

Examination of Sedimentation in Riparian Areas at Ft. Benning Military Installation, Georgia

Project Report – August 13, 2008

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Statement of Problem

Although sediment is listed as the most common non-point source (NPS) pollutant of surface waters in the United States (<http://www.epa.gov/owow/nps/facts/point1.htm>), we lack a clear understanding of sediment dynamics within watersheds. Specifically, we do not understand the influence of legacy sediment accumulation on total suspended solid (TSS) concentrations and loads in streams. The need for this information is particularly acute in the southeastern United States where agricultural land abuse in the 19th and early 20th centuries caused major erosion from uplands and subsequent deposition in riparian corridors (Trimble 1974). This period, known as the cotton era, was characterized by failure to incorporate conservation practices into farming activities (Lockaby 2008). Trimble (1974) estimates that the total erosion was sufficient to have lowered the entire Piedmont physiographic region by 10 - 30 cm.

It is clear that much of the sediment lost during the cotton era was deposited in lower topographic positions (Lockaby 2008). In the Piedmont of Georgia, Jackson et al. (2005) estimated that approximately 1.6 m of sediment from historic cotton farming had been deposited atop the original or antecedent floodplain of Murder Creek. This depth equated to erosion losses of 12.2 cm of topsoil across the entire watershed. In higher order streams such as the Roanoke River within North Carolina, deposition of historic sediments may have been much greater and is estimated at 6 m in some locations (Dr. Cliff Hupp, USGS - personal communication). Consequently, many streams in the eastern United States have undergone morphological changes in terms of burial of surrounding wetlands and a prevalence of incised channels with unstable streambanks (Walter and Merritts 2008, Jackson et al. 2005).

These sediment deposits also occur within stream channels and may be exported over time as contributions to the total sediment loads of streams and rivers. In Murder Creek, 22-35% of the suspended sediment load was thought to be associated with the bedload (Jackson et al. 2005). The potential for legacy bedloads to contribute to total stream loads has raised questions regarding whether land use activities are solely to blame for elevated concentrations (Smith 2006). This is a critical issue to land managers who may be cited by regulatory agencies for degradation of water quality.

The issue is not confined to the Southeast and currently is a major source of debate in connection with the Chesapeake Bay. In that region, as in the Southeast, the relationship of legacy sediment to water quality is unclear and Smith (2006) refers to the issue as the 'culprit or scapegoat' debate. Although the degree of stability associated with legacy sediment is not well understood in many locations, the issue is deemed sufficiently important by the Pennsylvania legislature to provide funds for conservation measures including legacy sediment remediation (PA Resource Protection and Management Act, 2007, Article XVII-E).

Clarification of the role of legacy sediments is a particularly critical issue at Ft. Benning, Georgia where the landscape was highly disturbed during the cotton era and remained so after

acquisition by the military in 1918. There is clear evidence of historic farming activity including the presence of old water wheels, remnants of small bridges and abandoned, farm road embankments. Although a detailed timeline regarding land use is unavailable for the location, there have been determinations that the landscape was 97% forested in 1827 based on survey records (L.M. Olsen, V.H. Dale, and T. Foster, unpublished report to SERDP) but was highly disturbed in 1944 (Maloney et al. 2008). Unfortunately, the 1827 and 1944 temporal snapshots represent pre- and post cotton era information but provide no insights on the extent of agriculture from 1830-1920.

To that end, our objectives were to examine the following aspects of the legacy sediment question at Ft. Benning:

- (1) the depth of historic sediment on the floodplains of Bonham Creek and Sally Branch.
- (2) recent (since 1964) sedimentation rates and sources using ^{137}Ce isotope analysis.
- (3) recent (last 2-3 decades) sedimentation rates using a dendrogeomorphic approach.
- (4) current export near new stream crossings on both streams.
- (5) amounts of historic sediment within stream beds.

Study Area

Ft. Benning straddles the fall line or the line of demarcation between the Piedmont and Coastal Plain physiographic regions in Georgia. Both Bonham Creek and Sally Branch are situated in the upper coastal plain in close proximity to the fall line. These are 4th order streams and portions of both watersheds lie within the newly constructed Digital Multipurpose and Practice Range Complex (DMPRC). The area of the Bonham Creek watershed is approximately 1270 ha and that of Sally Branch is 2530 ha while the respective slopes are 5.04 and 5.45 % (Bhat et al. 2006). Floodplain areas are 62 and 106 ha respectively.

The riparian zones are forested primarily with sweetgum (*Liquidamber styraciflua*), water oak (*Quercus nigra*), red maple (*Acer rubrum*), yellow poplar (*Liriodendron tulipifera*), and loblolly pine (*Pinus taeda*). Soils include the Bibb (Typic fluvaquent) and the Chastain series (Fluvaquentic endoaquept) (Lockaby et al. 2005). Several newly constructed, dirt roads cross each stream and seasonal precipitation was less than the 30 yr average during much of 2007 (Figure 1).

Methods

All sampling occurred from the summer of 2007 through summer, 2008 except for that associated with the sediment pins. The latter measurements began in January, 2007.

Soil cores – Sampling occurred in a grid pattern consisting of transects oriented perpendicular to the main axis of each stream. Transects were 50 m apart and extended from stream banks to uplands, a distance that ranged from 10 - 100 m. Along each transect, plots for core and dendrogeomorphic sampling were established at 10 m intervals (Figure 2).

Soil cores were extracted using an auger to 1.5 – 2.0 m depths which coincided with the occurrence of abrupt changes in texture and color from sandy clay to sand and dark gray to white respectively. At the juncture of the dark gray clayey and white sandy layers, dead tree roots, portions of residual stumps, and logs were sometimes visible (stumps and logs protruding from stream banks). Due to the aquic nature of the soils, the portion of the soil profile from an upper depth of approximately 30-45 cm and extending down into the sand was reduced and saturated continuously. In addition, profiles along stream banks were often used to estimate depths to the sandy layer and, when possible, cores were taken within the stream beds in order to estimate depths of historic sediment there (i.e. depth of bed load). The morphology of the sandy layer at depth along Bonham Creek and Sally Branch was similar to the description provided by Jackson et al. (2005) of the original floodplain surface at Murder Creek.

A total of 168 cores were collected, i.e. 118 from Bonham and 50 from Sally. Each core was divided into 30 cm intervals and subsampled for the following: color, texture, number of protruding live and dead roots, and bulk density. Also, relative elevations were recorded for all plots and within stream channels.

Elevations - Elevations were measured at each sampling point on both floodplains using a level and standard telescoping rod. For each section, all transect plots were surveyed to allow comparisons both between and among transect plots. Also, where transects intercepted streams, the relative elevations of the stream banks and bottom (mid-point across the creek) were surveyed.

Using ground elevations, topographic cross-sections were prepared for each stream transect. We then used the soil core depths to the original surface for each corresponding plot to prepare a historical topography relative to current conditions. Cross-sections were plotted for each transect and examined for trends related to stream beds. This approach allowed estimation of the depth of residual cotton era alluvium within channels.

Dendrogeomorphic sampling - On each plot, a maximum of three small trees (3-30 cm at the root collar) were sampled according to the procedure outlined in Hupp and Morris (1990). This consisted of severing the tree at the root collar and at the soil surface (the soil surface being above the root collar if sediment deposition was occurring and below if scouring or export dominated). The difference in age between the two points was ascertained and the distance above or below the root collar was expressed as an annual rate of sediment import or export respectively. A total of 367 trees were felled, i.e. 248 on Bonham Creek and 119 along Sally Branch.

¹³⁷Cesium atmospheric fallout fingerprint – Dr. Jerry Ritchie with the USDA Hydrology and Remote Sensing Laboratory in Beltsville, MD conducted the preliminary evaluations of sediment accretion and sources at Ft. Benning using Cs-137 methods. Dr. Ritchie has extensive experience analyzing Cs-137 activity as a marker for soil accretion and movement. These methods rely on the detection of ¹³⁷Cs, a radionuclide that was transmitted worldwide as a result of atomic bomb testing. Because ¹³⁷Cs readily adsorbs to sediment particles it has become a very useful marker/tracer for examination of sediment movement (Ritchie and McHenry 1990, Brigham et al. 2001). Sediment accretion in the Bonham Creek and Sally Branch floodplains was evaluated by collecting 35-cm soil cores (one per floodplain) which were divided into 5-cm increments. The analysis of sediment accretion and sources were conducted using Cs-137 methods starting in September 2007. For each core, soil increments were individually bagged in a freezer bag and labeled for transport to Auburn University. At Auburn, all samples were oven dried, crushed, and sieved to 2-mm. Samples were then shipped to Dr. Ritchie's facility in Beltsville for analysis of ¹³⁷Cs activity. Gamma-ray analyses were made at the U.S. Department of Agriculture's Agricultural Research Service Hydrology Lab in Beltsville, using the Canberra-2000 Genie-2000 Spectroscopy System to quantify ¹³⁷Cs activity (Bq kg⁻¹) in each sample.

To estimate floodplain soil accretion, maximum ¹³⁷Cs soil activity among each of the soil core increments was identified and the maximum ¹³⁷Cs activity was linked to the maximum exposure year of 1964 (year of maximum worldwide atomic bomb testing). A rate of accretion was calculated based on the depth of soil above the increment. For sediment sourcing, the collected sediment material and potential sources were analyzed for ¹³⁷Cs as described above. To quantify the relative contribution of each source to sediment in the creek, a simple mixing model was employed (see Nagle and Ritchie 2006 for details). It was understood that because of the limited scope of this work, all results were considered preliminary and may change with increased sampling.

Sediments were also collected from bedload material in the upper and lower reaches of Bonham Creek and Sally Branch. In addition, several soil samples were collected from potential sediment sources in the watershed including upland areas surrounding the floodplain, the floodplain, roadsides leading to creek crossings, and stream bank soil material. Each of these samples was treated as previously described.

Sediment pins – Whereas cores, dendrogeomorphic samples, and ¹³⁷Cesium fingerprinting were used to estimate longer term sedimentation, pins were installed to estimate current rates. Metal washers were welded to midpoints of 1m long, steel welding rods. These were deployed in a grid pattern at each of 7 road crossings on either Bonham Creek or Sally Branch. Rods were inserted into the soil until the washer was level with the soil surface and changes in distances from the soil surface to the washer were recorded monthly. A total of 330 rods were placed along stream banks at the crossings.

Summary of Results

Cores - The depth of the legacy alluvium averaged 176 cm and 172 cm on Bonham Creek and Sally Branch respectively. The overall mean of 174 cm is very close to the 1.6 m depth observed by Jackson et al. (2005) on Murder Creek in Georgia. There were no statistical differences among reaches or sides (east vs. west) of floodplains in terms of depth.

The depths and bulk densities recorded for the soil cores translate to a legacy sediment mass estimate of 2.3 t/m² on both Bonham Creek and Sally Branch. Expanded to a floodplain basis, we estimate that approximately 1.4 M and 2.4 M t of sediment accumulated on the Bonham and Sally floodplains respectively during the cotton era. These amounts equate to respective losses of 9.2 and 7.5 cm of topsoil across the watersheds of Bonham Creek and Sally Branch. Our estimates coincide closely with those of Jackson et al. (2005) for Murder Creek and Trimble (1974) for the entire Piedmont.

Elevations - In Bonham Creek, channel depths and their proximity to the original layer increased with distance downstream. In the highest reach measured, stream beds averaged 0.55 m above the original layer although the stream bed eventually intercepts the original surface further downstream (Figure 3). Although only one transect was sampled along the lower reach of Bonham Creek, it was apparent that channel depths were substantially deeper (averaging 1.83 m) than in upper reaches (1.16 m).

Based on existing and antecedent elevations, it was apparent that Sally Branch was more deeply incised into the alluvium than Bonham Creek (Figure 4). Using channel depth measurements (average top-of-bank to creek bottom), Bonham Creek had a significantly lower mean ($\pm$ SE) creek channel depth (1.36 ± 0.12 m) compared to Sally Branch (2.23 ± 0.09 m) ($P < 0.05$). Because of the deeper incision along Sally Branch, transects were more likely to intercept the estimated antecedent surface compared to Bonham Creek. Of the nine Sally Branch transects where adequate topographic data were available, all had stream bottom elevations that were below the original surface layer. This contrasts with only two (or 17%) of the transects analyzed for Bonham Creek.

Dendrogeomorphic sampling – The average time period over which sedimentation rates were estimated (i.e. average difference in age between stems at root collars vs. soil surfaces) was 18 years. Rate estimates averaged -0.06 cm/yr on Bonham Creek and 0.01 cm /yr on Sally Branch. These rates are negligible and, although there is noticeable variation in scouring and deposition patterns at a microsite scale level, suggest that the surfaces of both floodplains have been stable over the last two decades.

¹³⁷Cesium fallout – Cs-137 data indicated that sediment deposition had occurred in both the Bonham Creek and Sally Branch floodplains since 1964. However, results may have been skewed since only one core per floodplain was collected and collection locations lay within 15 m of road crossings along each stream. Given the spatial variation noted in the dendrogeomorphic

sampling combined with observations of greater deposition in the vicinity of road crossings, we discount the deposition suggested by the cesium data.

It appears that suspended sediments in both streams are most likely derived from in-channel sources as opposed to overland flow from uplands. Activity of ^{137}Cs in bedload material ranged from 0.00 to 1.46 Bq kg⁻¹ in Bonham Creek and 0.00 to 1.70 Bq kg⁻¹ in Sally Branch. Upland areas tended to have the highest ^{137}Cs activity ranging from 7.40 to 18.15 Bq kg⁻¹ in both watersheds. The closest ranges to those measured for the stream bedloads were from in-channel sources and possibly roadway sources.

Sediment pins – The pin sampling was designed to estimate accumulation or loss of sediment around each pin. Much of the period over which pin data were recorded was abnormally dry (Figure 1). Consequently, sediment movement over this time frame was likely less than what might have occurred in a period with average rainfall. During construction of crossings on Sally Branch, some sets of pins were destroyed by construction activity such as applications of large rock for stabilization of banks as well as excavation. Consequently, the Sally Branch sediment pin data are less comprehensive than the Bonham counterpart.

The period immediately after pin installation coincided with active construction of road crossings in the DMPRC and, as a result, there were soil losses of 1 – 6 cm at Bonham and Sally crossings between January – April, 2007 (Figure 5). Afterward, soil surfaces around pins either remained stable or exhibited some aggradation. Over the entire sampling period, sediment mass export averaged 216 kg/m² along Bonham Creek crossings. This is equivalent to 2160 t/ha and represents a considerable input of sediment to that stream.

Conclusions

It is apparent that the Bonham Creek and Sally Branch floodplains and stream channels have undergone very large volumes of sediment deposition and that original floodplain surfaces and stream bottoms were completely buried by that sediment. We estimate that 1.4 and 2.4 M t of sediment remain atop the historic floodplain surfaces of Bonham Creek and Sally Branch respectively. This amount and depth of sediment as well as the morphology of buried soil horizons are consistent with reports of widespread cotton era (1830-1920) erosion and deposition in the Piedmont physiographic region. This magnitude of erosion (approximately 8.3 cm across the two watersheds) and deposition would have caused major changes in the ecology of uplands, floodplains, and streams within the Bonham and Sally catchments.

The two watersheds present an interesting contrast in terms of sediment export and rate of return to pre-farming channel morphology. The Sally Branch watershed is larger and has slightly

greater slope compared to the Bonham Creek watershed and, as a result, stream discharge and velocity may be somewhat higher in the former system. The greater amount of stream flow in Sally Branch has been sufficient to evacuate the agricultural alluvium from the channel to a much greater extent than has occurred in the Bonham channel. Consequently, the hydrological contrasts between the two watersheds are clearly reflected in different rates of recovery from cotton era impacts.

The data presented here demonstrate both the magnitude and longevity of sedimentation impacts on floodplains and streams near the Georgia Piedmont. However, many questions remain regarding the dynamics of sediment stability and transport as well as implications for natural systems and current water quality issues. Consequently, the results of this study may guide additional inquiry toward a more complete appreciation of the influence of legacy sediment on current land management issues.

Bibliography

- Bhat, S., J.M. Jacobs, K. Hatfield, and J. Prenger. 2006. Relationship between stream water chemistry and military land use in forested watersheds in Fort Benning, GA. *Ecological Indicators* 6(2006):458-466.
- Brigham, M.E., C.J. McCollough, and P. Wilkinson. 2001. Analysis of Suspended Sediment Concentrations and Radioisotope Levels in the Wild Rice River Basin, Northwestern Minnesota, 1973–98. US Geological Survey, Water Resources Investigation Report 01-4192. Washington, DC.
- Jackson, C.R., J.K. Martin, D.S. Leigh, and L.T. West. 2005. A southeastern piedmont watershed sediment budget: evidence for a multi-millennial agricultural legacy. *Journal of Soil and Water Conservation* 60(6):298-313.
- Hupp, C.R. and E.E. Morris. 1990. A dendrogeomorphic approach to sedimentation in a forested wetland, Black Swamp, AR. *Wetlands* 10:107-124.
- Lockaby, B.G. 2008. Floodplain ecosystems of the Southeast: linkages between forests and people. *Wetlands*. In press.
- Lockaby, B.G., R. Governo, E. Schilling, G. Cavalcanti, and C. Hartsfield. 2005. Effects of sedimentation on soil nutrient dynamics in riparian forests. *J. Env. Qual.* 34:390-396.
- Maloney, K.O., J.W. Feminella, R.M. Mitchell, S.A. Miller, P.J. Mulholland, and J.N. Houser. 2008. Land use legacies and small streams: identifying relationships between historical land use and contemporary stream conditions. *Journal of North American Benthological Society* 27(2):280-294.

Nagle, G.N. and J.C. Ritchie. 2006. Wheat field erosion rates and channel bottom sediment sources in an intensively cropped northeastern Oregon drainage basin. *Land Degradation and Development* 15:15-26.

Ritchie, J.C. and R. McHenry. 1990. Application of radioactive fallout Cesium-137 for measuring soil erosion and sediment accumulation rates and patterns: a review. *Journal of Environmental Quality* 19: 215–233.

Smith, S.M. 2006. Legacy sediment – culprit or scapegoat? Paper No. 19-6, Abstract from 2006, Geological Society of America Annual Meetings, Philadelphia.

Trimble, S.W. 1974. Man-induced soil erosion on the southern Piedmont: 1700-1970. Soil and Water Conservation Society, Ankeny, Iowa. 188 p.

Walter, R.C. and D.J. Merritts. 2008. Natural streams and the legacy of water-powered mills. *Science* 319:299-304.

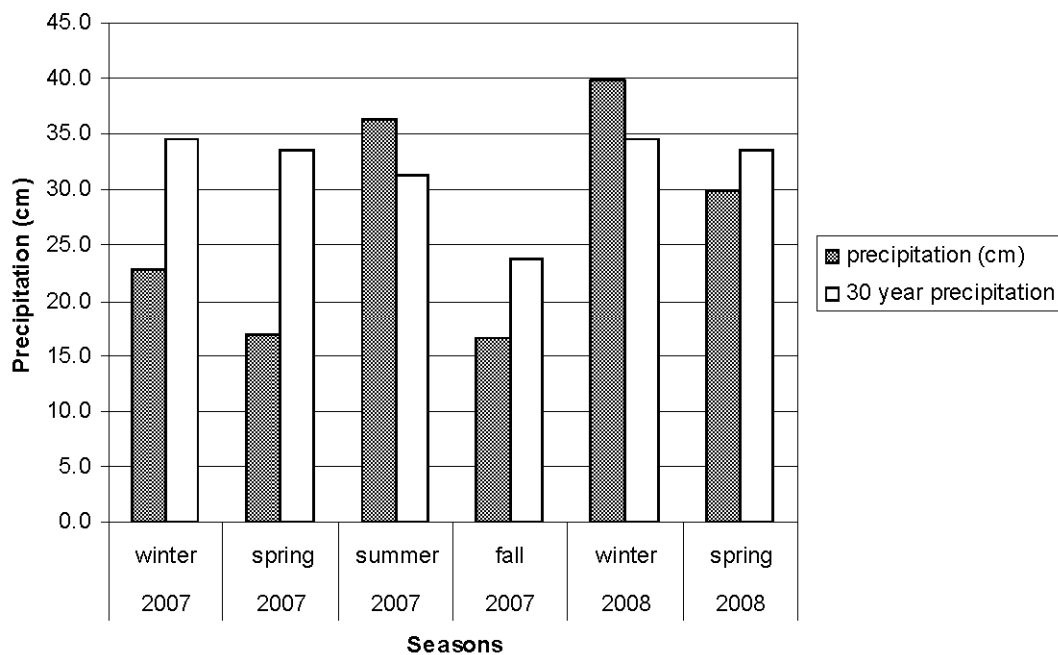


Figure 1. Monthly precipitation during study period compared to 30 year average precipitation.

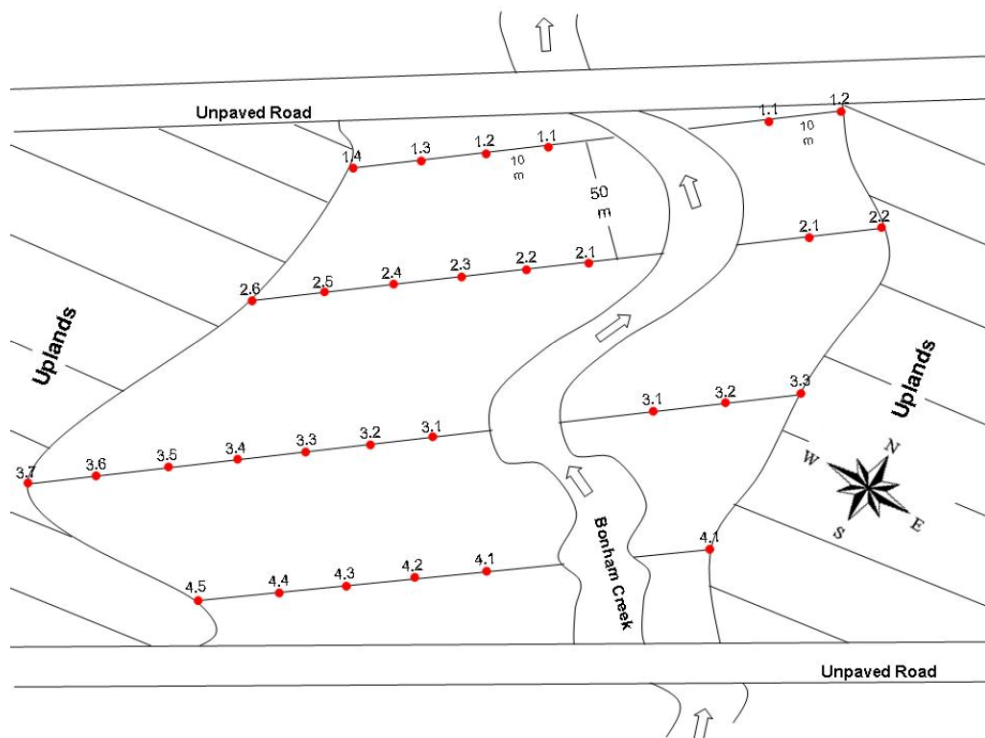


Figure 2. Generalized diagram of sampling transects and plots on floodplains of Bonham Creek and Sally Branch.

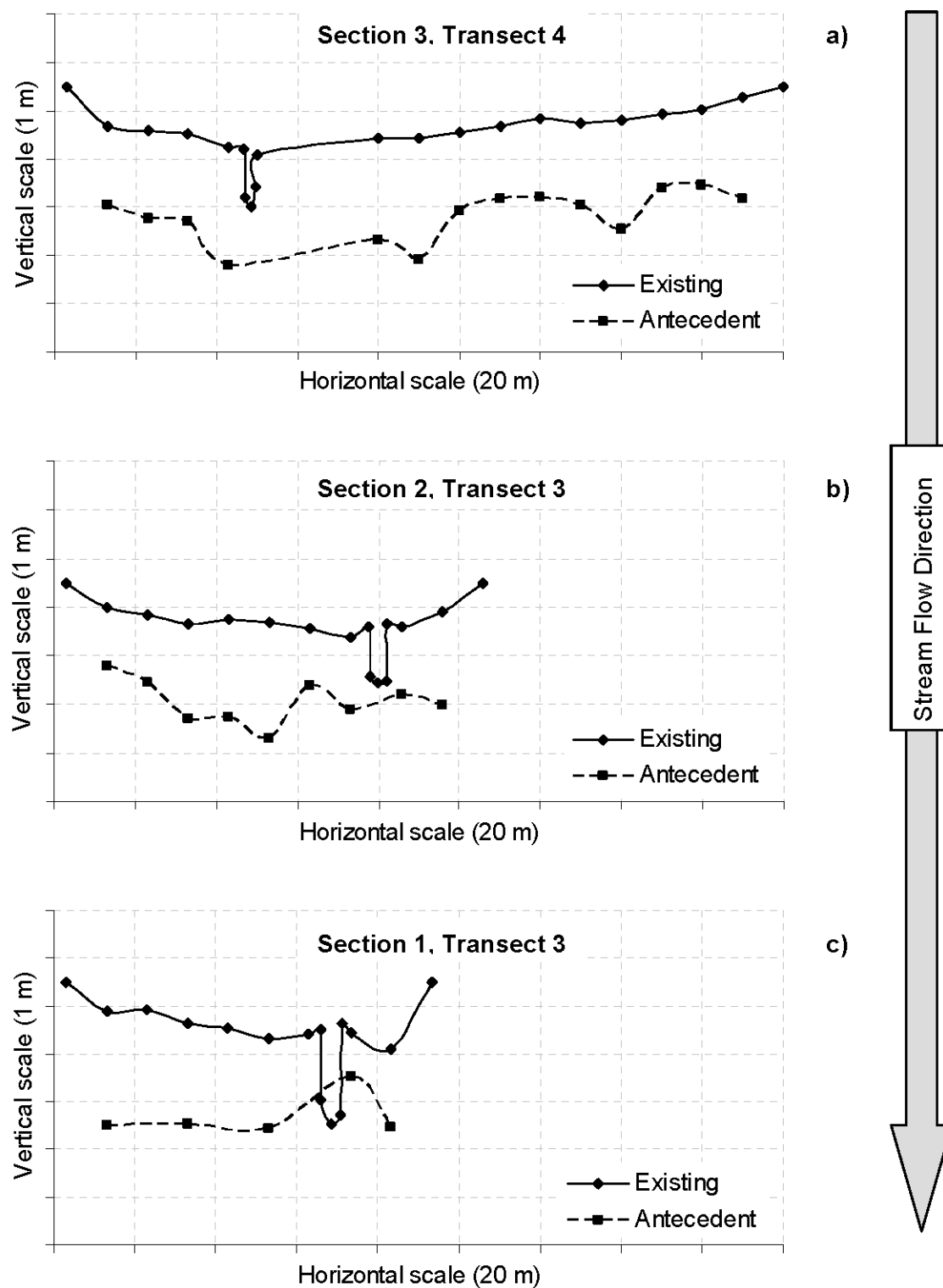


Figure 3. Current and antecedent elevations for representative transect along Bonham Creek.

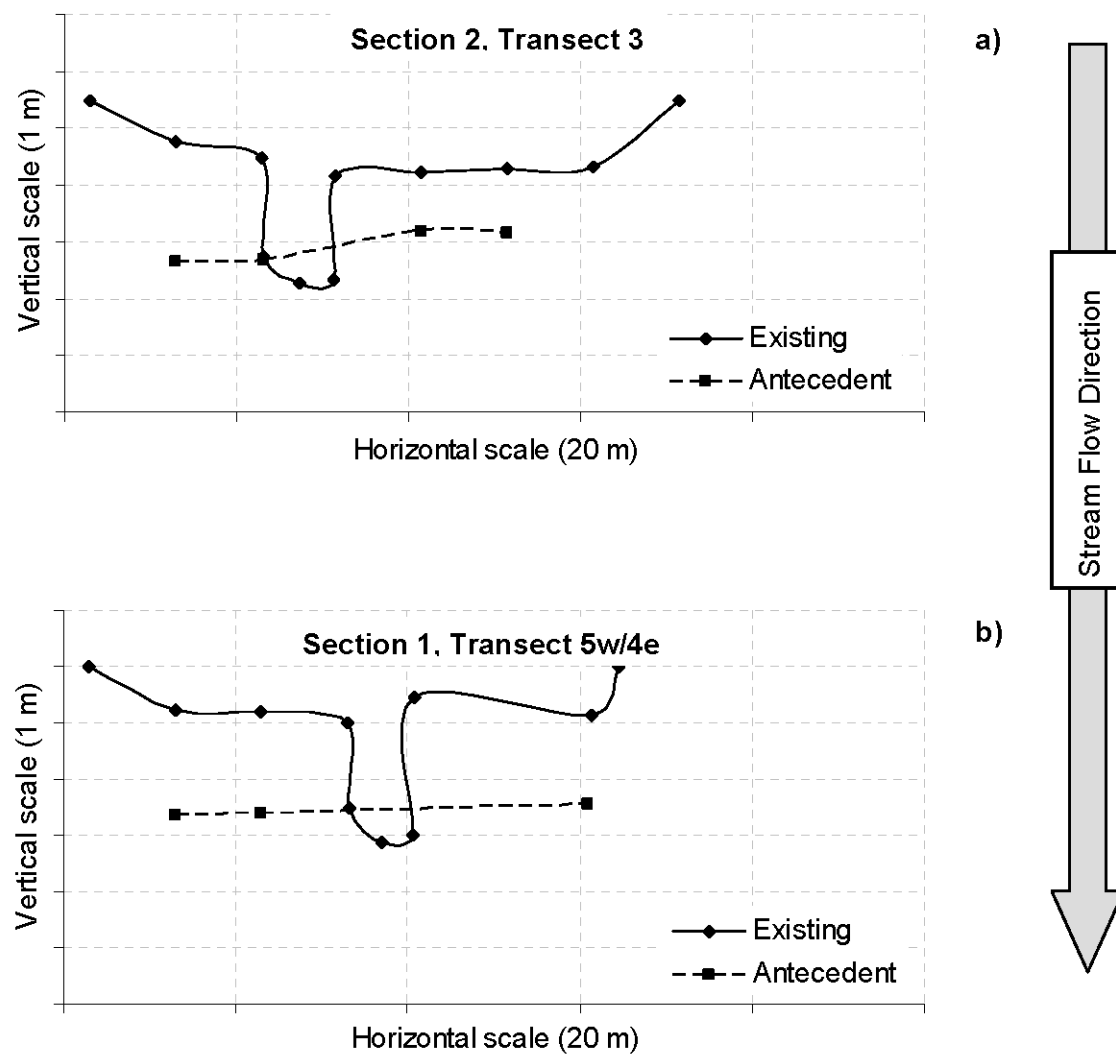


Figure 4. Current and antecedent elevations for representative transect along Sally Branch.

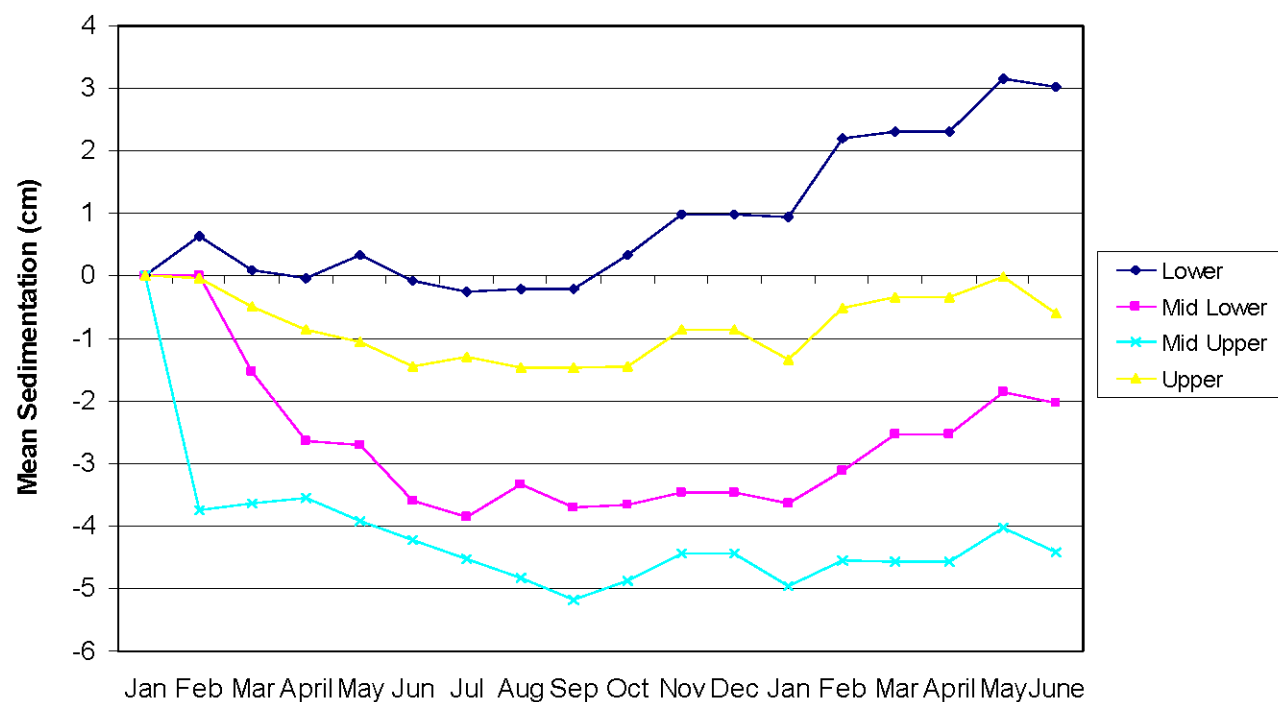


Figure 5. Monthly average depth of sediment near pins at road crossings along Bonham Creek.