# Cursory Fluvial Geomorphic Evaluation of the Apalachicola River in Support of the Jim Woodruff Dam Interim Operations Plan: Summary of Findings

Prepared by Michael D. Harvey, Ph.D., P.G.
Mussetter Engineering, Inc.

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## 1. INTRODUCTION

A final Biological Opinion (BO) for the Jim Woodruff Dam Interim Operations Plan (IOP) was issued by the U.S. Fish and Wildlife Service (USFWS) on September 5, 2006. The BO included five reasonable and prudent measures (RPM) for further limiting the amount of incidental take associated with water management operations at Jim Woodruff Dam at the head of the Apalachicola River. RPM4 of the BO, that is the subject of this memorandum, required an evaluation of the sediment dynamics and channel morphology trends in the Apalachicola River in order to improve the understanding of the dynamic channel conditions and how listed mussels (fat threeridge, *Amblema neislerii*; purple bankclimber, *Elliptoidus sloatianus*; Chipola slabshell, *Elipto chipolaensis*) are affected by the IOP. The goals of the evaluation were to:

1. Identify feasible water and/or habitat management actions that would minimize listed mussel mortality
2. Identify current patterns and trends in morphological changes, and
3. Identify additional information needed, if any, to predict morphological changes that may affect the listed mussels.

This evaluation, that was conducted for the Mobile District, U.S. Army Corps of Engineers (Corps), was based on available information, a 2-day boat-based inspection of the river from Jim Woodruff Dam at River Mile (RM) 106.5 to the mouth of the river at the City of Apalachicola (June 19 and 20, 2007) at RM 0 and best professional judgment. The 2-day field inspection was conducted in the company of mussel experts (Mr. Jerry Ziewitz, USFWS, Dr. Drew Miller, Ecological Applications, Inc. and Mr. Brian Zettle, Corps) and engineers from the Corps with extensive knowledge and experience of Corps operations on the river (Mr. Bill Stubblefield, P.E. and Mr. Terry Jangula, P.E.). The field inspection was focused on the non-tidal reach of the river that extended from the dam (RM 106.5) to RM 20 at the Sumatra gage (**Figure 1**).

Documents that were provided by the Corps and that were reviewed for this evaluation included:

- Apalachicola-Chattahoochee-Flint (ACF)1996 Annual Maintenance 5-year Report, Main Report, Mobile District, Corps of Engineers.

- ACF 1996 Annual Maintenance 5-Year Report Appendix, Mobile District, Corps of Engineers.
- ACF 2001 Annual Maintenance 5-Year Report, Mobile District, Corps of Engineers.
- ACF Navigation Maintenance Plan V1, Mobile District, Corps of Engineers.
- ACF Navigation Maintenance Plan V2, Mobile District, Corps of Engineers.
- ACF JWD IOP Biological Opinion Final Corrected prepared by the U.S. Fish and Wildlife Service, Panama City Field Office, September 5, 2006.
- USGS: (Darst and Light, 2007) Drying of Floodplain Forests Associated with Water-Level Decline in the Apalachicola River, Florida – Interim Results, 2006, Open File Report 2007-1019.
- USGS: Light, et. al, 1998. Aquatic Habitats in Relation to River Flow in the Apalachicola River Floodplain, Florida. USGS Professional Paper 1594.
- USGS: Light et al., 2006. Water-level Decline in the Apalachicola River, Florida, from 1954 to 2004, and Effects on the Floodplain Habitats. USGS Scientific Investigations Report 2006-5173.
- USACE, Mobile District, 2005: Analysis of Opposite Bank Erosion at Within-Bank Disposal Sites on the Apalachicola River.
- Apalachicola River 2002 Aerial Photography.
- Lidstone & Anderson, Inc. 1989. An Investigation of the Effects of Apalachicola River Training Dikes on Sediment Transport and Bank Erosion, Report Prepared for Mobile District, Corps of Engineers.
- USGS: Excerpts from an anonymous and un-dated document on Apalachicola River Channel Widening 2006.
- USGS: Smith and Vincent, 2004. Understanding the Physical Processes of the Apalachicola River and Floodplain: Preliminary Comments and Suggested Additional Analyses, February 3, 2004.


Additionally, the Corps provided ArcView files of banklines from 1941, 1963, 1993, 1999 and 2002 as well as other files that identified dredge material disposal sites, and the locations of recent mussel surveys.

Other documents reviewed for this evaluation included the literature on downstream effects of dams on alluvial rivers (Williams and Wolman, 1984; Ligon et al., 1995), the effects of active tectonics on alluvial rivers (Schumm et al., 2000) and the geology of Florida (Florida Geological Survey).

### 1.1. Background

The Apalachicola River formed by the confluence of the Chattahoochee and Flint Rivers (drainage area of about 17,600 mi$^2$) (**Figure 2**) has been modified anthropogenically since the 1800's (Light et al., 2006). Jim Woodruff Dam (Lake Seminole) at RM 106.5 was constructed between 1950 and 1954 and filled by 1957 (Odom, 1966). It is operated as a run-of-the river structure, and its primary influence on the downstream river is to limit the downstream sediment supply. Upstream from Jim Woodruff Dam are a further 15 mainstem dams on the Chattahoochee (13) and Flint (2) Rivers that also cause a reduction in the bed material sediment supply to the Apalachicola River. Hydrologic analysis of the streamflows at the Chattahoochee gage (1929-2004) indicate that the average annual discharge appears to be relatively unchanged in the post-dam period, but minimum flows have decreased and the seasonal distribution of flows have changed with higher fall and winter flows and lower spring and summer flows (Light et al., 2006). Hydrologic changes have not been attributed to the operation of Jim Woodruff Dam, and since 2000 a minimum flow of 5,000 cfs has been maintained by reservoir releases (Light et al., 2006). The average annual discharge at the Chattahoochee gage is 21,900 cfs, and the median flow is 15,900 cfs. Review of the peak flow record at the gage indicates that 7 of the 10 largest flows in the period of record (1920-2006) have occurred in the post-dam period (**Figure 3**).

Various navigation improvement projects have been implemented on the Apalachicola River since the 1800's, including construction of the Congressionally Authorized 9-foot by 100-foot navigation channel in 1953. Attempts to maintain the navigation channel by dredging alone were unsuccessful (Odom, 1966), and river training dikes were installed between 1963 and 1970 mainly upstream of RM 78 (USACE, 1968). Dredge material disposal was initially out-of-channel, but subsequently in-channel disposal was utilized. The last time there was significant dredging of the river was in 1999, and no dredging has been conducted since 2001 (Terry Jangula, Corps, personal communication). As part of the dredging operations snagging of woody debris from the channel was also conducted. Meander cutoffs were implemented for navigation purposes at RM 35.5, RM 36.5, RM 31.5 and RM 29 (Battle Bend) and RM 71.5 (Lower Poloway). Limestone outcrop in the bed of the river at RM 99.5 and RM 101.8 was removed in the 1950's to provide more satisfactory navigation depths (Odom, 1966), and it was again removed in the upper river reaches in the 1980s to improve navigation depths (Joanne Brandt, Corps, personal communication).

# 2. EXISTING CONDITIONS

In general terms, the Apalachicola River is a low gradient (S=0.00009), alluvial, meandering river with an average sinuosity of 1.44 in the non-tidal reach (Light et al., 2006). The river is located within the Gulf Coast Plain Physiographic province. From Chattahoochee to Blountstown (Upper Reach) the river forms the boundary between the rolling topography of the Tallahassee Hills on the east, and the Mariana Lowlands to the west and the width of the meanderbelt is somewhat constrained by the bounding hills (Figure 1). From Blountstown to the Gulf the river flows through the Coastal Lowlands, and has a much wider meanderbelt.

The non-tidal reach of the Apalachicola River (RM 106 to RM 20) has previously been subdivided into 3 subreaches (Light et al., 2006) and these subreach designations are utilized in this report (Figure 1):

1. Upper Reach (RM 106 – RM 78) (Jim Woodruff Dam to Blountstown)
2. Middle Reach (RM 78 –RM 42) ( Blountstown to Chipola Cutoff/ Wewahitchka gage)
3. Lower Reach (RM 42 – RM 20 (Chipola Cutoff/Wewahitchka gage to Sumatra gage)

## 2.1. Upper Reach

The Upper Reach extends from Jim Woodruff Dam (RM 106) to Blountstown (RM 78), a distance of 28 river miles. The valley floor slope in the reach is 0.00012, the channel slope is 0.000093 and the sinuosity is 1.3. In general terms, the river in this subreach is relatively straight, the banks are composed of cohesive, relatively erosion resistant materials, and the bed materials are composed of coarse sands, gravels and limestone outcrop (Chattahoochee Fm). Historically, the bed material in the reach was composed of poorly graded fine to medium sand ranging in size from 0.3 to 0.7 mm (Odom, 1966). As a result of dam construction, and possibly the effects of dredging and installation of the dikes, the river bed has degraded by about 5 feet near the dam and by about 2 feet at Blountstown (Light et al., 2006) (**Figure 4**), and the bed material has coarsened, both of which are river responses that are consistent with dam emplacement (Williams and Wolman, 1984: Ligon et al., 1995). It is conceivable that the amount of bed degradation would have been greater if the limestone outcrop was not present in the bed of the river at a number of locations through the subreach, and this could have led to accelerated mass bank failure of the relatively cohesive bank materials. USGS measurements of tree-line width of the main channel from aerial photography in 1941 and 2004 suggest that the mean width of the channel in this subreach has increased from 708 to 761 feet (53 feet), an increase of about 7.5 percent (**Figure 5**). Given the uncertainty associated with these measurements (Smith and Vincent, 2004) and the extensive presence of dredge material disposal sites within the reach that limit vegetation recovery, it is unclear whether the river has actually widened in this reach in the post-dam period. Field observations do not indicate that both channel banks are eroding along the reach, rather the bank erosion is currently limited to the outside of bends, which is to be expected. Comparative bank lines (1941, 1963, 1993, 1999, 2002) do not indicate much lateral adjustment of the channel in the reach.

Very little sediment appears to be stored within the subreach, except in the reach between RM 77.2 and RM 78.8, where annual dredging has been required downstream of two eroding bluffs located at RM 81 and RM 84 (Terry Jangula, personal communication). The bluffs are composed of the relatively erodible sandy Alum Bluff Group sediments that are overlain by unconsolidated to partly consolidated sands of the Citronelle Fm. Sediment supply to the reach downstream of the dam is limited to delivery by the tributaries that drain the Tallahassee Hills, local bank erosion and erosion of the bluffs. The observed bed degradation and the limited amount of sediment stored in the numerous dike fields in the reach indicate that the reach in general was supply limited following construction of the Jim Woodruff Dam.

## 2.2. Middle Reach

The Middle Reach extends from Blountstown (RM 78) to the Chipola Cutoff/ Wewahitchka gage area (RM 42), a distance of 36 river miles. The valley floor slope in the reach is 0.00018, the channel slope is 0.000094 and the sinuosity is 1.92. The river in this subreach is very sinuous and the banks are composed of a mixture of cohesive and noncohesive sediments that exhibit widespread erosion on the outside of the bends. The very high sinuosity of the river in the reach between RM 78 and RM 35 may well be the result of the river responding to active tectonics (Schumm et al., 2000). The axis of the northeast-southwest trending Gulf Trough geologic structure crosses the Apalachicola River near the confluence with the Chipola River at about RM 27 (**Figure 6**). The steeper valley floor (0.00018) on the down-dip side of the trough between about RM 78 and RM 35 requires the river sinuosity to be higher (1.92) to balance the river slope (0.000094) and thus the sediment continuity. Historically, the bed material in the reach was composed of relatively uniform sands that averaged 0.4 mm in size (Odom, 1966). As a result of dam construction, and possibly the effects of dredging the river bed has degraded by between 1 and 2 feet within the reach (Light et al., 2006), but there is no evidence that the bed material has coarsened. Sediment sources within the reach are primarily the eroding banks, many of which are composed of sands.

USGS measurements of tree-line width of the main channel from aerial photography in 1941 and 2004 indicate that the mean width of the channel in this subreach has increased from 596 to 689 feet (93 feet), an increase of about 16 percent (Figure 5). Given the uncertainty associated with these measurements (Smith and Vincent, 2004) and the extensive presence of dredge material disposal sites within the reach that limit vegetation recovery, it is unclear whether the river has actually widened in this reach in the post-dam period. Field observations do not indicate that both channel banks are currently eroding along the reach, rather the bank erosion is limited to the outside of bends, which is to be expected. Although channel widening could be a response to the upstream dams, in sand bed rivers the most likely response to the reduced sediment supply is bed degradation and not channel widening (Buchanan, 1985). Clearly, about 2 feet of bed degradation has occurred within the reach, but an increase in bank height of this magnitude (about 6 percent) is highly unlikely to cause bank stability thresholds to be exceeded and initiation of channel widening (Schumm et al., 1984; Harvey and Watson, 1986; Watson et al., 1988). However, the location of greatest channel widening (RM 78) is in an area where dredging has been required on an annual basis, and this aggradation could be the cause of localized channel widening. Additionally, the apparent widening in the reach between RM 43 and RM 46 (the “Hook and Bay” reach) is clearly due to the presence of unfilled portions of the laterally migrated 1941 channel. The lack of in-filling of the former channel locations could be due to a reduced upstream sediment supply in the post-dam period.

Comparative bank lines (1941, 1963, 1993, 1999, 2002) clearly indicate that the bends within the Middle subreach are migrating laterally as well as down-valley as a result of cutbank erosion and point bar deposition (Knighton, 1984). Analysis of bank erosion rates at banks opposite dredge disposal sites and without dredge disposal sites by the USACE did not indicate that the disposal sites were responsible for accelerated bank erosion rates. The analysis showed that the erosion rates were highest where the radii of curvature of the bends were smaller, and that the highest erosion rates were located in the reach between RM 40 and RM 60, which is the most sinuous portion of the river. The findings of the USACE study are totally consistent with the literature on erosion rates on meandering rivers (Nanson and Hickin, 1986; Harvey, 1989). Addition of the channel widths to the USACE radii of curvature and erosion rate data for the studied bends permits the Apalachicola River data to be compared with data from other rivers. The maximum erosion rates are associated with radius of curvature to channel width ratios (R/W) of between 1.5 and 2.5 (**Figure 7**), which is consistent with the trends reported in the geomorphic literature (Nanson and Hickin, 1986; Harvey, 1989). The maximum erosion rates (about 10 ft/yr) are consistent with those of the Alabama River (Harvey and Schumm, 1994), but are very low in comparison with those reported for other large alluvial rivers. The highest normalized erosion rates (erosion rate divided by channel width) on the Apalachicola River (**Figure 8**) are an order of magnitude lower than those reported for the Canadian rivers (0.14;

Nanson and Hickin, 1986) and the Sacramento River (0.26; Harvey, 1989). This does not suggest that the measured bank erosion on the Apalachicola River is in response to an upstream sediment deficit.

### 2.3. Lower Reach

The Lower reach extends from the Chipola Cutoff/ Wewahitchka gage area (RM 42) to the Sumatra gage at RM 20, a distance of 22 river miles (Figure 1). The valley floor slope in the upper portion of the subreach reach is 0.00018, the channel slope is 0.000086 and the sinuosity is 2.1. The upper portion of this subreach of the river (RM 42- RM 35) is very sinuous and the banks are composed of a mixture of cohesive and noncohesive sediments that exhibit widespread erosion on the outside of the bends that leads to active channel migration. As stated previously, this may well be the result of the river responding to active tectonics (Schumm et al., 2000). The high sinuosity in this part of the subreach could also be due to diversion of about 35 percent of the flow but not very much of the bed-material load into the Chipola Cutoff at RM 41.5 (Odom, 1966) which effectively increases the sediment supply to the subreach, which in turn accelerates the meander processes (Anthony and Harvey, 1991). Between RM 35 and RM 20 the sinuosity is much lower (1.27) and there is little evidence of channel migration. The lower valley floor slope (0.00012) on the up-slope side of the Gulf Trough syncline (downstream of the axis) is consistent with the presence of an active geologic structure (Figure 6). Comparative mean bed elevation data (1960 and 2001) suggest that the bed of the channel may have degraded between RM 29 and RM 35, possibly as a result of the cutting off of two bends in the reach. Stage data at the Sumatra gage do not indicate that the bed of the river has degraded or the channel has widened in the post-dam period (Figure 4; Light et al., 2006). Historically, the bed material in the reach was composed of relatively uniform sands that averaged 0.4 mm in size (Odom, 1966). Sediment sources within the reach are primarily the eroding banks, many of which are composed of sands as well as erosion and reworking of dredge material disposal sites (e.g., Sand Mountain).

USGS measurements of tree-line width of the main channel from aerial photography in 1941 and 2004 indicate that the mean width of the channel in this subreach has increased from 390 to 473 feet (83 feet), an increase of about 21 percent (Figure 5). Given the uncertainty associated with these measurements (Smith and Vincent, 2004) and the extensive presence of dredge material disposal sites, especially within the reach between RM 35 and RM 42 that limit vegetation recovery, it is unclear whether the river has actually widened in this reach in the post-dam period. Field observations do not indicate that both channel banks are eroding along the reach, rather the bank erosion is limited to the outside of bends, which is to be expected. However, channel cutoffs could be responsible for localized channel widening especially in the vicinity of Sand Mountain.

## 3. TRENDS

There is little doubt that the non-tidal reach of the Apalachicola River has responded to the construction of the upstream dams and the consequent reduction, or possibly elimination, of the bed material supply from upstream by degrading and possibly widening. Light et al. (2006) concluded that channel conditions in the last decade (1995-2004) had been relatively stable.

In the Upper Reach, the channel has degraded, but further degradation potential is limited by the presence of the limestone outcrop and coarser bed materials, as well as local sediment sources downstream of RM 84. The presence of relatively cohesive materials in the banks and the reinforcement of the toes of many of the banks with limestone or other geologically more erosion resistant materials limits the potential for bank erosion, lateral migration and channel widening. Additionally, the presence of extensive dike fields in the reach further limits the potential for lateral channel adjustment. Given the uncertainty in the comparative channel width data, it is not possible to speculate on future trends in channel width.

In the very sinuous Middle Reach, the riverbed has degraded by about 2 foot, but that amount of degradation is very unlikely to be sufficient to cause widespread instability of the channel and general channel widening. The channel is actively migrating as a result of cutbank erosion and point bar accretion, and as a result the hydraulic characteristics and resulting erosional and depositional components of the bends continue to change in time and space. Erosion rates within the highly sinuous reach are low in comparison to other large alluvial rivers, and are unlikely to increase over time. A number of bends have low radii of curvature (RM 62, RM 50, RM 43), and it is conceivable that in the not too distant future these bends could cutoff leading to reduced sinuosity and increased hydraulic slope. In fact, it appears that the cutoff process has already commenced at the bend centered on about RM 50. Given the uncertainty in the comparative channel width data, it is not possible to speculate on future trends in channel width.

The highly sinuous upper portion of the Lower Reach (RM 42 to RM 35) appears to be net aggradational, possibly as a result of diversion of about 35 percent of the flow of the Apalachicola River into the Chipola cutoff without a commensurate proportion of the bed material load. Between RM 35 and RM 29 the bed has degraded most probably as a result of the bend cutoffs, but further degradation is unlikely given the accelerated sediment supply to the river in the vicinity of RM 35. The channel in the sinuous upper portion of the reach is actively meandering and is likely to continue to do so. The low radii of curvature of the bends between RM 40 and RM 38 suggest that natural cutoffs could occur in the future, which would lead to a reduction in channel sinuosity and an increase in hydraulic slope. Given the uncertainty in the comparative channel width data, it is not possible to speculate on future trends in channel width.

# 4. MUSSEL HABITAT

During the course of the boat inspection of the non-tidal reach of the Apalachicola River, a number of locations where fat threeridge mussels (FTM) were present were identified by the mussel experts and these sites were inspected. Sites inspected that had FTM present included RM 73.2L (downstream end of a point bar) (**Figure 9**), RM 51.8L (downstream end of a point bar & mouth of Equiloxic Creek) (**Figure 10**), RM 48L (downstream of a sharp bend caused by erosion-resistant bank materials) (**Figure 11**), RM 47.2R (dike field) (**Figure 12**) and RM 43.1L (backwater-induced bank-attached bar) (**Figure 13**). While these sites have different macro-scale physical characteristics, they all have common meso- and micro-scale hydraulic characteristics (Harvey et al., 1993). All of the sites are located in flow separation zones (eddies) at higher flows than were present in the river (about 5,000 cfs) at the time of the field inspection. Within the eddy zones finer sediments (fine to medium sand and some silts and clays) are deposited against the bankline and appear to create conditions that provide suitable FTM habitat. In general, the flow separation zones occur on the inside of the bends downstream of the point bar apexes, and therefore, the FTM habitat appears to be related to meander bend dynamics. Consequently, the location of the preferred habitat is likely to change through time and space as the bends migrate laterally and down-valley. This is in contrast to the situation where eddy deposits are formed in fixed locations within canyons (Schmidt and

Rubin, 1995; Cenderelli and Cluer, 1998). Where the local sinuosity is very high and there are a number of very low radii of curvature bends present that cause upstream backwater, mid-channel and bank-attached bars are formed in the upstream limbs of the bend because of the very high energy losses through the bends (Bagnold, 1960; Harvey, 1989). Such conditions are present for example from RM 43 to RM 46. The eddy deposits associated with the backwater-induced bars also appear to create suitable habitat for the FTM.

Qualitative sampling data for the FTM in the Apalachicola River were provided by the Corps and Dr. Miller, and these data appear to support the hypothesis that the FTM habitat is formed and maintained by meander processes (**Table 1**). Within the limits of the ability to identify the FTM sampling sites on the 2002 aerial photography, it appears that the preferred habitat for the FTM is located downstream of the bend apexes within bank-attached eddy deposits and in eddy deposits associated with backwater-bars that have formed in the upstream limbs of the bends. It is of interest to note that the highest number of FTM were collected in the eddy deposits in a dike field at RM 47.4R, which does suggest that if the amount of available habitat is a limiting factor for the FTM it could be created.

Table 1. Locations of FTM habitat (Source of data Dr. D. Miller).

| Location (RM) | CPUE/hr | Site Description |
|---|---|---|
| 49.6R | 18 | d/s end of bend |
| 48.7R | 132 | crossing |
| 48.2L | 6 | d/s end of bend |
| 47.5L | 54 | d/s end of bend |
| 47.4R | 774 | dike field |
| 46.9R | 258 | d/s end of bend |
| 46.4L | 276 | d/s end of bend |
| 46.0R | 72 | backwater bar |
| 45.5L | 11 | d/s end of bend |
| 44.5R | 84 | d/s end of bend |
| 44.3L | 558 | d/s end of bend |
| 43.9R | 522 | point bar near apex |
| 43.4R | 84 | backwater bar |
| 43.1L | 486 | backwater bar |
| 43.0L | 354 | backwater bar |
| 42.7L | 120 | d/s end of bend |
| 42.2L | 144 | d/s end of bend |
| 42.1R | 12 | point bar apex |
| 41.3L | 18 | d/s end of bend |
| 41.0L | 48 | d/s end of bend |
| 40.6L | 3 | d/s end of bend |
| 40.5L | 30 | d/s end of bend |
| 40.4 | 0 | backwater bar |

FTM mortality observed in 2006 following the high sustained flows of 2005 (peak flow of 159,000 cfs at the Chattahoochee gage) is a matter of concern for the Corps and the USFWS. Three sites were inspected where FTM mortality had occurred following the 2005 high flows. These included RM 44L (**Figure 14**) and RM 43.6R (**Figure 15**) on the Apalachicola River and

Swift Slough (RM 40.2L) (**Figure 16**). Mortality of the FTM at each of the sites appears to be related to deposition of sandy bed material, and can be explained by the dynamics of the river. It is axiomatic that most changes in a meandering river occur during periods of high flow, since these are the conditions that cause sediment transport, bank erosion and sediment deposition. At RM 44L, the FTM mortality occurred in an eddy deposit on the downstream end of the bend centered at RM 44.5. Field observations of the conditions at the site (age and size of the willows) indicate that the eddy deposit has moved downstream through time in response to the shift of the bend caused by erosion of the opposing bank (**Figure 17**). Thus, at this site, suitable FTM habitat prior to the 2005 high flows is no longer present at the same location, and FTM present at the site appear to have been killed by excessive sedimentation that is expected as the bendway moves across and downvalley. However, the downstream shift of the eddy appears to be creating suitable FTM habitat downstream of that identified prior to 2005 which indicates that FTM habitat at a given location is likely to be ephemeral, but that new habitat is formed as the bends adjust.

At RM 43.6R, FTM mortality was associated with growth of a bank-attached bar on the outside of the bend. An extremely low radius of curvature bend is located downstream of this site at RM 43. During the high and long duration flows of 2005, the downstream bend created backwater conditions that induced further sedimentation on the bank-attached bar, which was probably responsible for the deaths of the FTM that were present at the site prior to 2005 when the site provided suitable habitat. Whether new suitable FTM habitat will be created in this general location is difficult to predict without a better knowledge of the hydraulic characteristics of the river at a range of higher flows. It is quite possible that the bank-attached bar has a limited lifespan as suitable habitat for FTM.

In the upper reaches of Swift Slough, which is a distributary channel for the Apalachicola River at about RM 40.2L, there is little doubt that relatively recent flows have introduced sandy bed material into the upper reaches of the slough and dead FTM were observed in the channel (**Figure 18**). Prior to 2005, there appears to have been a population of FTM in the upper reaches of Swift Slough, but the large numbers of mussels observed in the channel following the 2005 high flows were probably transported into the slough (Jerry Ziewitz, USFWS, personal communication). During the 2005 high and long duration flows it is quite likely that the cumulative energy losses created by the low radius of curvature bends between RM 38 and RM 40 created sufficient backwater to cause in-channel sedimentation at about RM 40. Additionally, the loss of about 35 percent of the flow without a commensurate amount of the sediment into the Chipola Cutoff was probably also responsible for in-channel sedimentation upstream of RM 40. Annual dredging of the reach between the cutoff and RM 40 was required historically to permit navigation (Terry Jangula, Corps, personal communication), and dredging has not been conducted since 2001, which could have led to a build up of bed material in the reach prior to and subsequent to the 2005 event. The hydraulics of the river at the mouth of Swift Slough are not known with certainty, but it is likely that during the high flows of 2005, sediment deposition was occurring while the bankfull flow was exceeded (about 50,000 cfs) and the overbank areas were submerged. During the recessional flows, it is quite possible that the bed material deposited in the river at the mouth of Swift Slough was re-entrained by flows entering Swift Slough which is a steep distributary with fairly high velocities (Light et al., 1998). Hydraulic modeling of the river and slough will be required to verify or reject this hypothesis. If the hypothesis is correct, it again points to the ephemeral nature of FTM habitat, which will change in response to changes in the meander planform and dynamics of the river.

# 5. CONCLUSIONS

Based on the review of the information, data and documents provided by the Corps, other information derived from the scientific literature, as well as the field inspection of the non-tidal reach of the Apalachicola River between Jim Woodruff Dam (RM 106.5) and the Sumatra gage (RM 20) the following are concluded:

1. Construction of Jim Woodruff Dam as well as the other federal and non-federal dams on the Chattahoochee and Flint Rivers has significantly reduced the bed material sediment load to the Apalachicola River, but the hydrology of the Apalachicola River has not changed significantly in the post-dam period.

2. The Apalachicola River has responded to the reduced bed material sediment supply from upstream by degrading. In the Upper Reach (RM 106.5 to RM 78) the degradation has ranged from about 5 feet in the upstream part of the reach to about 2 feet in the downstream part of the reach. Further degradation is likely to be prevented by the presence of limestone outcrop and possibly by coarser bed material. About 2 feet of degradation has occurred in the Middle Reach (RM 78 to RM 42). Between RM 35 and RM 29 in the Lower Reach degradation has occurred in response to bend cutoffs. Available data do not indicate that the river is continuing to degrade, and in fact the uniformity of the average channel slopes in all three reaches (0.000093 – 0.000095) suggests that the river may have attained a measure of equilibrium.

3. Because of the limitations of the data, and the extensive presence of un-vegetated dredge disposal sites along the river, it is very unclear whether the Apalachicola River in general has widened in response to the upstream dams. Clearly, local widening has occurred at specific locations where dredging and channel cutoffs have occurred.

4. Between RM 78 and RM 35 the Apalachicola River is a very sinuous (1.92) and actively meandering river which may be due to the presence of a tectonically-active trough (Gulf Trough) whose axis crosses the river just downstream of the mouth of the Chipola River. Maximum erosion rates on the outside of the bends are similar to those measured on the Alabama River, but are very low compared to other large alluvial rivers.

5. FTM habitat in the Apalachicola River appears to be associated with eddy deposits that are located on the inside of bends downstream of the point bar apexes, around bank-attached and mid-channel bars that are located in backwatered reaches upstream of low radii of curvature bends, and in dike fields.

6. FTM habitat is essentially ephemeral and changes location through time as the bends themselves adjust by lateral and downstream migration. Because of the limited mobility of FTM, sites that may have provided suitable habitat prior to a morphogenetically significant event such as the 2005 high flows may end up being unsuitable following the event which leads to mortality. The duration of site suitability for FTM is most probably related to the frequency and magnitude of high flow events. However, as existing habitat is lost as a result of meandering processes, new habitat is also created.

7. Over a longer period of time the hydraulic connections and sediment transport relations between the mainstem river and distributary channels such as Swift Slough will change

in response to changes in the planform and hydraulics of the mainstem. Ultimately, individual distributary channels are ephemeral features, but active meander processes are likely to create new channels as older channels are eliminated.

# 6. RECOMENDATIONS

This cursory geomorphological investigation of the non-tidal reach of the Apalachicola River has identified a number of issues that require resolution if the dynamics of the river and FTM habitat are to be more fully understood and predictable. Identified issues include:

1. Whether the river has in fact widened in response to the upstream dams, and if so what are the driving processes and mechanisms.

2. Whether the river has fully adjusted to the presence of the upstream dams or if further channel degradation will occur through time in the Middle and Lower Reaches. In other words, will the degradation that was experienced in the Upper Reach move downstream through time, or is the sediment supply within the reaches sufficient to maintain the channel bed at its current elevation.

3. Quantification of the spatial and temporal relationships between the meander dynamics of the river and the formation and maintenance of FTM habitat.

4. Assessment of the amount of habitat that is available for the FTM in the meandering reaches of the Apalachicola and whether the lack of habitat is a limiting factor for the species.

To address the identified issues it is recommended that the following be conducted:

1. An in-depth quantitative geomorphic assessment of the river between the dam and RM 20.

2. Development of a one-dimensional sediment-continuity analysis using the SIAM computer code.

3. Development of two-dimensional hydrodynamic models of selected FTM habitat sites located: (1) downstream of a bend, (2) in association with a backwater-induced bar complex, and (3) in the upper reach of a distributary channel.

4. In conjunction with the mussel experts use the results of the above to develop a physical process-biological response model that can be used to predict the impacts of water management operations at Jim Woodruff Dam on FTM habitat.

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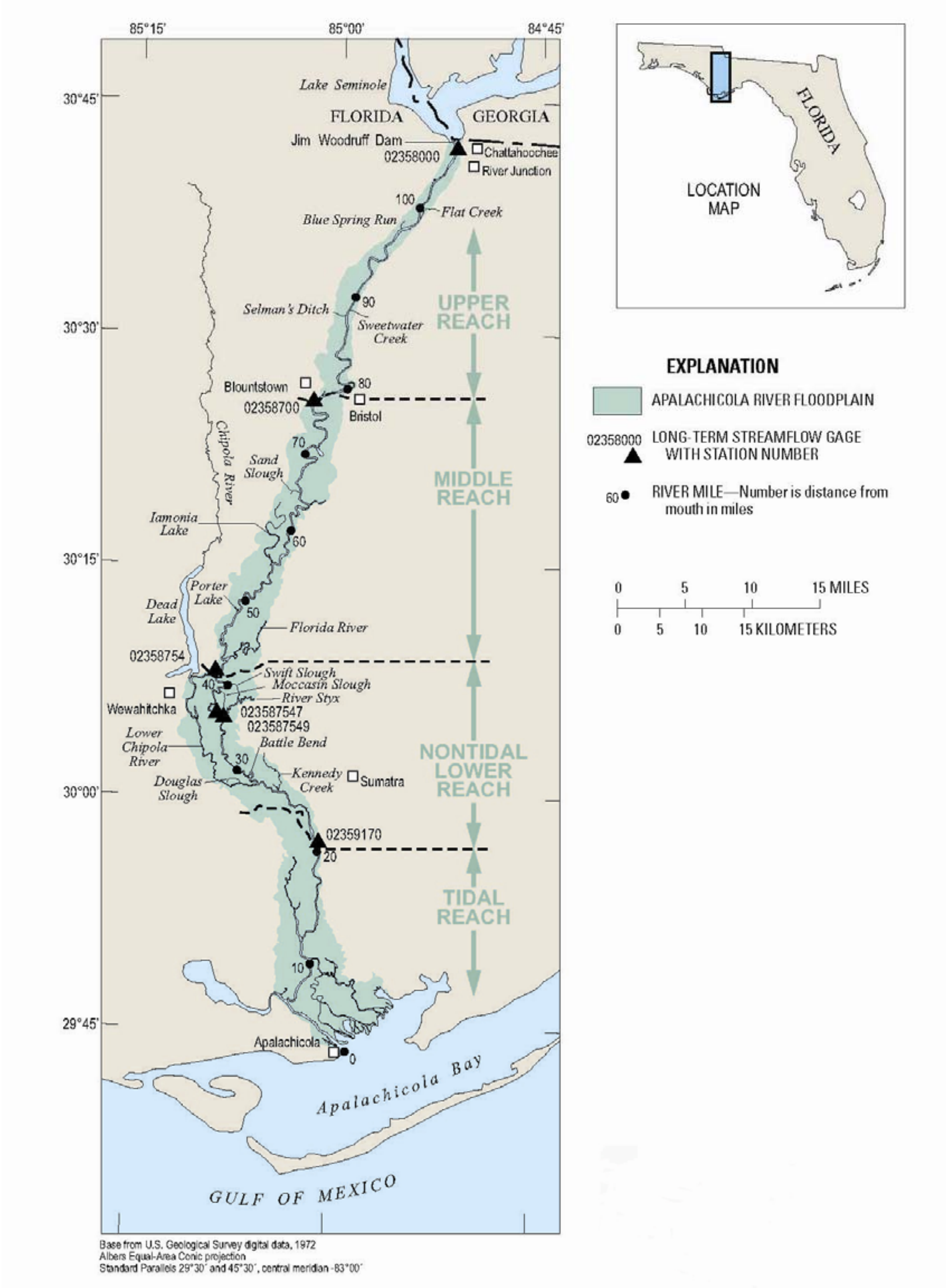


Figure 1. Major reaches of the Apalachicola River and location of long-term streamflow gaging stations (Light et al., 2006).

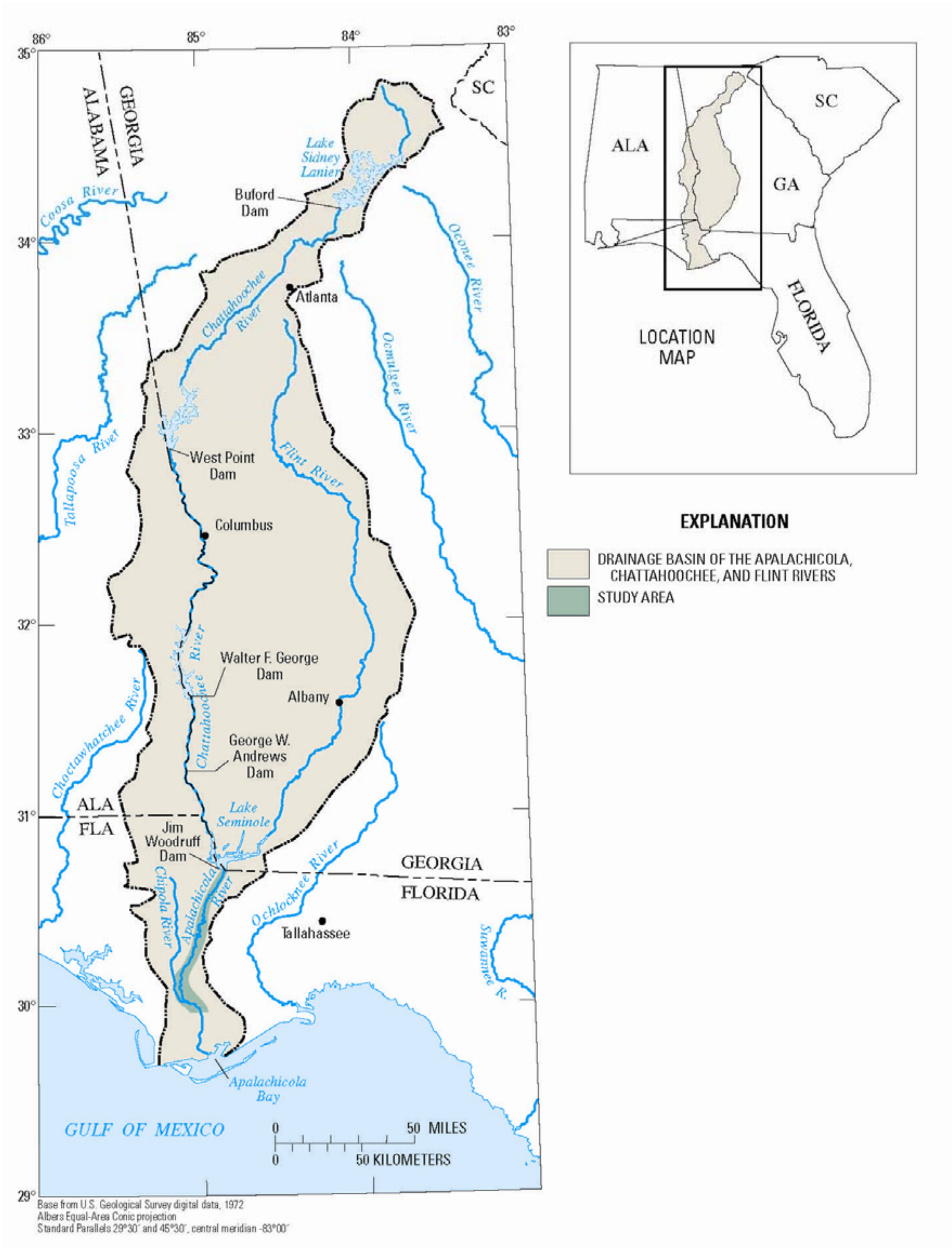


Figure 2. Drainage basin of the Apalachicola, Chattahoochee, and Flint Rivers in Florida, Georgia, and Alabama (Light et al., 2006).

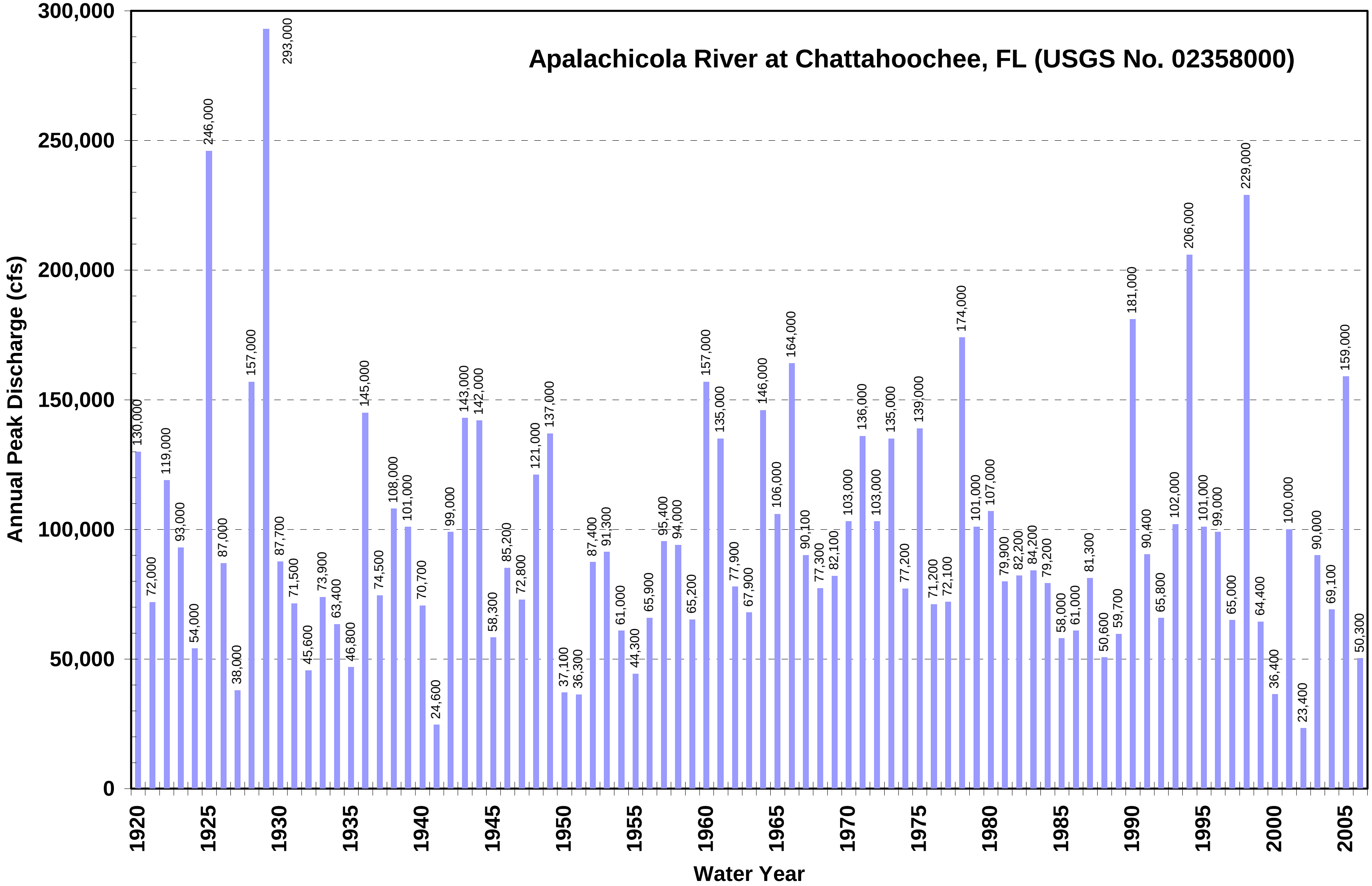


Figure 3. Annual peak flow record (1920-2006) for the Apalachicola River at Chattahoochee, Florida.

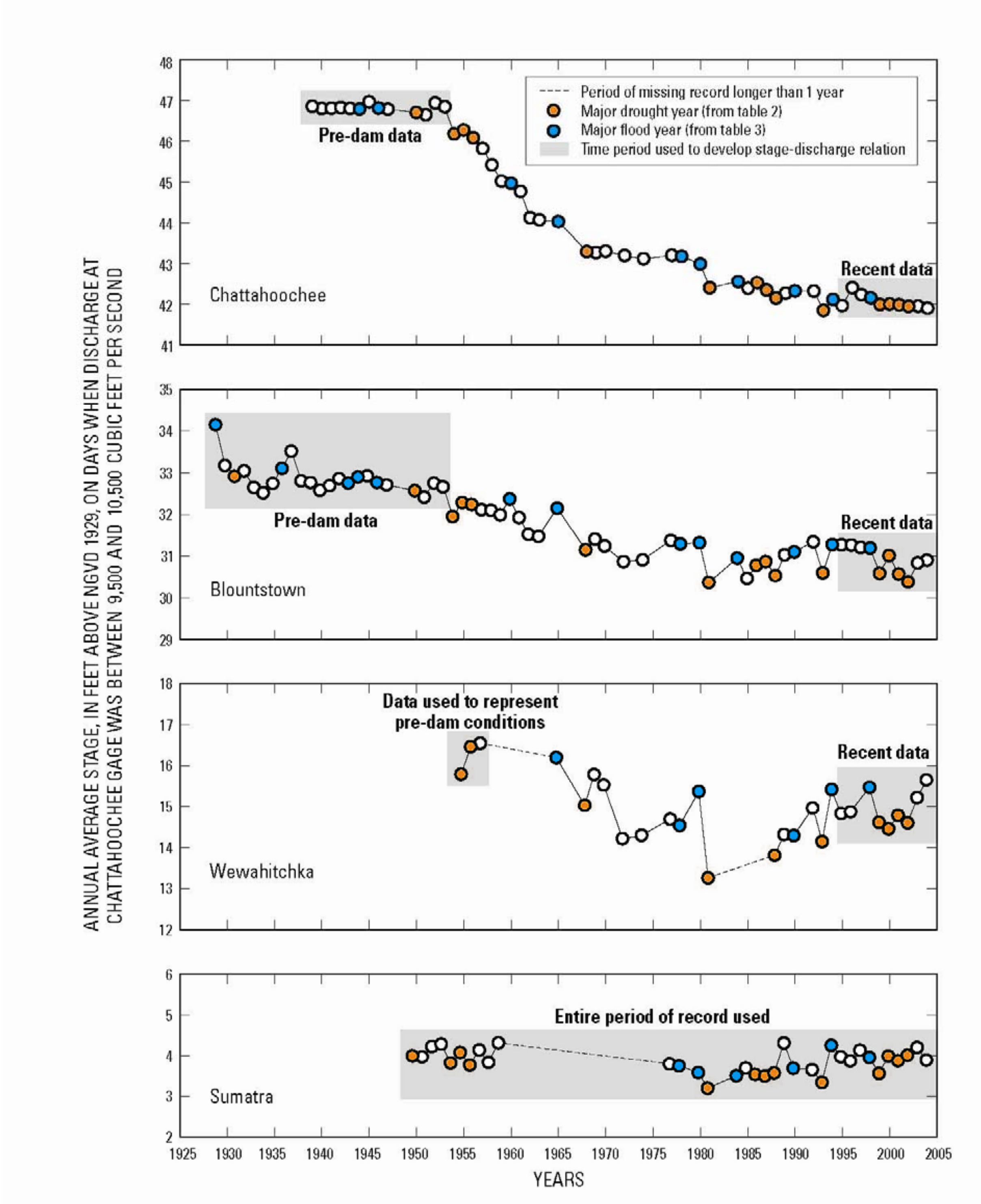


Figure 4. Average annual stages for the four gages on the Apalachicola River for flows at the Chattahoochee gage between 9,500 and 10,500 cfs (Flint et al., 2006).

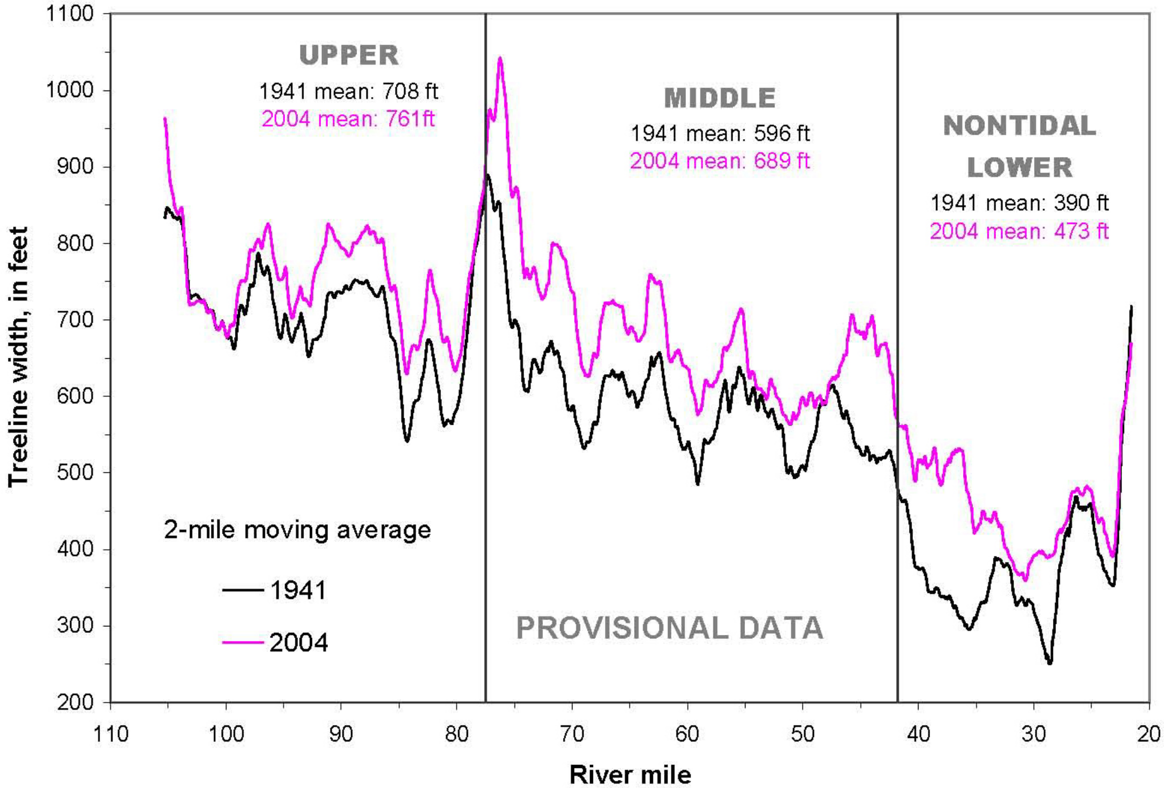


Figure 5. Tree-line width of main channel of nontidal reach of Apalachicola River, Florida, in 1941 and 2004. Widths were measured at approximately 2,800 points at 164-foot intervals along the channel centerline in aerial photographs. Data show a 2-mile (64-point moving average. River miles represent those depicted on the most recent USGS quadrangle maps available in 2005 (undated USGS data provided by Mobile District COE).

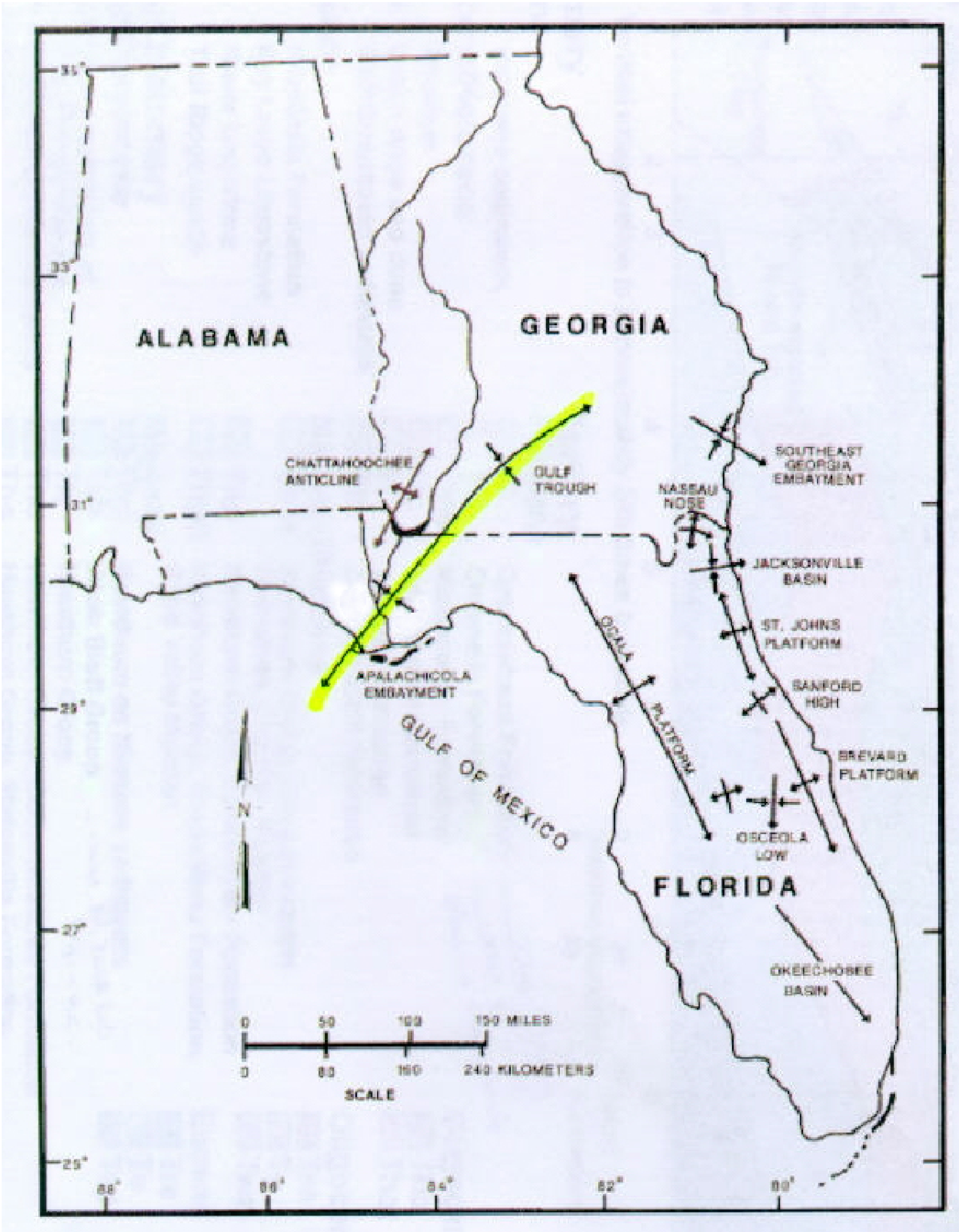


Figure 6. Map showing the location of geologic structures in the State of Florida. Highlighted is the Gulf Trough syncline that crosses the Apalachicola River.

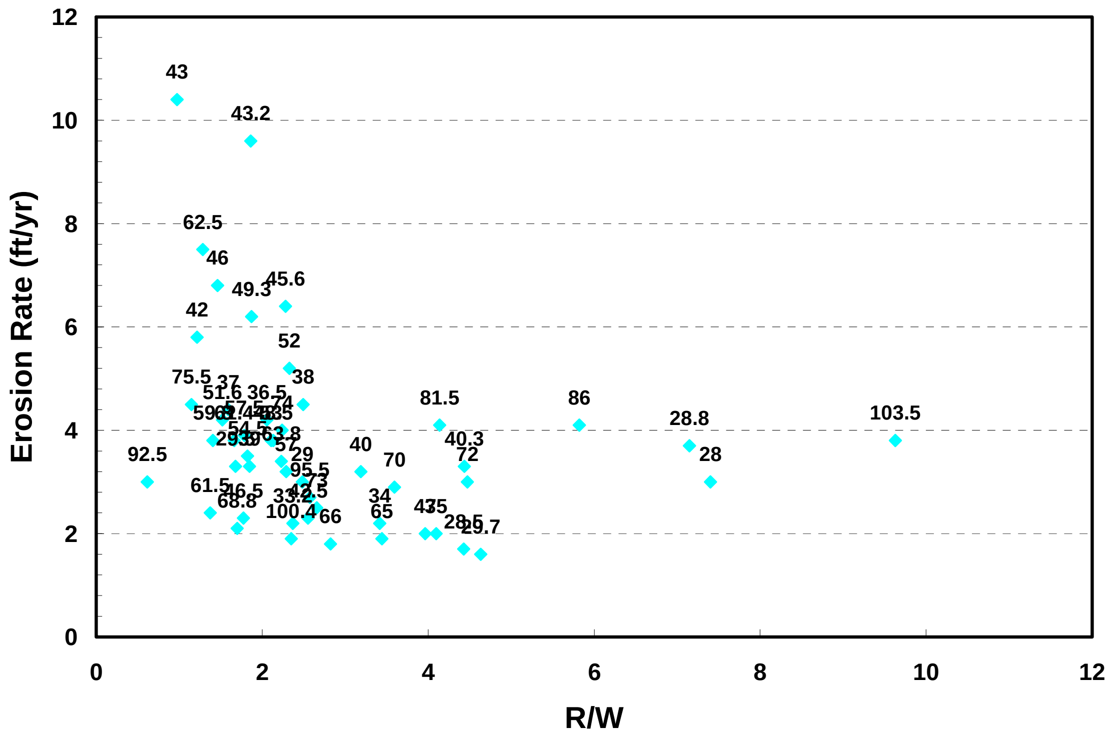


Figure 7. Erosion rates plotted against the radius of curvature to channel width ratio for bends in the Apalachicola River. Numbers shown on the figure are river miles (source of erosion rate and radius of curvature data is USACE).

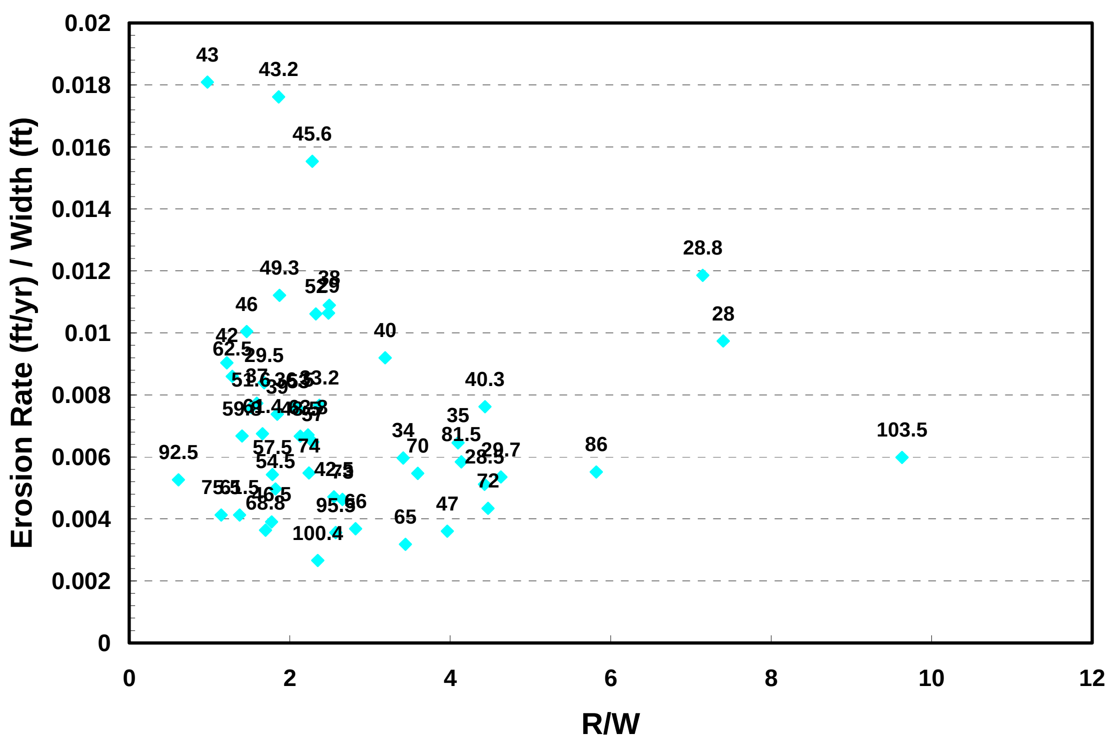


Figure 8. Normalized erosion rates plotted against the radius of curvature to channel width ratio for bends in the Apalachicola River. Numbers shown on the figure are river miles (source of erosion rate and radius of curvature data is USACE).

Figure 9. Upstream view of FTM habitat at RM 73.2L.

Figure 10. Upstream view of FTM habitat at RM 51.8L.

Figure 11. Upstream view of FTM habitat (upstream of house boat) at RM 48L.

Figure 12. View of sediment deposition and FTM habitat in the dike field at RM 47.2R.

Figure 13. FTM habitat associated with a backwater-induced bar at RM 43.1L.

Figure 14. Upstream view of FTM mortality site at RM 44L.

Figure 15. Upstream view of FTM mortality site at RM 43.6R (Kentucky Landing).

Figure 16. Upstream view of the mouth of Swift Slough with the Apalachicola in the background. Note the sand deposits in the bed of the slough.

Figure 17. Downstream view of willow succession at RM 44L.

Figure 18. Downstream view of sand waves on the bed of Swift Slough.