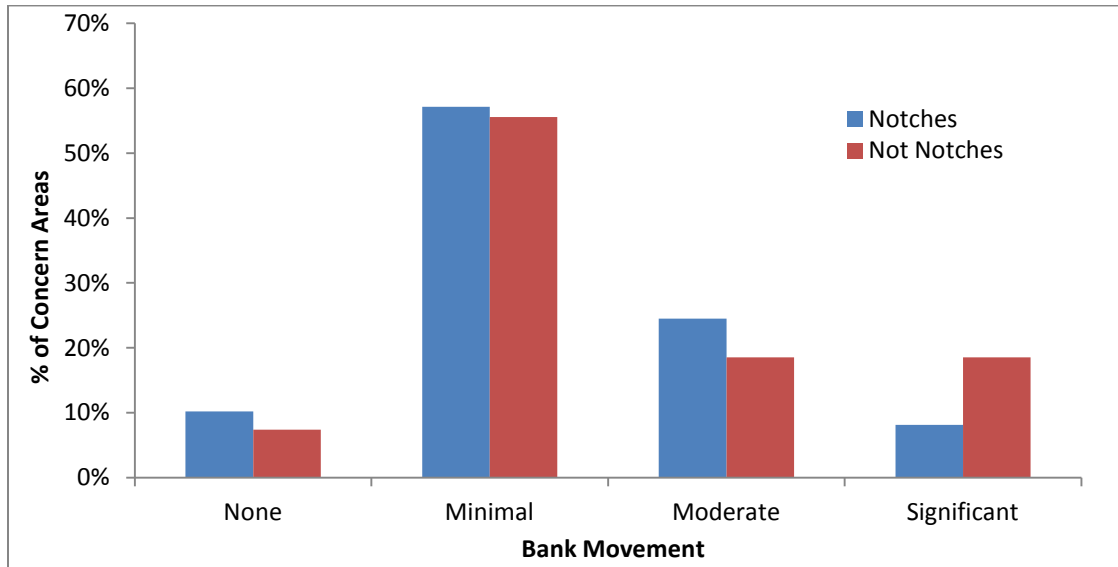
Kathy Kunkel submitted the following: “Please contact my office to arrange a meeting with landowners and levee district board members to review the damage area.”

### **Conclusion:**

Contact has been made by phone on three different occasions and by email on two different occasions. She has not responded with any specific areas of concern.

## 6.0 Summary

Eighteen individuals submitted a total of 82 locations. Of the 82 locations, 52 locations have a notch on a structure in the immediate area. Figure 6.0 below compares degree of erosion for notched and un-notched locations. As indicated in the figure, there is no trend or apparent difference in erosion between notched and un-notched locations.



**Figure 6-1: Comparison of notched and un-notched locations.**

*Minimal bank movement: less than 75 feet over 20 years. Moderate bank movement: between 75 – 150 feet over 20 years. Significant bank movement: Greater than 150 feet over 20 years.*

Locations with significant erosion, both notched and un-notched, will be evaluated for actions within the authority of the BSNP that might slow or halt further erosion. Possible actions include, but are not limited to; repair of existing structures to design elevation if the existing structure is low, raising the existing structure above design elevation if the erosion is a threat to the structure, construction of a new structure if the erosion is a threat to the proper functioning of existing structures. A total of 18 locations are listed on the current task order for repair. An additional 6 locations could be added for future repair. A summary of each landowner submittal can be seen in Table 6.1.

Table 6.1: Summary of Submittals by Landowner

| <b>Submitter</b>                     | <b>Stated Cause</b>        | <b># of Locations</b> | <b># of Locations Showing Bank Erosion</b> | <b># of Locations with Notch</b> | <b># of Locations Listed on Current Task Order</b> | <b># of Locations for Potential Later Repair</b> |
|--------------------------------------|----------------------------|-----------------------|--|----------------------------------|--|--|
| Dan Kuentzel                         | Notches                    | 15                    | 14   | 14                               | 2  | 2  |
| Dale Gloe                            | Notches/ Dikes too low     | 3                     | 1  | 1                                | 0  | 0  |
| Clarence Trachsel                    | Notches                    | 3                     | 2  | 2                                | 0  | 1  |
| Bill Lepage                          | Notches/ Dikes too low     | 15                    | 15   | 5                                | 2  | 0  |
| Stephen Diedrich                     | Notches                    | 1                     | 1  | 1                                | 0  | 0  |
| Adam Schuttler                       | Notches                    | 1                     | 1  | 1                                | 0  | 0  |
| Doris Linneman                       | Notches                    | 2                     | 2  | 2                                | 0  | 0  |
| Carol Studebeck/<br>Jeffrey Gebhardt | Notches/ Bank erosion      | 4                     | 4  | 2                                | 1  | 1  |
| Kelly & Tim Thorp                    | Notches                    | 28                    | 26   | 21                               | 6  | 2  |
| Mike Farley                          | High water through chute   | 1                     | 0  | 0                                | 0  | 0  |
| Kevin Casner                         | Notch/ Lack of maintenance | 5                     | 5  | 0                                | 2  | 0  |
| David Banks                          | Creek stabilization        | 1                     | 1  | 0                                | 0  | 0  |
| Larry Hicks                          | 2011 Flood                 | 2                     | 2  | 1                                | 2  | 0  |
| Jeffrey Gaskill                      | 2011 Flood                 | 1                     | 1  | 0                                | 1  | 0  |
| Paul Derks                           | 2011 Flood                 | 1                     | 1  | 1                                | 1  | 0  |
| Mark Schupp                          | Jameson Island             | 1                     | 1  | 1                                | 1  | 0  |



## **Works Cited**

United States Army Corps of Engineers (USACE). Omaha District. 1982. Riverine habitat and floodway restoration: Missouri river, Sioux City, Iowa to the mouth near St. Louis, Missouri: an evaluation of the notched structures in creating additional backwater areas. MRD sediment series no. 24. U.S. Army Corps of Engineers, Omaha District, Omaha, NE. 77 pages.