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Baseline Data for a Cedar Tree Revetment Monitoring Site near Wichita, Kansas

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PURPOSE: This US Army Corps of Engineers (USACE) National Regional Sediment Management technical note (RSM-TN) documents baseline data collected at a cedar tree revetment installation on a small creek near Wichita, KS. These data can be used in subsequent years to add to the understanding of the longevity, effectiveness, and failure modes of cedar tree revetments as bank stabilization.

INTRODUCTION: Cedar tree revetments are a popular, low-cost bank stabilization option installed by state conservation agencies and local conservation districts since the late 1980s. These revetments are constructed by longitudinally placing and anchoring cedar trees at the toe of eroding riverbanks.

In 2019, 2020, and 2021, the authors visited cedar tree revetment project sites in Kansas, Missouri, Tennessee, and Minnesota[*] (Shelley et al. 2022) The level of pre-project, as-built, and post-project monitoring varied significantly but was typically sparse. At several locations, the angle of the cabling suggested that the cedars may have both floated upwards and translated downstream. At even the most well-documented sites, the coordinates for the trees themselves were not recorded, which complicated the diagnosis of failure modes.

On March 24–25, 2021, researcher Dr. Charles Barden from Kansas State University invited engineers from the Kansas City District to observe and participate in the installation of a cedar tree revetment on McConnel Creek, downstream from McConnel Airforce Base in Wichita, KS (Figure 1). This installation provided an opportunity for a more thorough as-built assessment that can be used to assess effectiveness, longevity, and failure modes of this revetment in future years. In addition to survey cross sections collected within and downstream of the revetment, coordinates for each tree in the revetment were collected at the locations where the cables attach to the trees. This allows a baseline against which to compare future revetment translation or rotation as well as bank and channel changes.

[*] Shelley, J., C. Haring, and N. Chrisman. In preparation. *Evaluation of Cedar Tree Revetments for Bank Stabilization at the Locust Creek Conservation Area, Missouri: Quantifying Bank Erosion Volumes from Pre-Project to Post-Failure*. ERDC Technical Report. Vicksburg, MS: US Army Engineer Research and Development Center.

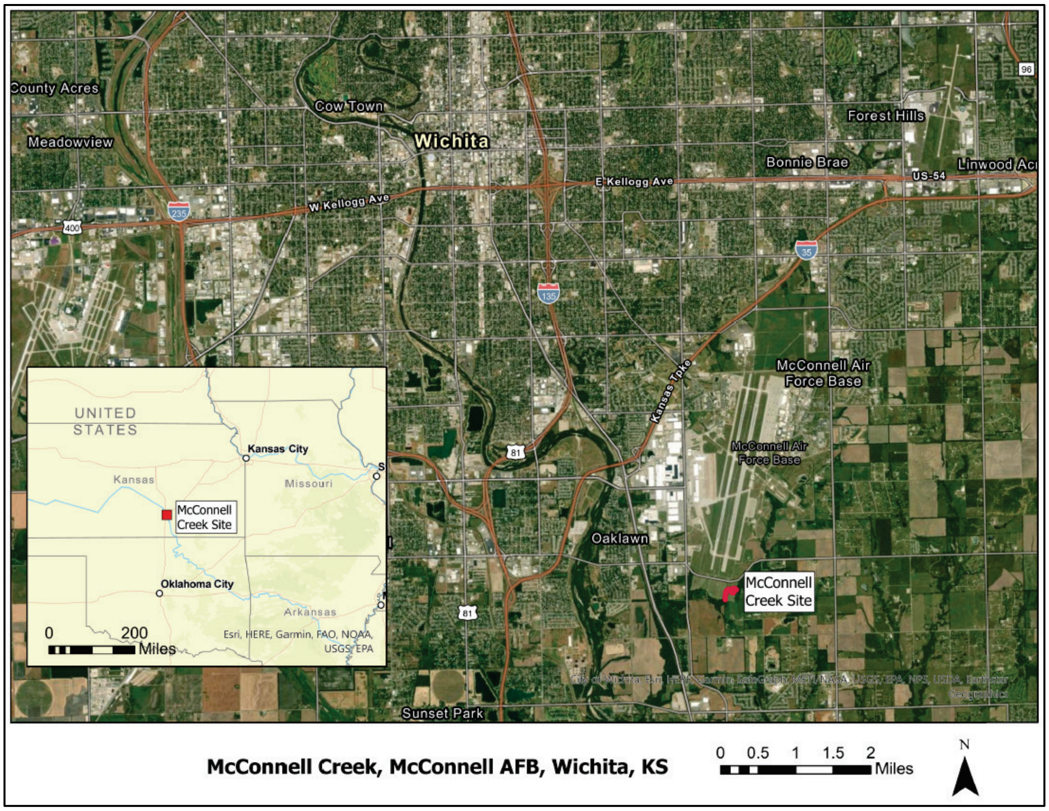

Figure 1. A map showing the location of the project just south of McConnel Airforce Base and Wichita, KS.

INSTALLATION METHOD: The trees were cut down in nearby fields, trucked to the site, rolled down the bank, and dragged by hand into place. Installation proceeded from downstream to upstream with trees overlapping by one-third to one-half their length. The revetment is 13 trees long, generally 1 tree high (Figure 2). The exception is at Tree #8 (the eighth starting from downstream) where the shape of the tree left some unprotected bank, so a second tree was stacked vertically to fill the gap. In all cases, the full tree was used, meaning branches on both sides were left attached to the trunk.

Figure 2. The completed cedar tree revetment with cedar trees anchored to the toe of the eroding bank.

Duckbill 88II-DBD earth anchors were driven using a gas-powered post driver and driving pole (Figure 3) to a depth of approximately 3 ft (0.9 m)*. The quarter-inch (6.35 mm) cables attached to the anchors were manually pulled in an attempt to set the anchors. However, it is unlikely that sufficient force was applied by hand to fully set the anchors. The loose end of the cable was then wrapped around the trunk of the trees and cinched tightly (Figure 4 and Figure 5).

Figure 3. An anchor is driven into the bank to secure one of the cedar trees.

Figure 4. A cable is wrapped around the cedar trunk and secured with a cable clamp.

* For a full list of the spelled-out forms of the units of measure used in this document, please refer to *US Government Publishing Office Style Manual*, 31st ed. (Washington, DC: US Government Publishing Office 2016), 248-52, https://www.govinfo.gov/content/pkg/GPO-STYLEMANUAL-2016/pdf/GPO-STYLEMANUAL-2016.pdf.

During installation, the tree was pushed into the bank as much as possible to bend the branches between the trunk and the bank and thus allow the cable to be as tight as possible prior to tightening the cable clamps. Each tree was anchored at the downstream, middle, and upstream end. Downstream anchors for one tree also served as upstream anchors for the next tree; the cable attached to a single earth anchor was wrapped around the tip end of one tree and the base of the next.

Figure 5. A cable clamp is used to secure the cable on the tapered end of a cedar tree. The coordinates for these connections are labeled "anchor points" in Table 1.

After the installation, live willow posts from locally harvested sandbar willows (*Salix exigua*) were pushed into the bank within the revetment area. Over time, these willows will grow branches that will further reduce velocities on the eroding bank.

DATA COLLECTED

Cross-Sectional Measurements. Five cross sections were collected at the site of the new revetment to monitor streambank erosion and geomorphic changes that might contribute to revetment failure (see the lower left corner of Figure 6.) Table 1 provides the data, with the point name indicating the cross-section number (1–5) from downstream to upstream. Cross section 1 is approximately 100 ft (30 m) downstream from the revetment. Cross section 2 is just barely downstream of the revetment. Cross section 3 crosses Tree #2 (the second from the downstream). Cross section 4 crosses in the middle of the revetment, which also coincides with bank erosion pins installed by Dr. Charles Barden during revetment installation. Cross section 5 crosses near the upstream end of the revetment.

Table 1. Cross-section data at the site installed March 24–25, 2021 (UTM* 14N FT, NAD 1983).**

Point	North	East	Elevation	Point	North	East	Elevation	Point	North	East	Elevation
X1-1	13657210	2141182	1303.086	X2-13	13657287	2141174	1301.118	X4-6	13657355	2141156	1295.549
X1-2	13657210	2141173	1302.553	X2-14	13657287	2141179	1303.165	X4-7	13657355	2141163	1295.728
X1-3	13657210	2141162	1299.586	X2-15	13657286	2141183	1303.611	X4-8	13657355	2141164	1296.304
X1-4	13657210	2141160	1295.906	X2-16	13657285	2141196	1302.934	X4-9	13657354	2141167	1298.804
X1-5	13657211	2141156	1294.823	X3-1	13657320	2141196	1304.207	X4-10	13657354	2141170	1300.485
X1-6	13657212	2141151	1295.117	X3-2	13657320	2141180	1303.199	X4-11	13657354	2141173	1300.376
X1-7	13657212	2141146	1295.793	X3-3	13657320	2141176	1301.979	X4-12	13657355	2141181	1302.342
X1-8	13657213	2141141	1302.132	X3-4	13657321	2141173	1300.029	X4-13	13657354	2141196	1303.589
X1-9	13657214	2141140	1304.084	X3-5	13657321	2141168	1298.468	X5-1	13657394	2141190	1303.486
X1-10	13657217	2141120	1304.539	X3-6	13657320	2141166	1295.93	X5-2	13657396	2141175	1302.706
X2-1	13657285	2141127	1304.96	X3-7	13657320	2141164	1295.497	X5-3	13657396	2141169	1301.039
X2-2	13657285	2141143	1304.316	X3-8	13657321	2141159	1295.668	X5-4	13657397	2141167	1296.37
X2-3	13657285	2141148	1302.72	X3-9	13657319	2141155	1295.606	X5-5	13657397	2141163	1295.543
X2-4	13657285	2141150	1300.718	X3-10	13657319	2141149	1300.114	X5-6	13657399	2141158	1295.308
X2-5	13657288	2141152	1296.245	X3-11	13657319	2141147	1301.801	X5-7	13657401	2141153	1295.55
X2-6	13657288	2141154	1295.637	X3-12	13657319	2141146	1304.038	X5-8	13657402	2141150	1296.314
X2-7	13657289	2141159	1295.329	X3-13	13657319	2141128	1304.993	X5-9	13657403	2141148	1299.885
X2-8	13657289	2141164	1295.436	X4-1	13657354	2141128	1305.001	X5-10	13657404	2141145	1301.68
X2-9	13657288	2141167	1296.06	X4-2	13657354	2141145	1304.806	X5-11	13657404	2141141	1304.965
X2-10	13657288	2141168	1298.316	X4-3	13657354	2141146	1300.543	X5-12	13657408	2141120	1305.179
X2-11	13657287	2141168	1298.325	X4-4	13657355	2141150	1296.254				
X2-12	13657287	2141171	1301.325	X4-5	13657355	2141153	1295.487				

*Universal Transverse Mercator
**North American Datum

Another revetment had been installed on the same creek in June 2020. At this site, only two anchors were installed per tree, as opposed to the March 2021 revetment that used three anchors per tree. Water flow in the 9 months since installation had stripped the fine branches of the trees at this site, causing the area of the older trees (i.e., the area perpendicular to flow) to be considerably smaller than for the newly installed trees. This reduces the drag imparted on the water by the trees and thus reduces the effectiveness of the revetment. Perhaps more important, as the branches on the bank-side of the trees deteriorate, the trunks will no longer be snug to the bank toe. This could allow flanking of the structure as well as displacement of the cedar trees during high flow, both of which the authors have observed at other, older sites. Four cross sections were collected throughout this revetted bank, as shown in the upper right corner of Figure 6. These cross sections were named using letters A, B, C, D, with A being the most upstream. Table 2 presents the data. Figure 7 shows the revetment.

Figure 6. The locations of the cross sections collected at McConnell Creek. Five cross sections were collected at the downstream site, and four were collected at the upstream site. Upstream cross sections are labeled A through D while downstream cross sections are labeled 1 through 5.

Figure 7. The upstream cedar tree revetment, installed June 2020. Photo was taken approximately 9 months post installation. Some deterioration of the trees is evident with many of the fine branches and needles missing.

Table 2. Cross-section data at the site installed early June 2020.

Point	North	East	Elevation	Point	North	East	Elevation
XA-1	13657867.48	2141654.345	1306.024	XC-1	13657803.24	2141685.99	1306.401
XA-2	13657862.82	2141667.142	1306.168	XC-2	13657815.17	2141697.71	1305.585
XA-3	13657862.82	2141669.083	1305.55	XC-3	13657815.93	2141698.36	1301.382
XA-4	13657863.05	2141672.968	1301.529	XC-4	13657818.9	2141701.4	1299.291
XA-5	13657862.04	2141675.247	1299.291	XC-5	13657821.5	2141704.82	1299.138
XA-6	13657862.07	2141677.392	1298.097	XC-6	13657824.78	2141708.65	1298.426
XA-7	13657861.54	2141681.347	1297.505	XC-7	13657826.45	2141710.3	1298.645
XA-8	13657860.41	2141685.556	1297.388	XC-8	13657829.31	2141713.05	1299.027
XA-9	13657858.01	2141692.428	1299.024	XC-9	13657830.21	2141713.79	1301.276
XA-10	13657857.5	2141694.499	1299.367	XC-10	13657831.58	2141715.32	1302.772
XA-11	13657856.49	2141698.521	1299.452	XC-11	13657833.98	2141718.56	1302.853
XA-12	13657856.19	2141700.154	1303.267	XC-12	13657835.78	2141721.01	1303.497
XA-13	13657855.82	2141702.8	1304.973	XC-13	13657837.9	2141723.15	1303.446
XA-14	13657853.31	2141712.352	1304.541	XD-1	13657822.24	2141740.36	1303.672
XB-1	13657850.71	2141707.678	1304.163	XD-2	13657820.67	2141737.96	1302.318
XB-2	13657850.26	2141703.368	1303.857	XD-3	13657817.38	2141736.42	1302.592
XB-3	13657849.96	2141700.155	1304.065	XD-4	13657815.39	2141735.16	1300.739
XB-4	13657848.53	2141695.585	1299.526	XD-5	13657813.28	2141734.67	1299.196
XB-5	13657847.75	2141691.235	1298.231	XD-6	13657811.52	2141733.06	1298.896
XB-6	13657846.55	2141684.652	1297.054	XD-7	13657807.82	2141730.23	1298.64
XB-7	13657846.11	2141679.315	1298.007	XD-8	13657804.01	2141727.76	1298.444
XB-8	13657847.1	2141674.411	1300.098	XD-9	13657801.54	2141725.45	1298.947
XB-9	13657845.21	2141671.513	1303.093	XD-10	13657799.16	2141723.58	1299.978
XB-10	13657845.23	2141670.989	1306.029	XD-11	13657798	2141722.48	1301.202
XB-11	13657839.28	2141653.261	1306.248	XD-12	13657797.48	2141722.01	1305.196
				XD-13	13657784.22	2141708.07	1305.978

Coordinates at Anchor Points. At the new revetment, each tree was anchored near the tip, middle, and base. The anchor points on the cedar trees (the locations where the cables attach to the tree) provide a baseline for the location and orientation of each tree. Table 1 provides the coordinates, elevation, and description for each anchor point. Note that the anchor points represent the locations where the cables attach to the trees (Figure 5), not the location where the anchors were driven into the bank. In Table 3, "top anchor" means the location where the cable attaches to a tree near the tip of the cedar tree, and "base anchor" means the location where the cable attaches to the tree near the base of the cedar tree. Due to time constraints, anchors on the June 2020 revetment were not surveyed.

Table 3. Anchor points on the March 2021 revetment (UTM 14N FT, NAD 1983).

Point	North	East	Elevation	Explanation
T1-1	13657312	2141153	1297.735	Top anchor of most downstream tree
T1-2	13657320	2141152	1297.301	Base anchor of most downstream tree
T2-1	13657319	2141153	1298.666	Top anchor of the 2nd tree
T2-2	13657322	2141153	1298.135	Middle anchor on the 2nd tree
T2-3	13657327	2141152	1297.189	Base anchor of the 2nd tree
T3-1	13657326	2141153	1298.233	Top end of 3rd tree
T3-2	13657331	2141152	1297.935	Middle anchor of the 3rd tree
T3-3	13657335	2141151	1298.066	Base anchor of the 3rd tree
T4-1	13657335	2141152	1298.722	Top anchor of the 4th tree
T4-2	13657342	2141151	1297.345	Base anchor of the 4th tree
T5-1	13657341	2141153	1297.802	Top anchor of the 5th tree
T5-2	13657347	2141152	1297.612	Middle anchor of the 5th tree
T5-3	13657349	2141151	1297.672	Base anchor of the 5th tree
T6-1	13657348	2141150	1298.859	Top anchor of the 6th tree
T6-2	13657351	2141150	1297.932	Middle anchor of the 6th tree
T6-3	13657354	2141150	1297.275	Base anchor of the 6th tree
T7-1	13657352	2141151	1297.157	Top anchor of the 7th tree
T7-2	13657356	2141150	1296.972	Middle anchor of the 7th tree
T7-3	13657360	2141150	1296.885	Base anchor of the 7th tree
T8-1	13657361	2141150	1297.119	Top anchor of the 8th tree (bottom of the two stacked)
T8-2	13657364	2141150	1297.12	Middle anchor of the 8th tree (bottom of the two stacked)
T8-3	13657369	2141150	1297.023	Base anchor of the 8th tree (bottom of the two stacked)
T8T-1	13657365	2141150	1298.851	Middle anchor of tree stacked on top of the 8th tree
T8T-2	13657369	2141149	1298.628	Base anchor of tree stacked on top of the 8th tree
T9-1	13657371	2141150	1297.111	Top anchor of the 9th tree
T9-2	13657375	2141149	1296.881	Middle anchor of the 9th tree
T9-3	13657379	2141147	1296.818	Base anchor of the 9th tree
T10-1	13657380	2141149	1298.453	Middle anchor of the 10th tree
T10-2	13657386	2141149	1296.782	Base anchor on the 10th tree
T11-1	13657385	2141148	1298.681	Top anchor of the 11th tree
T11-2	13657388	2141148	1298.132	Middle anchor of the 11th tree
T11-3	13657392	2141148	1297.85	Base anchor of the 11th tree
T12-1	13657391	2141150	1297.81	Top anchor of the 12th tree
T12-2	13657396	2141150	1297.455	Middle anchor of the 12th tree
T12-3	13657399	2141151	1297.216	Base anchor of the 12th tree
T13-1	13657400	2141151	1298.515	Middle anchor of the 13th tree
T13-2	13657403	2141151	1297.265	Base anchor of the 13th tree

Structure from Motion. Photographs were collected along the length of the newly installed revetment from different vantage points. The photographs were then provided to Structure from Motion (SfM) experts Tony Layzell and Alan Peterson of the Kansas Geological Survey (KGS) for post processing into a point cloud. KGS followed the same procedure it uses for creating point clouds from unmanned aircraft systems-based images (Layzell and Peterson 2020). However, post processing revealed that the creation of an accurate SfM point cloud was not possible. Alan Peterson gave the following reasons and potential solutions:

- Three pictures were taken from a single location—one angled upstream, one straight on, and one angled downstream. This proved difficult for the software to resolve. The solution is to take a single photo, then move and take another photo.
- The pictures were essentially co-linear, all taken from the height of the picture taker, which results in poor triangulation. The solution is to make multiple passes at varying heights.
- The GPS and inertial measurement unit sensor on the camera used to take the pictures was of poor accuracy compared to the relatively small distance between the picture taker and the subject bank. Better equipment, which could include a real-time kinematic-enabled camera, would overcome this problem. If using the same equipment (low-end cell phone), increasing the distance between the camera and the bank might help.
- Too large a percentage of the picture was open sky from which common points cannot be identified. The solution is to use a selfie stick to elevate the camera and angle it downward to capture less sky.

SUMMARY: Baseline data were collected at a newly installed cedar tree revetment site on McConnel Creek, KS. The locations where the cable attached to the cedars were recorded and cross sections in and downstream of the revetment were collected. Cross sections were also collected on a second revetment which was installed 9 months previously on the same stream in 2020. The 9-month revetment had a smaller perpendicular area than at the newly installed revetment. An attempt was made to post process field photos using Structure from Motion software, but the photograph collection strategy and equipment prevented the creation of a reliable point cloud. Potential solutions include taking only one photo from a given location, making multiple passes at varying heights, increasing the distance between the camera and the bank, using a selfie stick to allow more of a downward-angled shot, and if possible, upgrading the equipment.

The data documented in this technical note can be collected in subsequent years to better understand the effectiveness, longevity, and failure modes in this cedar tree revetment, which can inform future projects.

ADDITIONAL INFORMATION: USACE participation and data collection were funded by the USACE National Regional Sediment Management (RSM) program, a Navigation Research, Development, and Technology Transfer portfolio program administered by Headquarters, USACE. For information on the RSM program, please consult http://rsm.usace.army.mil or contact the USACE National RSM Program Manager, Dr. Katherine E. Brutsché, Katherine.E.Brutsche@erdc.dren.mil. For information regarding this RSM-TN, please contact John Shelley, John.Shelley@usace.army.mil.

This technical note should be cited as follows:

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