Susitna-Watana Hydroelectric Project
(FERC No. 14241)

Geomorphology Study (6.5)

Mapping of Geomorphic Features and Turnover within the Middle and Lower Susitna River Segments from 1950s, 1980s, and Current Aerials
Technical Memorandum

Prepared for

Alaska Energy Authority

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

Prepared by

Tetra Tech, Inc.

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TABLE OF CONTENTS

Summary vii

1. Introduction 1

2. Study Objectives 2

3. Study Area 2
- 3.1. General 2
- 3.2. Susitna River Segments 3

4. Methods 4
- 4.1. Variations from the Study Plan 4
- 4.2. Aerial Photography 4
- 4.3. Area of Geomorphic Delineation 4
- 4.4. Delineation of Geomorphic Features 5
  - 4.4.1. Delineation Procedure 5
  - 4.4.2. Geomorphic Feature Classifications 5
- 4.5. Analysis 8
  - 4.5.1. Long-term Assessment of Middle River and Lower River Channel Change from the 1950s, 1980s and 2012 Aerials 8
  - 4.5.2. Short-term Assessment of Channel Change from 2012 to 2013 Aerials 11
- 4.6. Quality Control 12
  - 4.6.1. Geomorphic Features 12
  - 4.6.2. Turnover 12
  - 4.6.3. Registration Error in the 1950s Aerials 13

5. Results 13
- 5.1. Long-term Assessment of Middle River and Lower River Channel Change from the 1950s, 1980s and 2012 Aerials 13
  - 5.1.1. Geomorphic Feature Area Tabulation 14
  - 5.1.2. Geomorphic Feature Overlay Analysis 14
  - 5.1.3. Turnover Results 14
  - 5.1.4. Middle Susitna River Segment Long-term Channel Change Assessment 15
  - 5.1.5. Lower Susitna River Segment Long-term Channel Change Assessment . 30
  - 5.1.6. Chulitna River Reach 37
  - 5.1.7. Talkeetna River Reach 38
  - 5.1.8. Yentna River Reach 39
- 5.2. Short-term Assessment of Channel Change from 2012 to 2013 Aerials 39
  - 5.2.1. Qualitative Evaluation of 2012 Middle River Geomorphic Features and the 2013 Aerial Photography 40
  - 5.2.2. Quantitative Assessment of the 2012 and 2013 Geomorphic Features in the Three Rivers Confluence 41

6. Discussion 43

7. References 46

8. Tables 48

9. Figures 74

LIST OF TABLES

Table 4.2-1. 1950s Aerial Photo Summary. 48
Table 4.2-2. Summary of 1980s aerial dates, discharges, and project river mile extents. 49
Table 4.2-3. Summary of 2012 aerial dates, discharges, and project river mile extents. 50
Table 5.1-1. Geomorphic feature areas for MR-1. 51
Table 5.1-2. Geomorphic feature areas for MR-2. 51
Table 5.1-3. Geomorphic feature areas for MR-3. 52
Table 5.1-4. Geomorphic feature areas for MR-4. 52
Table 5.1-5. Geomorphic feature areas for MR-5. 53
Table 5.1-6. Geomorphic feature areas for MR-6. 53
Table 5.1-7. Geomorphic feature areas for MR-7. 54
Table 5.1-8. Geomorphic feature areas for MR-8. 54
Table 5.1-9. Geomorphic feature areas for GAA-184. 55
Table 5.1-10. Geomorphic feature areas for GAA-173. 55
Table 5.1-11. Geomorphic feature areas for GAA-151. 56
Table 5.1-12. Geomorphic feature areas for GAA-144. 56
Table 5.1-13. Geomorphic feature areas for GAA-141. 57
Table 5.1-14. Geomorphic feature areas for GAA-138. 57
Table 5.1-15. Geomorphic feature areas for GAA-128. 58
Table 5.1-16. Geomorphic feature areas for GAA-115. 58
Table 5.1-17. Geomorphic feature areas for GAA-113. 59
Table 5.1-18. Geomorphic feature areas for GAA-104. 59
Table 5.1-19. Geomorphic feature areas for LR-1. 60
Table 5.1-20. Geomorphic feature areas for LR-2. 61
Table 5.1-21. Geomorphic feature areas for LR-3. 62
Table 5.1-22. Geomorphic feature areas for LR-4. 63
Table 5.1-23. Geomorphic feature areas for LR-5. 64
Table 5.1-24. Geomorphic feature areas for LR-6. 65
Table 5.1-25. Geomorphic feature areas for CL-1. 66
Table 5.1-26. Geomorphic feature areas for TK-1. 67
Table 5.1-27. Geomorphic feature areas for YN-1. 68
Table 5.1-28. Turnover values for Middle River geomorphic reaches. 69

Table 5.1-29. Turnover values for Middle River Geomorphic Assessment Areas...................... 70
Table 5.1-30. Turnover values for Lower River geomorphic reaches... 71
Table 5.1-31: Geomorphic reach delineations and classifications.. 72

LIST OF FIGURES

Figure 3.2-1. Susitna River geomorphology study area and large-scale river segments.............. 75
Figure 4.5-1. 1980s Geomorphic Feature Mapping of Channel or Land...................................... 76
Figure 4.5-2. 2012 Geomorphic Feature Mapping of Channel or Land 76
Figure 4.5-3. Turnover Mapping of 1980 to 2012... 77
Figure 4.5-4. Examples of vegetation encroachment and vegetation establishment.................. 78
Figure 4.5-5. Example Focus Area and Geomorphic Assessment Areas. 79
Figure 4.5-6. Discharge measurements at USGS gaging station on or near the Susitna River from June 2012 through October 2013. 80
Figure 4.6-1. Example of Registration Error. 81
Figure 5.1-1. Example of Turnover mapping in GAA-128 and GAA-138. 82
Figure 5.1-2. Map of the Middle Susitna River Segment showing the geomorphic reaches. 83
Figure 5.1-3. Map of the Lower Susitna River Segment showing the geomorphic reaches........ 84
Figure 6.1-1: 1950s to 1980s turnover rates for Middle River geomorphic reaches................... 85
Figure 6.1-2: 1980s to 2012 turnover rates for Middle River geomorphic reaches...................... 86
Figure 6.1-3: 1950s to 2012 turnover rates for Middle River geomorphic reaches...................... 87
Figure 6.1-4. 1950s to 1980s turnover rates for Lower River geomorphic reaches. 88
Figure 6.1-5. 1980s to 2012 turnover rates for Lower River geomorphic reaches....................... 89
Figure 6.1-6. 1950s to 2012 turnover rates for Lower River geomorphic reaches....................... 90

LIST OF APPENDICES

Appendix A. 1950s Middle Susitna River Segment Geomorphic Features
Appendix B. 1983 Middle Susitna River Segment Geomorphic Features
Appendix C. 2012 Middle Susitna River Segment Geomorphic Features
Appendix D. 1950s to 1980s Middle Susitna River Segment Channel Change Overlay
Appendix E. 1980s to 2012 Middle Susitna River Segment Channel Change Overlay
Appendix F. 1950s Lower Susitna River Segment Geomorphic Features
Appendix G. 1983 Lower Susitna River Segment Geomorphic Features

Appendix H. 2012 Lower Susitna River Segment Geomorphic Features
Appendix I. 1950s to 1980s Lower Susitna River Segment Channel Change Overlay
Appendix J. 1980s to 2012 Lower Susitna River Segment Channel Change Overlay
Appendix K. 1950s to 1980s Middle Susitna River Segment Turnover
Appendix L. 1980s to 2012 Middle Susitna River Segment Turnover
Appendix M. 1950s to 2012 Middle Susitna River Segment Turnover
Appendix N. 1950s to 1980s Lower Susitna River Segment Turnover
Appendix O. 1980s to 2012 Lower Susitna River Segment Turnover
Appendix P. 1950s to 2012 Lower Susitna River Segment Turnover
Appendix Q. 2012 Geomorphic Features in the Three River Confluence
Appendix R. 2013 Geomorphic Features in the Three River Confluence
Appendix S. 2012 to 2013 Three River Confluence Channel Change Overlay
Appendix T. 2012 Middle Susitna River Segment Geomorphic Features on the 2013 Aerials

LIST OF ACRONYMS AND SCIENTIFIC LABELS

Abbreviation	Definition
AEA	Alaska Energy Authority
AOW	Additional Open Water
BAB	Bar/Attached Bar
BIC	Bar Island Complex
Cfs	Cubic feet per second
CL-1	Chulitna River Reach
ER	Entrenchment ratio
EXP	Exposed Substrate
ft^2	Square Feet
FERC	Federal Energy Regulatory Commission
FIPS	Federal Information Processing Standard
GIS	Geographic Information System
GPS	Global Positioning System
LiDAR	Light Detection and Ranging
LR	Lower River
LR-1	Lower River Reach 1 (PRM 102.4 to PRM 87.9)
LR-2	Lower River Reach 2 (PRM 87.9 to PRM 65.6)
LR-3	Lower River Reach 3 (PRM 65.6 to PRM 44.6)
LR-4	Lower River Reach 4 (PRM 44.6 to PRM 32.3)
LR-5	Lower River Reach 5 (PRM 32.3 to PRM 23.5)
LR-6	Lower River Reach 6 (PRM 23.5 to PRM 3.3)
MC	Main Channel
MR	Middle River
MR-1	Middle River Reach 1 (PRM 187.1 to PRM 184.6)
MR-2	Middle River Reach 2 (PRM 184.6 to PRM 169.6)
MR-3	Middle River Reach 3 (PRM 169.6 to PRM 166.1)
MR-4	Middle River Reach 4 (PRM 166.1 to PRM 153.9)
MR-5	Middle River Reach 5 (PRM 153.9 to PRM 148.4)
MR-6	Middle River Reach 6 (PRM 148.4 to PRM 122.7)
MR-7	Middle River Reach 7 (PRM 122.7 to PRM 107.8)
MR-8	Middle River Reach 8 (PRM 107.8 to PRM 102.4)
NAD	North American Datum
NAVD	North American Vertical Datum
PDF	Portable document file
PRM	Project River Mile
RM	River Mile(s)
SC	Side Channel

Abbreviation	Definition
SCC	Side Channel Complex
SS	Side Sloughs
TD	Tributary Delta
TK-1	Talkeetna River Reach
TR	Tributary
US	Upland Slough
USGS	U.S. Geological Survey
VI	Vegetated Island
YN-1	Yentna River Reach

SUMMARY

The purpose of this work was to update the geomorphic mapping and assessment of channel change that were initially provided in *Mapping of Geomorphic Features and Assessment of Channel Change in the Middle and Lower Susitna River Segments from 1980s and 2012 Aerials* (Tetra Tech 2013a). The initial Technical Memorandum provided the results from tasks identified in RSP Study 6.5 Section 6.5.4.4 Study Component: Assess Geomorphic Change Middle and Lower Susitna River Segments. This update extends the previous 30 year analysis between the 1980s and 2012 by an additional 30 years with aerial photography from the 1950s, and also provides a short term analysis of geomorphic changes by comparing 2012 with 2013 aerial photography. The mapping presented in this technical memorandum supersedes the mapping from the initial technical memorandum (Tetra Tech 2013a).

In addition to assessment of geomorphic feature changes, a turnover analysis was performed to provide a graphical and quantitative determination of the area of floodplain that was converted to river channel and the area of river channel that was converted to floodplain over the period from the 1950s to 2012. Geomorphic features were simplified as either being a floodplain or channel feature, and the turnover analysis assessed areas that changed from floodplain to channel or vice versa over the given time periods. The turnover analysis showed a net channel to floodplain turnover throughout the Middle and Lower Susitna rivers and supported the conclusion of the initial geomorphic mapping technical memorandum, indicating that the primary factor in geomorphic change is an increase in vegetation.

Also, additional aerial photography acquired in 2013 was used to assess short term geomorphic changes observed between 2012 and 2013. The short-term analysis indicated that erosion was the primary mode of channel change as opposed to vegetation encroachment or establishment.

This technical memorandum and *Mapping of Geomorphic Features and Assessment of Channel Change in the Middle and Lower Susitna River Segments from 1980s and 2012 Aerials* (Tetra Tech 2013a) represent the completion of the goals and objectives listed in RSP Study 6.5 Section 6.5.4.4 and ISR Study 6.5 Section 7.2.1.4 “Assess Geomorphic Change Middle and Lower Susitna River Segments.” The turnover data and analyses presented in this 2014 technical memorandum will be used to support the bed evolution modeling and bank energy index analysis in ISR Study 6.6 Section 7.2.2.1, as well as the Riparian Instream Flow Study (Study 8.6), and Ice Processes Study (Study 7.6).

The 1950s, 1980s, 2012, and 2013 aerials were used to assess the channel change and turnover in the Middle and Lower River (ISR Study 6.5 Section 7.1.1.4). The Study Plan (RSP Sections 6.5.4.4.2.1 and 6.5.5.5.2.2.) indicates a decision will be made on whether to acquire additional historical aerial photography for the Middle and Lower Susitna River Segments after completion of the analysis of aerial photography from the 1950s, 1980s and present. In addition, the 2013 aerials that were flown to supplement the 2012 aerials document the river prior to, and after, the peak flow of ~90,000 cfs at Gold Creek which is one of the highest flows recorded in the period of record. As the objectives of this study were completed, no further analysis of aerial photography is necessary.

1. INTRODUCTION

The Alaska Energy Authority (AEA) is preparing a License Application that will be submitted to the Federal Energy Regulatory Commission (FERC) for the Susitna-Watana Hydroelectric Project using the Integrated Licensing Process. The Project is located on the Susitna River, an approximately 320-mile-long river in the Southcentral region of Alaska. The Project's dam site will be located at Project River Mile (PRM) 187.1. The results of this study will provide information needed to support the FERC's National Environmental Policy Act analysis for the Project license.

This technical memorandum updates the geomorphic feature mapping results presented in technical memorandum *Mapping of Geomorphic Features within the Middle and Lower Susitna River Segments from 1980s and 2012 Aerials* (Tetra Tech 2013a). The original Technical Memorandum provided the results from efforts identified in RSP Study 6.5 Section 6.5.4.4 Study Component: Assess Geomorphic Change Middle and Lower Susitna River Segments. **The mapping results presented in this technical memorandum supersede results from the original technical memorandum (Tetra Tech 2013a).**

The work presented in the original technical memorandum (Tetra Tech 2013a) involved two primary efforts. The first was to use the digital aerial images collected as part of the aquatic macrohabitat mapping task (Tetra Tech 2013b) and Geographic Information System (GIS) software to delineate (map) geomorphic features identified in the 1980s and 2012 aerials for the entire Middle and Lower Susitna River segments.

The second aspect of the original work consisted of identifying the channel change that had occurred in the Middle and Lower Susitna River segments between the 1980s and present condition (represented by 2012 aerial photography). As part of the original analysis, GIS was used to create overlays of the 1980s and current geomorphic feature delineation. GIS was also used to determine the area for each geomorphic feature for both periods. The geomorphic feature overlays and tabulation of summed geomorphic feature areas was performed by geomorphic reaches. An assessment of the channel change within each geomorphic reach between the 1980s and 2012 was developed from this information.

The two primary updates conducted and presented in this technical memorandum include the addition of the 1950s aerials and the results of the turnover analysis. The addition of the 1950s aerials doubles the time frame over which channel change is evaluated. The turnover analysis provides both a graphical and quantitative determination of the area of floodplain that was converted to river channel and the area of river channel that was converted to floodplain over the period from the 1950s to 2012. Both of these updates were added in response to licensing participants' comments.

Two secondary updates included in this technical memorandum involve the extension of the geomorphic feature mapping on the lower reaches of the Chulitna and Talkeetna rivers and the assessment of channel change between 2012 and 2013 as the result of large flow events.

In 2013, after the decision to model the Three Rivers Confluence with the 1-D Bed Evolution Model was made, the upstream limits of the area of geomorphic delineation were extended 4.4 miles upstream on the Talkeetna River and 9.1 miles upstream on the Chulitna River (ISR Study

6.5 Section 4.4.2.2). Geomorphic mapping and turnover analysis was conducted for portions of these two major tributaries where the 1-D Bed Evolution Model will be extended.

The large flows in September 2012 and June 2013 provided an opportunity to observe the influence of large flow events on channel change. The 2012 and 2013 aerial photography were used to qualitatively assess channel change in the Middle Susitna River Segment between 2012 and 2013. A more quantitative assessment of channel change between 2012 and 2013 in the area of the Three Rivers Confluence was also conducted.

2. STUDY OBJECTIVES

The overall purpose of the work presented in this technical memorandum is to compare existing, 1980s and 1950s geomorphic feature data from aerial photograph analysis to characterize channel stability and change and the spatial distribution of geomorphic features under unregulated flow conditions. Specific objectives of the effort presented are listed below:

- Map geomorphic features in the Middle and Lower Susitna River Segments, including the Chulitna and Talkeetna rivers in the Three Rivers Confluence area, from the aerials obtained representing the 1950s, 1980s and current conditions;
- Determine and tabulate the area of the geomorphic features within each geomorphic reach of the Middle and Lower Susitna River segments;
- Evaluate channel change in the Middle and Lower Susitna River segments by:
  - Preparing overlays of the 1950s, 1980s and current geomorphic features to assist in qualitatively describing channel change;
  - Quantitatively evaluate channel change with a turnover rate analysis that identifies the area of channel converted to floodplain and floodplain converted to channel for the periods of 1950s to 1980s and 1980s to present.
- Qualitative assessment of channel change in the Middle River Segment between 2012 and 2013 resulting from the large flows (and/or ice jams and ice runs in the 2013 breakup) through side by side comparison of the 2012 and 2013 aerial photography and the overlay of the mapped 2012 geomorphic features on the 2013 aerial photography;
- A quantitative assessment of channel change between 2012 and 2013 in the Three Rivers Confluence area by delineation of the geomorphic features on the recently acquired 2013 aerial photographs in the Three Rivers Confluence area and comparison with the geomorphic features delineated from the 2012 photography for the Talkeetna and Chulitna rivers and geomorphic reaches MR-8 and LR-1 of the Susitna River.

3. STUDY AREA

3.1. General

The Susitna River, located in Southcentral Alaska, drains an area of approximately 20,010 square miles and flows about 320 miles from its headwaters at the Susitna, West Fork Susitna, and East

Fork Susitna glaciers to Cook Inlet (U.S. Geological Survey [USGS] 2012). The Susitna River Basin is bounded on the west and north by the Alaska Range, on the east by the Talkeetna Mountains and Copper River Lowlands, and on the south by Cook Inlet. The highest elevation in the basin is Mt. McKinley at 20,320 feet while its lowest elevation is at sea level where the river discharges into Cook Inlet. Major tributaries to the Susitna River between the headwaters and Cook Inlet include the Chulitna, Talkeetna, and Yentna rivers, which are also glacially fed in their respective headwaters. The basin receives, on average, 35 inches of precipitation annually with average annual air temperatures of approximately 29°F.

3.2. Susitna River Segments

The overall study area extends from Cook Inlet to the Maclaren River confluence at PRM 261.3. Within the geomorphology study area, the Susitna River has been divided into three segments whose general characteristics are governed by the basin geology as described by Wilson et al. (2009). The segments are referred to as the Upper, Middle, and Lower Susitna River segments and are identified in Figure 3.2-1 with the associated extents:

- Upper Susitna River Segment: Maclaren River confluence (PRM 261.3 / RM 260) downstream to the proposed Watana Dam site (PRM 187.1 / RM 184)[1]
- Middle Susitna River Segment: Proposed Watana Dam site (PRM 187.1 / RM 184) downstream to the Three Rivers Confluence (PRM 102.4 / RM 98.5)
- Lower Susitna River Segment: Three Rivers Confluence (PRM 102.4 / RM 98.5) downstream to Cook Inlet (PRM 3.3 / RM 0)

The work presented in this technical memorandum covers the Middle and Lower Susitna River Segments. The Upper River is not part of the study effort documented in this or the initial technical memorandum (Tetra Tech 2013a). The general characteristics of the Middle Susitna River Segment are heavily influenced by bedrock outcrop as well as Quaternary-age glaciations. The morphologic characteristics of the Lower Susitna River Segment are dominated by sediment loading from the major tributaries and variable resistance to erosion of the Pleistocene-age, glacially-derived materials including tills (moraines), glacio-fluvial sediments in various elevation outwash-surfaces, and glacio-lacustrine sediments that control the width of the valley (Tetra Tech 2014b).

[1] Note: Project River Miles (PRMs) are the river mile system used for the current Susitna-Watana Project. River Miles (RMs) were the river mile system used in the 1980s project. The PRM delineation starts about 3 miles farther into Cook Inlet than the RMs and has a slightly different thalweg than that of the 1980s. Thus, PRM values are generally 3 to 4 miles higher than the RM values. Because this analysis is a temporal comparison, both systems are referenced.

4. METHODS

4.1. Variations from the Study Plan

There are no variances associated with the Assess Geomorphic Change Middle and Lower Susitna River Segments study component that is presented in this technical memorandum and scope identified in RSP Study 6.5 Section 6.5.4.4 and ISR Study 6.5 Section 4.4.2.2.

4.2. Aerial Photography

The digital color aerial photographs were collected in 2012 at a scale of 1:12,000 and with a pixel resolution of 1 foot or better. The processing methodology for the 2012 aerial photography along with the acquisition procedures for the 2012 and 1980s aerials are explained in *Mapping of Geomorphic Features within the Middle and Lower Susitna River Segments from the 1980s and 2012 Aerials* (Tetra Tech 2013a). The acquisition and processing of the 2013 aerial photography followed the methods presented in ISR Study 6.5 Section 4.5.1.1.2. The acquisition of the 1950s aerials was presented in ISR Study 6.5 Section 4.4.2.1.3. Acquisition dates for the 1950s, 1980s, and 2012 aerial photography are shown in Table 4.2-1, Table 4.2-2, and Table 4.2-3, respectively.

4.3. Area of Geomorphic Delineation

An area of geomorphic delineation was developed to define the outer limit of the geomorphic features to be mapped. The limit is referred to as the "geomorphic boundary." It encompasses the active channel area and serves as an estimate of the outer limits of areas that may be affected by the Project in terms of hydraulics and channel morphology. The boundary was defined in coordination with the Riparian Instream Flow Study (Study 8.6) and the Riparian Vegetation Study Downstream of the Proposed Watana Dam (Study 11.6). The upstream limit is the Watana Dam site (PRM 187.1) and the downstream limit is Cook Inlet (PRM 3.3). The lateral limits of the geomorphic boundary were set using the procedure described below.

As part of this updated memorandum, the extents of the geomorphic delineation were extended farther upstream on the Chulitna and Talkeetna rivers at the Three Rivers Confluence. The area of geomorphic delineation was extended an additional 5.1 miles to a total of 10.0 miles on the Talkeetna River and was extended 9.1 miles to a total of 12.4 miles on the Chulitna River. This was done to support the 1-D bed evolution modeling effort (Study 6.6) when the decision was made to extend the model up both of these major Susitna River tributaries.

The geomorphic boundary was delineated at an approximate scale of 1:3,000 using the 2012 color aerial photographs and images from the 2011 Matanuska-Susitna Borough light detection and ranging (LiDAR) survey. The outer limits were initially identified following the riverward edge of a terrace that typically ranged from approximately 20 to 40 feet above the main channel water-surface elevation at the time of this 2011 LiDAR survey. In areas where steep canyon or hillsides existed rather than a terrace, these features were followed at an elevation of approximately 20 to 40 feet above the adjacent channel water-surface elevation. In locations where tributaries joined the main channel and cut through the terrace or canyon walls, the boundary was extended upstream until the tributary water-surface elevation matched that of the main channel terrace at the tributary mouth. The corridor was then narrowed in some locations to reflect man-made features that constrain the river, primarily the railroad embankment. It was assumed that the Alaska Railroad will maintain this alignment, and the Susitna River will not migrate through the embankment; if it does, the Railroad will repair and reestablish the embankment in its original location. In a few locations, where hydrologic connections were judged to continue through the railroad embankment to aquatic habitats on the landward side of the embankment, the low-lying area landward of the railroad was included within the geomorphic boundary. This was done in order to include the habitat within the geomorphic features that may be affected by changes in water-surface elevations created by the Project. Lastly, a minimum buffer of 150 feet was added along the main channel water's edge, except in locations where the railroad embankment was identified as the outer limits of the boundary. For this exception, the boundary was not offset. The boundary for the 1950s and 2012 delineations continued up the Chulitna River for 12.4 miles and the Talkeetna River for 9.4 miles.

4.4. Delineation of Geomorphic Features

4.4.1. Delineation Procedure

All geomorphic features within the defined geomorphic boundary were delineated. While the delineations of geomorphic features reflected the aquatic habitat, they were not limited to the wetted habitat, but rather encompassed the entire bank to bank extent of the feature. Therefore, the geomorphic features followed defined bank lines and included the wetted habitat, exposed substrate, and other low-lying areas within the banks of the feature, as discernable from the aerial photography. Unlike aquatic habitat types, geomorphic features do not require a wetted connection to the Susitna River (Note: The methods and results for the aquatic macrohabitat mapping are presented in two separate technical memorandums [Tetra Tech 2013b and 2014a]). It is only necessary that a geomorphic feature or series of features, wet or dry, connect to the Susitna River. If the water body was isolated and there was not a connection, wet or dry, to the Susitna River, then the wetted area was mapped as additional open water (AOW).

Geomorphic feature delineations were made using ArcGIS 10.0 at a scale of 1:3,000. At that scale, it is estimated that the accuracy of delineation is within approximately 10-20 feet of the actual feature. Geomorphic feature delineations from the 2012 aerials were assisted by use of the 2011 Matanuska-Susitna LiDAR (Mat-Su Borough 2011) to determine elevation differences to better define the boundary between channel areas and floodplain or island areas. The LiDAR was used to determine bank and water-surface elevations in areas of shadows and under vegetation cover in the upper ends of sloughs. The LiDAR has a coordinate system of North American Datum (NAD) 1983 State Plane Alaska 4 FIPS 5004 feet and North American Vertical Datum (NAVD) 88. Mapping of geomorphic features was performed for all areas within the delineated geomorphic boundaries of the Middle and Lower Susitna River Segments.

4.4.2. Geomorphic Feature Classifications

Two sets of geomorphic feature classifications were utilized: one for the Lower Susitna River Segment and one for the Middle Susitna River Segment. Geomorphic features include the wetted area along with the exposed substrate contained within the banks with perennial vegetation. The geomorphic features are classified along a spectrum of connectivity between clear water sources upland (precipitation and groundwater sources for those in the floodplain and riverine subsurface flow for those in the area of the main channel) and turbid water from the direct surface connection to the main channel:

- Additional Open Waters
- Upland Slough
- Side Slough
- Side Channel
- Main Channel

Side sloughs and side channels are a transition in the spectrum because their aquatic macrohabitat changes when they become hydraulically disconnected at their upstream end from the turbid main channel. In addition to turbidity, habitat value may also change based on the water temperature or other water quality aspects of the source of flow.

4.4.2.1. Middle Susitna River Segment

The geomorphic classifications for the Middle Susitna River Segment were based on the aquatic habitat types defined in Trihey & Associates (1985). The wetted perimeter of macrohabitat types (main channel, side channel, side sloughs, upland sloughs) along with the exposed substrate and other low-lying areas within the banks defined the extent of a geomorphic feature. With the inclusion of tributaries, vegetated islands, and additional open water, the classification types were defined in 2012 as follows:

- **Main Channels (MC)** are those channels of the river that normally convey streamflow throughout the entire year. They are visually recognizable by their turbid, glacial water and high velocities. In general, they convey more than 10 percent (approximate) of the total flow passing a given location. Main channels can contain tributary mouth habitat, which is clear water plume that enters from an adjacent clear water tributary.
- **Side Channels (SC)** are also characterized by turbid, glacial water. Velocities often appear lower than in mainstem sites. In general, they convey less than 10 percent (approximate) of the total flow passing a given location. Side channel habitat may exist in well-defined channels or in areas possessing numerous islands and submerged gravel bars. When the upstream berms of side channels are dewatered and the channels contain clear water, they are classified as side sloughs. Side channels can contain tributary mouth habitat which is clear water plume that enters from an adjacent clear water tributary.
- **Side Sloughs (SS)** are off-channel features that contain clear water and typically occur outside the main channel. They are single discrete side sloughs. Small tributaries, upwelling groundwater, and local surface runoff are the primary sources of clear water for these areas. Side sloughs have non-vegetated upper thalwegs that are overtopped during periods of moderate to high mainstem discharge. When these areas are overtopped they convey turbid water and are then classified as side channels.
- **Upland Sloughs (US)** are off-channel features that typically occur outside the mainstem channel area. They contain clear water and depend on small streams, upwelling, and local surface runoff for their water supply. Upland sloughs possess vegetated upper thalwegs that are rarely overtopped by mainstem discharge.

- **Tributary (TR)** features are the portion of a tributary channel flowing across the floodplain. Tributaries are typically clear water channels.
- **Vegetated Island (VI)** is a discrete, large vegetated island that exists within or along the main channel. Vegetated islands have perimeters of perennial vegetation.
- **Additional Open Water (AOW)** is defined as standing water areas that are not channels, sloughs or rivers. These are isolated bodies of water without a discernible direct or indirect surface connection to the Susitna River.

4.4.2.2. Lower Susitna River Segment

For the Lower Susitna River Segment, geomorphic feature mapping classifications were adapted and modified from the habitat types in R&M Consultants, Inc. and Trihey & Associates (1985). These included: vegetated areas, exposed substrate, and aquatic macrohabitat types (main channel, side channels, side sloughs, tributaries, and upland sloughs). Features such as the side channel complex (SCC), bar island complex (BIC), bar/attached bar (BAB), tributary delta, and additional open water were added to the set of geomorphic features. Within this analysis mainstem is defined as a total of the channel areas and vegetated islands associated with the main channel, bar island complexes, and side channel complexes. Braid plain is defined as the total of main channel and bar island complexes. The classification types were defined in 2012 as follows:

- **Main Channel** features consist of areas within the river that normally convey streamflow throughout the entire year. They are visually recognizable by their turbid, glacial water and high velocities. In general, they convey more than 10 percent (approximate) of the total flow passing a given location. Vegetated islands, side channel complexes and bar island complexes were not included within the area calculation of the main channel.
- **Side Channel** features occur outside the main channel limits. They are single channels as opposed to the multiple and often interlaced/braided channels of the side channel complexes that occur within the mainstem. They are characterized by turbid, glacial water. Velocities often appear lower than in main channel. In general, they convey less than 10 percent (approximate) of the total flow passing a given location. When the upstream berms of side channels are dewatered and the channels contain clear water, they are classified as side sloughs.
- **Side Channel Complex** is an area within the mainstem that contains multiple side channels separated by vegetated islands. The islands are typically several to many channel widths long. The side channels are typically not separated by gravel bars, though gravel bars may occur within the side channels. Side channels within the side channel complexes convey turbid water. Side channel complexes have vegetated islands which constitute more than 50 percent of the complex area, unlike bar island complexes whose non-wetted areas are dominated by exposed substrate.
- **Bar Island Complex** is an area where there are multiple channels in braided patterns separated primarily by exposed substrate. Both gravel bars (exposed substrate) and vegetated island may occur within these complexes. Vegetated islands form a relativity small percentage of the total area of the complex (in contrast to side channel complexes). The channel braids within the bar island complex convey turbid water. Bar island complexes have

vegetated bars which constitute less than 50 percent of the complex, unlike side channel complexes.

- **Bar / Attached Bar** is an exposed substrate feature that is attached to the banks of the main channel(s). They are typically single discrete point bars or alternate bars and are not dissected by numerous channel threads. In some case, chute channels may dissect a bar / attached bars.
- **Side Slough** features are single discrete channels that contain clear water. These are off-channel features that typically occur outside the main channel. Small tributaries, upwelling groundwater, and local surface runoff are the primary sources of clear water for these areas. Side sloughs do not have mature trees in their upper thalwegs and are overtopped during periods of moderate to high mainstem discharge. When these areas are overtopped, they convey turbid water and are then classified as side channels.
- **Upland Slough** features are off-channel features that typically occur outside the mainstem channel area. They contain clear water and depend on small streams, upwelling, and local surface runoff for their water supply. Upland sloughs possess mature trees in their upstream thalwegs and are rarely overtopped by mainstem discharge.
- **Tributary** features are the portion of a tributary channel flowing across the Susitna floodplain. These are typically clear water channels.
- **Tributary Delta** is an exposed substrate feature of sediment deposited where the tributary meets the mainstem channel area. This would typically be a fan shaped area and the tributary may branch out into several channels across the delta/fan. Tributary fans were delineated as they enter areas from the apex (upstream end of the fan) downstream to its limits with the mainstem channel area.
- **Vegetated Island** is a discrete, large vegetated area surrounded by channels with a perimeter of mature, perennial vegetation or trees. If a grouping of vegetated islands is broken by numerous channels, it is defined as a side channel complex rather than several vegetated islands. In this case, the vegetated islands are delineated within and are considered part of the side channel complex.
- **Additional Open Water** features represent standing water areas that are not channels, side channels or sloughs.

For purpose of the GIS analysis, a background (BG) category was created to attribute the entire area of geomorphic delineation and facilitate quality control. Background was defined as non-wetted areas outside the main stem that are not relevant to the analysis. Riparian zone, islands within tributaries, and areas not relevant to analysis are classified as Background.

4.5. Analysis

4.5.1. Long-term Assessment of Middle River and Lower River Channel Change from the 1950s, 1980s and 2012 Aerials

The long-term assessment of channel change in the Middle River and Lower Susitna River Segments covered two principle periods: the 1950s to 1980s and the 1980s to 2012. A third period, from the 1950s to 2012, was added to the updated technical memorandum to assess the geomorphic change observed over approximately six decades. The tools used to develop the long term channel change included the tabulation of geomorphic feature areas at the three points in time, overlay of the geomorphic features mapped at the three points in time and the turnover analysis for the three periods.

Like the geomorphic feature overlay analysis, the turnover analysis identifies changes in geomorphic channel features and vegetation; however, it provides a more direct assessment of the exchange between channel area and floodplain area. It provides a rate at which an area occupied by channel is converted to floodplain and islands, and the rate at which area occupied by floodplain and islands is converted to channel. The turnover analysis is an alternative to the combination of the geomorphic feature area tabulation and overlay analysis for quantifying channel change over time where channel change is assessed by changes in area of the various geomorphic features. The turnover analysis simplifies the presentation of information in order to view the system in terms of two components: floodplain (land) and channel; channel change is then assessed by changes in these two components. Each has its purpose with the geomorphic feature areas tabulation and overlay analysis geared to identify changes in the distribution of the geomorphic features and the turnover analysis reflecting the dynamics of channel and floodplain building and destruction processes.

4.5.1.1. Geomorphic Feature Area Tabulation

The surface areas of the geomorphic features derived from the GIS mapping polygons were tabulated and compared between the 1950s, 1980s and 2012 for the Middle and Lower Susitna River segments. Area measurements (square feet) were calculated to the sixth decimal point and tabulated to a precision of 1,000 sq. ft. In some cases, the 1980s aerial coverage was a limiting factor as to what areas could be incorporated into the analysis. Only portions of the area of geomorphic delineation that were covered by both the 1980s and 2012 aerials could be used for a comparison of geomorphic features. The 1950s aerials covered all the extents of the 1980s and 2012 aerials and was not a limiting factor.

In the Lower Susitna River Segment, several areas within the geomorphic delineation boundary were not covered by the 1980s and 2012 aerial photography. These areas were identified and tracked for quality control, but were not presented in the results tabulated in this document. The areas of missing aerial coverage within the area of geomorphic delineation for 1980s or 2012 aerial photography sets were calculated and excluded from the geomorphic feature tabulation.

The various categories of geomorphic features were summed for comparison within each geomorphic reach. Overbank is the portion of the floodplain that is along the valley wall and does not include the vegetated islands. Overbanks were tabulated as the summation of tributary (TR), tributary delta (TD), additional open water (AOW), and background (BG) areas. To verify that all geomorphic features were accounted for, each feature was summed and the summation compared to the area within the geomorphic reach boundary. Comparisons between summed features area and the total area within the reach boundary were considered acceptable if the difference was less than 0.2 percent.

4.5.1.2. Geomorphic Feature Overlay Analysis

A spatial comparison of the Middle Susitna River Segment and the Lower Susitna River Segment was conducted qualitatively over the entire area of geomorphic feature mapping. This information was incorporated into the channel change discussion when it provided additional understanding of important processes that occurred within a geomorphic reach.

This comparison included:

- **Changes in Geomorphic Form** such as channel widths, lengths, and alignment
- **Identification of Geomorphic Processes** such as bank erosion, bar formation, lateral channel migration, meandering, and avulsion
- **Changes in Hydraulic Connections** due to the breaching of side sloughs and side channels
- **Identification of Biogeomorphic Process** such as beaver dam construction and failure
- **Identification of Vegetation Processes** such as encroachment, establishment (primary succession), and removal.

4.5.1.3. Turnover Analysis

To perform the turnover analysis, geomorphic features from the 1950s, 1980s, and 2012 were merged into either land or channel categories. The channel category included geomorphic features of upland sloughs (US), side sloughs (SS), side channels (SC), and main channels (MC). In the Lower River, bar island complexes (BIC), side channel complexes (SCC), and bar/attached bars (BAB) were also included as channels. The floodplain (land) category includes the vegetated islands (VI), background (BG), tributaries (TR), tributary deltas (TD), and additional open water (AOW) areas (TR and AOW were included as part of the floodplain (land) category because they are not Susitna River channels). Example of the mapping of the 1980s and 2012 channel and floodplain (land) categories is provided in Figures 4.5-1 and 4.5-2.

The geomorphic feature shapefile of the 1950s, 1980s, and 2012 were unioned into a “turnover” shapefile for both river segments. This preserved all the channel and land attributes of the parent shapefiles. Each polygon had an attribute of channel or land for the 1950s, 1980s, and 2012. An example of the turnover mapping is included as Figure 4.5-3. The spatial extents of the turnover analysis coincided with the geomorphic feature delineation boundary (Section 4.3).

Turnover was mapped for periods of 1950s to 1980s and the 1980s to 2012. This was done by categorizing the turnover category between the years. Categories were defined for the turnover of channel to floodplain and floodplain to channel. A turnover rate (in terms of 1,000 sq. ft. per year per mile) was calculated from the change in area divided by the duration of the period and length of the geomorphic reach or Geomorphic Assessment Area. Two static categories were defined for floodplain or channel areas that remained floodplain and channel areas, respectively, over the turnover period. Net turnover was calculated as the difference of the channel to floodplain area minus the floodplain to channel area. A total turnover rate was defined as the sum of both the channel to floodplain rate and the floodplain to channel rate. To aid in the discussion of vegetation processes, the terms for “vegetation encroachment” and “vegetation establishment” were defined as follows:

- **Vegetation encroachment** is an area of channel to floodplain turnover in a specific time period (1950s to 1980s or 1980s to 2012) that is an extension or expansion of an area of vegetation existing at the beginning of the specified time period.
- **Vegetation establishment** is an area of channel to floodplain turnover in a specific time period (1950s to 1980s or 1980s to 2012) that was completely surrounded by channel

features that existed at the beginning of the specified time period. Areas of vegetation establishment have perimeters that are not adjacent to vegetation existing at the beginning of the specified time period.

Examples of vegetation encroachment and vegetation establishment are presented in Figure 4.5-4.

The turnover analysis was conducted at four different spatial scales: segment, geomorphic reach, focus area (FA) and geomorphic assessment area (GAA) as described in ISR Study 6.5 Section 4.1.2.3.2. All four scales apply to the Middle Susitna River Segment. The Lower Susitna River Segment is divided into geomorphic reaches, but does not include Focus Areas or Geomorphic Assessment Areas. The segment and reach breaks for the Middle and Lower Susitna River segments were presented in the updated technical memorandum entitled *Geomorphic Reach Delineation and Characterization, Upper, Middle and Lower Susitna River Segments* (Tetra Tech 2014b). The Focus Areas are discussed in the technical memorandum entitled Adjustments to Middle River Focus Areas (R2 Resource Consultants, Inc. 2013). The Geomorphic Assessment Areas were presented in the Geomorphic Mapping of Focus Areas and Geomorphic Assessment Areas in ISR Study 6.5 Section 5.1.3.5. The Geomorphic Assessment Areas are an enlargement of the Focus Area boundaries to incorporate a complete set of geomorphic features within the boundary. Examples of a Focus Area and a Geomorphic Assessment Area are provided in Figure 4.5-5.

4.5.2. Short-term Assessment of Channel Change from 2012 to 2013 Aerials

The availability of aerial photography from 2012 and 2013 along with the large flow events that occurred in 2012 and 2013 provided an opportunity to assess channel change over a short period. To assess channel change between 2012 and 2013 resulting from the large flows on 6/2/2013 (90,700 cfs at Gold Creek and 146,000 cfs at Sunshine) and 9/21/2012 (72,900 cfs at Gold Creek and 198,000 cfs at Sunshine) the 2012 geomorphic features were qualitatively compared to the 2013 Middle River aerial photography for the entire Middle Susitna River Segment. For the Three Rivers Confluence area, a more detailed comparison of channel change was performed by mapping geomorphic features from the 2013 aerial photography in the Three Rivers Confluence area (MR-8, CL-1, TK-1, and LR-1) and comparing these with the geomorphic features mapped from the 2012 aerial photography. To illustrate the hydrology over this period, the flows for the Middle River from June 2012 to October 2013 is presented in Figure 4.5-6.

4.5.2.1. Qualitative Evaluation of 2012 Middle River Geomorphic Features and the 2013 Aerial Photography

The 2012 Middle River geomorphic features were compared to the 2013 aerial photography to qualitatively assess channel change between 2012 and 2013. In ArcGIS, the 2012 Middle River geomorphic features were overlaid on the 2013 aerial photography. Locations of erosion were noted and documented in a polygon shapefile. The spatial distribution of erosion was evaluated and summarized.

4.5.2.2. Quantitative Assessment of the 2012 and 2013 Geomorphic Features in the Three Rivers Confluence

Geomorphic features were delineated from the 2013 aerial photography for the reaches MR-8, CL-1, TK-1, and LR-1. The 2012 and 2013 geomorphic features were compared to quantitatively assess channel change between 2012 and 2013. The extent of the quantitative assessment was focused on the two mile radius from PRM 102.4. Locations of erosion along vegetated islands were noted and documented in a polygon shapefile. The maximum width of the erosion was identified, measured, and related to the overall channel change observed in the Three Rivers Confluence.

4.6. Quality Control

4.6.1. Geomorphic Features

The first step in quality control process involved the training of the staff developing the mapping. The Geomorphology Program Lead and the Geomorphology Task Lead provided training to the senior hydraulic engineers/geomorphologist and the GIS analysts to ensure appropriate identification and application of the classification categories. Senior hydraulic engineers/ geomorphologists reviewed the feature delineations for completeness, adherence to the classifications, and scale criteria. The senior hydraulic engineers/geomorphologists frequently consulted with the Geomorphology Program Lead and the Geomorphology Task Lead on the application of the definitions and for advice when differentiation between geomorphic classifications and/or features was challenging.

The next step in the quality control process was for the senior hydraulic engineer/ geomorphologist to provide markups of the mapping to the staff performing the delineation in comments on the GIS files, marked up portable document files (PDFs), and written instructions. Comments were provided for both specific items such as changing the classification of a specific feature or general concerns such as the quality of the digitization and proper interpretation of the definitions. The GIS analysts performed the corrections per the instructions of the reviewers. The reviewers conducted a back-check of the changes made to the classifications and provided additional instructions on changes. The correction/ review cycle was repeated if necessary. Throughout the process, the senior hydraulic engineers/geomorphologists consulted with the Geomorphology Program Lead or the Geomorphology Task Lead to refine definitions and help make decisions for unique situations encountered. The files were then reviewed for topology errors such as gaps between delineations (slivers) and overlaps. A final check was run on the tabulated areas for the reaches. Comparisons between summed features area, turnover, portions missing aerial coverage, and the total reach boundary area were considered acceptable for the geomorphic assessment areas, Middle, and Lower River reaches if the difference was less than 0.2 percent.

4.6.2. Turnover

The summed areas of the geomorphic features were compared to their outer boundary to ensure complete and non-overlapping coverage. The percent change in floodplain and channel areas in geomorphic features shapefiles were compared to the turnover analysis results.

4.6.3. Registration Error in the 1950s Aerials

Mapping control for the 1950s photography was derived from Landsat imagery. While the 100-foot pixel resolution of the Landsat imagery is rather low precision, the diagnostic statistics of the aerotriangulation adjustments showed sub-pixel residuals for the control points that were chosen. In an effort to improve the Landsat-based adjustment, three of the sets of photography that cover the Middle River were subjected to a shift after an initial aerotriangulation solution was reached. Holding rigid the relative locations and orientations of the exposures, the preliminary solution was registered to a small collection of points identified in the 2012 orthophotos. In every case, the shifts that resulted from this procedure were smaller in magnitude than the RMSE of the Landsat control. Improvement in the accuracy in some locations was likely balanced by lower accuracy in other locations and the method was not extended to all blocks. Additional details on the mapping control for the 1950s aerials were presented in ISR Study 6.5 Section 4.4.2.1.3.1.

Some systematic errors in the registration of the 1950s aerials were still identified after the adjustments described in the previous paragraph were performed. In some locations, similar features in the 1950s aerials are located about 20 to 50 feet north of their locations in the 1980s and 2012 aerial photography within the east-west oriented portions of MR-1 through MR-5. An example of the registration error in the 1950s geomorphic features as compared to the 2012 geomorphic features in the area of PRM 151 is presented in Figure 4.6-1. The shift here appears to be primarily registration error as the bedrock along the right side of the main channel at PRM 151 has not shifted in location since the 1950s. The registration error is also present in the turnover mapping and results as channel to floodplain turnover on the southeast side of the river and floodplain to channel turnover on the northwest side of the river. Total turnover results were influenced by the registration error for the 1950s to 1980s period. However, the shift in the 1950s aerial photos is typically within the estimated 10-20 foot accuracy of the delineation as previously mentioned in section 4.4.1. The net turnover values for the 1950s to 1980s period should exclude the turnover error since the same shift in both the floodplain to channel turnover and channel to floodplain turnover should cancel out.

5. RESULTS

5.1. Long-term Assessment of Middle River and Lower River Channel Change from the 1950s, 1980s and 2012 Aerials

The long term assessment of channel change covered the Middle and Lower Susitna River segments over two principle periods the 1950s to 1980s and the 1980s to 2012. A third overall period, from the 1950s to 2012, was also analyzed to assess the geomorphic change observed over approximately six decades.

The analysis of channel change in the Middle and Lower Susitna River segments is based on the comparison and analysis of the geomorphic features mapped for the 1950s, 1980s and 2012. To identify and quantify change tabulated areas were used for the various geomorphic features within a reach. The analysis also identified processes that result in channel change including vegetation encroachment, vegetation establishment (primary succession on gravel bars), bank erosion, lateral migration, and biogeomorphic processes such as beaver dam construction.

Comparative terms, such as increase and reduce, are a function of area differences (1980s vs. 1950s and 2012 vs. 1980s) determined from the tabulated geomorphic feature data. The overlay mapping along with tabulation of areas associated with geomorphic features and turnover are tools used in the discussion of the results.

5.1.1. Geomorphic Feature Area Tabulation

Aerial photographs with the geomorphic features mapped for the Middle Susitna River Segment are provided in Appendix A for the 1950s, Appendix B for the 1980s, and Appendix C for 2012. The Middle Susitna River Segment channel change overlay is provided in Appendix D for the 1950s and 1980s geomorphic features and in Appendix E for the 1980s to 2012 geomorphic features. The geomorphic mapping for the Lower Susitna River Segment sites is provided in Appendix F for 1950s, Appendix G for 1983, and Appendix H for 2012. The Lower Susitna River Segment channel change overlay is provided in Appendix I for the 1950s and 1980s geomorphic features and in Appendix J for the 1980s to 2012 geomorphic features. Tabulated geomorphic feature areas are provided in Table 5.1-1 through Table 5.1-8 for the Middle River geomorphic reaches, Table 5.1-9 through Table 5.1-18 for the Middle River Geomorphic Assessment Areas, and Table 5.1-19 through Table 5.1-27 for the Lower River geomorphic reaches.

5.1.2. Geomorphic Feature Overlay Analysis

Due to the qualitative comparison and comparatively subjective nature of geomorphic feature classification, the limitations of the geomorphic feature area tabulation and overlay analysis were addressed with a turnover analysis. For this reason, the analysis of geomorphic feature area (tabular and qualitative summary) was limited to that which would be necessary to develop or supplement the more robust turnover analysis. Changes in the classification of sloughs and channels were included with the respective reaches and geomorphic assessment areas (GAAs) of the turnover results.

5.1.3. Turnover Results

The turnover areas were tabulated by reach, as well as for Geomorphic Assessment Areas in the Middle River. Areas that were gained or lost from the 1950s to 2012 between reaches at confluences were calculated. The tabulated turnover areas represent areas that were located within the reach and had aerial photography during both time periods. Figure 5.1-1 shows an example of the turnover mapping from GAA-128 and GAA-138. The complete Middle River and Lower River turnover mapping results are included as Appendix K through Appendix P. Calculated turnover values are provided in Table 5.1-28 for the Middle River geomorphic reaches, Table 5.1-29 for the Middle River Geomorphic Assessment Areas, and Table 5.1-30 for the Lower River geomorphic reaches.

Relative stability rating criteria were established to categorize turnover rates. Categories representing: stable (or static), moderately stable, moderately dynamic, and dynamic were chosen for both the Middle and Lower Susitna River segments based on a total turnover rate (defined as the sum of both channel to floodplain and floodplain to channel turnover rate). Ranges for the relative stability criteria are listed below.

<u>Geomorphic Reach Stability Ratings Based on Total Turnover Rate</u>

Relative Reach Stability	**MR reaches and GAAs (ft^2/yr/mile)**	**LR reaches (ft^2/yr/mile)**
Stable	0 to 10,000	0 to 100,000
Moderately Stable	10,000 to 20,000	100,000 to 200,000
Moderately Dynamic	20,000 to 30,000	200,000 to 300,000
Dynamic	> 30,000	> 300,000

5.1.4. Middle Susitna River Segment Long-term Channel Change Assessment

The Middle Susitna River Segment can be generally divided into three geomorphic regions: Watana Dam (PRM 187.1) to Devils Canyon (PRM 166.1), Devils Canyon (PRM 166.1 to PRM 153.9), and Devils Canyon to the Three Rivers Confluence (PRM 102.4). From the Watana Dam site to the head of Devils Canyon, the slope is about 11 ft/mile and the channel is bounded by meta-sedimentary and gneissic rocks. The channel slope in Devils Canyon is about 31 ft/mile and the channel is bounded by granitic rocks. From Devils Canyon to the Three Rivers Confluence, the channel slope decreases progressively from about 12 ft/mile to about 7 ft/mile and the reduction in slope correlates to a reduction in the extent of bedrock outcrop along the channel and in the erosion resistance of the bounding materials (Pleistocene- and Holocene-age alluvial terraces) and the transition to an alluvial channel.

These general regions were further divided into eight geomorphically distinct reaches presented in Figure 5.1-2 and listed in Table 5.1-31. Middle River geomorphic reaches 1 through 3 comprise the upper middle portion. Reach 4 is the Devils Canyon segment, and Reaches 5 through 8 comprise the lower middle portion. Each geomorphic reach was classified based on its geomorphic characteristics including bed slope, bounding geology, average active channel width, channel branching, sediment storage capacity, and sinuosity. Further characteristics for each of the eight reaches are described in *Geomorphic Reach Delineation and Characterization, Upper, Middle and Lower Susitna River Segments Technical Memorandum* (Tetra Tech 2014b).

5.1.4.1. MR-1 (PRM 187.1 to PRM 184.6)

The Susitna River (current 660 feet active channel width) flows in a narrow, approximately 780 feet wide, bedrock-bounded canyon downstream of the Watana Dam site. The canyon is formed in Tertiary to Cretaceous-age gneiss. There is limited sediment storage potential in the reach because of the narrow valley bottom an entrenchment ratio (ER) of 1.2 and relatively steep slope (9.2 ft/mile). Alluvial sediments are stored within vegetated and non-vegetated mid-channel bars that tend to be located in local hydraulic expansion zones. The sinuosity of the reach is 1.03, and the average number of channels in the reach is 1.2.

Based on its turnover rate, MR-1 is classified as a stable reach. The total turnover rate for the period of the 1950s to 2012 is 7,400 ft^2/yr/mile. As there are few locations of sediment storage and the main channel is formed within a bedrock-bounded canyon, turnover rates should be similar between different time periods. The total turnover rate for the period from the 1950s to 1980s (15,000 ft^2/yr/mile) appears to be more than twice the rate of the 1980s to 2012 period

(6,100 ft²/yr/mile). Except for erosion along the vegetated islands at PRM 185.9 and PRM 185.3, for the remainder of the turnover area in MR-1 during the 1950s to 1980s approximately half appears to be registration error. The channel to floodplain turnover on the right bank is approximately equal to the floodplain to channel turnover on the left bank. The channel to floodplain turnover rate for MR-1 between the 1950s and 1980s is 7,900 ft²/yr/mile and comparable to the floodplain to channel turnover rate of 7,300 ft²/yr/mile for the same period.

The channel to floodplain turnover rate in MR-1 for the 1980s to 2012 was 1,000 ft²/yr/mile, and the floodplain to channel turnover rate was 5,100 ft²/yr/mile, for a net floodplain to channel turnover rate of 4,000 ft²/yr/mile. The loss of floodplain area can be attributed to erosion on two of the three vegetated mid-channel bars, as well as channel widening where the vegetation line can be observed to have retreated 10-30 ft along the right bank at PRM 186.4, PRM 185.7, PRM 185, and PRM 184.7. Average channel widths remained relatively unchanged from 570 ft in the 1950s and 1980s, but increased to 660 ft in 2012.

5.1.4.1.1. GAA-184 Watana Dam (PRM 185.7 to PRM 184.7)

GAA-184 Watana Dam extends one mile from PRM 185.7 to PRM 184.7, in the downstream portion of MR-1. GAA-184 is located in a bedrock-bounded canyon downstream of the Watana Dam site and is comprised of Tertiary to Cretaceous-age gneiss (Tetra Tech 2014b). Alluvial sediments in MR-1 are primarily stored within vegetated and non-vegetated mid-channel bars that tend to be located in local hydraulic expansion zones. The channel gradient of 11.5 ft/mile in GAA-184 is larger than the average channel gradient of 9.4 ft/mile in MR-1.

Similar to MR-1 as a whole, GAA-184 Watana Dam falls into the stable category based on turnover rates. The total turnover rate for the period of the 1950s to 2012 was 8,200 ft²/yr/mile. The active channel width of GAA-184 for all three time periods (1950s width = 740 ft, 1980s width = 730 ft, 2012 width = 750 ft) is larger than the 2012 MR-1 current reach active channel width of 660 ft because a portion of the right bank is composed of erodible glacial till.

Turnover from the 1950s to the 1980s in GAA-184 Watana Dam was limited to a few locations. The floodplain island at PRM 185.2 decreased in size by about 80% from the 1950s to 1980s. The floodplain island at PRM 185.3 right exhibited vegetation encroachment in the same period. The main channel widened at PRM 185.6, PRM 185.1, and PRM 184.7 as the vegetation line retreated 10 to 30 feet along the river right.

The net turnover trends were similar in GAA-184 and MR-1 for each time period, with a net floodplain to channel turnover between the 1950s and 1980s, and net channel to floodplain turnover for the 1980s to 2012 and 1950s to 2012 time periods. From the 1950s to the 1980s, the net turnover rate in GAA-184 was 1,400 ft²/yr/mile, while the MR-1 reach average net turnover rate was 600 ft²/yr/mile. For both the 1980s to 2012 and 1950s to 2012 time periods, net turnover rates for GAA-184 (1980s to 2012 rate = 3,500 ft²/yr/mile, 1950s to 2012 rate = 1,100 ft²/yr/mile) were comparable to the MR-1 reach average net turnover rates (1980s to 2012 rate = 4,000 ft²/yr/mile, 1950s to 2012 rate = 1,800 ft²/yr/mile).

5.1.4.2. MR-2 (PRM 184.6 to PRM 169.6)

The Susitna River with a current 720 feet active channel width flows in a wider, approximately 1,500 feet, bedrock-bounded canyon between the Tsusena Creek confluence and about PRM 173, where the canyon narrows to about 1,000 feet. The wider, upper part of the reach is formed in more erodible Cretaceous-age Kahiltna Flysch meta-sedimentary rocks and the narrower, lower part between PRM 173 and PRM 169.6 is formed in less-erodible Tertiary to Cretaceous-age gneiss. The average slope of the reach is 10.8 ft/mile. There are considerably more, compared with MR-1, alluvial sediments stored in vegetated islands, mid-channel bars and in vegetated discontinuous floodplain segments in this reach with an entrenchment ratio of 2.1. This is particularly true of the wider, upper portion of this reach. It is likely that Fog Creek, a south bank tributary, is a local source of sediment in the upper portions of this reach. In the lower, narrower part of the reach, alluvial sediments are stored within discontinuous vegetated floodplain segments and in unvegetated mid-channel bars. The sinuosity of the reach is 1.06 and the average number of channels in the reach is 1.4.

Based on the total turnover rate, MR-2 is classified as a stable reach. The total turnover rate for the period of the 1950s to 2012 is 8,600 ft^2/yr/mile. This value may be exaggerated due to registration error along the main channel.

The channel to floodplain turnover in MR-2 can be described as vegetation encroachment increasing the size of previously vegetated areas. This occurred primarily outside of the main channel at PRM 183, PRM 173.3 left, PRM 176 left, within GAA-173 Stephan Lake Complex, and PRM 172.3 right. MR-2 had a net turnover rate of 2,500 ft^2/yr/mile of channel to floodplain for the period from the 1950s to the 1980s.

Floodplain to channel turnover in MR-2 depicts different amounts in the mapping between the two periods of the 1950s and 1980s and 1980s to 2012. The reason being that the 1950s to 1980s floodplain to channel turnover rate results (5,700 ft^2/yr/mile) were likely overestimated due to shadows and registration error in the 1950s imagery. Floodplain to channel turnover appears to have occurred between the 1980s and 2012 due to vegetation removal from the banks at numerous locations such as PRM 183.6, PRM 179.8, PRM 175.8, PRM 175.2 and PRM 173.2.

While there were some small areas of vegetation encroachment (1980s to 2012 channel to floodplain turnover rate = 3,400 ft^2/yr/mile), the floodplain to channel turnover rate was larger (turnover rate = 4,800 ft^2/yr/mile). This led to a net floodplain to channel turnover rate of 1,400 ft^2/yr/mile for the 1980s to 2012 time period. Channel widths over time also remained stable with average widths of 720 ft in the 1950s, 700 feet in the 1980s, and 720 feet in 2012.

The tabulated geomorphic feature areas in MR-2 exhibited major differences between the two periods of the 1950s to 1980s and 1980s to 2012. Side slough area decreased by 79 percent from the 1950s to the 1980s, but increased by over 4,000 percent from the 1980s to 2012 (1950s area = 139,000 sq. ft., 1980s area = 29,000 sq. ft., 2012 area = 1.4 million sq. ft.). The apparent increase in side slough area is due to a lower discharge in the 2012 photos, leading to what had been a side channel on river right at PRM 175 in the 1980s to be classified as a side slough in 2012 and likely does not represent a physical change in feature classification. Upland slough area increased by 28 percent from the 1950s to the 1980s, and also increased by over 100 percent from the 1980s to 2012 (1950s area = 90,000 sq. ft., 1980s area = 115,000 sq. ft., 2012 area = 268,000 sq. ft.). Channel conversion to uplands sloughs at PRM 178.4, PRM 176.3, and PRM 175.3 account for the majority of the upland slough area increase between the 1980s and 2012.

5.1.4.2.1. GAA-173 Stephan Lake Complex (PRM 175.7 to PRM 173.6)

GAA-173 Stephan Lake Complex extends 2.1 miles from PRM 175.7 to PRM 173.6, in the lower half of MR-2. GAA-173 is located in a bedrock-bounded (Tetra Tech 2014b) canyon comprised of Cretaceous-Tertiary age gneiss. Alluvial sediments are stored in vegetated islands, mid-channel bars, and vegetated discontinuous floodplain segments. The channel gradient of GAA-173 is 10.8 ft/mile, the same as the MR-2 reach average channel gradient.

GAA-173 Stephan Lake Complex is moderately stable based on the turnover rates. The total turnover rate for the GAA-173 Stephan Lake Complex was 15,000 ft^2/yr/mile for the 1950s to 2012. The active channel widths of GAA-173 (1950s width = 990 ft, 1980s width = 940 ft, 2012 width = 890 ft) are considerably larger than the 2012 MR-2 reach active channel width of 720 ft.

Two main factors comprise the turnover values in GAA-173 Stephan Lake Complex: vegetation encroachment and vegetation removal. Channel to floodplain turnover rates in GAA-173 Stephan Lake Complex (1950s to 2012 rate = 12,000 ft^2/yr/mile) were greater than MR-2 (1950s to 2012 rate = 4,600 ft^2/yr/mile) due to the vegetation encroachment around the islands at PRM 175.2, PRM 174.8, and PRM 174.2. Channel widening or vegetation retreat of 20 to 40 feet has occurred at PRM 175.2 and PRM 173.6. Registration error is evident in the 1950s imagery in GAA-173 Stephan Lake Complex and results in slight overestimation of turnover rates using this imagery (1950s to 1980s and 1950s to 2012).

By comparing the net turnover values, a realistic comparison can be made between the overall channel change in MR-2 and local changes at GAA-173 Stephan Lake Complex. Both had net channel to floodplain turnover rates from the 1950s to 1980s (MR-2 net rate = 2,500 ft^2/yr/mile) and GAA-173 Stephan Lake Complex (7,900 ft^2/yr/mile). However, for the 1980s to 2012 the net turnover rate for MR-2 switched from floodplain to channel (1,400 ft^2/yr/mile), while GAA-173 Stephan Lake Complex had a greater channel to floodplain turnover rate (8,900 ft^2/yr/mile). The primary difference between the two appears to be the channel widening through the majority of MR-2 compared to the vegetation encroachment outside of the main channel in the GAA-173 Stephan Lake Complex.

Changes in the classification of geomorphic features within GAA-173 were affected both by high discharges in the 1980s imagery and reduction in the hydraulic connection at the upper end of a channel. The change in the side slough and side channel area follows the similar explanation as MR-2. A physical reduction in the hydraulic connection at the head of the channel at PRM 175 was responsible for the classification change from SC in the 1950s to SS in the 1980s and is not due to differences in flow rates in the imagery. The channel was completely encroached upon by vegetation by 2012.

5.1.4.3. MR-3 (PRM 169.6 to PRM 166.1)

The Susitna River (590 feet active channel width) flows in a narrow (about 780 feet wide), bedrock-bounded canyon from PRM 169.6 to PRM 166.1 (Tetra Tech 2014b). The canyon is formed in Paleocene-age granitic rocks. Because of the relatively narrow canyon (ER=1.3) and steep slope (12.3 ft/mile), the alluvial sediment storage potential in the reach is low. Alluvial sediments are stored within a few vegetated mid-channel bars in the reach, and there is little evidence of even discontinuous floodplain segments within the reach. The sinuosity of the reach is 1.02 and the average number of channels in the reach is 1.1 indicating the reach is primarily single channel.

MR-3 is classified as a stable reach based on its total turnover rate for the 1950s to 2012 of 3,000 ft^2/yr/mile. Floodplain to channel turnover in the 1980s to 2012 period (rate of 4,200 ft^2/yr/mile) was the dominant turnover mechanism and occurred as 10 to 60 feet of main channel widening.

The net rates for turnover in MR-3 depict opposite trends between the 1950s and 1980s and the 1980s to 2012. From the 1950s to 1980s, channel to floodplain turnover (turnover rate = 2,600 ft^2/yr/mile) was larger than floodplain to channel turnover (turnover rate = 1,600 ft^2/yr/mile) for an overall net channel to floodplain turnover rate of 1,000 ft^2/yr/mile. From the 1980s to 2012; however, the channel to floodplain turnover rate of 600 ft^2/yr/mile and the floodplain to channel turnover rate of 4,200 ft^2/yr/mile resulted in a net floodplain to channel turnover rate of 3,600 ft^2/yr/mile. Channel widths reflect the stability of MR-3 with the reach average widths of 580 ft. in the 1950s, 570 ft. in the 1980s, and 590 ft. in 2012.

5.1.4.4. MR-4 (PRM 166.1 to PRM 153.9)

The Susitna River (310 feet active channel width) flows in a very narrow (370 feet wide), very steep (30.6 ft/mile), bedrock-bounded canyon, referred to as Devils Canyon (Tetra Tech 2014b). The narrow canyon has formed in Paleocene-age granitic rocks that are probably not faulted given the very narrow width of the canyon. Because of the narrow canyon (ER=1.2) and steep slope, there is very little, if any, alluvial sediment stored within the reach. The sinuosity of the reach is 1.03 and the reach is almost entirely single channel.

Devils Canyon is the most stable reach within the Middle Susitna River Segment. Turnover and geomorphic change was minimal; most features did not change. As MR-4 is a bedrock-bounded canyon with only two vegetated islands at PRM 163.5 and PRM 158.8, turnover rates were the lowest in for all Middle and Lower River geomorphic reaches. The total turnover rate for the reach from the 1950s to 2012 was 2,500 ft^2/yr/mile with an appreciable portion of this likely attributable to registration error in the 1950s aerials and shadows obscuring the banks in the 2012 aerials. Very little geomorphic change was documented in areas that were clearly visible in each set of aerials. The stability of MR-4 is also evident in the minor changes in average channel widths of 320 feet in both the 1950s and 1980s, and 310 feet in 2012. The 10 feet of difference is within the resolution of the digitization process.

5.1.4.5. MR-5 (PRM 153.9 to PRM 148.4)

From PRM 153.9 to PRM 148.4, the Susitna River (510 feet active channel width) flows through a bedrock-bounded canyon similar in width to MR-1 and MR-3 (about 850 feet), but nearly double the width of Devils Canyon in MR-4. The relatively narrow canyon has formed in Cretaceous-age Kahiltna Flysch meta-sedimentary rocks. The somewhat wider canyon and lower slope (12.3 ft/mile) compared to MR-4 (Devils Canyon) allow some alluvial sediment storage within the reach, primarily in a few vegetated mid-channel islands and discontinuous floodplain segments in the slightly wider parts of the reach (ER=1.7). The sinuosity of the reach is 1.03 and the average number of channels in the reach is 1.2.

In terms of its total turnover rate for the period of the 1950s to 2012 of 8,700 ft^2/yr/mile MR-5 is classified as a stable reach. Turnover primarily occurred as vegetation encroachment along the vegetated bars of Slough 21A. There was an increase in floodplain area for all time periods resulting in net channel to floodplain turnover for all periods (net channel to floodplain turnover rates of 2,300 ft^2/yr/mile for the 1950s to 1980s, 3,300 ft^2/yr/mile for the 1980s to 2012, and 2,800 ft^2/yr/mile for the 1950s to 2012).

Registration error appears to have been significant in the 1950s aerials. This error may represent on the order of 30 to 70 feet of the main channel bank shift from PRM 151 to the downstream limit of MR-5 at PRM 148.3. The results for the total turnover rate for the period of the 1950s to 1980s was 15,000 ft^2/yr/mile, although the 1980s to 2012 rate of 6,700 ft^2/yr/mile is probably more representative of the true stability of MR-5. Channel widths narrowed very slightly from 530 feet in the 1950s, 520 feet in the 1980s, and 510 feet in 2012.

5.1.4.5.1. GAA-151 Portage Creek (PRM 152.3 to PRM 151.8)

GAA-151 Portage Creek extends 0.5 miles from PRM 152.3 to PRM 151.8 in the upper portion of MR-5. GAA-151 is located in a bedrock-bounded (Tetra Tech 2014b) narrow canyon formed in Cretaceous-age Kahiltna Flysch meta-sedimentary rocks and contains a significant tributary, Portage Creek. GAA-151 is a single channel with no mid-channel bars or islands. As such, sediment storage is limited. The channel gradient of GAA-151 of 12.2 ft/mile is nearly the same as the MR-5 reach channel gradient of 12.1 ft/mile, but the active channel width of GAA-151 is slightly smaller (1950s width = 460 feet, 1980s width = 440 feet, 2012 width = 440 feet) than the 2012 MR-5 reach active channel width of 510 feet.

The lowest amounts of turnover among the ten Geomorphic Assessment Areas occurred in GAA-151 for all time periods, with a maximum turnover rate of 3,500 ft^2/yr/mile from channel to floodplain occurring between the 1950s and the 1980s. Channel to floodplain turnover rates for GAA-151 (1950s to 1980s rate = 3,200 ft^2/yr/mile, 1980s to 2012 rate = 700 ft^2/yr/mile, 1950s to 2012 rate = 1,200 ft^2/yr/mile) were less than the MR-5 reach average channel to floodplain turnover rates (1950s to 1980s rate = 8,500 ft^2/yr/mile, 1980s to 2012 rate = 5,000 ft^2/yr/mile, 1950s to 2012 rate = 5,800 ft^2/yr/mile) for all time periods.

The floodplain to channel turnover rates for GAA-151 were not appreciable for the 1950s to 1980s (300 ft^2/yr/mile) and 1950s to 2012 (200 ft^2/yr/mile), and were substantially less than the MR-5 reach average floodplain to channel turnover rate for the same periods (1950s to 1980s rate = 6,200 ft^2/yr/mile, 1950s to 2012 rate = 3,000 ft^2/yr/mile). From the period between the 1980s and 2012, however, the floodplain to channel turnover rate was essentially equal for GAA-151 (2,000 ft^2/yr/mile) to MR-5 reach average turnover rate (1,700 ft^2/yr/mile). Turnover rates on the order of 1,000 to 2,000 ft^2/yr/mile are at the limit of the mapping ability considering map resolution and accuracy of the line work.

Net channel to floodplain turnover occurred between the 1950s and 1980s (rate of 3,000 ft^2/yr/mile) and 1950s to 2012 (rate of 1,000 ft^2/yr/mile) time periods, whereas the turnover for the 1980s to 2012 period were net floodplain to channel (rate of 1,200 ft^2/yr/mile). The MR-5 reach turnover was net channel to floodplain for all three time periods (1950s rate = 2,300 ft^2/yr/mile, 1980s rate = 3,300 ft^2/yr/mile, 2012 rate = 2,800 ft^2/yr/mile).

5.1.4.6. MR-6 (PRM 148.4 to PRM 122.7)

In Middle River geomorphic reach 6 (MR-6), the Susitna River flows through a bedrock-bounded canyon composed of Cretaceous-age Kahiltna Flysch meta-sedimentary rocks averaging 2,350 feet in width with an active channel width of 990 feet. In the wider parts of the reach, alluvial sediments are stored in continuous vegetated floodplain segments and within numerous vegetated islands and bars, as well as in unvegetated mid-channel bars (ER=2.4) (Tetra Tech 2014b). Channel slope decreases nearly 15 percent from 12.3 ft/mile in MR-5 to 10.7 ft/mile. The reach is relatively straight at a sinuosity of only 1.09. The multiple channel nature of this reach is evidenced by the average number of channels calculated at 2.4. Where the valley bottom is wider within the reach, the alluvial deposits tend to be more vegetated, and where the valley bottom is narrower, the alluvial deposits tend to be less vegetated.

MR-6 is a dynamic reach and the turnover rates further support this conclusion. The total of 1950s to 2012 channel to floodplain (23,000 ft^2/yr/mile) and floodplain to channel turnover rates (14,000 ft^2/yr/mile) is 37,000 ft^2/yr/mile. The only Middle River geomorphic reach with a higher total turnover rate is MR-8 (38,000 ft^2/yr/mile). Both MR-6 and MR-8 had more than twice the total turnover rate as the third most dynamic reach MR-7 (16,000 ft^2/yr/mile). Compared to the Geomorphic Assessment Areas in MR-6, the reach average for MR-6 (37,000 ft^2/yr/mile) was greater than GAA-144 Slough 21 (30,000 ft^2/yr/mile) and GAA-141 Indian River (19,000 ft^2/yr/mile) and less than GAA-138 Gold Creek (41,000 ft^2/yr/mile) and GAA-128 Slough 8A, (53,000 ft^2/yr/mile).

In MR-6, the turnover analysis reveals that the even though the areas of channel to floodplain turnover are similar for the reach, there were differences in the distribution of floodplain increase attributable to vegetation encroachment versus vegetation establishment. In both periods, the 1950s to 1980s and 1980s to 2012, floodplain area increased by similar amounts of the total area in the reach (1950s to 1980s turnover = 6.6 percent, 1980s to 2012 turnover = 5.5 percent). The turnover rates for the channel to floodplain for the 1950s to 1980s was 28,000 ft^2/yr/mile and for the 1980s to 2012 it was 26,000 ft^2/yr/mile, essentially equal. The period of the 1950s to 1980s had two areas of vegetation encroachment that exceeded 1,000,000 sq. ft. They occurred at PRMs 130 and PRM 127. In the period of the 1980s to 2012, there was only one area (PRM 124.7 area = approximately 575,000 sq. ft.) of vegetation encroachment that was larger than 500,000 sq. ft. The largest areas of the vegetation establishment ranged between 200,000 sq. ft. and 500,000 sq. ft. These locations include PRMs 144.8 and PRM 138, PRM 137.2, and PRM 125 in the 1950s to 1980s and at PRM 137.9, PRM 133.4, PRM 128.4, and PRM 127.8 in the 1980s to 2012.

Unlike the channel to floodplain turnover, the amounts of floodplain to channel turnover differs between the 1950s to 1980s and 1980s to 2012. Floodplain to channel turnover was twice the amount during the 1950s to 1980s (turnover = 5.2 percent), than the 1980s to 2012 (turnover = 2.6 percent). The turnover rates for the floodplain to channel for the 1950s to 1980s was 22,000 ft^2/yr/mile and for the 1980s to 2012 it was 12,000 ft^2/yr/mile. The 1950s to 1980s floodplain to channel turnover rate is higher than the 1980s to 2012 rate partially because of a few locations with large turnover in the 1950s to 1980s period. Approximately 1,000,000 sq. ft. of floodplain to channel turnover occurred at both PRMs 133.4 and PRM 146 in the period from the 1950s to 1980s as the main channel shifted. Channel widths decreased consistently from 1,090 feet in the 1950s, 1,060 feet in the 1980s and 990 feet in 2012.

5.1.4.6.1. GAA-144 Slough 21 (PRM 146.1 to PRM 143.6)

GAA-144 Slough 21 extends 2.5 miles from PRM 146.1 to PRM 143.6 and is the upper most Geomorphic Assessment Area in MR-6, the longest geomorphic reach in the Middle River. GAA-144 is located in a bedrock-bounded canyon comprised of Cretaceous-age Kahiltna Flysch meta-sedimentary rocks with inset glacial and glacio-fluvial deposits. The channel gradient of 13.8 ft/mile in GAA-144 is larger than the MR-6 reach channel gradient of 10.8 ft/mile. The active channel widths of GAA-144 for each time period (1950s width = 910 feet, 1980s width = 930 feet, 2012 width = 920 feet) are slightly smaller than the 2012 MR-6 reach active channel width of 990 feet.

Slough 21 GAA-144 is a moderately dynamic area. The total turnover rate for the 1950s to 2012 was 30,000 ft^2/yr/mile. Registration error likely accounts for an appreciable portion of the higher total turnover rate for the 1950s to 1980s (50,000 ft^2/yr/mile) compared to the 1980s to 2012 (20,000 ft^2/yr/mile).

From the 1950s to 1980s, channel to floodplain turnover primarily occurred as vegetation establishment at PRM 144.8 and vegetation encroachment around the island in the mouth of Slough 21. Vegetation encroachment was also prevalent along Slough 20, Side Channel 21, and Slough 21. Vegetation establishment also occurred with the formation of the island at PRM 144.

From the 1980s to 2012, a similar trend of channel to floodplain turnover occurred. Vegetation establishment between the vegetated islands along Side Channel 21 continued with the creation of a new island at PRM 145.2 left. The inlet to Slough 21 continued to experience vegetation encroachment. The train of islands along Side Channel 21 became more defined with the establishment of vegetated islands at PRM 144.2 left and PRM 143.8 left and the merging of the two islands at PRM 144.8.

The largest area of floodplain to channel turnover from the 1950s to 1980s occurs on river left from PRM 146.3 to PRM 145.8, in the present-day location of the powerline crossing over the Susitna River. Up to 480 feet of floodplain was eroded away between the 1950s and 1980s. A major contributor to this behavior appears to be the loss of the vegetated island at PRM 146.3 between the 1950s and 1980s. In this area, the former island and split main channels of the 1950s were replaced with a braided main channel by the 1980s. The erosion of the left bank decreased between the 1980s and 2012, likely due to the formation of a main channel on the right with side channels and vegetated islands on the left. The erosion at PRM 146 is the main reason the turnover in Slough 21 GAA-151 had a net floodplain to channel turnover rate of 3,300 ft^2/yr/mile in the 1950s to 1980s as compared to the net channel to floodplain rate of 1,800 ft^2/yr/mile in the 1980s to 2012.

Floodplain to channel turnover primarily occurred on the right side of the vegetated islands that separate Side Channel 21 and Slough 21 from the main channel. Approximately, 100 feet of erosion occurred along the left side of the main channel at PRM 145.5 and 145 between the 1950s and 1980s. Erosion continued along the left of the main channel at PRM 145 through the period of the 1980s to 2012 for approximately 150 feet. Erosion of 200 feet along the left of the main channel occurred at PRM 144.5 during the 1980s to 2012.

Changes in the classification of sloughs occurred in GAA-144 Slough 21 between the 1980s and 2012. The side slough at PRM 145.7 (the upstream branch of Slough 21) lost its hydraulic connection to the main channel and was classified as an upland slough by 2012. Similarly, the hydraulic connection between the side slough at PRM 144 and the main channel became disconnected and was classified as an upland slough in 2012. The downstream end of this slough is Waterfall Creek which outlets to the main channel at PRM 143.6.

5.1.4.6.2. GAA-141 Indian River (PRM 143.6 to PRM 140.1)

GAA-141 Indian River is 3.4 miles long within Geomorphic Reach MR-6. GAA-141 Indian River is in a bedrock-bounded canyon. Additional geologic information for GAA-141 Indian River is presented in the ISR Study 6.5 Section (5.1.3).

GAA-141 Indian River is classified as a moderately stable area based on a total turnover rate of 18,900 ft²/yr/mile for the 1950s to 2012 period comprised of a channel to floodplain turnover rate of (11,000 ft²/yr/mile) and floodplain to channel turnover rate (7,900 ft²/yr/mile). This is less dynamic than the 1950s to 2012 MR-6 reach average total turnover rate (37,000 ft²/yr/mile).

In GAA-141 Indian River, channel to floodplain turnover appears to be due to approximately equal parts of vegetation encroachment and vegetation establishment. Vegetation encroachment is evident in Slough 19 and Slough 15 B in the 1950s to 1980s and the 1980s to 2012, respectively. It was also present around the floodplain islands at PRM 143 and 140.6 in the 1950s to 2012 period. Three new vegetated floodplain islands were created in the period from the 1950s to 1980s and four new floodplain islands over the period of 1980s to 2012. The turnover rates for the channel to floodplain for the 1950s to 1980s was 16,000 ft²/yr/mile and for the 1980s to 2012 it was 10,000 ft²/yr/mile. There was a net channel to floodplain turnover for both the 1950s to 1980s (1,500 ft²/yr/mile) and 1980s to 2012 (4,600 ft²/yr/mile).

In GAA-141 Indian River, floodplain to channel turnover occurred through the loss of two floodplain islands and a main channel shift. Floodplain islands at PRM 142.7 and PRM 142.5 were eroded away during the 1950s to 1980s period. The main channel shifted a maximum of 170 feet into the left bank at PRM 143.2.

Several channels in GAA-141 Indian River became less hydraulically connected between the 1950s and 2012. This conversion was accompanied by vegetation encroachment and manifested as channel to floodplain turnover. Gold Creek Slough at PRM 140.2 appears to have converted from an upland slough to floodplain between the 1980s and 2012. Also as a result of vegetation encroachment, several side channels converted to side sloughs. Slough 15 (PRM 140.9 right) and Slough 19 (PRM 143.2 left) became disconnected on the upstream end and were reclassified as upland sloughs in the 1980s. In the 1950s, Slough 15 was a side slough and Slough 19 was a side channel. Slough 15B (PRM 141.4) underwent a similar change from the 1950s to 1980s when it changed from a side channel to a side slough. From the 1980s to 2012, Slough 16 (PRM 141.2 right) also changed from a side channel to a side slough.

Indian River itself experienced significant channel to floodplain turnover from the 1950s to 2012. In the 1950s, the lower mile was a braided channel approximately 400 feet wide. By 2012, this portion of Indian River had become a single or split channel ranging from 40 to 100 feet wide.

5.1.4.6.3. GAA-138 Gold Creek (PRM 140.1 to PRM 137.0)

The GAA-138 Gold Creek is 3.1 miles long within Geomorphic Reach MR-6 Gold Creek enters within the boundary of the Geomorphic Assessment Area (Note: Gold Creek is not within the Focus Area boundary). GAA-138 Gold Creek is classified as a dynamic area based on its total turnover rate. The total of 1950s to 2012 channel to floodplain (27,000 ft²/yr/mile) and floodplain to channel turnover rate (15,000 ft²/yr/mile) is 41,000 ft²/yr/mile. This is more dynamic than the 1950s to 2012 MR-6 reach average total turnover rate (37,000 ft²/yr/mile).

In the period of the 1950s to 2012, floodplain area increased by an average of 5.9 percent of the total area of GAA-138 (net channel to floodplain turnover of 5.4 percent for 1950s to 1980s and 6.4 percent for 1980s to 2012). There were notable differences between the vegetation behaviors in these two periods that can be described as vegetation establishment and vegetation encroachment. The majority of the channel to floodplain turnover during the 1980s to 2012 was encroachment around three groups of floodplain islands at PRM, 139.7, PRM 138.2, and PRM 137.2. Approximately 1 million square feet of vegetation established at the downstream end of the floodplain islands at PRM 138 and PRM 137.2 between the 1950s and 1980s. The vegetation establishment continued on the downstream end of the floodplain island at PRM 138 during the period of the 1980s to 2012. The turnover rates for the channel to floodplain for the 1950s to 1980s was 27,000 ft^2/yr/mile and for the 1980s to 2012 it was 34,000 ft^2/yr/mile. There was a net channel to floodplain turnover for both the 1950s to 1980s (3,100 ft^2/yr/mile) and 1980s to 2012 (22,000 (ft^2/yr/mile) though the former rate was nearly an order of magnitude smaller than the latter rate.

Unlike the channel to floodplain turnover, the floodplain to channel turnover differs between the 1950s to 1980s and 1980s to 2012 which accounts for the large difference in the net turnover for these periods. The turnover rates for the floodplain to channel for the 1950s to 1980s was 23,000 ft^2/yr/mile and for the 1980s to 2012 it was 13,000 ft^2/yr/mile. The largest areas of floodplain to channel turnover occurred around PRM 137.7 right and PRM 137.4 left between the 1950s and 1980s.

There were several significant changes to geomorphic features in GAA-138 Gold Creek between the 1950s and 2012 related to channel to floodplain turnover. Vegetation encroachment was evident along Slough 10 (PRM 137.2 right), Slough 12 (PRM 138.8), Slough 13 (PRM 139 left) and PRM 137.2 left during the 1950s to 1980s. Slough 13 was extended downstream a total of 1,100 feet by vegetation encroachment along the edge of a main channel gravel bar from the 1950s to 1980s. Vegetation encroachment filled in the former upstream connection of Slough 12 (PRM 139 left) between the 1950s and 1980s causing it to change classification from a side slough to an upland slough. A slough was created between the 1980s and 2012 between the floodplain islands at PRM 138 and 137.9. Vegetation encroachment is apparent in Slough 11 between the 1980s and 2012.

Floodplain to channel turnover is evident in the evolution of Slough 11 in the period between the 1950s and 1980s. This channel appears to have avulsed across the floodplain from PRM 139 to PRM 140. In the 1950s Slough 11 was approximately 1,200 feet long and 40 feet wide but by the 1980s the slough had connected to the mainstem approximately 4,800 feet upstream and also widened to over 100 feet in several places. As mentioned in the previous paragraph, some of the widening was countered in the 1980s to 2012 period by encroachment of vegetation.

5.1.4.6.4. GAA-128 Slough 8A (PRM 130.4 to PRM 128.1)

GAA-128 Slough 8A (2.3 miles-long), part of MR-6, is inset between Kahiltna Flysch metasediments. From 2012 and 2013 survey data, the gradient along this section of the Susitna River is 8.6 feet/mile which is less than the reach-average gradient of 10.7 feet/mile. The shallower slope within the Geomorphic Assessment Area may contribute to the slightly wider active channel width compared to the reach average. Current (2012) active channel width of GAA-128 (1,080 feet) is roughly 100 feet or 10 percent wider than the reach-average active channel width (990 feet). The active channel width in GAA-128 has narrowed over time, as the active channel width was 1,370 feet in the 1950s and 1,130 feet in the 1980s. The downstream constrictions of Skull Creek (river left) and bedrock outcrop (river right) create backwater conditions that under high flows are zones of preferred sediment deposition. This is evidenced by the presence of younger geomorphic surfaces just upstream of the constriction (i.e. vegetated bars, young floodplain, and mature floodplains) that become progressively older moving upstream (ISR Study 6.5 Section 5.1.3.5.1). These zones are similarly preferred locations for ice-jam formation and are evidenced by documented historical and recent (2012) ice jams (HDR 2013a; HDR 2013b).

The channel to floodplain turnover rate in GAA-128 between the 1950s and 1980s was nearly three times the turnover rate of floodplain to channel area (channel to floodplain= 62,000 ft^2/yr/mile; floodplain to channel = 22,000 ft^2/yr/mile). The resulting net turnover rate, 41,000 ft^2/yr/mile channel to floodplain, is more than twice that of the other Geomorphic Assessment Areas. It is roughly 6.5 times greater than the reach average net turnover rate (6,200 ft^2/yr/mile) and nearly three times greater than any of the average net turnover rates of the 8 geomorphic reaches in the 1950s to 1980s or 1980s to 2012.

The net increase in channel to floodplain turnover (41,000 ft^2/yr/mile) between the 1950s to 1980s resulted from vegetation establishment and encroachment on mid-channel gravel bars (exposed at 19,000 cfs in 1950s aerial photography), mid-channel islands, and overbank floodplain margins. About one-third of this turnover (1.5 million sq. ft.) occurred in the upstream end of the Geomorphic Assessment Area through establishment of shrubs and a young poplar stand on nearly 0.5 miles of a main channel gravel bar. Similarly, roughly 500,000 sq. ft. of vegetation encroachment (likely in combination with sedimentation) caused the inlet of Half-Moon Slough to become a side slough by the 1980s; by 2012, Half-Moon Slough had become hydraulically disconnected and an upland slough. In Slough 8A vegetation encroachment has occurred on most of the exposed sediment visible on the 1950s aerial photographs.

The channel to floodplain net turnover rates between the 1950s to 1980s reduced by nearly 85 percent during the 1980s to 2012 period, from 41,000 ft^2/yr/mile to 6,400 ft^2/yr/mile. Channel to floodplain turnover in GAA-128 Slough 8A continued in the similar general locations in the 1980s to 2012 period but was significantly less around the island upstream of the Slough 8A inlet in the more recent period. Locations of channel to floodplain turnover between the 1950s to the 1980s occur as vegetation establishment on previously barren mid-channel bars and encroachment of vegetation around the side-channel margins as identified by the 2012 aerial photography. Vegetation encroachment also continued in the west fork of Slough 8A. In the 1980s to 2012 period, a mid-channel island (PRM 128.4) became established upstream of a 1980s vegetated island. At Half-Moon Slough, a side slough in the 1980s, sand deposition and vegetation colonization at the inlet and fine sediment deposition and beaver activity at the mouth has reduced connectivity of the feature with lateral channels thereby causing a feature change to an upland slough by 2012.

The floodplain to channel turnover rate of 20,000 ft^2/yr/mile has remained approximately the same over both periods in GAA-128, floodplain destruction and channel formation occurred throughout the site between the 1980s to 2012 study period; however, the largest areas of erosion occurred along the Skull Creek Side Channel and the mid-channel island upstream of Slough 8A (up to 175 feet in width for nearly 2,000 feet in both places).

5.1.4.7. MR-7 (PRM 122.7 to PRM 107.8)

Within geomorphic reach 7 (MR-7), the Susitna River flows through a bedrock-bounded canyon averaging 2,050 feet wide with an active channel width of 850 feet. Because of the relatively wide valley and low slope (8.3 ft/mile), there is high sediment storage potential within the reach.

Alluvial sediments are stored primarily within continuous vegetated floodplain segments and in vegetated islands and mid-channel bars.

MR-7 is classified as a moderately stable reach with a total of the 1950s to 2012 channel to floodplain (11,000 ft^2/yr/mile) and floodplain to channel turnover rates (5,000 ft^2/yr/mile) of 16,000 ft^2/yr/mile. No other Middle River reach has a total turnover rate between 10,000 ft^2/yr/mile and 30,000 ft^2/yr/mile. The individual total turnover rates for MR-1 through MR-5 are lower than 10,000 ft^2/yr/mile and MR-6 and MR-8 are higher than 30,000 ft^2/yr/mile. Compared to the Geomorphic Assessment Areas in MR-7, the reach average for MR-7 (16,000 ft^2/yr/mile) was greater than GAA-115 Slough 6A (14,000 ft^2/yr/mile) and less than Oxbow 1 GAA-113 (20,000 ft^2/yr/mile). Ice shearing of vegetation (PRM 108.1) appears in the 1980s aerial imagery and contribute to floodplain to channel turnover in MR-7.

In MR-7, a few primary locations are responsible for the vast majority of the channel to floodplain turnover. At PRM 121, the main floodplain island experienced significant vegetation encroachment through both the 1950s to 1980s and 1980s to 2012 periods. The largest area (160,000 sq. ft.) of floodplain establishment in MR-7 between the 1950s and 1980s occurred just upstream at PRM 121.3. By comparison the largest area of vegetation establishment in MR-7 was 580,000 sq. ft. at PRM 120.5. Downstream at PRM 117.3 the largest area (880,000 sq. ft.) of floodplain encroachment in MR-7 occurred at the upstream extent of GAA-115 Slough 6A. The two mile portion extending upstream experienced both vegetation encroachment and establishment through the 1980s to 2012. The third main location of channel to floodplain turnover in MR-7 was between PRM 115.3 and PRM 114.2, within Oxbow 1 GAA-113, and is covered in more detail under the discussion of GAA-113.

The floodplain to channel turnover in MR-7 occurred in the same few main locations as those listed for channel to floodplain turnover in the previous paragraph. At PRM 121 left, the main channel experienced about 40 and 100 feet of erosion in the periods of the 1950s to 1980s and 1980s to 2012, respectively. Approximately 100 feet of width was lost from the island at PRM 117.8 in both the 1950s to 1980s and 1980s to 2012. The third main location of floodplain to channel turnover in MR-7 was between PRM 115.3 and PRM 114.2, within Oxbow 1 GAA-113, and is covered in more detail in the discussion of GAA-113. The turnover rates for the floodplain to channel for the 1950s to 1980s period was 9,000 ft^2/yr/mile and for the 1980s to 2012 period it was 5,000 ft^2/yr/mile.

Within MR-7 the channel to floodplain turnover and floodplain to channel turnover exhibited opposite trends in the 1950s to 1980s and 1980s to 2012. Channel to floodplain turnover, increased by more than twice the amount (percent of the total reach area) in the 1980s to 2012 compared to the 1950s to 1980s (1950s to 1980s turnover = 2.1 percent, 1980s to 2012 turnover = 4.7 percent). Floodplain to channel turnover in the same periods had the opposite trend. It decreased by 50 percent in 1980s to 2012 compared to the 1950s to 1980s. In effect, the net channel to floodplain turnover for MR-7 is -0.3 percent in the 1950s to 1980s and +3.5 percent in the 1980s to 2012. These percentages correspond to a net channel to floodplain rate of -1,200 ft^2/yr/mile for in the 1950s to 1980s and 14,000 ft^2/yr/mile in the 1980s to 2012. MR-7 and MR-4 were the only MR reaches to have a net floodplain loss in the 1950s to 1980s. Channel widths also had alternating trends, with average width increasing slightly from 920 ft in the 1950s to 930 feet in the 1980s, and a decrease in average width to 850 feet in 2012.

A few key geomorphic changes occurred in MR-7 between the 1950s and 2012. Most notable were the conversion of side channels to side sloughs at PRM 121.5, PRM 119, PRM 117.2 during the 1950s to 1980s. Several upland sloughs between PRM 113 and PRM 109 and at PRM 117.3 left changed in extent due to biogeomorphic processes between the 1950s and 2012.

5.1.4.7.1. GAA-115 Slough 6A (PRM 117.3 to PRM 115.3)

GAA-115 Slough 6A (2.0 miles long) is laterally confined by riprap and a Pleistocene-age moraine on river left and Holocene-age terrace inset from bedrock on river right. GAA-113 is immediately downstream of GAA-115. GAA-115 is upstream of a constriction caused by riprap and bedrock outcrop and just downstream of an alluvial fan at the mouth of Unnamed Tributary PRM 117.4. The 8.6 ft/mile gradient and 910 feet active channel width are representative of MR-7 reach average parameters (8.3 ft/mile and 850 feet active channel width).

Based on the total turnover rates of 20,000 ft^2/yr/mile in both time periods of the 1950s to 1980s and the 1980s to 2012, GAA-115 falls at the cutoff between classification as a moderately stable and a moderately dynamic reach. The total turnover rate for the 1950s to 1980s is comprised of 9,800 ft^2/yr/mile of channel to floodplain turnover and 10,000 ft^2/yr/mile of floodplain to channel turnover. The total turnover rate for the 1980s to 2012 is comprised of 16,000 ft^2/yr/mile of channel to floodplain turnover and 4,900 ft^2/yr/mile of floodplain to channel turnover. The total turnover rate from the 1950s to 2012 is 14,000 ft^2/yr/mile based on a channel to floodplain turnover rate of 9,800 and floodplain to channel turnover rate of 4,500 ft^2/yr/mile over this period. Active channel width has slightly decreased over time, from 960 feet in the 1950s and 1980s, to 910 feet by 2012. Historic ice jams were documented throughout the main channel including a 2-mile long ice jam (i.e., Lane Creek Jam) at PRM 116 (HDR 2013a; HDR 2013b).

Over the two study periods of 1950s to 1980s and 1980s to 2012, the magnitude of the net floodplain to channel turnover in GAA-115 increased. The floodplain to channel turnover from the 1950s to 1980s was 300 ft^2/yr/mile and 11,000 ft^2/yr/mile from the 1980s to 2012. While there is a net floodplain to channel turnover during the 1950s to 1980s study period in GAA-115, it is minimal at 300 ft^2/yr/mile. Floodplain to channel turnover, from the 1950s to the 1980s, occurred along the right bank of the main channel, upstream of the constriction at PRM 116.5, along the Terrace and Old Floodplain surface for nearly three-quarters of a mile. In the 1980s to 2012 floodplain to channel turnover, 4,900 ft^2/yr/mile, was narrow (about 25 feet on the average for the period) and limited to a few areas along the river right at PRM 116.5, PRM 115.8 right, and along the left side of the dominant main channel island.

During the period of the 1950s to 1980s, channel to floodplain turnover occurred as vegetation encroachment occurred on the mid-channel islands near PRM 116. This expanded the extent of the vegetation around the small island approximately 100,000 sq. ft. and 50,000 sq. ft. along the large island. On the upstream end of the sight, near PRM 117.3, a large gravel bar in the 1950s was encroached upon by vegetation by the 1980s.

In the 1980s to 2012 study period GAA-115 had a channel to floodplain turnover rate of 16,000 ft^2/yr/mile. Channel to floodplain turnover from the 1980s to 2012 include the channel margin of the island at PRM 115.4. The mid-channel island at PRM 117.3 on the gravel bar also exhibited vegetation encroachment. Lastly, over 150,000 sq. ft. of Slough 6A underwent channel to floodplain turnover on the river right floodplain through biogeomorphic processes of beaver dam construction verified during the 2013 field season.

5.1.4.7.2. Oxbow 1 GAA-113 (PRM 115.3 to PRM 113.6)

GAA-113 Oxbow 1 (1.7 miles long) is laterally confined by riprap and a Pleistocene-age moraine on river left and a Holocene-age outwash terrace inset below bedrock on river right. Longitudinally, GAA-113 is upstream of a constriction caused by a moraine and outwash terrace and downstream of GAA-115. GAA-113 contains three tributaries including Gash Creek (PRM 115.0), Slash Creek (114.9), and Unnamed Tributary PRM 113.7. The 7.7 ft/mile gradient of GAA-113 and 850 feet active channel width are representative of MR-7 reach average parameters (8.3 ft/mile and 850 feet active channel width). A paleo-channel network set on Holocene terraces is present along the right bank of the site. Younger geomorphic surfaces (i.e. vegetated bars, young floodplains and mature floodplains are present within the active channel upstream of the constriction at PRM 114 (ISR Study 6.5, Appendix A.2).

Ice activity has been noted for both historical and current time periods in GAA-113 Oxbow 1. Recent ice jams (2012) were observed within the main channel at the following locations: upstream of Unnamed Tributary PRM 113.7, at the inlet of a side channel at PRM 114.3, upstream of a side channel inlet at PRM 114.5, upstream of a side channel inlet at 114.8 and along the mid-channel island at PRM 115 (HDR 2012; HDR 2013). Historical ice jams were all observed within the main channel and were distributed throughout the site. Vegetation margins on mid-channel islands appear to be sheared in the 1983 and 2012 aerial photography, likely due to ice.

GAA-113 Oxbow 1 can be described as moderately dynamic based on the total turnover rate between the 1950s and 2012 of 20,000 ft^2/yr/mile. This is comprised of a channel to floodplain turnover rate of 13,000 ft^2/yr/mile and the floodplain to channel rate of 7,000 ft^2/yr/mile. Active channel width has fluctuated over time, where width increased between the 1950s to 1980s, from 920 feet to 950 feet and decreased by roughly 10 percent to 850 feet by 2012 (due to vegetation encroachment on mid-channel islands).

GAA-113 Oxbow 1 had the greatest net floodplain to channel turnover rate (5,700 ft^2/yr/mile) compared to the other nine Geomorphic Assessment Areas in both periods of the 1950s to 1980s and 1980s to 2012. The primary erosion of floodplain occurred on approximately 2,000 feet length off the left bank with a width of over 200 feet. On the right, the bank was eroded roughly 75 feet for approximately 1,000 feet in length. Between the 1980s and 2012, the net turnover rate was 18,000 ft^2/yr/mile of channel to floodplain turnover.

Channel to floodplain turnover primarily occurred as vegetation encroachment in the side channel at PRM 114 right and around the mid–channel islands, and vegetation establishment associated with the creation of an island at PRM 114.4. The channel to floodplain turnover in GAA-113 Oxbow 1 between the 1950s and 1980s (7,000 ft^2/yr/mile) is comparable with the reach average rate (7,800 ft^2/yr/mile). Between the 1980s and 2012, there was an increase in channel to floodplain turnover to 18,000 ft^2/yr/mile which is 30 percent greater than the reach average channel to floodplain turnover rate of 14,000 ft^2/yr/mile.

Two locations of geomorphic feature change in GAA-115 occurred as side channels became side sloughs. Side channels at PRM 113.7 and PRM 115.0 in 1983 changed classifications to side sloughs by 2012.

5.1.4.8. MR-8 (PRM 107.8 to PRM 102.4)

The Susitna River in geomorphic reach 8 (MR-8) averages 1,130 feet in active width with an increase in width as it approaches the Three Rivers Confluence at PRM 102.4. The average gradient of the river increases about 0.5 ft/mile to 8.8 ft/mile compared with MR-7. Sediment storage in MR-8 is predominantly within limited areas of active, relatively low elevation floodplain and vegetated islands that are inset below fairly extensive areas of relatively inactive, higher elevation terrace and vegetated islands. Just upstream of the confluence, the bulk of the alluvial sediments are stored in active unvegetated braid bars. The large entrenchment ratio of 7.9 is the result of the wide floodplain created by the transition into the confluence of the Susitna, Chulitna, and Talkeetna rivers. This reach is a transition between the confined single-channel dominated morphology of the Middle River to the multiple channel and braided morphology of the Lower River.

MR-8 is rated as a dynamic reach with a total turnover rate from the 1950s to 2012 of 38,000 ft^2/yr/mile comprised of a channel to floodplain turnover rate of 21,000 ft^2/yr/mile and floodplain to channel turnover rate of 17,000 ft^2/yr/mile. Geomorphic reach MR-8 has the greatest reach average total turnover rate in the Middle River. Both MR-6 (37,000 ft^2/yr/mile) and MR-8 had more than twice the total turnover rate as the third most dynamic reach MR-7 (16,000 ft^2/yr/mile). Compared to the Geomorphic Assessment Areas in MR-8, the reach average total turnover rate for MR-8 (38,000 ft^2/yr/mile) was greater than GAA-104 Whiskers Slough (23,000 ft^2/yr/mile). In the water years 2012 and 2013, there were ice jams in MR-8 (HDR 2013a; HDR 2013b). Ice features such as ice channels (PRM 139.8 and PRM 135.4) and vegetation shearing appear in the aerial imagery and contribute to the dynamic nature of GAA-104 Whiskers Slough and MR-8.

From the 1950s to 2012, floodplain area increased by 3.1 percent of the total reach area (1950s to 1980s channel to floodplain turnover = 1.8 percent, 1980s to 2012 channel to floodplain turnover = 1.6 percent). Although, these percentages are similar, the floodplain to channel turnover differs spatially in the periods of the 1950s to 1980s and 1980s to 2012. Approximately 750,000 sq. feet of vegetation establishment occurred at both PRM 105.0 and PRM 102.7 in the 1950s to 1980s. During 1980s to 2012, the largest area of vegetation establishment was approximately 250,000 sq. ft. (PRM 104.0) and the majority of the channel to floodplain turnover resulted from vegetation encroachment.

Unlike the channel to floodplain turnover, the area of floodplain to channel turnover differs appreciably between the 1950s to 1980s and 1980s to 2012. Floodplain to channel turnover was 50 percent greater during the 1950s to 1980s (turnover = 1.7 percent), than the 1980s to 2012 (turnover = 1.1 percent). The turnover rates for the floodplain to channel for the 1950s to 1980s period was 23,000 ft^2/yr/mile and for the 1980s to 2012 period it was 16,000 ft^2/yr/mile. The 1950s to 1980s floodplain to channel turnover rate is higher than the 1980s to 2012 rate due to relatively more turnover at PRMs 105.4 left, PRM 104.4 right, PRM 102.9 right, and PRM 102.5 left. Approximately 1,500,000 sq. ft. of floodplain to channel turnover occurred at PRM 104.4 in the period from the 1950s to 2012 as the main channel shifted to the right. About 70 percent of this turnover occurred between the 1950s to 1980s period.

Floodplain to channel turnover occurred between the Middle and Lower Susitna River segments at the confluence of the Chulitna and Susitna Rivers where the confluence shifted 1,400 feet to the northeast between the 1950s and 2012. This was due to the leftward migration of the

Chulitna River into MR-8. During the period of the 1950s to 2012, this caused a 3.3 million sq. ft. reduction in the floodplain area of MR-8. Channel widths remained relatively constant with only a slight decrease in average widths of 1,290 feet in the 1950s, 1,210 feet in the 1980s, and 1,130 feet in 2012.

Several geomorphic feature classification changes occurred in MR-8 between the 1950s and 2012. Most of these were within GAA-104 Whiskers Slough and are described in the following subsection. Downstream of GAA-104 Whiskers Slough, a side slough at PRM 103.3 left in the 1950s and 1980s lost its upstream hydraulic connection and was classified as an upland slough in 2012.

5.1.4.8.1. GAA-104 Whiskers Slough (PRM 107.4 to PRM 104.2)

The GAA-104 Whiskers Slough is 3.2 miles long and spans the majority of Geomorphic Reach MR-8. GAA-104 Whiskers Slough is rated as a moderately dynamic portion of MR-8 with the total of 1950s to 2012 channel to floodplain (16,000 ft^2/yr/mile) and floodplain to channel turnover (7,200 ft^2/yr/mile) rates of 23,000 ft^2/yr/mile. This is not as dynamic as the reach average total turnover rate from 1950s to 2012 for MR-8 of 37,000 ft^2/yr/mile. The total turnover rate for MR-8 is higher than FA-104 Whiskers Slough Geomorphic Assessment Area because of the very high turnover rates at the downstream end of MR-8 near the Three Rivers Confluence. In water years 2012 and 2013, there were ice jams in GAA-104 Whiskers Slough (HDR 2013a; HDR 2013b). Ice processes that result in the formation of chute channels (PRM 105.4 left 2012) and vegetation shearing (1980s and 2012) may be responsible for some of the features observed in the aerial imagery and contribute to the dynamic nature of GAA-104 Whiskers Slough.

Changes to specific geomorphic features in GAA-104 Whiskers Slough were noted in the aerial imagery. Between the 1950s and 1980s, vegetation establishment on the gravel bar at PRM 105.0 left split the main channel and created the Whiskers Slough East Side Channel. Slough 3A decreased its connection to the Whiskers West Side Channel due to conversion to an upland slough from a side slough during the 1950s to 1980s period. There was vegetation encroachment evident along Whiskers Slough PRM 105.1 left, Slough 3B PRM 105.5, and Slough 3A. Slough 2 was breached by the turbid water and was classified as a side channel in 2012 (at 12,900 cfs at Gold Creek) when it had been a side slough in 1980s (at 12,500 cfs at Gold Creek).

5.1.5. Lower Susitna River Segment Long-term Channel Change Assessment

This section presents the channel change developed for the Lower Susitna River Segment. This includes channel change for major Susitna River tributaries, the Chulitna, Talkeetna, and Yentna rivers. Tables 5.1-19 through 5.1-27 present the geomorphic feature areas mapped by geomorphic reach for 1983 and 2012 in the Lower Susitna River and Chulitna, Talkeetna, and Yentna tributaries. The tables also include the percent change from 1983 to 2012.

In the Lower Susitna River Segment, from the Three Rivers Confluence (PRM 102.4) to Cook Inlet (PRM 3.3), the bed slope progressively decreases from 6 ft/mile to about 1.5 ft/mile. The channel is bounded primarily by Pleistocene-age glacial, fluvio-glacial, and glacio-lacustrine deposits. The Lower River is distinctly different from the Middle River. The character of the river changes dramatically below the Three Rivers Confluence as the width of the river more than triples from the widest portions in the Middle Susitna River Segment, and it adopts a braided channel form.

The Lower Susitna River Segment is divided into six distinct geomorphic reaches based on bed slope, bounding geology, average active channel width, channel branching, sediment storage capacity, and sinuosity. The six Lower River geomorphic reaches are presented in Figure 5.1-3 and Table 5.1-31. Further geomorphic characterization of the six reaches is provided in *Geomorphic Reach Delineation and Characterization, Upper, Middle and Lower Susitna River Segments* (Tetra Tech 2014b).

5.1.5.1. LR-1 (PRM 102.4 to PRM 87.9)

This reach of the Susitna River (3,340 feet active width) includes the Three Rivers Confluence downstream of PRM 102.4 and extends downstream to a valley bottom constriction at PRM 87.9. The Susitna River triples its width in LR-1 compared with MR-8. This is the result of the added flow and sediment loads from the Chulitna and Talkeetna rivers. However, the width of the valley floor at approximately 9,200 feet wide is nearly identical to 8,960 feet width in the MR-8 immediately upstream. LR-1 is confined on the east side primarily by Upper Pleistocene-age moraines and glacial outwash surfaces and on the west side by Upper Pleistocene-age lacustrine deposits intercalated with glacial outwash surfaces. The average channel gradient for the reach is 6.2 ft/mile. In general, because of the combined sediment delivery from the Three Rivers Confluence, the reach is net aggradational and the bulk of the alluvial sediment is stored in active, unvegetated braid bars upstream of the valley floor constriction at PRM 87.9. Within the reach, there are also locations where alluvial sediments are stored within vegetated islands and mid-channel bars, and the reach is bounded on each side by a vegetated floodplain of varying width. The sinuosity of the reach is 1.12 and the average number of channels is 4.0. Based on 13 samples collected in 2013 as part of ISR Study 6.6, the average median bed material size is 53 mm.

LR-1 is rated as a moderately stable Lower River reach based on its total turnover rate. The total of 1950s to 2012 channel to floodplain (84,000 ft^2/yr/mile) and floodplain to channel turnover rate (58,000 ft^2/yr/mile) is 142,000 ft^2/yr/mile. In comparison to adjacent reaches, this is approximately 4 times the total turnover rate for MR-8 (38,000 ft^2/yr/mile), but only 30 percent of the total turnover rate of Chulitna River above the confluence CL-1 (487,000 ft^2/yr/mile). It is similar to the next downstream Lower River reach at 80 percent of the total turnover rate of LR-2 (180,000 ft^2/yr/mile). The total turnover rate in LR-1 of 142,000 ft^2/yr/mile is 25 percent greater than the total turnover rate of 107,000 ft^2/yr/mile for the Talkeetna River (TK-1) at the confluence.

From the 1950s to 2012, LR-1 channel to floodplain turnover occurred over 13 percent of the total reach area. The channel to floodplain turnover area percentages were nearly double in the 1980s to 2012 (9.9 percent of the reach area) compared to the 1950s to 1980s (5.4 percent of the reach area). The primary location of channel to floodplain turnover from the 1950s to 2012 in LR-1 occurred from PRM 100 right to PRM 95 right over the period (36 million sq. ft.). The largest area of floodplain establishment (3 million sq. ft.) occurred during the 1980s to 2012 period at PRM 101. This is the vegetated island in the dominant mid-channel bar of the Three Rivers Confluence.

The majority of the floodplain to channel turnover in LR-1 occurred in three locations (PRM 101, PRM 95 and PRM 89.5) and was due to main channel shifting. Over the period of the 1950s to 2012, the main channel progressively shifted to the left approximately two miles at PRM 95 and one mile left at PRM 89.5. At PRM 101, there was approximately 2,000 feet of lateral migration into the right overbank floodplain between the 1950s and 2012. This has occurred concurrently with the shift of the Three Rivers Confluence intersection point to the northeast by 1,400 feet, the vegetation establishment on the dominant mid-channel bar, and the progressive leftward (northward) shift of the Chulitna River (CL-1). The floodplain to channel turnover was approximately equal in both the 1950s to 1980s (5.8 percent of the reach area) and 1980s to 2012 (5.7 percent of the area).

The net turnover rate for LR-1 was from 4,800 ft^2/yr/mile floodplain to channel in the 1950s to the 1980s and switched in the 1980s to 2012 period to 59,000 ft^2/yr/mile of channel to floodplain. Over the entire 1950s to 2012 period, the net turnover rate was 26,000 ft^2/yr/mile channel to floodplain. The 1950s to 2012 net turnover rate corresponds to the second highest net channel to floodplain rate of turnover in the LR and equal to that of LR-4. It is more than 5 times the net rate of MR-8 (4,600 ft^2/yr/mile). The channel width history over the period shows a small decrease in channel area as the reach average active channel widths were 3,500 feet, 3,490 feet and 3,340 feet in the 1950s, 1980s and 2012, respectively.

5.1.5.2. LR-2 (PRM 87.9 to PRM 65.6)

This reach of the Lower Susitna River Segment is dominated by multiple channels with an average of 5.6 channels totaling an average channel width of 3,120 feet. The average slope of the channel is 4.9 ft/mile, the sinuosity is 1.16, with an entrenchment ratio of 2.5. This reach of the Susitna River can be further subdivided into upper and lower subreaches. The upper reach extends from the valley floor constriction formed by Upper Pleistocene-age glacial outwash on the east bank and Upper Pleistocene-age moraines on the west bank at PRM 87.9, down to about PRM 74.4. Within this subreach, the valley floor is confined on the east by Upper Pleistocene-age glacial outwash and on the west side by similar aged moraines. The valley floor width varies from about 4,000 to 5,200 feet and the alluvial sediments are primarily stored in vegetated islands, bars and continuous floodplain segments (channel classified as MC2). Between PRM 74.4 and PRM 65.6, where there is a valley floor constriction most probably created by the Kashwitna River fan on the east bank and Upper Pleistocene-age moraines on the west bank, the planform of the river changes to anastomosed as a result of the imposed baselevel control. The bulk of the alluvial sediments within the lower subreach are stored in longitudinally extensive, relatively stable, vegetated floodplain segments (channel classified as MC3). The valley floor width is on the order of 8,000 feet upstream of the constriction. The east side of the valley is composed of Upper Pleistocene-age glacio-lacustrine deposits and the west side by similar-aged moraines. The greater width of the valley in the lower subreach suggests that the Upper Pleistocene-age glacial outwash that forms the east bank in the upper subreach is more erosion-resistant than the glacio-lacustrine deposits in the lower subreach.

LR-2 is rated as a moderately dynamic reach in terms of its 1950s to 1980s and 1980s to 2012 turnover rates. The two 30-year periods had total turnover rates greater than 200,000 ft^2/yr/mile and the 1950s to 2012 period was similar at180,000 ft^2/yr/mile. The total turnover rate for the 1950s to 1980s is 237,000 ft^2/yr/mile and is comprised of 136,000 ft^2/yr/mile of channel to floodplain turnover and 100,000 ft^2/yr/mile of floodplain to channel turnover. The total turnover rate for the 1980s to 2012 is 212,000 ft²/yr/mile and is comprised of 155,000 ft²/yr/mile of channel to floodplain turnover and 57,000 ft²/yr/mile of floodplain to channel turnover. LR-2 experienced greater turnover than reach LR-1 which had a total turnover rate from 1950s to 2012 of 142,000 ft²/yr/mile and less dynamic than LR-3 with a total turnover rate from 1950s to 2012 of 237,000 ft²/yr/mile.

From the 1950s to 2012, LR-2 channel to floodplain turnover represented 20 percent of the reach area. The channel to floodplain turnover area percentages were nearly equal in both the 1950s to 1980s (11.6 percent of the reach area) and 1980s to 2012 (11.9 percent of the reach area). The primary location of channel to floodplain turnover in LR-2 occurred from PRM 79 left to PRM 67 left. Over the period of the 1950s to 2012, the channel to floodplain turnover had consolidated two main side channel complexes from PRM 74 to PRM 69 and PRM 71 to PRM 67. This began in the 1950s to 1980s as floodplain establishment between PRM 73 and 71 and floodplain encroachment at PRM 75 left, PRM 70 left and PRM 68 left. Then in the 1980s to 2012, the vegetated islands within side channel complexes coalesced with the vegetation encroachment at PRM 71.8 left, PRM 71 left, and PRM 69.2 left.

Floodplain to channel turnover in LR-2 was the greatest around PRM 71. The high turnover in this area is related to a westward shift of the main channel. In the 1950s the main channel was along the left (east side) between PRM 73 and PRM 71. By 1980s, the main channel had shifted to the right (west) between PRM 73 and PRM 71, while two side channels became more prominent at PRM 71 left. The inlets to the side channels occur at PRM 74 left and PRM 73 right. The channel to floodplain turnover from the 1950s to 1980s was 8.5 percent of the total reach area. Over the period from the 1980s to 2012, the floodplain to channel percent reduced by nearly one half to 4.4 percent of the total reach area. Another large portion of the floodplain to channel turnover occurred at PRM 78.5. The main channel eroded a maximum width of 1,500 feet between the 1950s and 1980s.

Accompanying the erosion discussed in the previous paragraph, there was also floodplain creation on the opposite side of the river. This erosion was followed by vegetation encroachment on river left at PRM 70 between the 1980s and 2012. The overall effect from the 1950s to 2012 was a region of new floodplain area PRM 79 left to PRM 67 left. This was the primary area of channel to floodplain turnover in LR-2. Floodplain to channel turnover was significantly less than channel to floodplain turnover in LR-2. For the period of 1950s to 2012, LR-2 exhibited the greatest net gain in floodplain area (10 percent of the reach area) compared to the other LR reaches. This corresponds to a net channel to floodplain turnover rate of (66,000 ft²/yr/mile). The corresponding active channel widths reflect this net reduction in channel area with widths of 3,890 in the 1950s, 3,670 in the 1980s, and 3,120 in 2012.

5.1.5.3. LR-3 (PRM 65.6 to PRM 44.6)

This reach has the highest average number of channels of all the Lower River reaches at an average value of 8.8. Consistent with the multiple channels, the river planform is anastomosed for most of the reach (classified as MC3). The valley floor constriction at PRM 44.6 forms a downstream baselevel control for the river in this reach and is likely partially responsible for the planform (Smith and Smith 1980; Knighton and Nanson 1993; Makaske 2001). The Susitna River (4,040 feet active channel width) within this reach is bounded by Upper Pleistocene-age lacustrine deposits on the east and west sides of the valley, the apparent reason for a wider valley floor (16,000 feet). The bulk of the alluvial sediments within the reach are stored in longitudinally extensive, relatively stable, vegetated floodplain segments that are referred to as the Delta Islands. The average slope of the channel in the reach is 4.7 ft/mile and the sinuosity of the primary anastomosed channel averages 1.23.

Based on the total turnover rates of 300,000 ft²/yr/mile in the 1950s to 1980s and 300,000 ft²/yr/mile in the 1980s to 2012 turnover rates, MR-3 falls at the cutoff between classification as a moderately dynamic and a dynamic reach. The total turnover rate for the 1950s to 1980s is comprised of 140,000 ft²/yr/mile of channel to floodplain turnover and 160,000 ft²/yr/mile of floodplain to channel turnover. The total turnover rate for the 1980s to 2012 is comprised of 180,000 ft²/yr/mile of channel to floodplain turnover and 120,000 ft²/yr/mile of floodplain to channel turnover. The total turnover rate from the 1950s to 2012 is 240,000 ft²/yr/mile based on a channel to floodplain turnover rate of 130,000 and floodplain to channel turnover rate of 110,000 ft²/yr/mile over this period. In terms of turnover, it was more dynamic than the other five Lower River reaches but the Chulitna River total turnover rate for the same period was over twice as high at 490,000 ft²/yr/mile.

From the 1950s to 2012, LR-3 channel to floodplain turnover represented 9.5 percent of the total reach area. The increases in floodplain area were nearly equal in both the 1950s to 1980s (5.4 percent of the reach area) and 1980s to 2012 (6.3 percent of the reach area). The primary areas of channel to floodplain turnover in LR-3 occurred around PRM 55, PRM 51, and PRM 45. Areas of vegetation establishment at each of these locations exceeded 1 million sq. ft. in the period of the 1950s to 1980s. Creation of floodplain continued at a high rate during the 1980s to 2012 period at all three locations with the area converted to floodplain ranging from 4 million sq. ft. to 9 million sq. ft.

Floodplain to channel turnover was also appreciable and covered 8.1 percent of the total area of LR-3 from the 1950s to 2012. The majority of the floodplain to channel turnover appears to have happened in stages in three portions of LR-3; right along PRM 62 to PRM 56, left of the main channel from PRM 55 to PRM 53, and right from PRM 53 to PRM 47. During the 1950s to 1980s, the majority of the bank erosion was along the river right from PRM 62 to PRM 56. Erosion resulted in a maximum width of 1,800 feet at PRM 59.3. Also during the period of the 1950s to 1980s, the inlets to the dominant side channel (PRM 56 to PRM 47) east of the Delta Islands widened through floodplain to channel turnover between PRM 57 to PRM 55.

During the 1980s to 2012, floodplain to channel turnover switched over to the left side of the main channel between PRM 55 to PRM 53. This area of turnover was created as the main channel shifted leftward from the 1950s to a more central location in the braid plain. An avulsion of a side channel, through the overbank floodplain at PRM 54 right happened at this location between the 1980s and 2012. From PRM 53 to PRM 47 along the river right, floodplain to channel turnover continued through both periods of the 1950s to 1980s and 1980s to 2012. This includes erosion of more than 1,000 feet into the right overbank floodplain at PRM 51 and PRM 47.2. The main channel presently occupies these locations.

Over the course of the period from the 1950s to 2012, LR-3 has undergone a 1.4 percent net conversion from channel to floodplain. This corresponds to a net rate of 19,000 ft²/yr/mile. The average of the actual rates of channel to floodplain (128,000 ft²/yr/mile) and floodplain to channel turnover (109,000 ft²/yr/mile) are an order of magnitude greater. Review of the average channel widths of these periods show a reduction commensurate with the increase in floodplain with an average total channel width in 1950s of 4,290 feet, 4,400 feet in the 1980s and 4,040 feet in 2012.

5.1.5.4. LR-4 (PRM 44.6 to PRM 32.3)

The Susitna River has a 2,750 feet active channel width in this reach as it flows between Upper Pleistocene-age lacustrine deposits on both the east and west sides of the valley. Valley floor width is about 12,300 feet and a valley floor constriction is created by the Yentna River alluvial fan and the moraine-draped, Late Cretaceous-age, granodiorite outcrop on the west side and volcanic tuff on the east side of the river at PRM 29.9 (Susitna Station downstream reach boundary). The bulk of the alluvial sediments in the reach are stored in vegetated islands and mid-channel bars and in continuous, vegetated floodplains on both sides of the river. The average slope of the channel in the reach is very flat at 1.0 ft/mile, the sinuosity is 1.24, and on average there are 5.1 channels in the reach. Based on 15 samples collected in 2013 as part of ISR Study 6.6 Section 6.1.9.1, the average median bed material size is 33 mm.

Based on the turnover results, LR-4 is rated as a moderately stable reach of the Lower River. The total turnover rate from the 1950s to 2012 is 124,000 ft^2/yr/mile of which channel to floodplain turnover contributes 75,000 ft^2/yr/mile and floodplain to channel turnover contributes 49,000 ft^2/yr/mile. In terms of comparison its adjacent Lower River reaches it had a lower turnover rate than LR-3 just upstream (total turnover from 1950s to 2012 = 240,000 ft^2/yr/mile) and a higher rate of turnover than LR-5 just downstream (total turnover from 1950s to 2012 = 95,000 ft^2/yr/mile).

Floodplain to channel turnover in LR-4 has occurred including significant erosion of the overbank floodplain. The majority of the erosion occurred during the 1980s to 2012 period and at PRM 40 there was 800 feet of erosion of the right overbank floodplain. This resulted in the main channel avulsing to the left side of the braid plain. From the 1950s to 2012, erosion of the main channel into the overbank floodplain occurred at PRM 38.5 to the right and at PRM 37 to the left. Main channel length and sinuosity of LR-4 increased by 4 percent from the 1950s to 1980s and 5 percent from the 1980s to 2012 (1950s length = 59,700 ft., 1980s length = 61,700 ft., 2012 length = 64,400 ft.). From the 1950s to 1980s, the floodplain to channel turnover was 4.1 percent of the total reach area and primarily occurred between PRM 41.5 and PRM 34 in large sections ranging from 600 feet to 1000 feet wide and up to one-half mile long. This trend continued during the 1980s to 2012 period erosion consuming 3.1 percent of the total reach area.

Channel to floodplain turnover followed a similar trend as the floodplain to channel turnover in LR-4. Vegetation encroachment occurred on the inside bend of the main channel adjacent to where it had eroded the outside banks at PRM 40 right, PRM 38.5 right, and PRM 37 left over the period of the 1950s to 2012. Additional vegetation encroachment occurred on the inside of the bend at PRM 43.5 during the 1950s to 1980s. From the 1950s to 1980s channel to floodplain turnover was 6 percent of the total reach area and primarily occurred mid-channel as vegetation encroachment of islands in bar island complexes and side channel complexes. From the 1980s to 2012, floodplain to channel turnover occurred over 4.2 percent of the reach and primarily consisted of vegetation encroachment around the vegetated islands. From the 1950s to 2012, there was a net channel to floodplain turnover in LR-4 of 26,000 ft^2/year/mile. The corresponding active channel widths reflect this net reduction in channel area with widths of 2,980 in the 1950s, 2,780 in the 1980s, and 2,750 in 2012.

5.1.5.5. LR-5 (PRM 32.3 to PRM 23.5)

Within LR-5 which extends from the Yentna River confluence downstream to PRM 32.3 and PRM 23.5, the Susitna River has an active channel width of 3,250 feet. It is confined by Upper Pleistocene-age glacio-lacustrine deposits on the east bank as well as the Late Cretaceous-age granodiorite outcrop on the west side of the river at Susitna Station (PRM 29.9). The valley floor width is about 8,880 feet and the river slope is very low at 1.3 ft/mile. The relatively constricted valley limits the sediment storage potential within the reach and the bulk of the sediment is stored in mid-channel bars, vegetated islands and discontinuous floodplain segments. The sinuosity is 1.13 and on average there are 1.9 channels in the reach, with the initial portion of channel single threaded and the lower portion splitting into 2 channels.

Based on total turnover rates, LR-5 is the least dynamic reach in the Lower River. The total turnover rate over the six decades was 95,000 ft^2/yr/mile. The floodplain to channel turnover rate at 62,000 ft^2/yr/mile was almost double the channel to floodplain turnover rate of 34,000 ft^2/yr/mile resulting in a net floodplain to channel turnover rate of 28,000 ft^2/yr/mile.

Floodplain to channel turnover dominated the turnover in LR-5. This majority of this turnover occurred in the left side channel (PRM 27 to PRM 25) during the 1950s to 1980s. The bank erosion had a maximum width of 1,000 ft on the outside of the channel bends at PRM 25 and PRM 24.5 and resulted from lateral meander migration. The erosion of the outer bends continued through the 1980s to 2012 to a lesser degree, about 400 feet in width. From the 1950s to the 1980s there was 4.9 percent of floodplain to channel turnover. This was the largest amount of turnover in LR-5 during either study period. During the 1980s to 2012, the floodplain to channel turnover reduced by over 50 percent to 2 percent of the total reach area.

The majority of channel to floodplain turnover was isolated to a few locations in LR-5. There was 2.5 million sq. ft. of vegetation establishment at PRM 25 in the 1950s to 1980s. From the 1950s to 1980s the channel to floodplain turnover was 2.7 percent of the reach total area. In the 1980s to 2012, vegetation establishment occurred between the two vegetated islands at PRM 28 and PRM 27 which were previously not vegetated. Vegetation encroachment proceeded during the 1980s to 2012 around the vegetated island at PRM 25 that formed since the 1950s. During the 1980s to 2012 the channel to floodplain turnover dropped to 1.4 percent of the total reach area.

Between the 1950s and 2012, LR-5 experienced a net floodplain to channel turnover of 2.8 percent of the total reach area over the six decades studied corresponding to a rate of 27,600 ft^2/yr/mile. LR-5 had the greatest amount of net floodplain to channel turnover in the Lower River between the 1950s and 2012. The geomorphic reach of CL-1 was the only other reach to have a net floodplain to channel turnover rate (27,000 ft^2/yr/mile). The channel width history over the period reflect the net increase in channel area as the reach average active channel widths were 2,910 feet, 3,240 feet and 3,250 feet in the 1950s, 1980s and 2012, respectively.

5.1.5.6. LR-6 (PRM 23.5 to PRM 3.3)

This is the downstream most reach as the Susitna River flows into Cook Inlet and forms a delta-distributary system with longitudinally continuous, vegetated and relatively stable inter-distributary channel delta plain segments. The delta is bounded to the east by Upper Pleistocene-age, glacioestuarine deposits and to the west by Holocene-age estuarine deposits. The active

Castle Mountain Fault, with evidence of Holocene-age displacement (Labay and Haeussler 2001), crosses the river at the head of the reach. The width of the delta plain is about 31,000 feet and the river slope in the reach is extremely flat (1.5 ft/mile). The sinuosity is 1.43, and on average, there are 6.2 channels in the reach. The average active channel width of the reach is 5,280 feet.

The total turnover rate from the 1950s to 2012 of 213,000 ft²/yr/mile places LR-6 in the moderately dynamic reach category relative to other Lower River reaches. The total turnover rate is comprised of nearly equal contributions from channel to floodplain turnover at 114,000 ft²/yr/mile and floodplain to channel turnover 100,000 ft²/yr/mile. It was the second most dynamic reach in the Lower River with the highest 1950s to 2012 total turnover rate being attributed to LR-3 at 240,000 ft²/yr/mile.

Floodplain to channel turnover occurred in LR-6 as lateral channel migration and side channel widening. Lateral channel migration of areas of larger than 5 million sq. ft. occurred at PRM 21.8, PRM 16, and PRM 13.5 during the 1950s to 1980s. Floodplain to channel turnover continued in these areas to a lesser degree during the 1980s and 2012. Over the 1950s to 2012 period, each of the three areas either equaled or exceeded 10 million sq. ft. The channel between PRM 11 and PRM 9 widened by 600 percent from the 1950s to 2012 (1950s width = 100 ft, 1983 width = 200 ft., 2012 width = 600 ft.). Floodplain to channel turnover was 4.0 percent of the reach from the 1950s to 1980s and 2.8 percent of the reach in the 1980s to 2012.

From the 1950s to 2012, LR-6 channel to floodplain turnover represented 6.9 percent of the total reach area. The channel to floodplain turnover area percentage doubled from the 1950s to 1980s (2.5 percent of the reach area) and 1980s to 2012 (5.1 percent of the reach area). In both periods, the channel to floodplain turnover areas (1950s to 1980s area = 51 million sq. ft., 1980s to 2012 area = 103 million sq. ft.) was predominantly vegetation encroachment; although there were a few areas of vegetation establishment occurred that were approximately 1 to 2 million sq. ft. The largest channel to floodplain turnover areas was the result of vegetation encroachment along vegetated islands in side channels during the 1980s to 2012 at PRM 20 (8 million sq. ft.) and PRM 7 left (21 million sq. ft.)

The net rate of turnover for LR-6 was 14 ft²/yr/mile of channel to floodplain turnover. As a percent of the total reach area, this is only 0.9 percent. Although, 0.9 percent is a relatively low percentage of net turnover compared to other reaches, it was a large area at 17 million sq. ft. The channel width over the period corresponding decreased from 5,440 ft in the 1950s, to 5,720 ft in the 1980s, to 5,280 ft in 2012.

5.1.6. Chulitna River Reach

The Chulitna River Reach (CL-1) joins the Susitna River at PRM 102 at the Three Rivers Confluence. The reach extends approximately 3.2 miles upstream of the Susitna River. Aerial coverage from the 1980s was limited to the portion downstream of Chulitna River Mile 1.4. The tabulated values for turnover analysis were similarly limited to the lower 1.4 Chulitna River miles for the 1950s to 1980s and 1980s to 2012. Turnover was mapped for the period of 1950s to 2012 for lower 12.4 miles of the Chulitna River, but the calculated values of turnover reported below are all for the lower 1.4 miles to be consistent with the data available from the 1980s.

The average annual sediment load of the Chulitna River was estimated to be 8.6 million tons/year (Tetra Tech 2014c). This is 62 percent of the total sediment load estimated for the

Three Rivers Confluence. The remainder of the estimated average annual load is composed of 3.4 million tons/year from the Susitna River or 25 percent and the 1.9 million tons from the Talkeetna River or 13 percent. In contrast, the percentage of average annual flow contributed at Three Rivers Confluence is 36, 46, and 17 for the Chulitna, Susitna, and Talkeetna rivers, respectively (Tetra Tech 2013c). The dominance of the Chulitna River in terms of sediment supply is reflected in the channel from downstream of the Three Rivers Confluence, which resembles the Chulitna River much more so than the Susitna River even though their flow contributions are similar.

The river planform changes from a single channel to multiple channels at Chulitna River Mile 3.2 as the river exits a more confined area. Evidence indicates that the Chulitna River Reach is net aggradational and the bulk of the alluvial sediment is stored in active unvegetated braid bars (Tetra Tech 2014b). Within the reach, there are also locations where alluvial sediments are stored within vegetated islands and mid-channel bars, and the reach is bounded on each side by a vegetated floodplain of varying width.

The lower 1.4 miles of the CL-1 is a very dynamic reach; between the 1950s and 2012, it had more than twice the total turnover rate at 490,000 ft^2/yr/mile compared to the Lower River reach, LR-3, with the highest total turnover rate of 240,000 ft^2/yr/mile. The CL-1 total turnover rate from the 1950s to 2012 was based on 230,000 ft^2/yr/mile of channel to floodplain turnover and 260,000 ft^2/yr/mile of floodplain to channel turnover. This is due to the northward shift of the Chulitna in CL-1. There was a maximum of 3,200 feet of erosion at Chulitna River Mile 0.9 which accounted for 26 million sq. ft. of floodplain to channel turnover over the 1950s to 2012 time period. Erosion of this area contributed to the northeast migration of the confluence of the Chulitna River and Susitna Rivers. This topic is also discussed for MR-8 in Section 5.1.1.8 above. The net turnover rate for CL-1 was 27,000 ft^2/yr/mile of floodplain to channel for the period of the 1950s to 2012. The channel change in channel widths over the period corresponding varied over this period from 4,970 feet in the 1950s, to 6,980 feet in the 1980s, to 5,510 feet in 2012.

5.1.7. Talkeetna River Reach

The Talkeetna River Reach (TK-1) joins the Susitna River at PRM 101, which is part of the Three Rivers Confluence area. Aerial coverage from the 1980s was limited to the portion downstream of Talkeetna River Mile 2.0. The tabulated values for turnover analysis were similarly limited to the lower 2 miles of the Talkeetna River. However, turnover was mapped for the period of 1950s to 2012 for the lower 9.4 miles of the Talkeetna River, though all turnover rates provided are only for the lower 2.0 miles.

The Talkeetna River is the smallest of the three rivers at the confluence and on an average annual basis, contributes 13 percent of the sediment load and 17 percent of the flow at the Three Rivers Confluence (Tetra Tech 2013c, 2014c). The planform changes from a single channel to anastomosed about a quarter of the way downstream through the reach. The bulk of the alluvial sediments within the reach are stored in longitudinal vegetated floodplain islands and attached bars.

Turnover in the lower 4 miles of the Talkeetna River is dominated by shifting of the multiple channels and vegetation encroachment around islands. The lower 2 miles of the TK-1 is rated as moderately dynamic relative to turnover in the Lower Susitna River Segment based on a total turnover rate from the 1950s to 2012 of 107,000 ft^2/yr/mile. The total turnover rate is comprised of a channel to floodplain contribution of 66,000 ft^2/yr/mile and floodplain to channel contribution of 40,000 ft^2/yr/mile. For the lower 2 miles of TK-1 reach, there was a net turnover channel to floodplain at a rate of 26,000 ft^2/yr/mile for the period of the 1950s to 2012. The channel widths over the three periods decreased from 1,210 feet in the 1950s, to 980 feet in the 1980s, to 890 feet in 2012.

5.1.8. Yentna River Reach

The Yentna River Reach (YN-1) joins with the Susitna River at PRM 32.3 and defines the reach break between geomorphic reaches LR-4 and LR-5. Aerial coverage from the 1980s was limited to the portion downstream of Yentna River Mile 1.9. The tabulated values for turnover analysis were similarly limited to the lower 1.9 Yentna River miles. Turnover was mapped for the period of 1950s to 2012 for the portion downstream of Yentna River Mile 3.1.

Review of the average annual flow and estimated sediment load for Susitna Station indicates that the Yentna River contributes 40 percent of the total Susitna River mean annual flow of 48,600 cfs at the Susitna Station and 43 percent of the total sediment load of 33.7 million tons/year (Tetra Tech 2013c, 2014c). The bulk of the alluvial sediments in the reach are stored in vegetated islands, mid-channel bars, and continuous vegetated floodplains on both sides of the river.

The lower 2.1 miles of the Yenta River reach YN-1 is rated moderately dynamic relative to turnover in the Lower Susitna River Segment. The total turnover rate for the period of 1950s to 2012 was 168,000 ft^2/yr/mile with a channel to floodplain rate of 98,000 ft^2/yr/mile and a floodplain to channel turnover rate of 70,000 ft^2/yr/mile. A large area of floodplain to channel turnover over the period from the 1950s to 2012 occurred about 1.5 miles upstream of the Yentna River confluence with the Lower River. At this location, the river eroded 700 feet into the left bank between the 1950s and 1980s. During the period of the 1980s to 2012, floodplain to channel turnover in YN-1 resulted primarily from the widening of a side channel on river right between 0.5 miles to 1.7 miles upstream of the confluence. In this area, the width of the side channel increased from about 100 feet in the 1980s to 700 feet in 2012. Adjacent to the channel widening, there was substantial vegetation encroachment around the islands in the main channel between the 1980s and 2012. The encroachment accounted for the majority of the channel to floodplain turnover in YN-1 over the period of the 1950s to 2012.

Over the reach as a whole, there was a net turnover of channel to floodplain at an average rate of 28,000 ft^2/yr/mile for the period of the 1950s to 2012. The channel widths over the three periods decreased from 3,100 ft in the 1950s, to 3,030 ft in the 1980s, to 2,460 ft in 2012. The reductions in channel widths reflect the overall increase in floodplain relative to channel area over the past six decades.

5.2. Short-term Assessment of Channel Change from 2012 to 2013 Aerials

There were two types of analyses conducted to assess short term channel change. They differed in spatial extent and methods. A qualitative analysis was conducted for the entire Middle River and a quantitative analysis was done for the Three Rivers Confluence. Both were used to assess short-term channel change between 2012 and 2013 resulting from the large flows on 6/2/2013 (90,700 cfs at Gold Creek) and 9/21/2012 (72,900 cfs at Gold Creek) and/or ice jams and ice runs in the 2013 breakup. The qualitative comparison identified the locations of channel change in the entire Middle River between the 2012 geomorphic features and the 2013 aerial photographs. For the quantitative comparison, the 2013 geomorphic features were first delineated from the 2013 aerial photographs within the Three Rivers Confluence for the reaches of MR-8, CL-1, TK-1, and LR-1. The 2013 geomorphic features were then overlain with the 2012 geomorphic features so the dimensions of channel change could be identified and measured. The quantitative comparison focused on the channel change within a 2-mile radius from PRM 102.4.

5.2.1. Qualitative Evaluation of 2012 Middle River Geomorphic Features and the 2013 Aerial Photography

Based on the comparison of the 2012 and 2013 aerial photography, erosion was the dominant geomorphic process in the Middle River during the period of comparison. Incidences of erosion were identified in the mapping presented in Appendix T. Likely potential causes of the erosion observed include high flows and ice processes. On 9/21/2012 the peak flow at Gold Creek reached 72,900 cfs (198,000 cfs at Sunshine); corresponding to approximately a 20-year flood. On 6/2/2013 there was 90,700 cfs flood at the Gold Creek gage (146,000 cfs at Sunshine). This was greater than the 50-year return period discharge of 87,500 cfs at the Gold Creek gage and approaching the 100-year peak of 98,000 cfs. The discharges during the open-water period for the following gages were plotted for water years 2012 and 2013 in Figure 4.5-6: Susitna River at Gold Creek, Chulitna River near Talkeetna, Talkeetna River near Talkeetna, Susitna River at Sunshine, and Susitna River at Susitna Station. In water year 2013, ice jams were noted at the following locations (HDR 2013a; HDR 2013b) and are potential locations where ice processes may have contributed to the observed erosion in MR-6 through MR-8.

- PRM 146 (main channel)
- PRM 137 (main channel)
- PRM 134 (main channel)
- PRM 130
- PRM 128
- PRM 125.2 (main channel)
- PRM 115.5 (main channel)
- PRM 104 (main channel)

In the 2013 aerial photography there is evidence of the ice jam locations listed above. There was vegetation shearing at PRM 145.6 left and PRM 135.5 to PRM 133.0. The erosion around PRM 135 is mentioned in the results for MR-6.

The channel change observed in the Middle River between 2012 and 2013 was limited to erosion. Changes in the hydraulic connectivity of channels or in the vegetation and biogeomorphic processes were not observed. The magnitude of the erosion is discussed per reach in the following sections.

5.2.1.1. MR-1, MR-2, MR-3, MR-4, and MR-5 (PRM 187.1 to PRM 148.4)

No appreciable channel change was detected from review of the 2012 and 2013 aerial photography in the upper five reaches of the Middle River between 2012 and 2013.

5.2.1.2. MR-6 (PRM 148.4 to PRM 122.7)

In MR-6, there were 47 instances of channel change between 2012 and 2013 in seven primary locations. These locations had multiple instances of erosion centered around PRM 143.9, PRM 143.1, PRM 139.7, PRM 138.7, PRM 137.6, PRM 135.5, PRM 131.7, PRM 130.0, PRM 129.2, and PRM 125.2. Between PRM 146 and PRM 143 there was a reduction in the length of the small floodplain islands. At PRM 139, vegetation was removed from within Slough 11. Approximately 100 feet was removed from the head of the island in the side channel at PRM 138.6 left. At PRM 137.8, the main channel widened by about 100 feet on both the right and left sides. The area near PRM 135 saw several instances of erosion and vegetation shearing by ice in 2013. Over 300 feet of erosion occurred at the head of the floodplain island at PRM 132.1 and in the side channel downstream at PRM 131.6. There were several instances of main and side channel erosion at PRM 130 (the upstream end of GAA-128 Slough 8A) and around the side channels at PRM 129. There were three instances of erosion in the side channels near PRM 125.1 right.

5.2.1.3. MR-7 (PRM 122.7 to PRM 107.8)

There were only seven instances of erosion between 2012 and 2013 in MR-7. This occurred near four primary areas of PRM 122, PRM 121, PRM 118, and PRM 115. The width of erosion ranged between 20 to 50 feet, with a maximum of 75 feet at PRM 121.9. The main channel experienced widening of about 10 to 25 feet at PRM 122.2 and PRM 117.9. Greater main channel widening of about 70 feet occurred at PRM 121.9 and PRM 117.1. The head of the vegetated islands were eroded at PRM 121.1 and PRM 115.2. The side channel at PRM 118.2 widened by 25 feet.

5.2.1.4. MR-8 (PRM 107.8 to PRM 102.4)

There were six instances of erosion between 2012 and 2013 in MR-8. This occurred in the primary locations of PRM 104.3 and PRM 103.1. Three islands around PRM 104.3 experienced erosion of 10 to 30 feet on their left sides. The head of the island at PRM 103.5 was eroded by about 110 feet. Entire islands and portions of adjacent islands were eroded at PRM 103.1 and PRM 102.9.

5.2.2. Quantitative Assessment of the 2012 and 2013 Geomorphic Features in the Three Rivers Confluence

The channel change observed in the Three Rivers Confluence between 2012 and 2013 was limited to erosion. Changes in the hydraulic connectivity of channels or in the vegetation and biogeomorphic processes were not observed. Vegetation establishment and encroachment were not observed within the comparison of geomorphic features. This would be expected for a short term view as these are processes that progress at a slower but likely more consistent rate than erosion. The locations of erosion were identified in the Three River Confluence between 2012 and 2013 within an approximate 2-mile radius of PRM 102.4. The locations of erosion were numbered to facilitate identification and added as labels in Appendix Q through Appendix S. The mapping of geomorphic features in the Three Rivers Confluence is presented in Appendix Q for 2012 and Appendix R for 2013. The overlay mapping of the 2012 and 2013 geomorphic features is presented in Appendix S. The magnitude of the erosion is discussed per geomorphic reach in the following sections.

5.2.2.1. Middle River: MR-8 (PRM 104.5 to PRM 102.4)

The erosion in the lower 2.1 miles of MR-8 was predominantly along river right. The erosion ranged from about 40 to 70 feet. The only instance of erosion on river left happened on the downstream left side of the reach. The main channel migrated into the overbank floodplain for a maximum of 130 feet. This is labeled in the mapping as erosion location number 5.

5.2.2.2. Lower River: LR-1 (PRM 102.4 to PRM 99.0)

Erosion in the Lower River reach of the Three Rivers Confluence is most prominent in the vicinity of the bar island complex at PRM 101.5. At this location flow is split around this bar island complex or depositional bar and floodplain islands. The erosion on the floodplain islands that define the outer channels' banks has served to increase the width of the braid plain by about 130 feet across the section with end points of numbered 13 and 14. Erosion represents an eastward shift of the boundary between the Lower River and the Talkeetna River at number 13. The main channel shifted to the right about 90 feet into the floodplain island in the main channel at number 12.

A trend of width increases in the braid plain continued in the downstream direction at PRM 101. The Lower River braid plain increased by about 100 feet just downstream of the confluence with the Talkeetna River. The main channel shifted to the right about 60 feet into the floodplain island in the main channel at number 15. Further downstream the main channel eroded about 50 feet into a floodplain island at PRM 100.

5.2.2.3. Chulitna River: CL-1

Erosion in the lower 1.6 miles of the Chulitna River mainly occurred along the right side of the braid plain. They ranged between 50 to 150 feet, but had a maximum of 460 feet at number 7. A secondary main channel eroded 50 feet into the downstream side of the floodplain island (number 9) that represented the boundary between the Chulitna River and the Middle River. Erosion at numbers 8, 9 and 10 indicate a widening of the Chulitna River braid plain by about 100 feet near its confluence with the Susitna River.

5.2.2.4. Talkeetna River: TK-1

Erosion in the lower 0.8 miles of the Talkeetna River occurred mostly on the outside of bends with attached bars. The erosion ranged between 50 and 130 feet on the outside bends at numbers 19, 20, and 21. The island that comprises the majority of the boundary between the Talkeetna River and Lower River was eroded on several sides. The other noted erosion location, number 22, was 30 feet wide on the east side of the island that forms the boundary between the Lower River and Talkeetna River.

6. DISCUSSION

This 2014 study effort updates the previous geomorphic feature mapping technical memorandum (Tetra Tech 2013a) by incorporating geomorphic feature mapping from 1950s aerial photography, a turnover analysis, and a short term analysis of geomorphic feature changes using 2013 aerial photography. The analysis of channel change and the turnover analysis were conducted on the three sets of aerial photography and provided an excellent history over the past 60 years. The set of 1950s aerial photography is the earliest high quality coverage available; no additional high quality aerial photography covering large portions of the study area was located.

The turnover analysis provided a simplified method of describing geomorphic changes in the Susitna River. Rather than assessing changes in each geomorphic feature, the features were combined as being either a channel feature or a floodplain feature. When comparing channel or floodplain features over time, increases in vegetation and narrowing of channels is associated with net channel to floodplain turnover. A net floodplain to channel turnover indicates an increase in channel width and a removal of vegetation by erosion. As each geomorphic reach varies in length, turnover was presented as normalized rates so that turnover in different geomorphic reaches could be compared to each other. Turnover rates were calculated by dividing the calculated turnover areas by the length of each reach and the span of time between each set of aerials: 30 years for the 1950s to 1980s and 1980s to 2012 analyses, and 60 years for the 1950s to 2012 analysis.

The previous technical memorandum identified increased vegetation as the primary factor in geomorphic change, the turnover analysis described in this technical memorandum further validates that conclusion, identifying greater channel to floodplain turnover throughout the Middle and Lower Susitna River segments. The Middle River becomes less stable approaching the Three Rivers Confluence. However, the Lower River had less consistent trends in stability by geomorphic reach as shown in the following tables:

Relative Reach Stability	MR Total Turnover Rate (ft^2/yr/mile)	Middle River Reaches
Dynamic	> 30,000	MR-6, MR-8
Moderately Dynamic	20,000 to 30,000	N/A
Moderately Stable	10,000 to 20,000	MR-7
Stable	0 to 10,000	MR-1, MR-2, MR-3, MR-4, MR-5

Relative Reach Stability	LR Total Turnover Rate (ft^2/yr/mile)	Lower River Reaches
Dynamic	> 300,000	CL-1, LR-3
Moderately Dynamic	200,000 to 300,000	LR-2, LR-6
Moderately Stable	100,000 to 200,000	LR-1, TK-1, LR-4, YN-1
Stable	0 to 100,000	LR-5

In the Middle River, net channel to floodplain turnover rates increased between the periods of the 1950s to 1980s and the 1980s to 2012 for MR-4 through MR-8. Net channel to floodplain turnover rates decreased in MR-1 through MR-3 over the same two periods. From the 1950s to the 1980s, there was net channel to floodplain turnover in all the Middle River reaches, except for MR-4 and MR-7. During the 1980s to 2012, all the Middle River reaches, expect for MR-1, MR-2, and MR-3, had net channel to floodplain turnover.

Among the Middle River geomorphic reaches, MR-6, MR-7, and MR-8 exhibited the greatest amounts of turnover during the period of the 1980s to 2012. The net channel to floodplain turnover rate exceeded 7,000 ft^2/yr/mile between 1980s to 2012 for MR-6, MR-7, and MR-8. All the other Middle River geomorphic reaches had net turnover rates less than 4,000 ft^2/yr/mile. The relative sizes of the net turnover rates are compared to the channel to floodplain and floodplain to channel rates in the Middle River in Figure 6.1-1, Figure 6.1-2, and Figure 6.1-3 for the periods of the 1950s to 1980s, 1980s to 2012, and 1950s to 2012, respectively.

Compared to the Middle River, the Lower River had a stronger trend of increasing channel to floodplain turnover between the two periods of the 1950s to 1980s and 1980s to 2012. Five out of six of the Lower River geomorphic reaches had an increase in net channel to floodplain rate between those two periods. LR-4 was the exception. During the 1950s to 1980s, LR-2 and LR-4 were the only Lower River reaches to have a net channel to floodplain turnover rate. For comparison, during the 1980s to 2012 period, LR-1, LR-2, LR-3, LR-4, and LR-6 all had net channel to floodplain turnover rates. The relative sizes of the net turnover rates are compared to the channel to floodplain and floodplain to channel rates in Figure 6.1-4, Figure 6.1-5, and Figure 6.1-6 for the periods of the 1950s to 1980s, 1980s to 2012, and 1950s to 2012, respectively. The portions of Chulitna River and Yentna River studied followed the channel to floodplain trend in the Middle and Lower River. Net channel to floodplain turnover rates increased between the 1950s to 1980s and 1980s to 2012 for the portions of Chulitna River and Yentna River studied, but not for the Talkeetna River. The portion of the Talkeetna River studied had net channel to floodplain turnover for both time periods of the 1950s to 1980s and the 1980s to 2012.

The mapping of channel change that occurred between 2012 and 2013 indicates that erosion was the primary process contributing to channel change in LR-1, the Middle River and the Three Rivers Confluence, as opposed to vegetation establishment or encroachment. The incidences of erosion were the greatest in MR-6 followed by MR-7, MR-8, and MR-3, while the degree of erosion was the greatest in CL-1, followed by LR-1, TK-1 and MR-8. These two sets of recent aerial photographs provide an understanding of short-term channel change in relation to a large flow event that was the intent of acquiring additional historical aerial photography.

This technical memorandum and *Mapping of Geomorphic Features and Assessment of Channel Change in the Middle and Lower Susitna River Segments from 1980s and 2012 Aerials* (Tetra Tech 2013a) represent the completion of the goals and objectives listed in RSP Study 6.5 Section 6.5.4.4 and ISR Study 6.5 Section 7.2.1.4 “Assess Geomorphic Change Middle and Lower Susitna River Segments.” The turnover results data presented in this 2014 technical memorandum will be used to support the bed evolution modeling and bank energy index in ISR Study 6.6 Section 7.2.2.1, as well as the Riparian Instream Flow Study (Study 8.6), and Ice Processes Study (Study 7.6).

The 1950s, 1980s, 2012, and 2013 aerials were used to assess the channel change and turnover in the Middle and Lower River (ISR Study 6.5 Section 7.1.1.4). The Study Plan (RSP Sections 6.5.4.4.2.1 and 6.5.5.5.2.2.) indicates a decision will be made on whether to acquire additional historical aerial photography for the Middle and Lower Susitna River Segments after completion of the analysis of aerial photography from the 1950s, 1980s and present. In addition, the 2013 aerials that were flown to supplement the 2012 aerials document the river prior to, and after, the peak flow of ~90,000 cfs at Gold Creek which is one of the highest flows recorded in the period of record. As the objectives of this study were completed, no further analysis of aerial photography is necessary.

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8. TABLES

Table 4.2-1. 1950s Aerial Photo Summary.

Aerial Coverage (PRM)		Date	Used for Mapping	Discharge (cfs)	
From	To	(MM/DD/YYYY)		Gold Creek	Sunshine[1]
Middle Susitna River Segment					
191.5	187	8/15/1949		25,800	--
187	158.5	8/15/1949	X	25,800	--
158.9	158.5	8/10/1949		29,900	--
158.5	151.8	8/10/1949	X	29,900	--
151.8	140.9	8/10/1949		29,900	--
151.8	102	7/3/1951	X	19,000	--
Lower Susitna River Segment					
102	33.4	7/3/1951	X	(19,000)[2]	*45,100*[1]
45.2	40	7/11/1954		(19,000)	*47,200*
40	38.5	7/11/1954	X[3]	(19,000)	*47,200*
38.3	33.4	7/23/1953		(19,300)	*48,000*
33.4	28.5	7/23/1953	X	(19,300)	*48,000*
31.3	28.5	7/25/1953		(20,000)	*49,800*
28.5	27.4	7/25/1953	X	(20,000)	*49,800*
27.4	26	7/25/1953		(20,000)	*49,800*
27.4	21.5	8/12/1952	X	(24,400)	*61,400*
21.5	20.6	8/12/1952		(24,400)	*61,400*
21.5	0	9/2/1952	X	(28,700)	*70,600*

Notes:

1 Discharges shown in italics are synthesized flows from the extended flow record developed by the USGS (2012) and may not reflect actual flows

2 Discharges in parentheses are measured flows at Gold Creek and were used to develop the USGS extended flow record (USGS 2012)

3 07/11/1954 Aerial photos only used on the river right floodplain

Table 4.2-2. Summary of 1980s aerial dates, discharges, and project river mile extents.

Aerial Coverage (PRM)		Date	Discharge (cfs)	
From	To	(MM/DD/YYYY)	Gold Creek	Sunshine Station
Upper Susitna River Segment				
251	187	7/19 and 7/20/1980	35,800 & 31,600	---
Middle Susitna River Segment				
187	152	7/19 and 7/20/1980	35,800 & 31,600	---
158	102	9/11/1983	12,500 (12,200 published)	---
Lower Susitna River Segment				
102	0	9/6/1983	---	36,600

Table 4.2-3. Summary of 2012 aerial dates, discharges, and project river mile extents.

Aerial Coverage (PRM)		Date	Discharge (cfs)	
From	To	(MM/DD/YYYY)	Gold Creek	Sunshine Station
Upper Susitna River Segment				
266.5	231.5	10/20/2012	7,410	---
231.5	187	9/30/2012	17,000	---
Middle Susitna River Segment				
187	143.6	9/30/2012	17,000	---
143.6	102	9/10/2012	12,900	---
119	102	7/27/2012	22,200	---
Lower Susitna River Segment				
102	63	7/27/2012	---	53,000
102	78	9/10/2012		38,200
78	69	9/30/2012	---	48,000
69	33.5	10/10/2012	---	55,000
33.5	22.5	9/30/2012		48,000
22.5	0	10/10/2012	---	55,000

Table 5.1-1. Geomorphic feature areas for MR-1.

MR-1						
Year	Channel			Floodplain		
	Main and Side Channel	Side Slough	Upland Slough	Islands	Overbank	Islands and Overbank
	ft²					
1950s	7,516,000	0	0	424,000	4,775,000	5,199,000
1983	7,471,000	0	0	376,000	4,868,000	5,244,000
2012	7,794,000	0	0	279,000	4,643,000	4,922,000
Percent Change 1950s to 1983	-1%	0%	0%	-11%	2%	1%
Percent Change 1983 to 2012	4%	0%	0%	-26%	-5%	-6%
Percent Change 1950s to 2012	4%	0%	0%	-34%	-3%	-6%

Table 5.1-2. Geomorphic feature areas for MR-2.

MR-2						
Year	Channel			Floodplain		
	Main and Side Channel	Side Slough	Upland Slough	Islands	Overbank	Islands and Overbank
	ft²					
1950s	56,644,000	139,000	90,000	10,997,000	98,655,000	109,652,000
1983	55,551,000	29,000	115,000	8,448,000	102,383,000	110,831,000
2012	54,702,000	1,416,000	268,000	8,998,000	101,140,000	110,138,000
Percent Change 1950s to 1983	-2%	-79%	28%	-23%	4%	1%
Percent Change 1983 to 2012	-2%	4783%	133%	7%	-1%	-1%
Percent Change 1950s to 2012	-3%	919%	198%	-18%	2%	0%

Table 5.1-3. Geomorphic feature areas for MR-3.

MR-3						
Year	Channel			Floodplain		
	Main and Side Channel	Side Slough	Upland Slough	Islands	Overbank	Islands and Overbank
	ft²					
1950s	10,711,000	0	0	414,000	9,230,000	9,644,000
1983	10,601,000	0	0	436,000	9,318,000	9,754,000
2012	11,008,000	0	1,000	368,000	8,979,000	9,347,000
Percent Change 1950s to 1983	-1%	0%	0%	5%	1%	1%
Percent Change 1983 to 2012	4%	0%	N/A	-16%	-4%	-4%
Percent Change 1950s to 2012	3%	0%	N/A	-11%	-3%	-3%

Table 5.1-4. Geomorphic feature areas for MR-4.

MR-4						
Year	Channel			Floodplain		
	Main and Side Channel	Side Slough	Upland Slough	Islands	Overbank	Islands and Overbank
	ft²					
1950s	20,487,000	0	0	38,000	22,390,000	22,428,000
1983	20,767,000	0	0	45,000	22,104,000	22,149,000
2012	20,093,000	0	0	46,000	22,778,000	22,824,000
Percent Change 1950s to 1983	1%	0%	0%	18%	-1%	-1%
Percent Change 1983 to 2012	-3%	0%	0%	2%	3%	3%
Percent Change 1950s to 2012	-2%	0%	0%	21%	2%	2%

Table 5.1-5. Geomorphic feature areas for MR-5.

MR-5						
Year	Channel			Floodplain		
	Main and Side Channel	Side Slough	Upland Slough	Islands	Overbank	Islands and Overbank
	ft²					
1950s	15,445,000	0	0	1,507,000	18,364,000	19,871,000
1983	15,023,000	0	0	1,636,000	18,657,000	20,293,000
2012	14,494,000	0	0	2,073,000	18,748,000	20,821,000
Percent Change 1950s to 1983	-3%	0%	0%	9%	2%	2%
Percent Change 1983 to 2012	-4%	0%	0%	27%	0%	3%
Percent Change 1950s to 2012	-6%	0%	0%	38%	2%	5%

Table 5.1-6. Geomorphic feature areas for MR-6.

MR-6						
Year	Channel			Floodplain		
	Main and Side Channel	Side Slough	Upland Slough	Islands	Overbank	Islands and Overbank
	ft²					
1950s	144,165,000	3,927,000	457,000	60,836,000	137,214,000	198,050,000
1983	134,189,000	8,572,000	681,000	67,832,000	135,326,000	203,158,000
2012	127,708,000	3,934,000	1,431,000	73,700,000	139,827,000	213,527,000
Percent Change 1950s to 1983	-7%	118%	49%	11%	-1%	3%
Percent Change 1983 to 2012	-5%	-54%	110%	9%	3%	5%
Percent Change 1950s to 2012	-11%	0%	213%	21%	2%	7%

Table 5.1-7. Geomorphic feature areas for MR-7.

MR-7						
Year	Channel			Floodplain		
	Main and Side Channel	Side Slough	Upland Slough	Islands	Overbank	Islands and Overbank
	ft²					
1950s	72,068,000	29,000	196,000	15,231,000	86,663,000	101,894,000
1983	71,295,000	1,000,000	572,000	15,233,000	86,089,000	101,322,000
2012	65,180,000	921,000	737,000	20,863,000	86,488,000	107,351,000
Percent Change 1950s to 1983	-1%	3348%	192%	0%	-1%	-1%
Percent Change 1983 to 2012	-9%	-8%	29%	37%	0%	6%
Percent Change 1950s to 2012	-10%	3076%	276%	37%	0%	5%

Table 5.1-8. Geomorphic feature areas for MR-8.

MR-8						
Year	Channel			Floodplain		
	Main and Side Channel	Side Slough	Upland Slough	Islands	Overbank	Islands and Overbank
	ft²					
1950s	35,289,000	747,000	771,000	9,337,000	187,784,000	197,121,000
1983	32,851,000	875,000	850,000	9,813,000	185,469,000	195,282,000
2012	31,887,000	319,000	1,103,000	9,435,000	185,887,000	195,322,000
Percent Change 1950s to 1983	-7%	17%	10%	5%	-1%	-1%
Percent Change 1983 to 2012	-3%	-64%	30%	-4%	0%	0%
Percent Change 1950s to 2012	-10%	-57%	43%	1%	-1%	-1%

Table 5.1-9. Geomorphic feature areas for GAA-184.

GAA-184						
Year	Channel			Floodplain		
	Main and Side Channel	Side Slough	Upland Slough	Islands	Overbank	Islands and Overbank
	ft²					
1950s	3,908,000	0	0	258,000	2,088,000	2,346,000
1983	3,865,000	0	0	249,000	2,141,000	2,390,000
2012	3,976,000	0	0	235,000	2,044,000	2,279,000
Percent Change 1950s to 1983	-1%	0%	0%	-3%	3%	2%
Percent Change 1983 to 2012	3%	0%	0%	-6%	-5%	-5%
Percent Change 1950s to 2012	2%	0%	0%	-9%	-2%	-3%

Table 5.1-10. Geomorphic feature areas for GAA-173.

GAA-173						
Year	Channel			Floodplain		
	Main and Side Channel	Side Slough	Upland Slough	Islands	Overbank	Islands and Overbank
	ft²					
1950s	10,632,000	39,000	72,000	4,210,000	8,080,000	12,290,000
1983	10,159,000	11,000	73,000	3,028,000	9,762,000	12,790,000
2012	8,734,000	864,000	60,000	3,653,000	9,722,000	13,375,000
Percent Change 1950s to 1983	-4%	-72%	1%	-28%	21%	4%
Percent Change 1983 to 2012	-14%	7755%	-18%	21%	0%	5%
Percent Change 1950s to 2012	-18%	2115%	-17%	-13%	17%	8%

Table 5.1-11. Geomorphic feature areas for GAA-151.

GAA-151						
Year	Channel			Floodplain		
	Main and Side Channel	Side Slough	Upland Slough	Islands	Overbank	Islands and Overbank
	ft²					
1950s	1,299,000	0	0	0	1,820,000	1,820,000
1983	1,246,000	0	0	0	1,872,000	1,872,000
2012	1,265,000	0	0	0	1,853,000	1,853,000
Percent Change 1950s to 1983	-4%	0%	0%	0%	3%	3%
Percent Change 1983 to 2012	2%	0%	0%	0%	-1%	-1%
Percent Change 1950s to 2012	-3%	0%	0%	0%	2%	2%

Table 5.1-12. Geomorphic feature areas for GAA-144.

GAA-144						
Year	Channel			Floodplain		
	Main and Side Channel	Side Slough	Upland Slough	Islands	Overbank	Islands and Overbank
	ft²					
1950s	11,251,000	670,000	0	2,299,000	11,444,000	13,743,000
1983	11,829,000	352,000	0	2,396,000	11,088,000	13,484,000
2012	11,806,000	69,000	172,000	2,288,000	11,330,000	13,618,000
Percent Change 1950s to 1983	5%	-47%	0%	4%	-3%	-2%
Percent Change 1983 to 2012	0%	-80%	N/A	-5%	2%	1%
Percent Change 1950s to 2012	5%	-90%	N/A	0%	-1%	-1%

Table 5.1-13. Geomorphic feature areas for GAA-141.

GAA-141						
Year	Channel			Floodplain		
	Main and Side Channel	Side Slough	Upland Slough	Islands	Overbank	Islands and Overbank
	ft²					
1950s	15,690,000	132,000	105,000	3,179,000	26,280,000	29,459,000
1983	15,403,000	138,000	222,000	3,101,000	26,523,000	29,624,000
2012	14,705,000	354,000	239,000	4,600,000	25,490,000	30,090,000
Percent Change 1950s to 1983	-2%	5%	111%	-2%	1%	1%
Percent Change 1983 to 2012	-5%	157%	8%	48%	-4%	2%
Percent Change 1950s to 2012	-6%	168%	128%	45%	-3%	2%

Table 5.1-14. Geomorphic feature areas for GAA-138.

GAA-138						
Year	Channel			Floodplain		
	Main and Side Channel	Side Slough	Upland Slough	Islands	Overbank	Islands and Overbank
	ft²					
1950s	16,555,000	364,000	215,000	2,993,000	28,895,000	31,888,000
1983	15,545,000	1,136,000	138,000	7,809,000	24,394,000	32,203,000
2012	14,081,000	109,000	673,000	5,292,000	28,867,000	34,159,000
Percent Change 1950s to 1983	-6%	212%	-36%	161%	-16%	1%
Percent Change 1983 to 2012	-9%	-90%	388%	-32%	18%	6%
Percent Change 1950s to 2012	-15%	-70%	213%	77%	0%	7%

Table 5.1-15. Geomorphic feature areas for GAA-128.

GAA-128						
Year	Channel			Floodplain		
	Main and Side Channel	Side Slough	Upland Slough	Islands	Overbank	Islands and Overbank
	ft²					
1950s	14,750,000	2,176,000	0	13,740,000	5,856,000	19,596,000
1983	11,127,000	2,766,000	2,000	16,119,000	6,507,000	22,626,000
2012	12,401,000	968,000	97,000	16,662,000	6,395,000	23,057,000
Percent Change 1950s to 1983	-25%	27%	N/A	17%	11%	15%
Percent Change 1983 to 2012	11%	-65%	4750%	3%	-2%	2%
Percent Change 1950s to 2012	-16%	-56%	N/A	21%	8%	15%

Table 5.1-16. Geomorphic feature areas for GAA-115.

GAA-115						
Year	Channel			Floodplain		
	Main and Side Channel	Side Slough	Upland Slough	Islands	Overbank	Islands and Overbank
	ft²					
1950s	10,102,000	0	63,000	2,302,000	16,682,000	18,984,000
1983	9,862,000	35,000	284,000	2,379,000	16,589,000	18,968,000
2012	9,380,000	0	185,000	2,730,000	16,855,000	19,585,000
Percent Change 1950s to 1983	-2%	N/A	351%	3%	-1%	0%
Percent Change 1983 to 2012	-5%	-100%	-35%	15%	2%	3%
Percent Change 1950s to 2012	-7%	0%	194%	19%	1%	3%

Table 5.1-17. Geomorphic feature areas for GAA-113.

GAA-113						
Year	Channel			Floodplain		
	Main and Side Channel	Side Slough	Upland Slough	Islands	Overbank	Islands and Overbank
	ft²					
1950s	8,023,000	0	0	3,124,000	5,994,000	9,118,000
1983	8,328,000	0	0	3,164,000	5,651,000	8,815,000
2012	7,124,000	322,000	0	3,947,000	5,751,000	9,698,000
Percent Change 1950s to 1983	4%	0%	0%	1%	-6%	-3%
Percent Change 1983 to 2012	-14%	N/A	0%	25%	2%	10%
Percent Change 1950s to 2012	-11%	N/A	0%	26%	-4%	6%

Table 5.1-18. Geomorphic feature areas for GAA-104.

GAA-104						
Year	Channel			Floodplain		
	Main and Side Channel	Side Slough	Upland Slough	Islands	Overbank	Islands and Overbank
	ft²					
1950s	16,163,000	628,000	408,000	3,193,000	59,444,000	62,637,000
1983	15,690,000	535,000	320,000	3,687,000	59,601,000	63,288,000
2012	14,955,000	271,000	333,000	4,465,000	59,811,000	64,276,000
Percent Change 1950s to 1983	-3%	-15%	-22%	15%	0%	1%
Percent Change 1983 to 2012	-5%	-49%	4%	21%	0%	2%
Percent Change 1950s to 2012	-8%	-132%	-23%	28%	1%	3%

Table 5.1-19. Geomorphic feature areas for LR-1.

LR-1									
Year	Channel							Floodplain	
	Main Channel (MC)	Side Channel Complex (SCC)	Bar Island Complex (BIC)	Bar Attached Bar (BAB)	Side Channel (SC)	Upland Slough (US)	Side Slough (SS)	Total Islands[1]	Overbank[2]
	ft²								
1950s	82,434,000	29,725,000	152,041,000	0	2,316,000	859,000	235,000	118,448,000	202,920,000
1983	73,434,000	22,858,000	163,389,000	0	5,579,000	615,000	1,190,000	101,520,000	216,269,000
2012	71,135,000	18,218,000	148,951,000	0	3,207,000	730,000	1,911,000	111,545,000	233,636,000
Percent Change 1950s to 1983	-11%	-23%	7%	0%	141%	-28%	406%	-14%	7%
Percent Change 1983 to 2012	-3%	-20%	-9%	0%	-43%	19%	61%	10%	8%
Percent Change 1950s to 2012	-14%	-39%	-2%	0%	38%	-15%	713%	-6%	15%

Notes:

1 Total Islands is the summation of all vegetated islands (VI MC, VI SCC, VI BIC, VI SC, and VI SS).

2 Overbank is summation of Tributary (TR), Tributary Delta (TD), Additional Open Water (AOW), and Background (BG).

Table 5.1-20. Geomorphic feature areas for LR-2.

LR-2									
Year	Channel							Floodplain	
	Main Channel (MC)	Side Channel Complex (SCC)	Bar Island Complex (BIC)	Bar Attached Bar (BAB)	Side Channel (SC)	Upland Slough (US)	Side Slough (SS)	Total Islands	Overbank
	ft²								
1950s	152,886,000	120,573,000	181,902,000	0	594,000	1,361,000	126,000	213,984,000	168,977,000
1983	132,878,000	79,412,000	216,331,000	0	1,288,000	752,000	1,159,000	225,927,000	182,655,000
2012	142,407,000	84,228,000	130,472,000	0	7,846,000	1,061,000	2,057,000	289,022,000	183,309,000
Percent Change 1950s to 1983	-13%	-34%	19%	0%	117%	-45%	820%	6%	8%
Percent Change 1983 to 2012	7%	6%	-40%	0%	509%	41%	77%	28%	0%
Percent Change 1950s to 2012	-7%	-30%	-28%	0%	1221%	-22%	1533%	35%	8%

Notes:

1 Total Islands is the summation of all vegetated islands (VI MC, VI SCC, VI BIC, VI SC, and VI SS).

2 Overbank is summation of Tributary (TR), Tributary Delta (TD), Additional Open Water (AOW), and Background (BG).

Table 5.1-21. Geomorphic feature areas for LR-3.

LR-3									
Year	Channel							Floodplain	
	Main Channel (MC)	Side Channel Complex (SCC)	Bar Island Complex (BIC)	Bar Attached Bar (BAB)	Side Channel (SC)	Upland Slough (US)	Side Slough (SS)	Total Islands	Overbank
	ft²								
1950s	141,780,000	193,170,000	126,048,000	0	9,344,000	1,820,000	3,169,000	656,515,000	599,675,000
1983	112,019,000	120,577,000	247,828,000	0	3,253,000	2,631,000	680,000	591,190,000	653,343,000
2012	126,610,000	160,038,000	155,122,000	0	5,343,000	2,451,000	1,225,000	635,057,000	645,675,000
Percent Change 1950s to 1983	-21%	-38%	97%	0%	-65%	45%	-79%	-10%	9%
Percent Change 1983 to 2012	13%	33%	-37%	0%	64%	-7%	80%	7%	-1%
Percent Change 1950s to 2012	-11%	-17%	23%	0%	-43%	35%	-61%	-3%	8%

Notes:

1 Total Islands is the summation of all vegetated islands (VI MC, VI SCC, VI BIC, VI SC, and VI SS).

2 Overbank is summation of Tributary (TR), Tributary Delta (TD), Additional Open Water (AOW), and Background (BG).

Table 5.1-22. Geomorphic feature areas for LR-4.

LR-4									
Year	Channel							Floodplain	
	Main Channel (MC)	Side Channel Complex (SCC)	Bar Island Complex (BIC)	Bar Attached Bar (BAB)	Side Channel (SC)	Upland Slough (US)	Side Slough (SS)	Total Islands	Overbank
	ft²								
1950s	81,006,000	66,999,000	34,303,000	0	10,138,000	1,024,000	0	341,866,000	101,521,000
1983	60,670,000	65,136,000	45,564,000	0	8,557,000	481,000	0	345,500,000	106,478,000
2012	94,451,000	55,676,000	12,423,000	0	9,294,000	1,248,000	0	348,877,000	110,039,000
Percent Change 1950s to 1983	-25%	-3%	33%	0%	-16%	-53%	0%	1%	5%
Percent Change 1983 to 2012	56%	-15%	-73%	0%	9%	159%	0%	1%	3%
Percent Change 1950s to 2012	17%	-17%	-64%	0%	-8%	22%	0%	2%	8%

Notes:

1 Total Islands is the summation of all vegetated islands (VI MC, VI SCC, VI BIC, VI SC, and VI SS).

2 Overbank is summation of Tributary (TR), Tributary Delta (TD), Additional Open Water (AOW), and Background (BG).

Table 5.1-23. Geomorphic feature areas for LR-5.

LR-5									
Year	Channel							Floodplain	
	Main Channel (MC)	Side Channel Complex (SCC)	Bar Island Complex (BIC)	Bar Attached Bar (BAB)	Side Channel (SC)	Upland Slough (US)	Side Slough (SS)	Total Islands	Overbank
	ft²								
1950s	104,784,000	7,110,000	20,590,000	0	1,262,000	1,254,000	180,000	46,846,000	335,741,000
1983	86,976,000	0	61,382,000	0	853,000	1,508,000	29,000	45,390,000	325,762,000
2012	129,912,000	926,000	16,816,000	0	4,811,000	1,664,000	0	49,103,000	319,266,000
Percent Change 1950s to 1983	-17%	-100%	198%	0%	-32%	20%	-84%	-3%	-3%
Percent Change 1983 to 2012	49%	U	-73%	0%	464%	10%	-100%	8%	-2%
Percent Change 1950s to 2012	24%	-87%	-18%	0%	281%	33%	-100%	5%	-5%

Notes:

1 Total Islands is the summation of all vegetated islands (VI MC, VI SCC, VI BIC, VI SC, and VI SS).

2 Overbank is summation of Tributary (TR), Tributary Delta (TD), Additional Open Water (AOW), and Background (BG).

Table 5.1-24. Geomorphic feature areas for LR-6.

LR-6									
Year	Channel							Floodplain	
	Main Channel (MC)	Side Channel Complex (SCC)	Bar Island Complex (BIC)	Bar Attached Bar (BAB)	Side Channel (SC)	Upland Slough (US)	Side Slough (SS)	Total Islands	Overbank
	ft²								
1950s	212,750,000	220,216,000	138,925,000	0	643,000	3,651,000	4,360,000	620,599,000	811,782,000
1983	189,444,000	210,871,000	199,858,000	0	0	4,027,000	6,043,000	614,063,000	788,619,000
2012	298,210,000	106,821,000	142,664,000	0	7,410,000	3,700,000	4,524,000	681,302,000	768,294,000
Percent Change 1950s to 1983	-11%	-4%	44%	0%	-100%	10%	39%	-1%	-3%
Percent Change 1983 to 2012	57%	-49%	-29%	0%	U	-8%	-25%	11%	-3%
Percent Change 1950s to 2012	40%	-51%	3%	0%	1052%	1%	4%	10%	-5%

Notes:

1 Total Islands is the summation of all vegetated islands (VI MC, VI SCC, VI BIC, VI SC, and VI SS).

2 Overbank is summation of Tributary (TR), Tributary Delta (TD), Additional Open Water (AOW), and Background (BG).

Table 5.1-25. Geomorphic feature areas for CL-1.

Chulitna									
Year	Channel							Floodplain	
	Main Channel (MC)	Side Channel Complex (SCC)	Bar Island Complex (BIC)	Bar Attached Bar (BAB)	Side Channel (SC)	Upland Slough (US)	Side Slough (SS)	Total Islands	Overbank
	ft²								
1950s	9,599,000	10,875,000	15,100,000	0	195,000	938,000	0	8,961,000	34,777,000
1983	7,696,000	3,956,000	36,703,000	0	1,971,000	1,234,000	0	13,783,000	23,621,000
2012	6,155,000	10,508,000	26,348,000	0	695,000	288,000	137,000	22,297,000	20,207,000
Percent Change 1950s to 1983	-20%	-64%	143%	0%	911%	32%	0%	54%	-33%
Percent Change 1983 to 2012	-20%	166%	-28%	0%	-65%	-77%	U	62%	-113%
Percent Change 1950s to 2012	-36%	-3%	74%	0%	256%	-69%	U	149%	-42%

Notes:

1 Total Islands is the summation of all vegetated islands (VI MC, VI SCC, VI BIC, VI SC, and VI SS).

2 Overbank is summation of Tributary (TR), Tributary Delta (TD), Additional Open Water (AOW), and Background (BG).

Table 5.1-26. Geomorphic feature areas for TK-1.

Talkeetna									
Year	Channel							Floodplain	
	Main Channel (MC)	Side Channel Complex (SCC)	Bar Island Complex (BIC)	Bar Attached Bar (BAB)	Side Channel (SC)	Upland Slough (US)	Side Slough (SS)	Total Islands	Overbank
	ft²								
1950s	5,238,000	1,451,000	3,018,000	2,811,000	280,000	0	0	18,794,000	40,264,000
1983	3,933,000	1,615,000	934,000	2,463,000	674,000	68,000	636,000	20,682,000	40,519,000
2012	5,021,000	1,407,000	354,000	1,618,000	809,000	186,000	0	20,717,000	40,416,000
Percent Change 1950s to 1983	-25%	11%	-69%	-12%	141%	U	U	10%	-100%
Percent Change 1983 to 2012	28%	-13%	-62%	-34%	20%	174%	-100%	0%	-29%
Percent Change 1950s to 2012	-4%	-3%	-88%	-42%	189%	U	0%	10%	14%

Notes:

1 Total Islands is the summation of all vegetated islands (VI MC, VI SCC, VI BIC, VI SC, and VI SS).

2 Overbank is summation of Tributary (TR), Tributary Delta (TD), Additional Open Water (AOW), and Background (BG).

Table 5.1-27. Geomorphic feature areas for YN-1.

Yentna									
Year	Channel							Floodplain	
	Main Channel (MC)	Side Channel Complex (SCC)	Bar Island Complex (BIC)	Bar Attached Bar (BAB)	Side Channel (SC)	Upland Slough (US)	Side Slough (SS)	Total Islands	Overbank
	ft²								
1950s	20,611,000	0	13,238,000	0	517,000	13,000	0	8,352,000	16,336,000
1983	9,363,000	2,000	19,665,000	0	4,538,000	0	0	9,021,000	16,797,000
2012	9,144,000	0	0	0	16,426,000	0	1,691,000	16,890,000	15,017,000
Percent Change 1950s to 1983	-55%	U	49%	0%	778%	-100%	0%	8%	3%
Percent Change 1983 to 2012	-2%	-100%	-100%	0%	262%	0%	U	87%	-11%
Percent Change 1950s to 2012	-56%	0%	-100%	0%	3077%	-100%	U	102%	-8%

Notes:

1 Total Islands is the summation of all vegetated islands (VI MC, VI SCC, VI BIC, VI SC, and VI SS).

2 Overbank is summation of Tributary (TR), Tributary Delta (TD), Additional Open Water (AOW), and Background (BG).

Table 5.1-28. Turnover values for Middle River geomorphic reaches.

GAA	Period (years)	Turnover (sq. ft. x 10³)			Turnover as % of GAA			Turnover in ft²x10³/yr/mile			
		Channel to Floodplain	Floodplain to Channel	Net[1]	Channel to Floodplain	Floodplain to Channel	Net[1]	Channel to Floodplain	Floodplain to Channel	Net[1]	Total Turnover
184	Δt_1	292	248	44	4.7	4.0	0.7	9.4	8.0	1.4	17
	Δt_2	50	161	-110	0.8	2.6	-1.8	1.6	5.0	-3.5	6.6
	Δt_3	225	293	-68	3.6	4.7	-1.1	3.6	4.6	-1.1	8.2
173	Δt_1	922	421	501	4.0	1.8	2.2	14	6.6	7.9	21
	Δt_2	882	298	584	3.8	1.3	2.5	13	4.5	8.9	18
	Δt_3	1,520	439	1,090	6.6	1.9	4.7	12	3.4	8.4	15
151	Δt_1	58	5	53	1.9	0.2	1.7	3.2	0.3	3.0	3.5
	Δt_2	12	31	-19	0.4	1.0	-0.6	0.7	2.0	-1.2	2.7
	Δt_3	41	7	34	1.3	0.2	1.1	1.2	0.2	1.0	1.4
144	Δt_1	1,860	2,120	-260	7.2	8.2	-1.0	23	27	-3.3	50
	Δt_2	798	665	133	3.1	2.6	0.5	11	9.2	1.8	20
	Δt_3	2,180	2,300	-130	8.5	9.0	-0.5	14	15	-0.8	30
141	Δt_1	1,770	1,600	165	3.9	3.5	0.4	16	15	1.5	31
	Δt_2	1,020	560	461	2.2	1.2	1.0	10	5.6	4.6	16
	Δt_3	2,280	1,650	626	5.0	3.6	1.4	11	7.9	3.0	19
138	Δt_1	2,660	2,340	316	5.4	4.8	0.6	27	23	3.1	50
	Δt_2	3,130	1,170	1,960	6.4	2.4	4.0	34	13	22	47
	Δt_3	5,080	2,800	2,270	10	5.7	4.6	27	15	12	41
128	Δt_1	4,660	1,630	3,030	13	4.5	8.3	62	22	41	84
	Δt_2	1,760	1,330	431	4.8	3.6	1.2	26	20	6.4	46
	Δt_3	5,520	2,060	3,460	15	5.6	9.5	39	14	24	53
115	Δt_1	629	646	-16	2.2	2.2	-0.1	9.8	10	-0.3	20
	Δt_2	902	286	616	3.1	1.0	2.1	16	4.9	11	20
	Δt_3	1,150	549	600	3.9	1.9	2.1	9.4	4.5	4.9	14
113	Δt_1	384	688	-300	2.2	4.0	-1.8	7.2	13	-5.7	20
	Δt_2	1,060	180	882	6.2	1.0	5.1	22	3.7	18	26
	Δt_3	1,290	712	578	7.5	4.2	3.4	13	7.0	5.7	20
104	Δt_1	1,780	1,130	649	2.2	1.4	0.8	18	11	6.4	29
	Δt_2	1,570	577	996	2.0	0.7	1.2	17	6.3	11	23
	Δt_3	3,040	1,400	1,640	3.8	1.8	2.1	16	7.2	8.5	23

Notes:

Δt_1 = 1950s to 1980s.

Δt_2 = 1980s to 2012

Δt_3 = 1950s to 2012

[1]A positive net value indicates greater channel to floodplain turnover, a negative net value indicates greater floodplain to channel turnover

Table 5.1-29. Turnover values for Middle River Geomorphic Assessment Areas.

Reach	Period (years)	Turnover (sq. ft. x 10³)			Turnover as % of Reach			Turnover in ft²x10³/yr/mile			
		Channel to Floodplain	Floodplain to Channel	Net	Channel to Floodplain	Floodplain to Channel	Net	Channel to Floodplain	Floodplain to Channel	Net	Total Turnover
MR-1	Δt_1	614	568	46	4.8	4.5	0.4	7.9	7.3	0.6	15
	Δt_2	82	406	-320	0.6	3.2	-2.5	1.0	5.1	-4.0	6.1
	Δt_3	441	719	-280	3.5	5.7	-2.2	2.8	4.6	-1.8	7.4
MR-2	Δt_1	3,820	2,640	1,180	2.3	1.6	0.7	8.2	5.7	2.5	14
	Δt_2	1,650	2,320	-680	1.0	1.4	-0.4	3.4	4.8	-1.4	8.3
	Δt_3	4,320	3,820	508	2.6	2.3	0.3	4.6	4.0	0.5	8.6
MR-3	Δt_1	280	170	110	1.4	0.8	0.5	2.6	1.6	1.0	4.2
	Δt_2	66	474	-410	0.3	2.3	-2.0	0.6	4.2	-3.6	4.8
	Δt_3	160	458	-300	0.8	2.2	-1.5	0.7	2.1	-1.4	2.8
MR-4	Δt_1	605	883	-280	1.4	2.1	-0.6	1.6	2.3	-0.7	3.9
	Δt_2	1,090	415	673	2.5	1.0	1.6	2.8	1.1	1.7	3.8
	Δt_3	1,150	755	396	2.7	1.8	0.9	1.5	1.0	0.5	2.5
MR-5	Δt_1	1,540	1,120	422	4.4	3.2	1.2	8.5	6.2	2.3	15
	Δt_2	801	272	528	2.3	0.8	1.5	5.0	1.7	3.3	6.7
	Δt_3	1,960	1,010	951	5.6	2.9	2.7	5.8	3.0	2.8	8.7
MR-6	Δt_1	23,000	17,900	5,110	6.6	5.2	1.5	28	22	6.2	50
	Δt_2	19,200	8,870	10,400	5.5	2.6	3.0	26	12	14	38
	Δt_3	36,700	21,200	15,500	11	6.1	4.5	23	14	9.9	37
MR-7	Δt_1	3,700	4,280	-570	2.1	2.5	-0.3	7.8	9.0	-1.2	17
	Δt_2	8,190	2,160	6,030	4.7	1.2	3.5	19	5.0	14	24
	Δt_3	9,980	4,520	5,460	5.7	2.6	3.1	11	5.0	6.0	16
MR-8	Δt_1	4,190	3,940	248	1.8	1.7	0.1	24	23	1.4	47
	Δt_2	3,700	2,460	1,250	1.6	1.1	0.5	24	16	8.0	39
	Δt_3	6,980	5,450	1,530	3.1	2.4	0.7	21	17	4.6	38

Notes:

Δt_1 = 1950s to 1980s.

Δt_2 = 1980s to 2012

Δt_3 = 1950s to 2012

¹A positive net value indicates greater channel to floodplain turnover, a negative net value indicates greater floodplain to channel turnover

Table 5.1-30. Turnover values for Lower River geomorphic reaches.

Reach	Period (years)	Turnover (sq. ft. x 10^3)			Turnover as % of Reach			Turnover in $ft^2 x 10^3$/yr/mile			
		Channel to Floodplain	Floodplain to Channel	Net	Channel to Floodplain	Floodplain to Channel	Net	Channel to Floodplain	Floodplain to Channel	Net	Total Turnover
LR-1	Δt_1	31,600	33,800	-2,200	5	6	-0.4	68	73	-4.8	141
	Δt_2	58,100	33,400	24,800	10	5.7	4.2	138	79	59	218
	Δt_3	74,100	51,200	22,900	13	9	3.9	84	58	26	142
LR-2	Δt_1	97,300	71,500	25,800	12	9	3.1	136	100	36	237
	Δt_2	100,000	36,600	63,800	12	4.4	7.6	155	57	99	212
	Δt_3	167,000	77,600	89,600	20	9	11	123	57	66	180
LR-3	Δt_1	93,900	106,000	-12,000	5	6.1	-0.7	140	157	-17	297
	Δt_2	109,000	72,400	36,400	6	4.2	2.1	179	119	60	298
	Δt_3	164,000	140,000	24,700	9	8	1.4	73	82	-9.1	237
LR-4	Δt_1	38,100	26,000	12,200	6	4.1	1.9	97	66	31	163
	Δt_2	26,800	19,500	7,300	4	3.1	1.2	75	55	20	130
	Δt_3	56,200	36,800	19,400	9	5.8	3.1	145	96	48	124
LR-5	Δt_1	14,000	25,500	-11,000	3	4.9	-2.2	52	95	-43	147
	Δt_2	7,500	10,300	-2,800	1.4	2.0	-0.5	29	40	-11	70
	Δt_3	17,800	32,200	-14,000	3	6.2	-2.8	314	266	47	95
LR-6	Δt_1	51,300	81,000	-30,000	2.5	4.0	-1.5	82	129	-47	211
	Δt_2	103,000	56,200	46,900	5	2.8	2.3	176	96	80	272
	Δt_3	138,000	121,000	17,200	7	6.0	0.9	114	100	14	213
CL-1	Δt_1	4,200	14,000	-9,700	5.2	17.3	-12.1	93.8	311.4	-217.6	405
	Δt_2	16,900	9,290	7,570	20.3	11.2	9.1	415.3	228.9	186.4	644
	Δt_3	19,700	21,900	-2,300	24.7	27.5	-2.9	230.2	256.9	-26.8	487
TK-1	Δt_1	6,250	3,710	2,540	8.8	5.2	5.2	97.7	58.0	39.8	156
	Δt_2	4,460	3,800	660	6.3	5.4	5.4	76.9	65.5	11.4	142
	Δt_3	8,090	4,910	3,180	11.5	7.0	7.0	66.3	40.3	26.0	107
YN-1	Δt_1	3,010	5,400	-2,400	5.1	9.1	9.1	44.8	80.4	-35.6	125
	Δt_2	10,500	4,750	5,760	17.8	8.0	8.0	172.6	78.0	94.5	251
	Δt_3	12,500	8,960	3,550	21.1	15.1	15.1	97.7	69.9	27.7	168

Notes:

Δt_1 = 1950s to 1980s.

Δt_2 = 1980s to 2012

Δt_3 = 1950s to 2012

[1]A positive net value indicates greater channel to floodplain turnover, a negative net value indicates greater floodplain to channel turnover

Table 5.1-31: Geomorphic reach delineations and classifications

Reach Designation	Reach Breaks (PRM / *RM*)[1]		Reach Classification	Slope (ft/mi)	Lateral Constraints
	Upstream	Downstream			
Upper Susitna River Segment (UR)					
UR-1	261.3 / *260.0*	248.6 / *247.7*	SC2	NA	Quaternary Basin Fill
UR-2	248.6 / *247.7*	234.5 / *233.0*	SC1	NA	Quaternary Basin Fill
UR-3	234.5 / *233.0*	224.9 / *223.1*	SC1	NA	Quaternary Basin Fill
UR-4	224.9 / *223.1*	208.1 / *205.7*	SC2	NA	Granodiorite
UR-5	208.1 / *205.7*	203.4 / *200.8*	SC1	NA	Quaternary Basin Fill
UR-6	203.4 / *200.8*	187.1 / *184.3*	SC2	NA	Quaternary Basin Fill
Middle Susitna River Segment (MR)					
MR-1	187.1 / *184.3*	184.6 / *181.9*	SC2	9	Tertiary-Cretaceous Gneiss
MR-2	184.6 / *181.9*	169.6 / *166.4*	SC2	10	Cretaceous Kahiltna Flysch Tertiary-Cretaceous Gneiss
MR-3	169.6 / *166.4*	166.1 / *163.0*	SC2	17	Paleocene Granites
MR-4	166.1 / *163.0*	153.9 / *150.3*	SC1	30	Paleocene Granites
MR-5	153.9 / *150.3*	148.4 / *144.9*	SC2	12	Cretaceous Kahiltna Flysch
MR-6	148.4 / *144.9*	122.7 / *118.9*	SC3	10	Cretaceous Kahiltna Flysch with undifferentiated Upper Pleistocene moraines, kames, lacustrine deposits
MR-7	122.7 / *118.9*	107.8 / *104.1*	SC2	8	Cretaceous Kahiltna Flysch with undifferentiated Upper Pleistocene moraines, kames, lacustrine deposits
MR-8	107.8 / *104.1*	102.4 / *98.6*	MC1/SC3 (Reach is a transition from SC3 to MC1 as the Three Rivers Confluence is approached)	8	Upper Pleistocene moraines, outwash and Holocene Alluvial Terrace deposits

Reach Designation	Reach Breaks (PRM / *RM*)[1]		Reach Classification	Slope (ft/mi)	Lateral Constraints
	Upstream	Downstream			
Lower Susitna River Segment (LR)					
LR-1	102.4 / *98.6*	87.9 / *83.8*	MC1	5	Upper Pleistocene Outwash, Moraine and Lacustrine deposits
LR-2	87.9 / *83.8*	65.6 / *61.4*	MC2/MC3	5	Upper Pleistocene Outwash, Moraine and Lacustrine deposits
LR-3	65.6 / *61.4*	44.6 / *40.3*	MC3	4	Upper Pleistocene Glaciolacustrine deposits
LR-4	44.6 / *40.3*	32.3 / *28.3*	MC2	2	Upper Pleistocene Glaciolacustrine deposits
LR-5	32.3 / *28.3*	23.5 / *19.4*	SC2	2	Upper Pleistocene Glaciolacustrine and Moraine deposits and Late Cretaceous granodiorite
LR-6	23.5 / *19.4*	3.3 / *0.0*	MC4	1.4	Upper Pleistocene Glaciolacustrine and Holocene Estuarine deposits

Notes:

1 First Value is in current Project River Miles (PRM). Second value, in italics, is in the 1980s River Mile (*RM*) System.

9. FIGURES

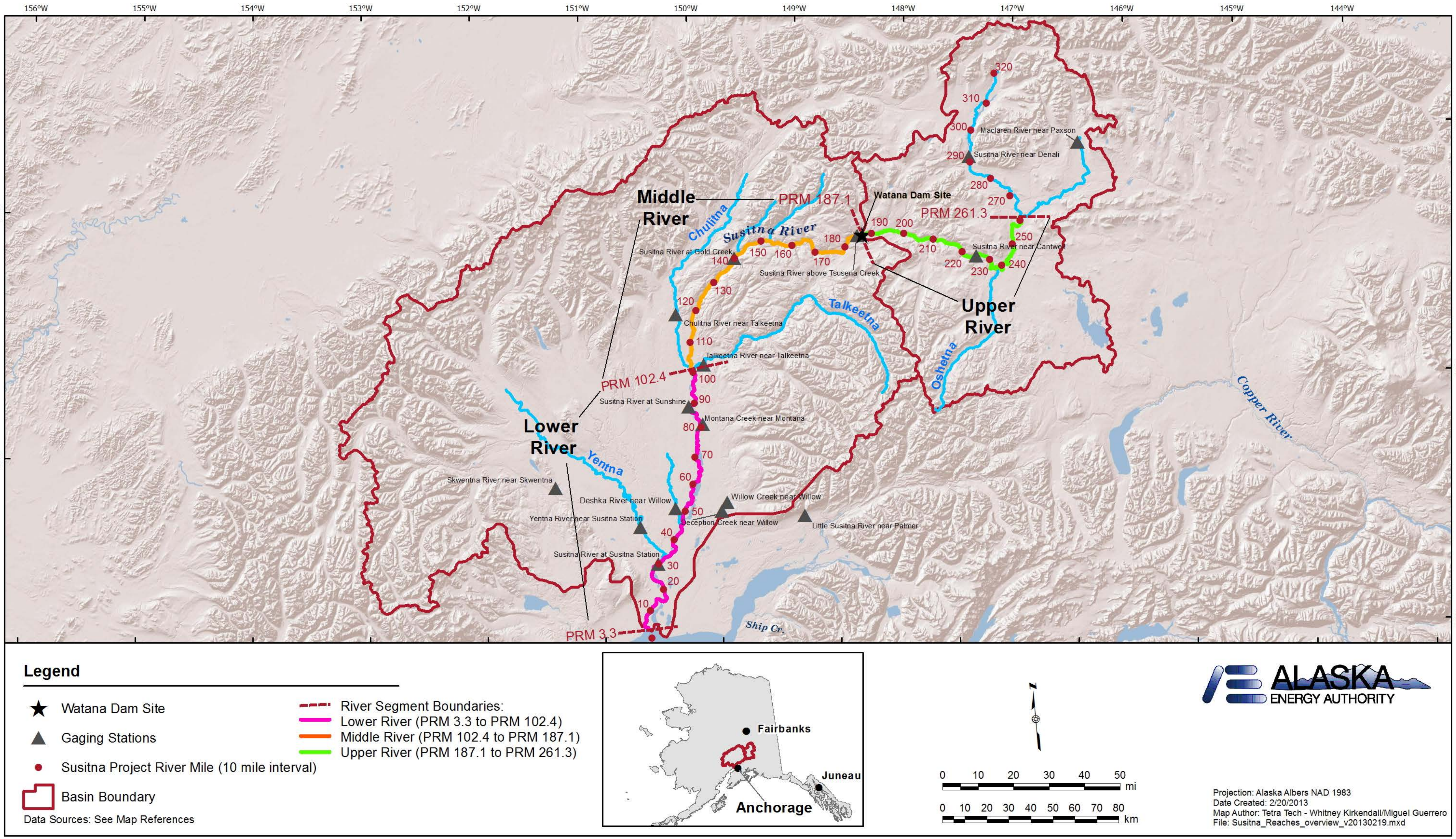

Figure 3.2-1. Susitna River geomorphology study area and large-scale river segments.

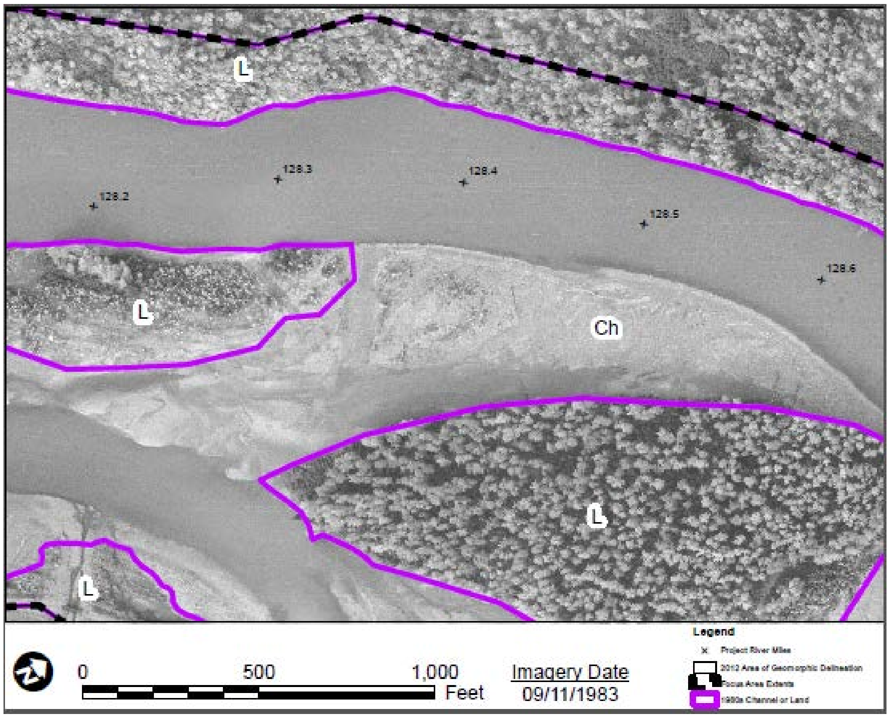

Figure 4.5-1. 1980s Geomorphic Feature Mapping of Channel or Land.

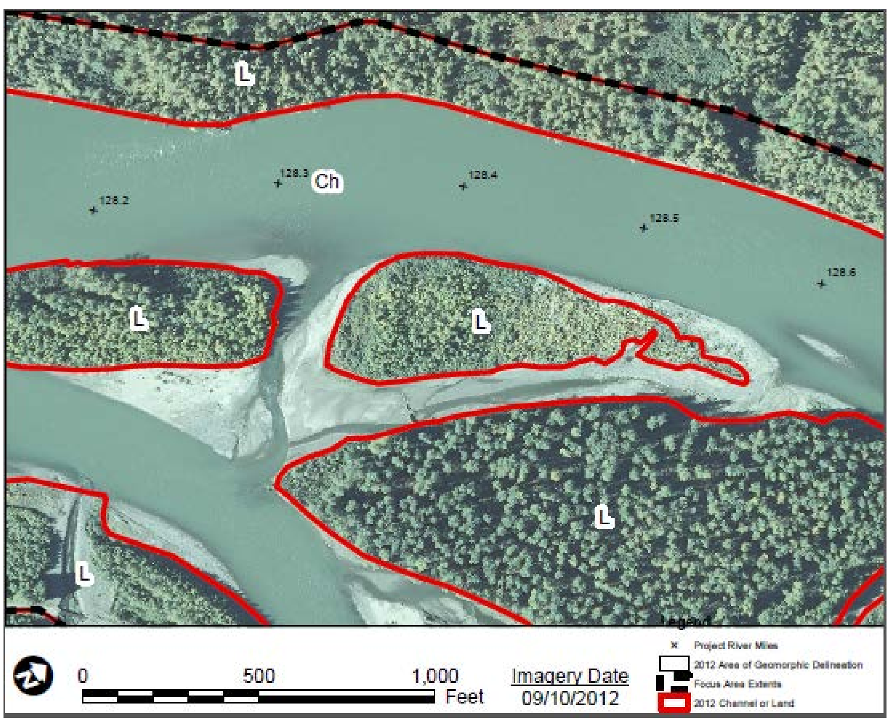

Figure 4.5-2. 2012 Geomorphic Feature Mapping of Channel or Land.

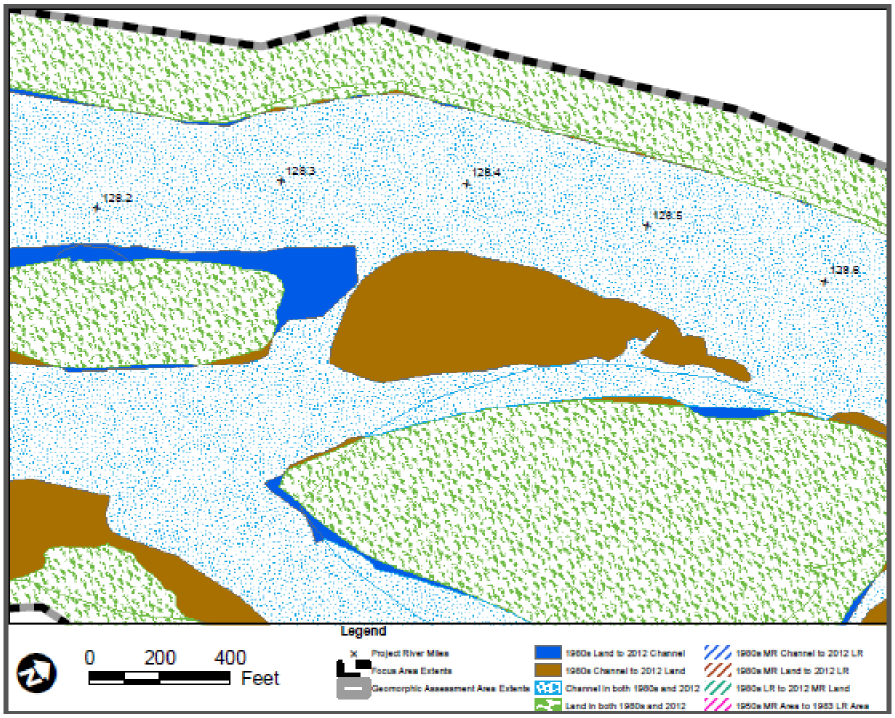

Figure 4.5-3. Turnover Mapping of 1980 to 2012.

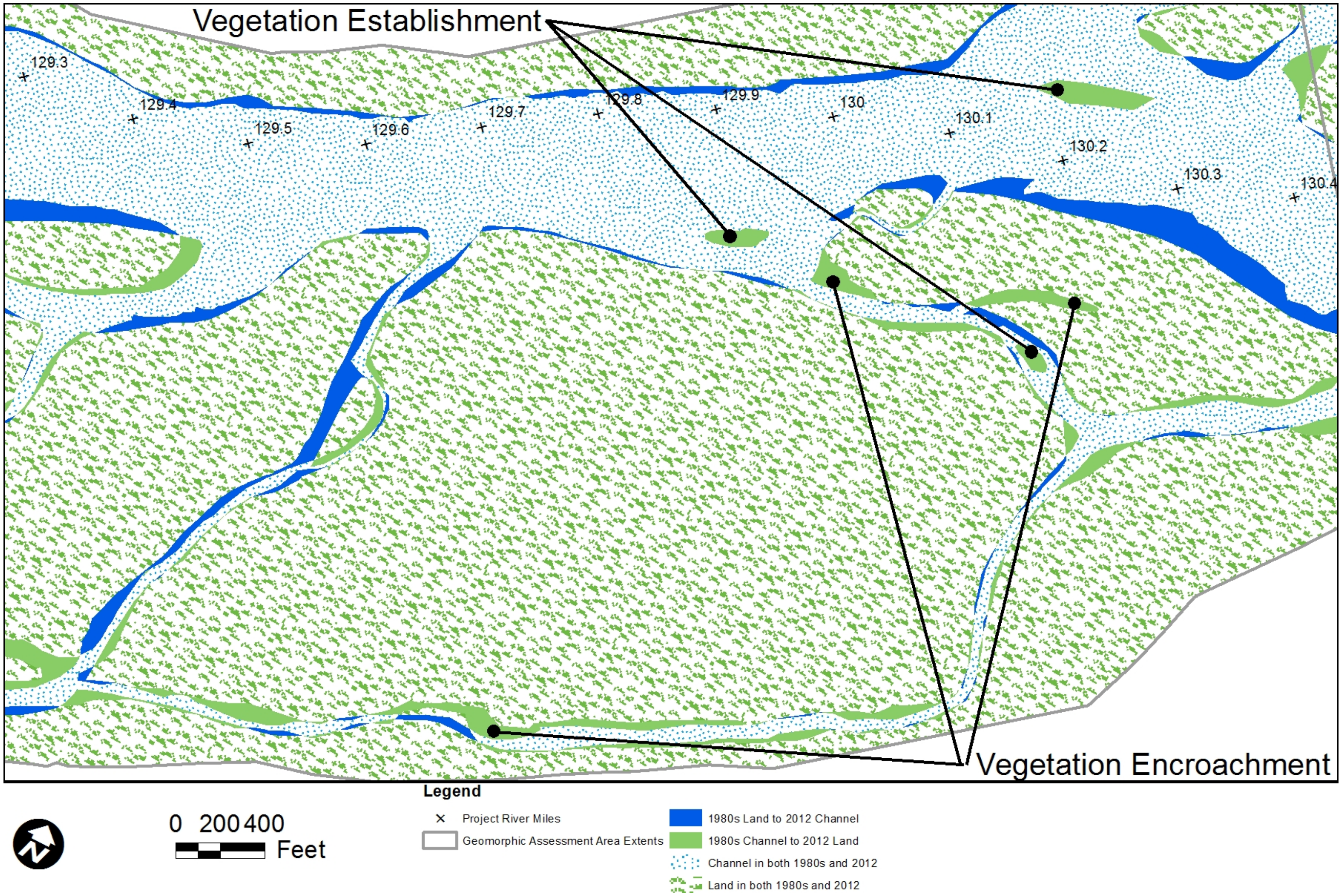

Figure 4.5-4. Examples of vegetation encroachment and vegetation establishment.

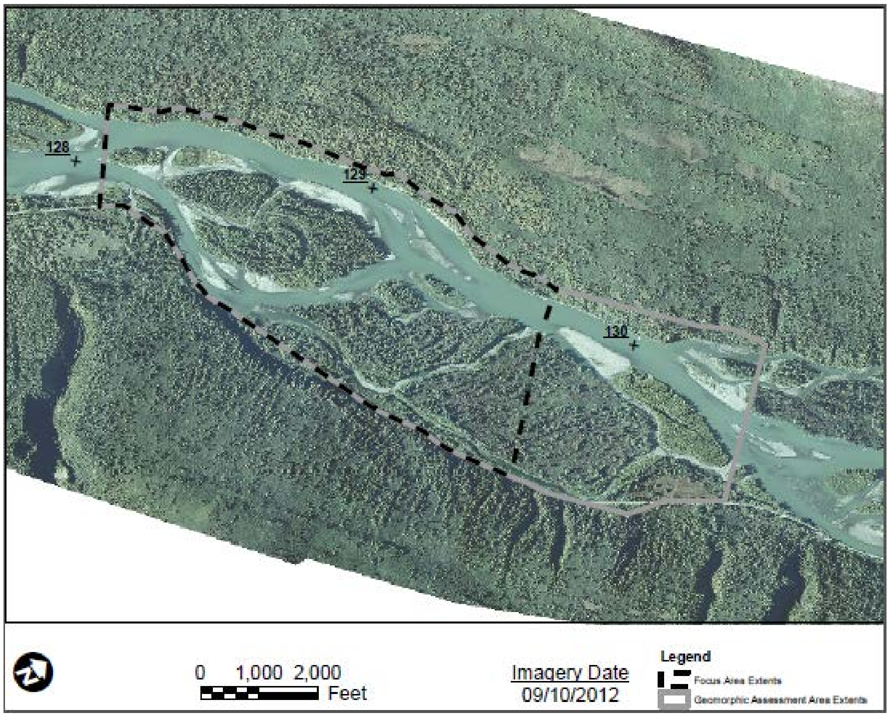

Figure 4.5-5. Example Focus Area and Geomorphic Assessment Areas.

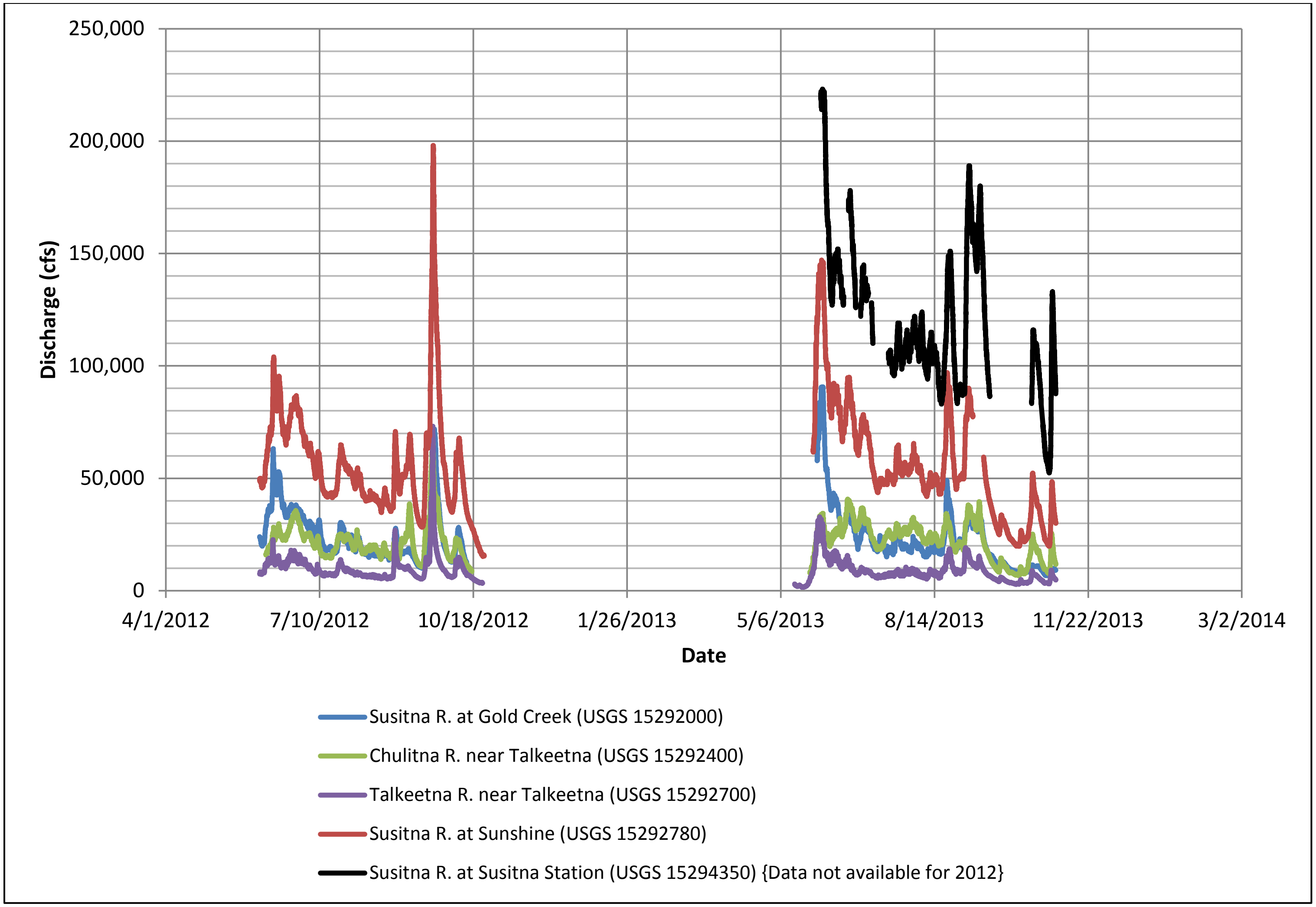

Figure 4.5-6. Discharge measurements at USGS gaging station on or near the Susitna River from June 2012 through October 2013.

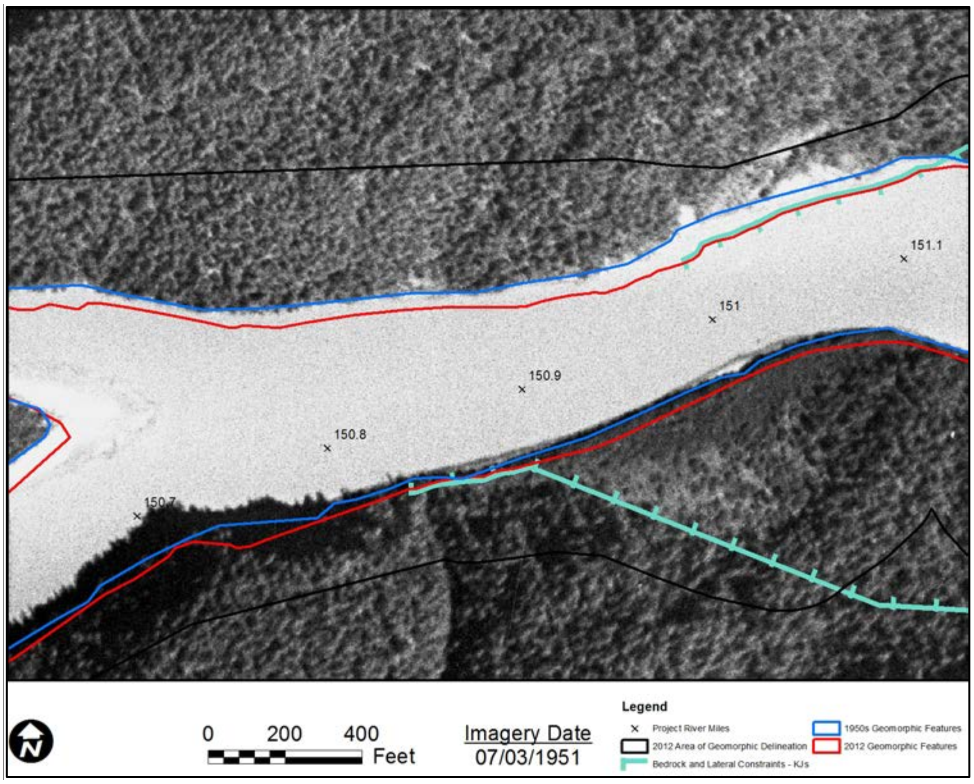

Figure 4.6-1. Example of Registration Error.

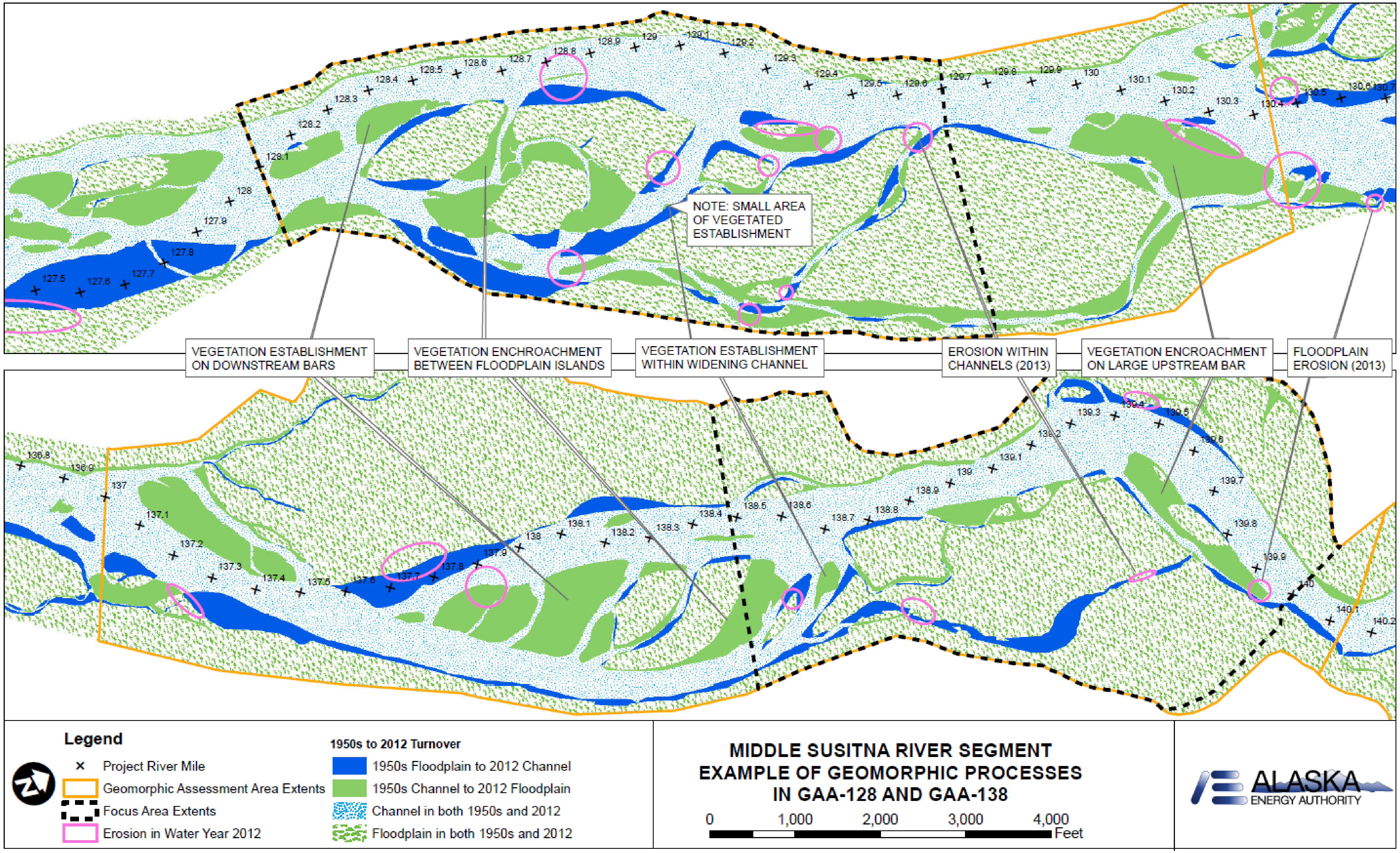

Figure 5.1-1. Example of Turnover mapping in GAA-128 and GAA-138.

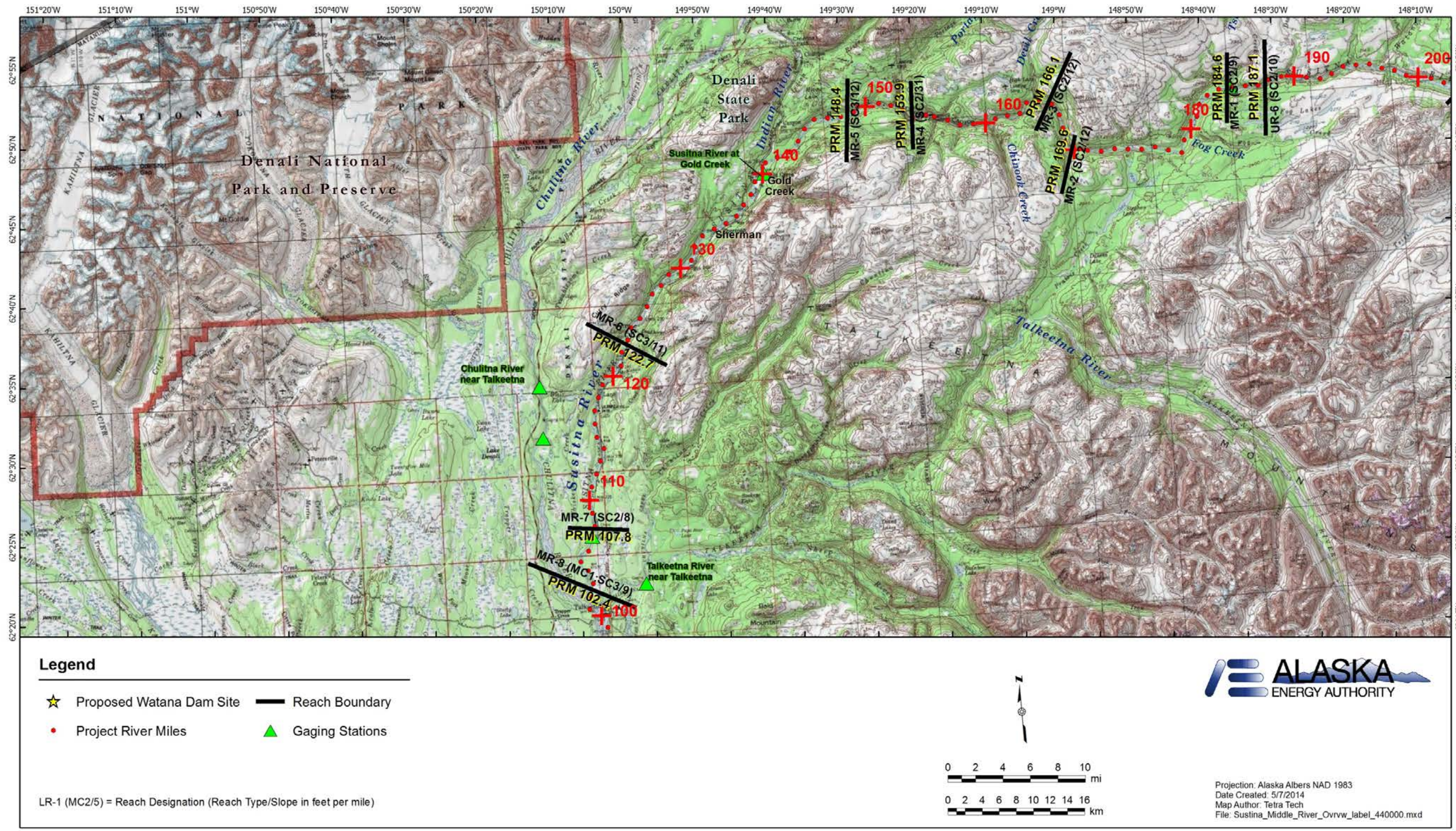

Figure 5.1-2. Map of the Middle Susitna River Segment showing the geomorphic reaches.

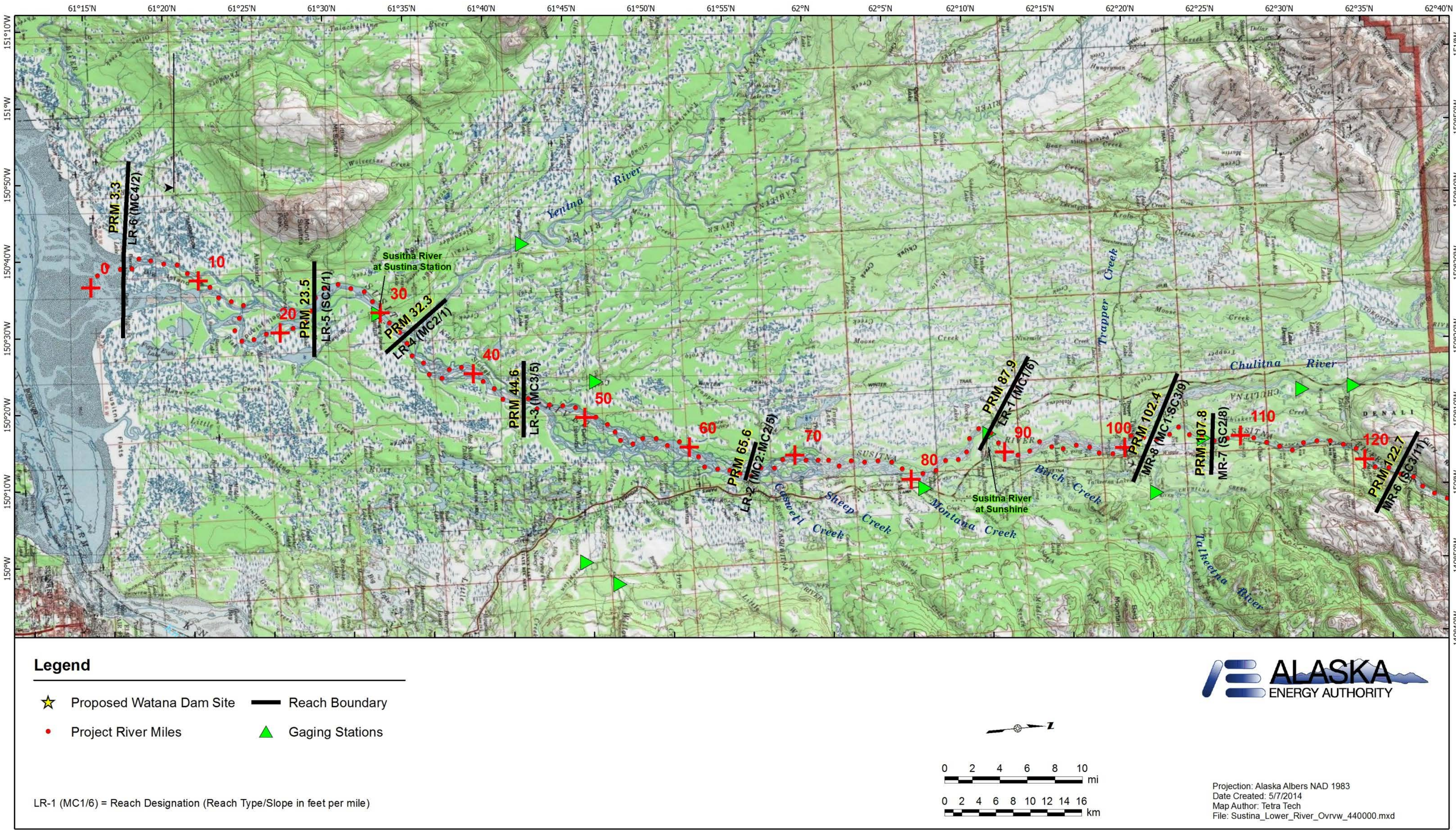

Figure 5.1-3. Map of the Lower Susitna River Segment showing the geomorphic reaches.

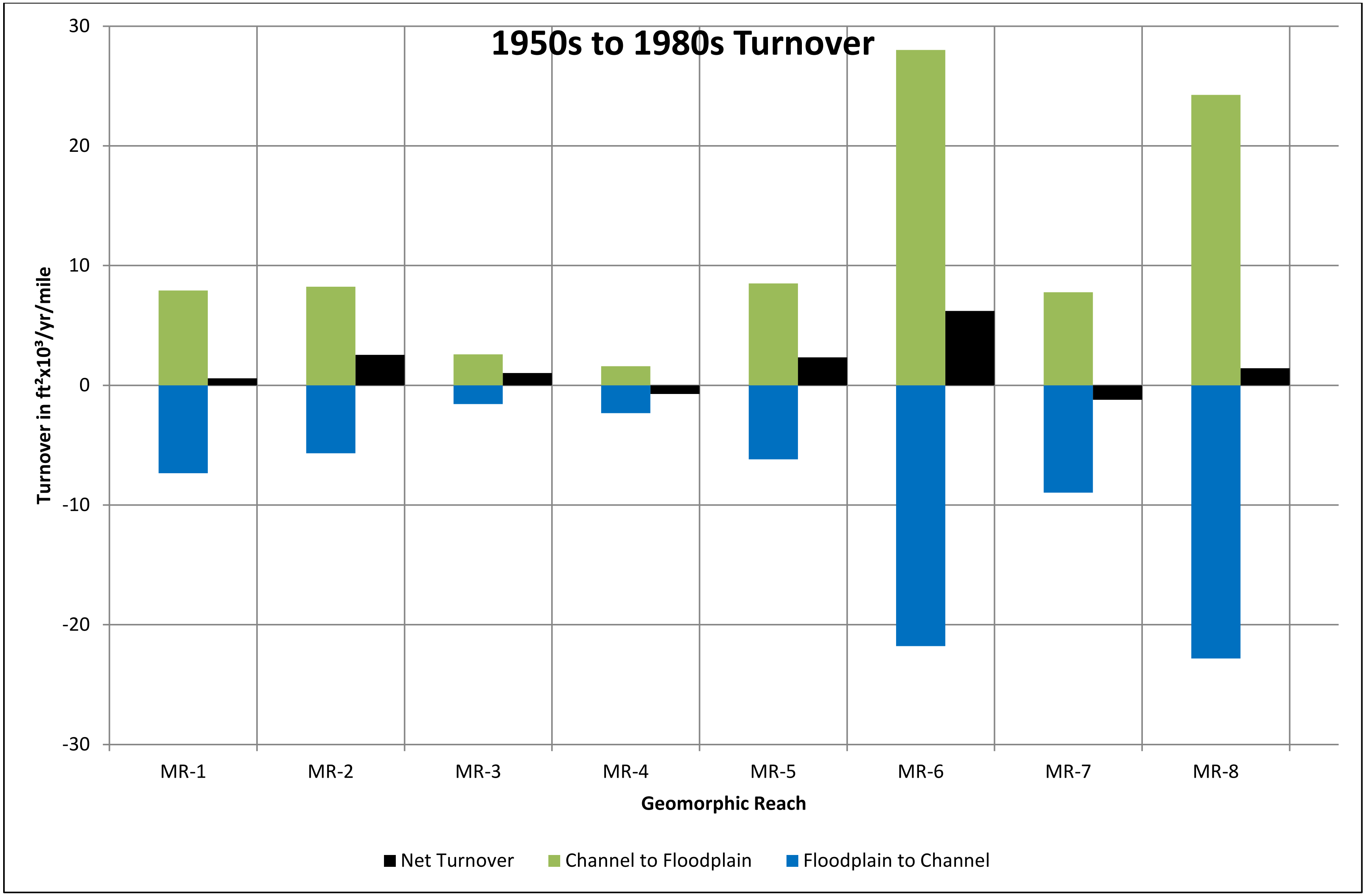

Figure 6.1-1: 1950s to 1980s turnover rates for Middle River geomorphic reaches.

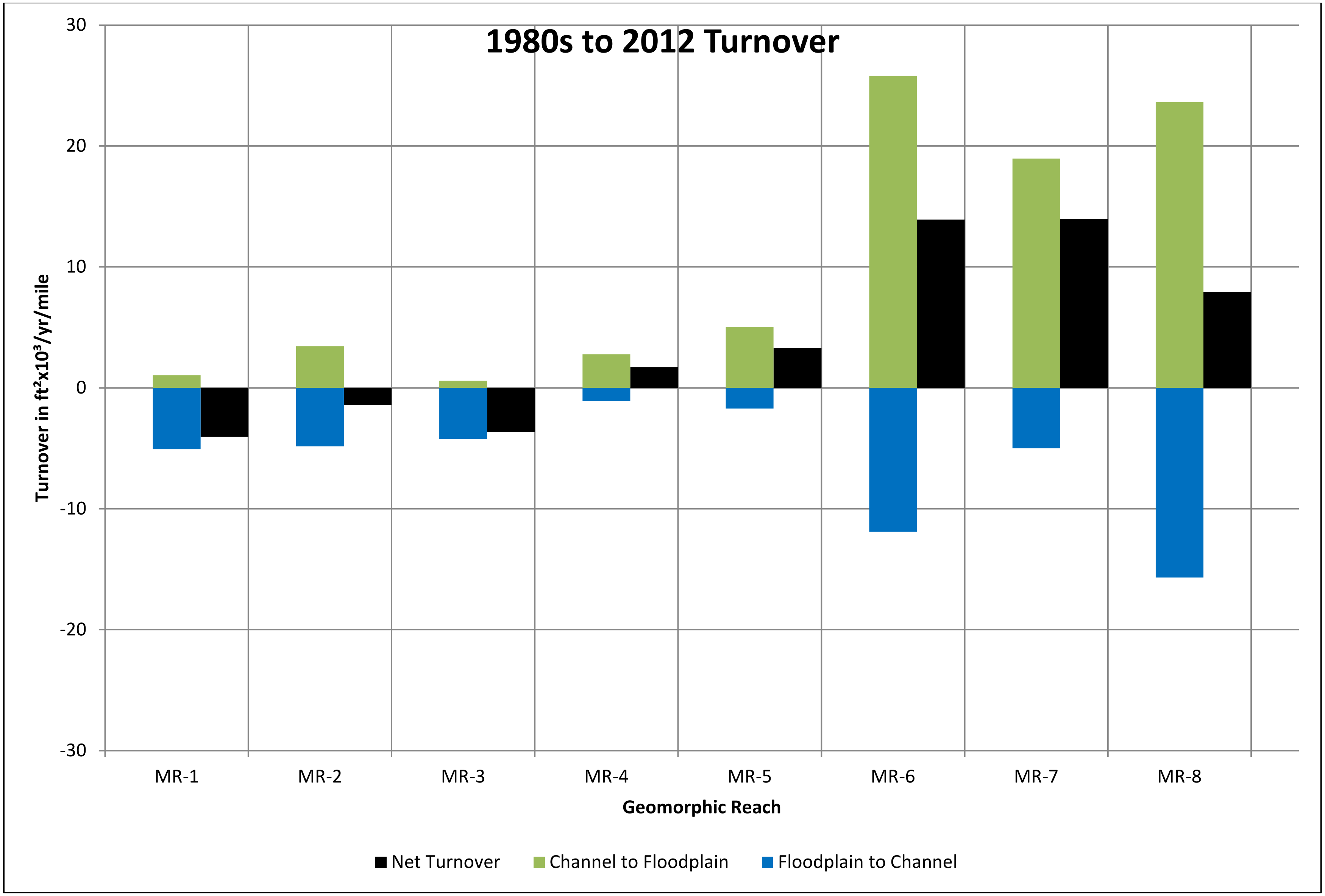

Figure 6.1-2: 1980s to 2012 turnover rates for Middle River geomorphic reaches.

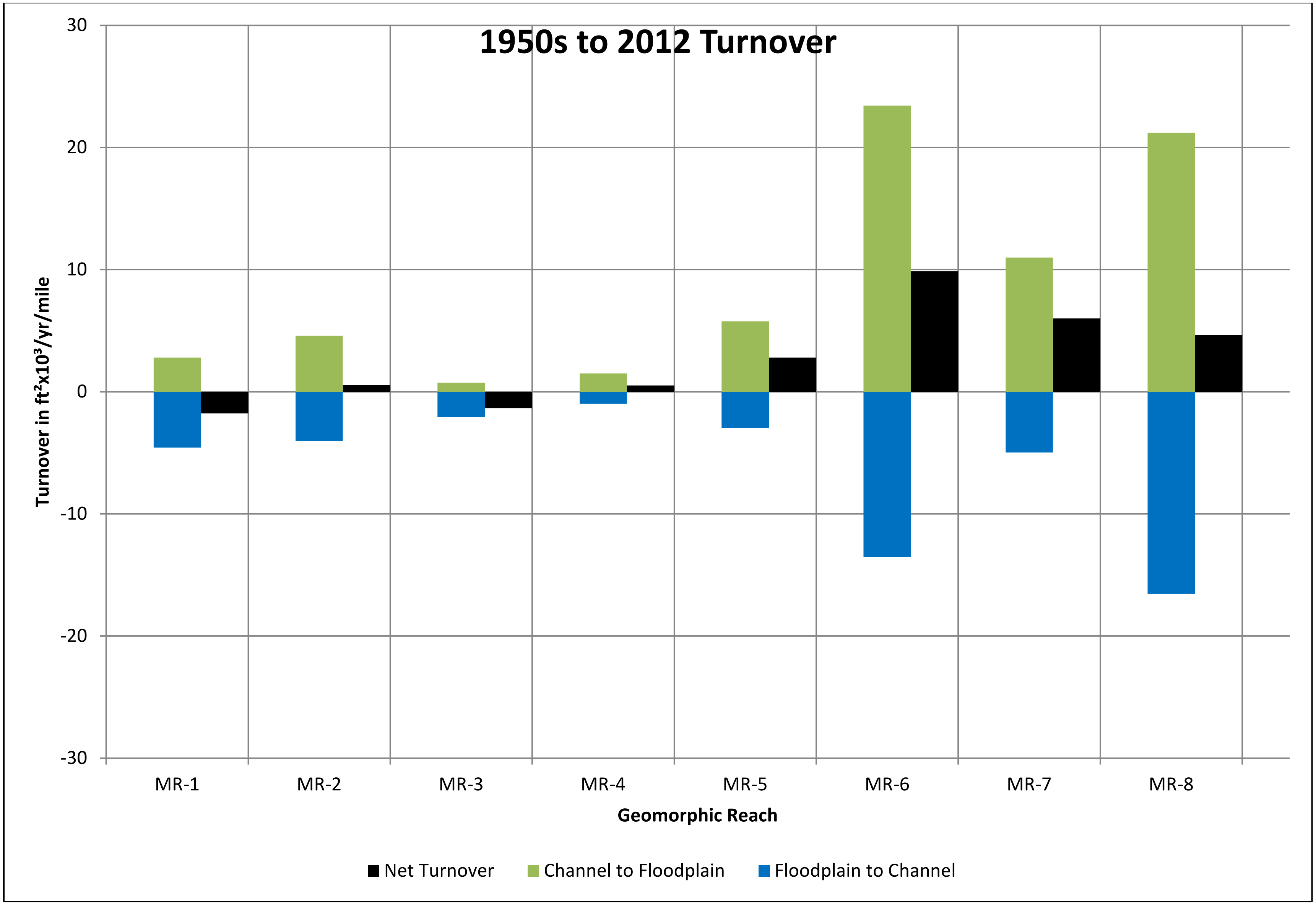

Figure 6.1-3: 1950s to 2012 turnover rates for Middle River geomorphic reaches.

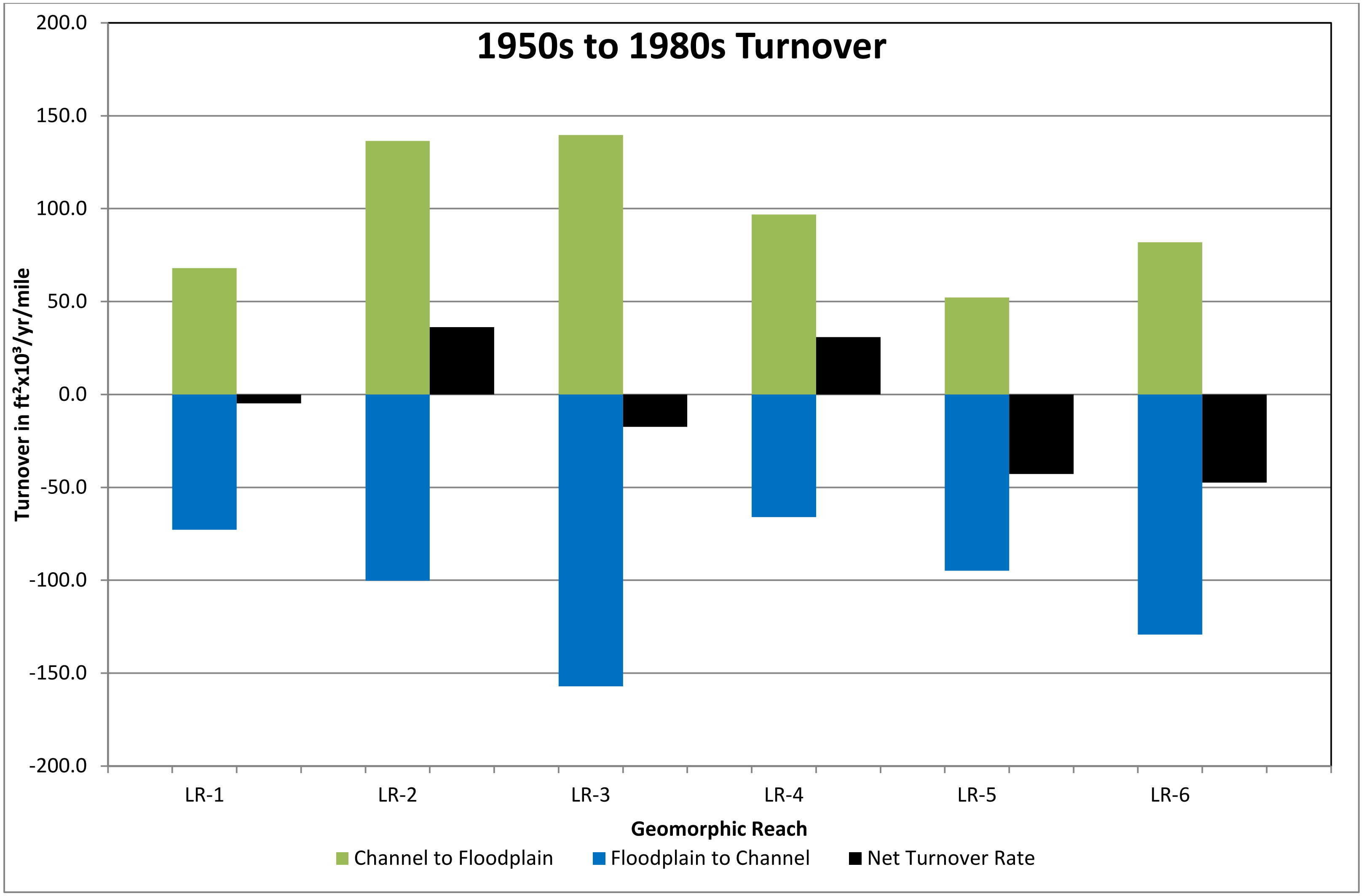

Figure 6.1-4. 1950s to 1980s turnover rates for Lower River geomorphic reaches.

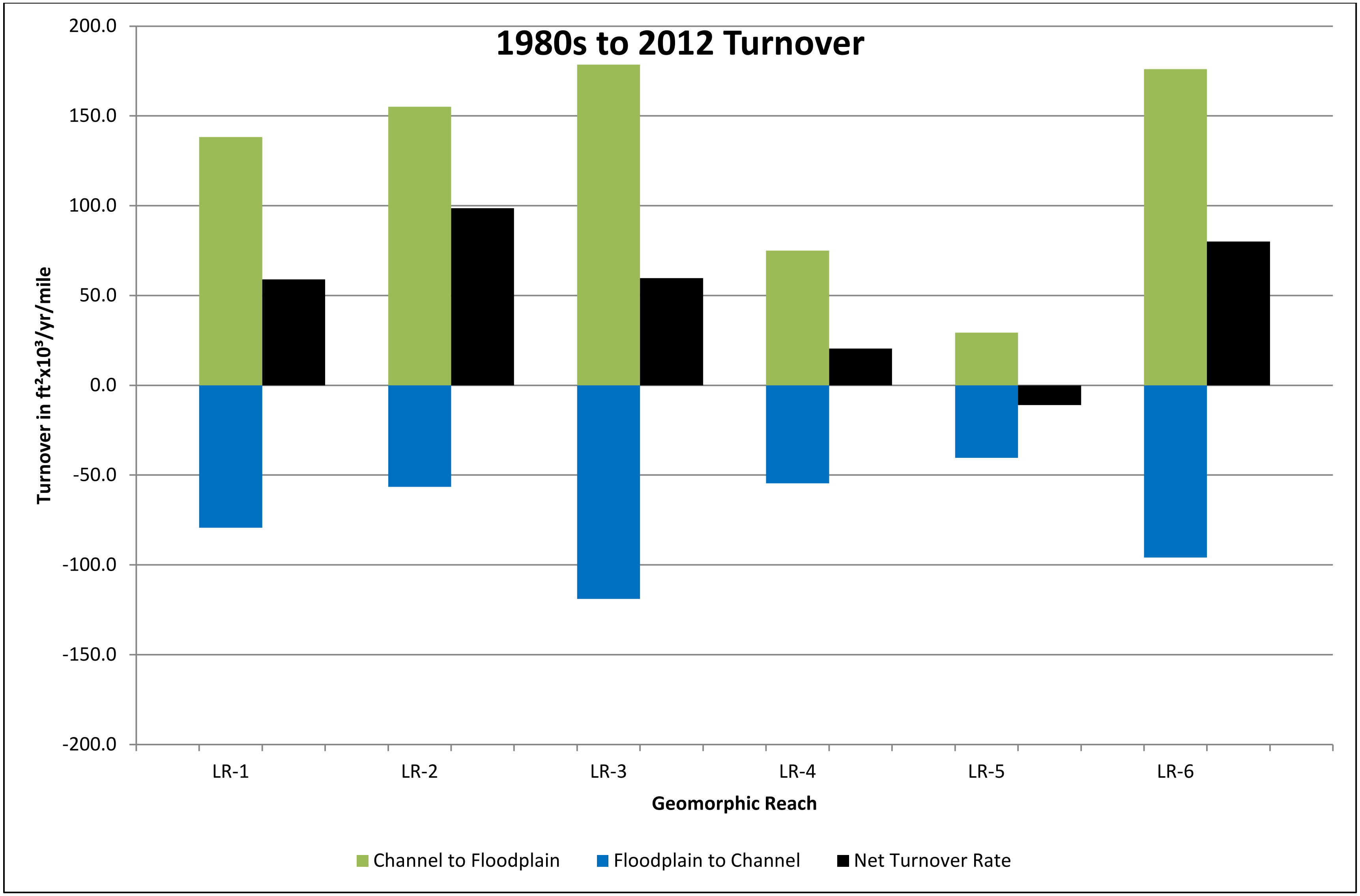

Figure 6.1-5. 1980s to 2012 turnover rates for Lower River geomorphic reaches.

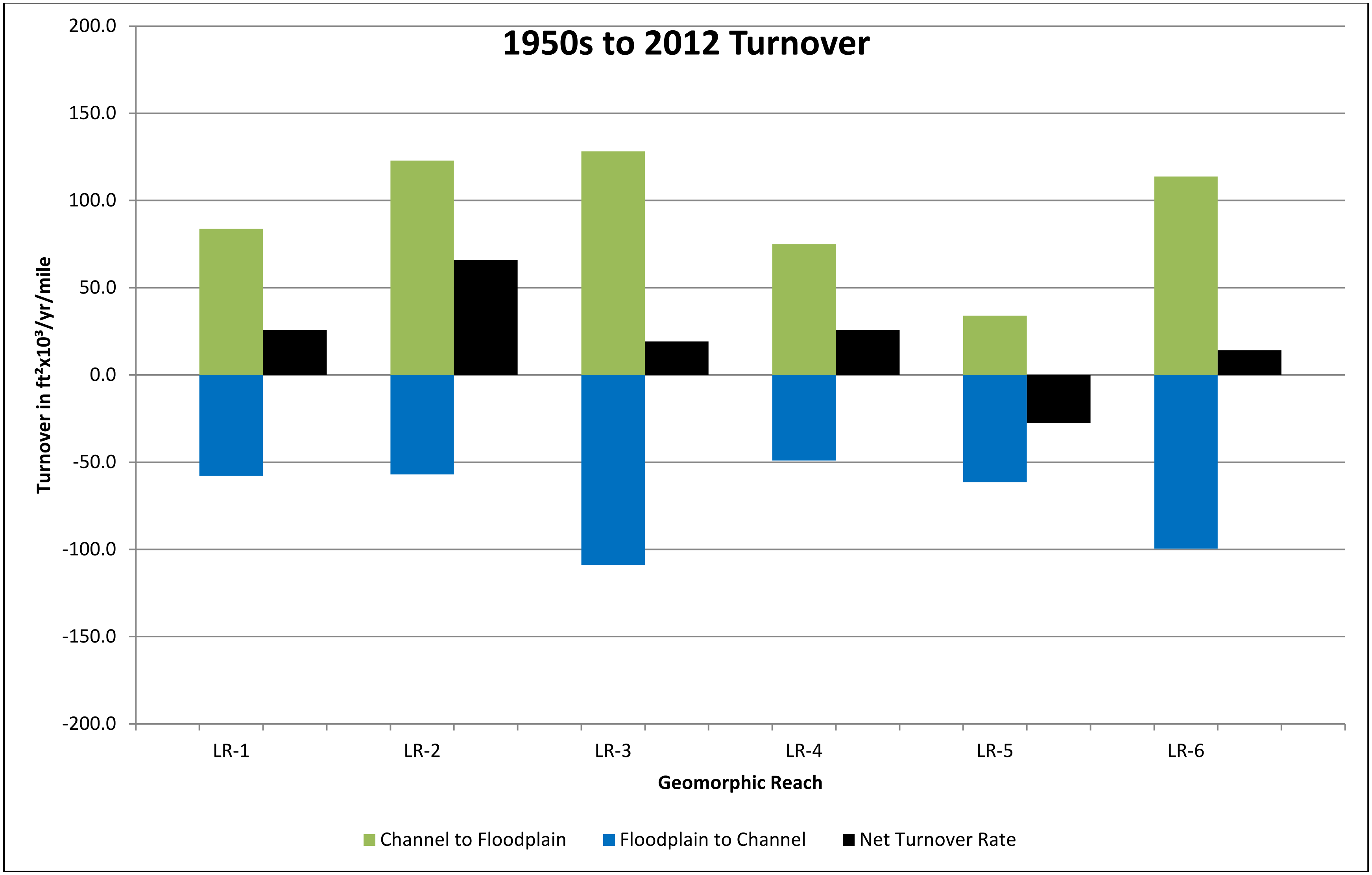

Figure 6.1-6. 1950s to 2012 turnover rates for Lower River geomorphic reaches.