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Habitat assessment and ecological restoration design for an unnamed tributary of Stone Dam Creek, Conway, Arkansas

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ABSTRACT

Urbanization can lead to increased sedimentation, erosion, pollution, and runoff into streams. The United States Environmental Protection Agency's (USEPA) Rapid Bioassessment Protocols (RBPs) are sets of guidelines that can be used to assess a habitat's sedimentology, hydrology, vegetation, and geomorphology to determine impairment. An unnamed tributary of Stone Dam Creek on the University of Central Arkansas (UCA) campus in Conway, Arkansas runs partially underground and through the urbanized UCA campus watershed. The stream was assessed using the USEPA's RBPs to determine impairment of the stream, and received a RBP score of 71.2 out of 200 compared to 153.5 in a reference stream. An ecological restoration design was then prepared for a 2-year, 1-hour rainfall event to address areas of impairment. The goal was to increase the RBP score by increasing cross-sectional area of the stream as well as by improving stream morphology where possible. With the proposed design, modeled stream velocity was reduced throughout the stream by an average of 19.6%. It was assessed that as a result of the reduction in velocity and changes to morphology, RPB scores would increase throughout the stream reach.

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MEET THE STUDENT-AUTHOR

Paige Boyle

I grew up in Bentonville, Arkansas and graduated with honors from Bentonville High School in 2011. I graduated from the University of Arkansas in May 2015 with a B.S. in Environmental, Soil and Water Science, and minors in Horticulture and Wildlife Habitat. During my undergraduate time at the University of Arkansas, I served as a student ambassador for the Dale Bumpers College of Agricultural, Food and Life Sciences; president of the Crop, Soil and Environmental Sciences Undergraduate Club; two-time intern for Boston Mountain Solid Waste District; and summer intern for the University of Arkansas Ecosystem Research Experience for Undergraduates (REU). I would like to thank Dr. Mary Savin for all her guidance as my academic and club advisor, research mentor, and professor. I would also like to thank Dr. Marty Matlock and the entire Arkansas Ecosystem REU program for providing the opportunity to conduct this research, and James McCarty for his patient supervision and instruction. I will be pursuing a graduate degree at the University of Arkansas starting in the fall of 2015.

INTRODUCTION

Streams in densely populated areas can often exhibit "urban stream syndrome" which describes a series of changes in urban stream channels. These changes can include increased stream discharge, sediment, nutrients, pollutants, and temperature, and decreased biodiversity (Shoredits and Clayton, 2013; Walsh et al., 2005). Many restoration efforts focus on aesthetics (Charbonneau and Resh, 1992; Palmer et al., 2005; Shoredits and Clayton, 2013), yet do not specifically address ecological restorative needs. Ecological restoration focuses on restoring the stream to a natural, dynamic, and self-sustaining system, with increased ecological services (Palmer et al., 2005) such as habitat availability, nutrient and sediment cycling, and disturbance regulation (Costanza et al., 1997).

Several researchers have developed potential ecological restoration plans for on-campus streams on the Ohio State University at Marion (Huang et al., 2009), University of California at Berkeley (Charbonneau and Resh, 1992), and the University of Arkansas at Fayetteville (pers. comm., Matthew A. Van Eps, Watershed Conservation Resource Center) campuses. Implementation of the Strawberry Creek restoration at University of California at Berkeley successfully resulted in reintroduction and spawning of native fish, increased family richness of macroinvertebrates, increased water quality, and decreased erosion in the restored reach of the stream (Charbonneau and Resh, 1992). The Mullins Creek restoration on the University of Arkansas campus included in-stream features to divert flow away from the banks, along with bioengineering materials and re-vegetation using native species to reduce erosion along the banks (pers. comm., Matthew A. Van Eps, Watershed Conservation Resource Center).

The U.S. Environmental Protection Agency (USEPA) Rapid Bioassessment Protocols (RBP) provide guidelines for habitat assessment based on various parameters related to sedimentology, hydrology, vegetation, and geomorphology (Barbour et al., 1999). The RBP are useful for determining whether a stream is impaired (Stephens et al., 2008; Winger et al., 2005). The RBP can also be used in conjunction with other metrics to determine the cause of impairment (Mažeika et al., 2004; Stephens et al., 2008; Winger et al., 2005) or to monitor and compare restored sites (Price and Birge, 2005).

The purpose of this project was to measure the geomorphology of a 138-meter section of an unnamed tributary of Stone Dam Creek on the University of Central Arkansas (UCA) campus, Conway, Ark. This was done through surveying the stream thalweg (the line of lowest elevation within a valley or watercourse) to create a stream profile. Measuring the profile along the deepest point, the thalweg, allows the survey to capture changes in morphology, and also allows comparison between current stream condition and future changes in stream channel aggradation patterns (Madej, 1999). Six stream reach cross sections were also surveyed to determine current water holding capacity of the tributary. Additionally, the USEPA's RBP habitat assessment methodology was conducted to determine ecological impairment of the stream. An ecological restoration design was then developed for the tributary based off the stream profile and cross-section data, with the goal of increasing the storage capacity of the tributary and improving the habitat assessment RBP score.

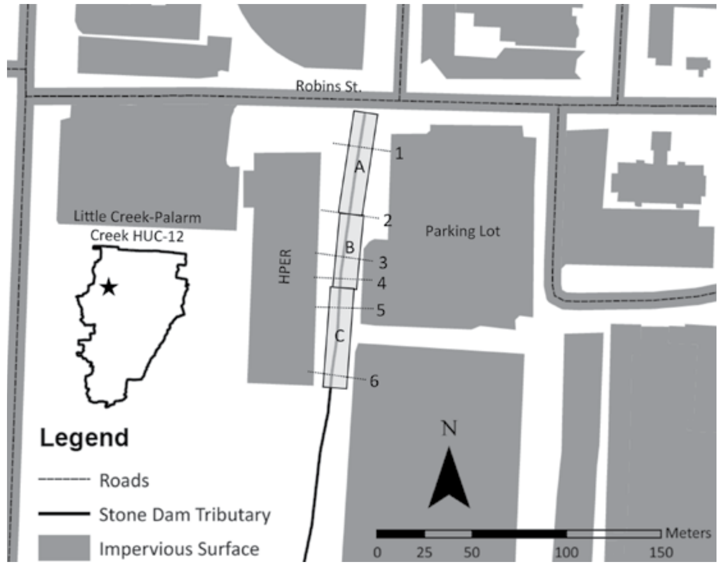

Fig. 2. Map of the study area within the Little Creek-Palarm Creek HUC-12 watershed. Study sections where Rapid Bioassessment Protocol assessment was performed are labeled A, B, and C. Surveyed cross sections are labeled 1-6.

MATERIALS AND METHODS

Study Area. The unnamed tributary leads into Stone Dam Creek on the UCA campus in Conway, Ark. It is part of the 109.04 km^2 Little Creek–Palarm Creek watershed, which is 35.5% urban cover and home to three major universities (ANRC, 2006). The tributary is highly channelized, and runs underground until it surfaces between a large parking lot and the UCA's Health, Physical Education, and Recreation (HPER) building (Fig. 1), which is currently undergoing construction. The area under study begins where the tributary exits the culvert south of Robins Street and ends at the far end of the HPER building, a total length of 138 m. The area was further broken up into three sections, with breaks between sections 1 and 2 at the dam and between sections 2 and 3 at the point of change in canopy cover (Fig. 2).

Fig. 1. Downstream view of the unnamed tributary of Stone Dam Creek on the University of Central Arkansas campus, Conway, Ark. University of Central Arkansas Health, Physical Education, and Recreation building shown on the right, with a large parking lot to the left.

Reference Area. A similar restoration effort was conducted on Mullins Creek on the University of Arkansas campus in Fayetteville, Ark. between July and October, 2014 (pers. comm., Matthew A. Van Eps, Watershed Conservation Resource Center). The study area and reference stream share similar flow characteristics, low density urban/forest land use, and position in the larger watershed as a headwater stream. Additionally, both streams surface from underground drainage in similar manners after spending a considerable distance underneath their respective campuses. Mullins Creek and the study area suffer loss of riparian zones due to development, severe bank erosion, poor habitat, and sedimentation, which make the two streams well suited for comparison.

The Mullins Creek restoration utilized in-stream features to divert flow away from the banks, as well as revegetation efforts with native flora (Fig. 3) to increase habitat diversity and stabilize stream banks (pers. comm., Matthew A. Van Eps, Watershed Conservation Resource Center). Based on their similarities, a habitat assessment RBP was conducted on a 50-m reach of Mullins Creek to determine an estimate of what the unnamed Conway tributary habitat assessment goal could be after restoration. An average of four assessors' scores was taken.

Fig. 3. Upstream view of Mullins Creek on the University of Arkansas campus, Fayetteville, Ark.

Habitat Assessment Parameters. A visual habitat assessment was conducted in early July, 2014 for each of the three sections of the unnamed tributary, using the USEPA RBP habitat assessment for high gradient streams (Barbour et al., 1999). The high gradient approach was used because the study site consisted of the riffle-run morphology consistent with high gradient streams (Barbour et al., 1999). Parameters covered include: Epifaunal Substrate/Available Cover, Embeddedness, Velocity/Depth Regime, Sediment Deposition, Channel Flow Status, Channel Alteration, and Frequency of Riffles. Each of these parameters was graded on a 0-20 score, with 0-5 indicating Poor condition, 6-10 Marginal, 11-15 Suboptimal, and 16-20 Optimal. Bank Stability, Vegetative Protection, and Riparian Vegetative Zone Width were measured by individual bank, looking downstream, with each bank receiving a separate score of up to 10 points with 0-2, 3-5, 6-8, and 9-10 indicating Poor, Marginal, Suboptimal, and Optimal conditions, respectively. Each parameter has a description and criteria to follow when assigning a score (Barbour et al., 1999).

Each section received an average of three assessors' scores, with an overall average score for the entire study area calculated from the three average scores. An average of three assessors' scores was used due to inexperience with RBP habitat assessment scoring. This score was compared to the Mullins Creek score to determine whether the unnamed tributary was impaired when compared to a successfully restored creek.

Physiochemical Assessment. Other measurements were conducted for the purpose of determining water quality and for mapping the current geomorphology of the tributary bed. Rapid Bioassessment Protocol physiochemical parameters including water temperature and dissolved oxygen were recorded (Barbour et al., 1999). Percent riffle, run, and pool was estimated for the entire study site and stream width was measured at bankfull height. *In situ* water measurements were conducted using a YSI 550A dissolved oxygen meter (YSI Inc., Yellow Springs, Ohio) to determine dissolved oxygen concentration and temperature.

Stream Profile and Cross Sections. The thalweg was surveyed to produce a stream profile. Cross sections were surveyed along six transects across the study area to measure among different morphology types. Surveying was conducted using a Leica TCP1201 total station (Leica Geosystems, Inc., Norcross, Ga.) and Carlson Explorer data collector (Carlson Software, Maysville, Ky.). The data were downloaded onto ArcGIS (Esri, Redlands, Calif.), and Jag3D was used to correct the data points for georeferencing. Survey measurements provided reference points which were utilized when preparing the restoration design for the tributary. The measured stream profile was then used to determine potential sites for morphology alteration, while the cross-sectional areas helped determine points with potential for widening the stream cross-sectional area. Increasing the cross-sectional area will decrease the velocity and reduce erosion hazard within the stream.

Rational Method. ArcGIS was used to delineate the drainage area for the tributary. This information was then used as the area factor in the Rational Method (Eq. 1),

$$Q = CiA \qquad \text{Eq. (1)}$$

where Q = maximum rate of runoff, C = runoff coefficient, i = average intensity, A = drainage area (Marek, 2014; Bledsoe and Watson, 2001). Rational Method was used to determine peak rate of runoff for a 2-year, 1-hour storm event for the area (Marek, 2014; U.S. Department of Commerce, 1955). Using this calculated input, we could then plan the restoration design to decrease velocity of the stream by increasing cross-sectional areas of the measured transects.

Restoration Design. A stream restoration design was conducted based on the above measurements and with the following goals: 1) design for a 2-year, 1-hour rainfall event; 2) decrease velocity within the stream; and 3) create a profile with <7:1 distance between riffles to width of stream ratio (Barbour et al., 1999).

Table 1. Average scores (n = 5) and category description based on Rapid Bioassessment Protocols (Barbour et al., 1999) for Mullins Creek reference reach on the University of Arkansas campus, Fayetteville, Ark.

Habitat Parameter	Average Score	Category Description
Epifaunal Substrate/Available Cover	13.5	Suboptimal – 40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).
Embeddedness	13.75	Suboptimal – Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.
Velocity/Depth Regime	18	Optimal – All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow).
Sediment Deposition	18.25	Optimal – Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.
Channel Flow Status	16	Optimal – Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.
Channel Alteration	9.25	Marginal – channelization may be extensive; embankments or shoring structures present on both banks; and 40-80% of stream reach channelized and disrupted.
Frequency of Riffles (or bends)	19	Optimal – Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width of the stream <7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, placement of boulders or other large, natural obstructions is important.
Bank Stability (Score each bank)	Left bank – 9 Right bank – 8.5	LB – Optimal – Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. Less than 5% of bank affected. RB – Suboptimal – Moderately stable; infrequent, small areas of erosion mostly healed over. Five percent to thirty percent of bank in reach has areas of erosion.
Vegetative Protection (Score each bank)	Left bank – 9.25 Right bank – 8.5	LB – Optimal – More than 90% of the stream bank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally. RB – Suboptimal – 70-90% of the stream bank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than 50% of the potential plant stubble height remaining.
Riparian Vegetative Zone Width (Score each bank)	Left bank – 6 Right bank – 4.5	LB - Suboptimal – Width or riparian zone 12-18 meters; human activities (i.e. parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone. RB – Marginal – Width of riparian zone 6-12 meters; human activities have impacted zone only minimally.

RESULTS AND DISCUSSION

The reference stream's mean habitat assessment score was determined to be 153.5 out of a possible 200 points. Average scores by parameter and a description of the category class that each score falls under are provided in Table 1. The Mullins Creek site demonstrates a successful ecological restoration on a college campus, and provides a reference goal for the restoration of the tributary in Conway.

The study area morphology consisted of approximately 15% riffle, 85% run, and 0% pool. The deepest point of the stream, measured 2.03 m downstream from the culvert, was 0.40 m deep. High water mark was estimated to be at 1 m. The three sections were measured to be 51.8 m, 38.7 m, and 47.5 m each in length. With a stream bankfull width of 9.4 m, the section areas were calculated to be 0.49 km^2, 0.36 km^2, and 0.45 km^2, respectively. Water temperature of the stream was 26.1 °C and dissolved oxygen was measured to be 6.68 mg/L, both of which comply with the primary criteria of 31 °C or less and greater than 5 mg/L, respectively, for streams in the Arkansas River Valley (ADEQ, 2014).

Overall average habitat assessment score equaled 71.2 out of a possible 200. Average scores by parameter and a description of the category class that each score falls under are provided in Table 2. Figure 4 shows the stream profile, measured at the thalweg, as well as the measured water level. The profile shows the measured morphology of the tributary, indicating where riffles and runs are currently located along the study area. Figure 4 also shows the proposed restoration plan's profile.

The poor scores for epifaunal substrate/available cover and frequency of riffles (Table 2) indicate that habitat diversity is lacking in the stream system, which reduces the number of niches available to insects, fish, and macroin-

Table 2. Average scores (n = 3) and category description based on Rapid Bioassessment Protocols (Barbour et al., 1999) for an unnamed tributary of Stone Dam Creek, Conway, Ark.

Habitat Parameter	Average Score	Category Description
Epifaunal Substrate/Available Cover	2.2	Poor - Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
Embeddedness	4	Poor – Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
Velocity/Depth Regime	6.4	Marginal – Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).
Sediment Deposition	10.3	Marginal – Moderate deposition of new gravel, sand of fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.
Channel Flow Status	10.1	Marginal – Water fills 25-75% of the available channel and/or riffle substrates are mostly exposed.
Channel Alteration	6.7	Marginal – Channelization may be extensive; embankments or shoring structures present on both banks; and 40-80% of stream reach channelized and disrupted.
Frequency of Riffles (or bends)	4.7	Poor – Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ratio of >25.
Bank Stability (Score each bank)	Left bank – 4.4 Right bank – 4.8	Marginal – Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.
Vegetative Protection (Score each bank)	Left bank – 6.3 Right bank – 7.3	Suboptimal – 70-90% of the stream bank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.
Riparian Vegetative Zone Width (Score each bank)	Left bank – 1.7 Right bank – 2.3	Poor – Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.

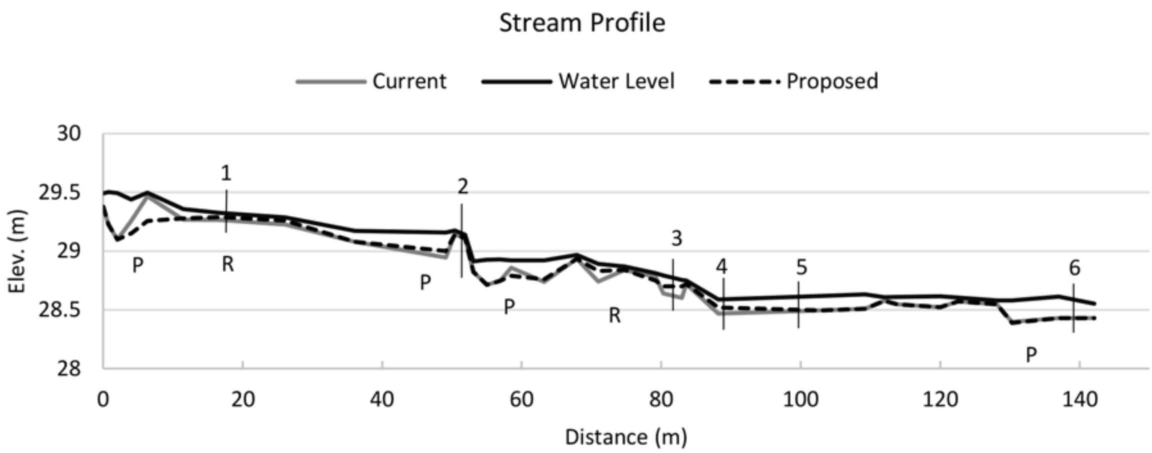

Fig. 4. Current and proposed stream profiles and measured water level of an unnamed tributary of Stone Dam Creek, Conway, Ark. Surveyed cross sections are labeled as 1-6. Areas of pools (P) and riffles (R) are labeled along the profile.

vertebrates (Barbour et al., 1999). The proposed profile improves existing geomorphology in the stream with the purpose of restoring a more natural channel structure. The main limiting factor in this design is the dam structure and the position of bedrock within the channel. The new profile elongates and deepens existing pools and increases the frequency of riffles from >25:1 to 4.5:1 ratio of distance between riffles divided by width of the stream. A change in riffle frequency would raise the RBP score for that parameter from poor to optimal. Creation of more diverse morphology, including deep pool areas, also increases the velocity/depth regimes present from two to three, which would increase the parameter score from marginal to suboptimal/optimal.

The low score for riparian width indicates that the riparian zone is less than 6 m wide (Barbour et al., 1999). Mayer et al. (2005) claimed that grass buffers needed to be over 5 m wide to be effective at reducing nitrogen from runoff before it enters the stream, which suggests that the current riparian zone is too narrow. In addition, riparian buffers provide bank stability and important habitat for biota. Riparian width is limited at this site due to the presence of the HPER building and the parking lot which border the site. This is a potential problem because the surrounding construction and parking lot can contribute pollutants such as oils, inorganics (including heavy metals), and sediment to runoff entering the stream (Davis et al., 2010; McQueen et al., 2010). Currently, the riparian zone consists largely of blackberry shrubs and herbaceous materials. Re-vegetating with a more diverse mixture of classes of native plants could help increase the habitat assessment score (Barbour et al., 1999).

Low habitat assessment scores for bank stability indicate a possible erosion hazard. Using the rational method (Eq. 1), peak flow (Q) was calculated to be 1.33 m^3/s. To address the risk of erosion, cross sections were designed to increase area, which would reduce stream velocity and reduce the erosion hazard. The bedrock that was predominant along the streambed, as well as the presence of the HPER building and the sidewalk bordering the parking lot restricted the amount of alteration possible for the cross sections; however, cross-sectional area was increased on all 6 transects by creating a step cross-sectional profile (Fig. 5). This allows a higher channel during high flow conditions. Velocities for the cross sections 1-6 were reduced by 18.6%, 11.9%, 10%, 13.9%, 36%, and 27%, respectively, with the proposed designs. The reduction in erosion would also reduce the amount of fine sediment and reduce embeddedness, which would further increase the habitat assessment score.

In summary, if implemented, this restoration design would increase habitat diversity and availability, decrease velocity and erosion hazard, and increase ecosystem services in a highly degraded stream channel. Improving pools in the stream profile and further defining riffles will increase the diversity of niches available to in-stream organisms. Increasing the stream cross-sectional area will reduce velocity and reduce risk of erosion along the stream banks. Further study to determine a suitable riparian zone width and plant composition, with a focus on diversity and the use of native plants, would further increase the ecological services provided by the stream system.

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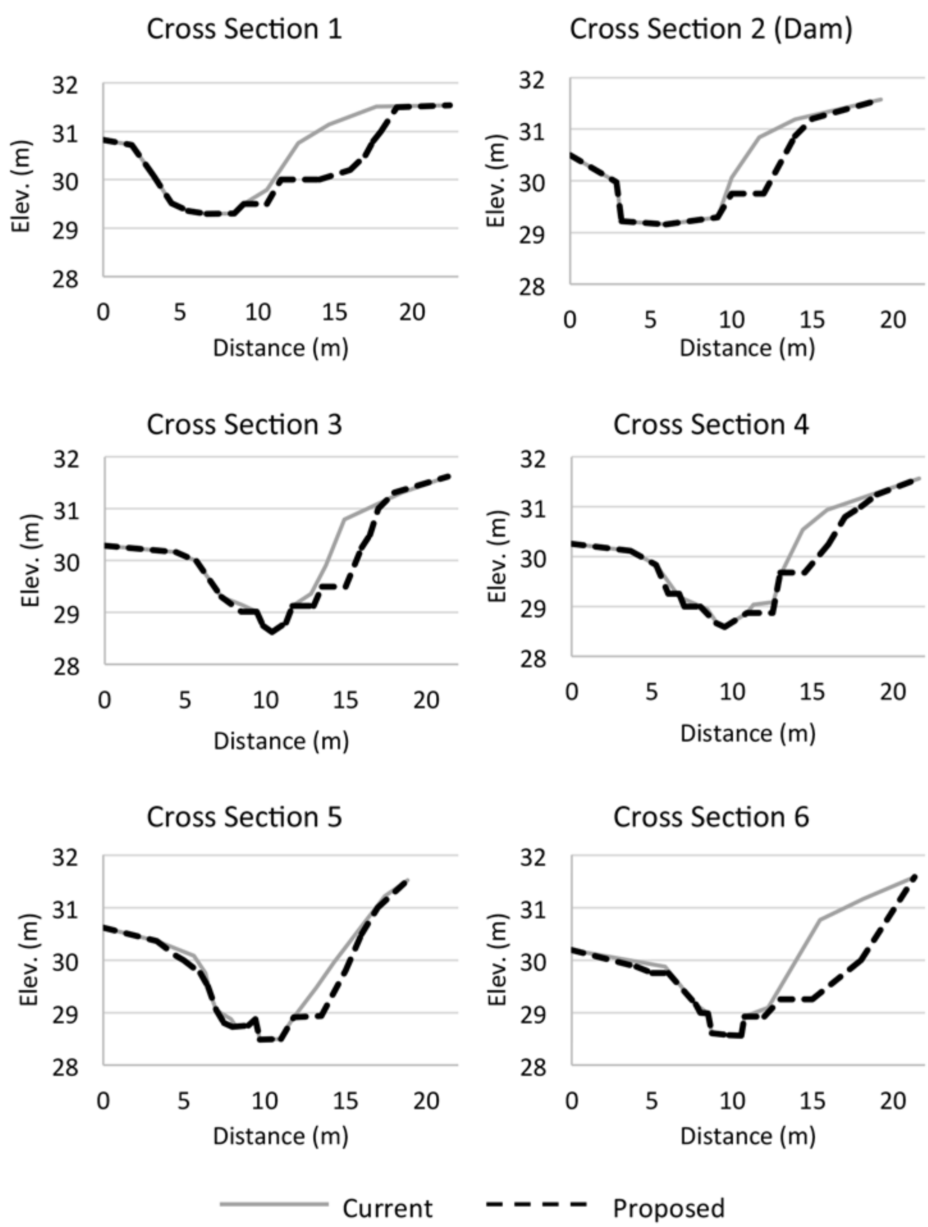

Fig. 5. Cross-sectional view of the six cross sections, measured and proposed, at an unnamed tributary of Stone Dam Creek, Conway, Ark. See Fig. 2 for location of cross sections.

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