July 5, 2024

Chelton, LLC
PO Box 460010
Fort Lauderdale, Florida 33487

Attn: David Schneider
Email: davidschneider@cheltonllc.com

Re: Former Kilmer Landfill Streambank Survey and Restoration
Technical Memorandum
Project Number 25237279

Dear Mr. Schneider:

Terracon Consultants, Inc. (Terracon) is pleased to submit the enclosed Technical Memorandum for the above-referenced project. This report is in response to the Mile High Flood District's (MHFD)'s request that Terracon conduct a bank stability analysis study prior to implementation of new bank stabilization efforts. The Technical Memorandum documenting the outcome of the site visit is attached.

Based on conditions observed at the time of the site investigation, the banks are currently eroding.

It is Terracon's opinion that proposed bank stabilization efforts done without addressing the identified root causes identified within this Technical Memorandum will eventually fail or transfer energy to other sections of the reach causing further degradation of bank and channel. Additional observation is recommended to evaluate the long-term trend of the stability of this reach. Continued periodic monitoring of the reach is also a requirement of the Notice of Environmental Use Restriction associated with the site.

We appreciate the opportunity to be of service to you on this project. Please feel free to contact any of the undersigned if you have questions or require additional information.

Sincerely,

Terracon Consultants, Inc.

Matt Leisses
Senior Environmental Scientist

Michael E. Lower
Department Manager

Jeffrey Attig
Project Manager

1.0 INTRODUCTION

Terracon Consultants, Inc. (Terracon) was retained by Chelton LLC (client), to conduct a stability evaluation of the stream bank for a section of Ralston Creek. The study area stretches from the Croke Canal to approximately 300 feet upstream of the Joyce Street culvert. This effort is in response to a proposed recreational vehicle parking lot proposed south of Ralston Creek on the property formally known as the Kilmer Landfill located at latitude 39.819724 and longitude -105.170815 in the City of Arvada, Jefferson County, Colorado. Land use along the stream consists of a medium density residential development and a recreational trail to the north and a capped landfill consisting of a sparsely vegetated field to the south.

2.0 Methodology

Terracon staff conducted a stream bank evaluation using multiple assessment approaches. The stability of the banks was evaluated visually and through measurement. Data gathered was included in a Bank Assessment for Non-point source Consequences of Sediment (BANCS) model. This methodology generates predictions of bank sediment loss within the study area. A plant inventory was conducted to identify the plant community within the riparian area. Habitat was observed and recorded to estimate the existing biological function the reach currently supports.

The two tools used in the BANCS method are the Bank Erosion Hazard Index (BEHI) and the Near Bank Stress (NBS) assessments. Ratings determined from various parameters for these two assessments were used to calculate an average estimated erosion rate for each segment of the bank throughout the reach. The erosion rates are based on a combination of the United States Fish and Wildlife Service (USFWS) Bank Erosion Rates Curve and Rosgen's Colorado Bank Erosion Rates Curve. The study area began at the end of a section of riprap lined banks and ended prior to another section of rock lined banks. Rock protected banks are not evaluated for BANCS analysis as they are not considered sources of sediment within this methodology.

Visual observations and field measurements were taken to evaluate the general stability, general assessment of conditions, and habitat within the study reach.

The bankfull width and depth were estimated throughout the reach and were used in the BANCS evaluations. Bankfull is the incipient point of flooding based upon an approximate 1.5 year storm interval. The width of the channel at the bankfull elevation was used to estimate the width-to-depth ratio. This is estimated by dividing the bankfull width by the estimated mean bankfull depth. Width to depth ratios help identify stream type and stability when compared to other parameters such as slope, entrenchment, and sinuosity.

An entrenchment ratio was estimated at points through the site. This ratio is estimated by dividing the flood-prone width (the width at twice the maximum depth of bankfull) by the bankfull width. Incision ratios were estimated by dividing the bank height by the bankfull height. Entrenchment and incision ratios provide an indication of vertical channel stability.

The hydraulic flow of Ralston Creek is manipulated for flood mitigation and prevention. Therefore, regional curves for estimated predicted bankfull dimensions were not used due to the affected hydrology, and a stable reach upstream of the canal (upstream of the study reach) was measured for bankfull width and depth for reference.

3.0 Results

The stream reach was evaluated for general stability. A head cut was observed at the start of the reach and was arrested at approximately the limits of the riprap at the upstream terminus of the study reach. The observed vertical incision was surmised to be the result of excessive stream bed mobilization during storm events. Based on preliminary measurements and bankfull estimates, the reach had an overall low width to depth ratio (overall less than 10) and most of the banks have a high bank to height ratio and was estimated to be a Rosgen G stream type. This indicates vertical degeneration of the stream channel. High entrenchment and incision ratios were found throughout the study area confirming the vertical instability of the channel. The mobilization of streambed material is contributing to the vertical and horizontal instability within the study reach.

Ratings for the BEHI ranged from Low/Low to Very High/High (Appendix A). The dominate rating was Moderate/High. The substrate of the banks consisted primarily of highly erodible sand which contributed to the elevated erosion scores. The BANCS survey resulted in an estimate of 11.8 feet per year of predicted rate of bank erosion (for this site, that equates to 6726.9 cubic feet per year and 191.6 tons per year) and a predicted erosion rate of 3.0 tons per year per foot.

Measurements were taken to estimate fluvial geomorphological dimensions. Upstream dimensions were taken as a reference comparison. The upstream reference reach (stable) bankfull dimensions include a width of 11 feet and a mean depth of 0.75 feet. The width to depth ratio is approximately 15. The floodprone width is over 40 feet wide which results in an entrenchment ratio of greater than 2.7. These are stable values for a Rosgen C stream type. The bankfull measurements below the canal within the identified study area resulted in the following values:

- 6.5 feet wide and 1.3 feet mean depth at bankfull resulting in a width to depth ratio of 5 and an entrenchment ratio of 1.7 and incision ratio of 3.0;
- 8.8 feet wide and 1 feet mean depth at bankfull resulting in a width to depth ratio of 8.8 and an entrenchment ratio of 1.6 and incision ratio of 4.0; and,

- 10.9 feet wide and 0.75 feet mean depth (area of previous bank stabilization work) at bankfull resulting in a width to depth ratio of 14.5 and an entrenchment ratio of 1.45 and incision ratio of 3.1.

These values indicate a destabilized channel. The areas where no previous bank stabilization efforts occurred were generally less stable as compared to the areas where previous stabilization work occurred. However, the previous work is currently being undermined because of channel incision from the narrow, high, and steep valley constraints and disconnection from the floodplain.

Desktop survey and observations resulted in general characteristics of channel stability. The stream banks on both sides of the channel were historically manipulated as material was added to the landfill. The banks were graded to their current steep slopes and raised elevations as opposed to forming naturally through fluvial processes. These elevations vary but banks are generally 3 to 12 feet higher within the study area compared to the stable upstream reference reach. The steep and narrow banks result in high entrenchment and incision ratios and generally low width to depth ratios. This confinement yields accelerated sheer stress and velocity compared to the upstream reference reach due to the disconnection from the floodplain. The resulting excessive energy has a high capacity for sediment transportation for both the volume and size of bed material (competency and capacity). These conditions result in vertical channel incision.

Intermittent Grade control within the channel was observed consisting of tree roots and periodic rip rap placement. The grade controls serve to lessen incision where they exist.

The study reach contained mature trees throughout the reach that are supporting soil retention. The mature trees, eastern cottonwoods with intermittent-stage willow and ash trees, are the primary surface cover in the BEHI rating and contribute to streambank stabilization. The network of tree roots prevents further bank erosion and is the main source of habitat within the study reach. The tree canopy provides thermal regulation for the stream channel. This mature tree stand is providing an essential function for the study reach.

Numerous species of flora and fauna were observed within the study area. The flora community consisted of 35 identified species and is available upon request. The inventory contains numerous native and non-native species. Fauna observed consisted primarily of 15 bird species observed during the site visit. No fish or macroinvertebrate sampling occurred during the site visit. Two garter snakes were observed during the site visit. Serval bird nesting sites were observed for both cavity and nest building dwellers. Mammals observed included squirrels, and tracks and scat signified the presence of racoons and opossums.

As previously stated, a stream bank stabilization project was constructed in sections of the reach. These areas occurred within sections 7A, 8A, 5B, and portions of 6B. The streambank stabilization work consisted of bank grading, biodegradable erosion control blankets, soil lifts along 7A, and seeding and live stakes. The vegetation within these areas is generally in good condition and the live stakes are thriving. In sections 7A, 5B, and portions of 6B, the

channel incision is causing an undercut in the banks. This is threatening the stability of the stabilization work and the biodegradable erosion control blankets are exposed. 5B has the most significant erosion within the previously repaired sections. Blankets along 5B were observed 4 feet above the water surface. Section 8A is stable and in good condition.

Sharp meanders were observed throughout the reach. The highest rates of erosion were observed along sharp meanders. These meanders are predicted to be a result of historic grading and the presence of tree roots. Layers of gravel bed material were observed at the historic elevation of the streambed. The meander at section 5B contained a relic gravel streambed layer that is over 3 feet higher than the current channel invert. This indicates the channel has eroded over 3' vertically within this section since previous stabilization efforts.

4.0 Conclusions

The root causes of instability within the reach were identified as valley confinement and low radius of curvature (sharp corners along the meanders). These causes cannot be repaired without significant impacts to adjacent land use and the mature forest stand. Impacts would include potential exposure of utilities, relocation of pedestrian trails (because of the need of laying back the streambank grading at stable slopes), exposing previously closed landfill material along the right bank, removing mature trees (some greater than 6' diameter at breast height) which would subsequently eliminate shading, existing bank and channel protection, and habitat.

The previous installation and design of the improvements of the bank stabilization appear to be executed correctly. However, due to the root causes of degradation, these improvements are not functioning or at risk of failure in 3 of the 4 areas. Prior to visiting the site, bank treatments were discussed as potential mitigation for the bank degradation. It is the opinion of Terracon that these options would be unsuccessful due to the valley constraints. Any fill within the channel would further constrain the valley by reducing cross section width thereby increasing the energy and sediment transport within the channel and exacerbating the root causes. Grading the banks back at less steep stable slopes would obliterate the mature trees, and "spot fixes" would likely fail as did previous efforts to stem localized erosion.

Areas identified for stream bank improvements without impacting mature trees is limited. Section 5B could benefit from bank stabilization efforts including grading that would not significantly impact mature trees nor exacerbate the root causes identified. A larger segment of the study area could be improved by installing live stakes if plant establishment could occur prior to bank failure as seen in previous efforts.

Stream stability for this reach will require significant efforts. A permanent fix requires floodplain reconnection and partial realignment of the channel to avoid the tortuous sinuosity. This will require impacting the landfill on the right bank and/or potential utilities and recreation trail on the left bank. Furthermore, stream realignment will result in the removal of most of the mature trees that provide essential riparian functions.

Another option includes bank grading, armoring, and incorporation of in-channel grade controls. This would also require the removal of numerous mature trees as well as importing a large quantity of boulders to create a stable reach. The solution could potentially transfer accelerated energy to downstream reaches, which would need to be analyzed as part of the design process. Both options would incur significant costs, and neither are recommended at this time based on their impacts to the mature trees that are providing significant stream and habitat benefits and buffers from surrounding land use.

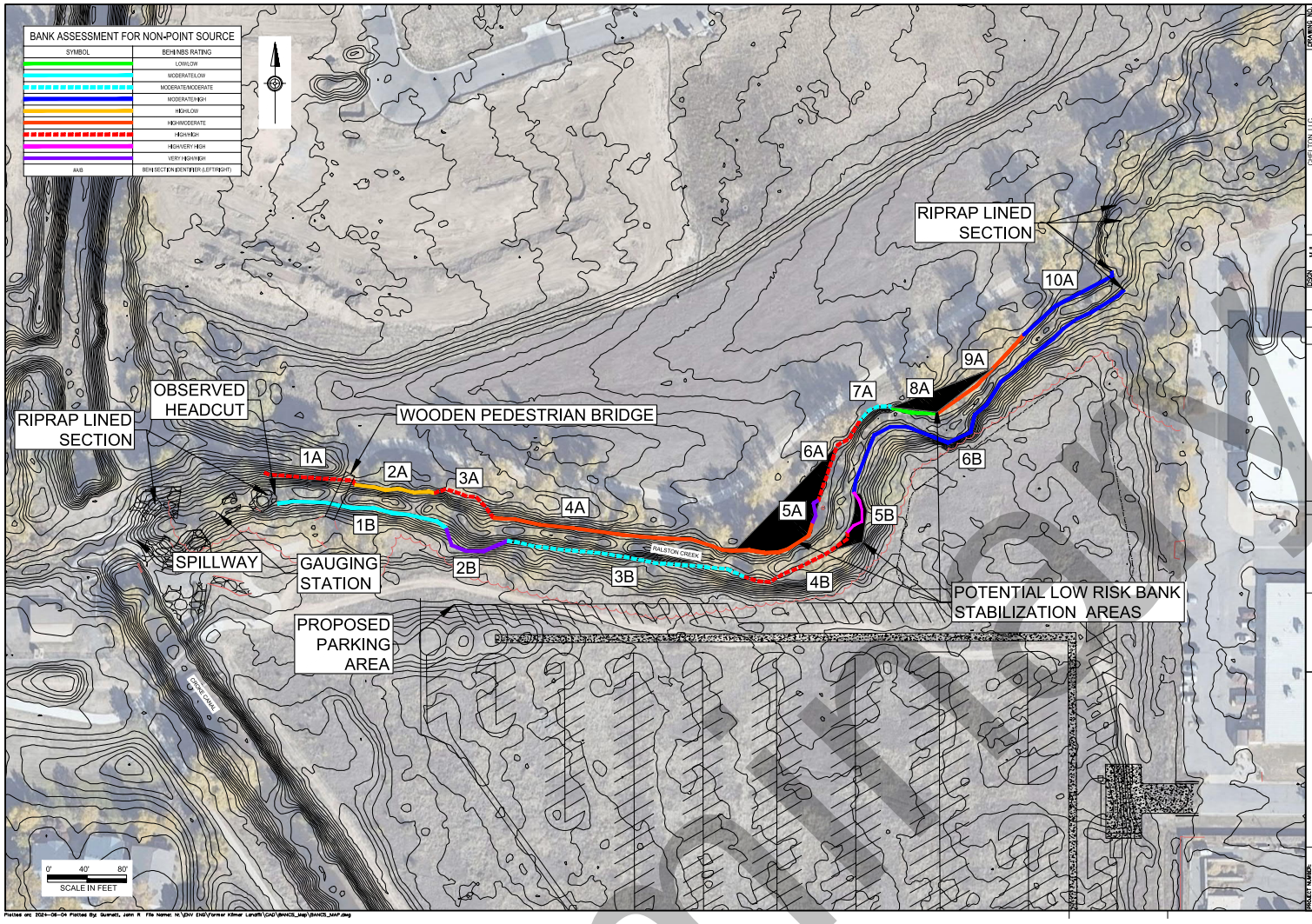
There are opportunities to provide the stream localized floodplain relief. The two sections include widening along the left bank near 5A through 9A. However, these sections include areas beyond the property limits owned by Chelton, LLC and would require removal of several mature trees. The right bank section near 5B could also be regraded and stabilized. Secondary adverse effects could occur at 5B like in previous stabilization attempts. This meander has a radius of curvature that is a lower value than what is considered stable for the reach. While this would not address the root causes of the source of instability, stabilizing this section would prevent further bank retreat as there are no mature trees along this section to prevent further degradation of the banks.

A streambed lift was considered for the reaches below sections 4A and 3B. This would be a costly solution that would require additional studies, disturbance of adjacent property, and the installation of grade control features.

It is recommended that the channel be monitored again in three years to observe the changes in the stream channel to estimate the long-term trend. If the stream continues to actively degrade to the point that it threatens infrastructure and mature trees are lost due to degradation, a restoration or stabilization could be justified. Conversely, the surface protection provided by the tree roots could arrest further erosion or the stream could evolve to a stable condition through bank widening and collapsing as depicted in Rogen's stream evolutionary predictions. The long-term trend should be verified prior to advancing stabilization efforts that may be ineffective or cause greater harm to the reach.

APPENDIX A

BANCS MAP



APPENDIX B

PHOTOGRAPHIC LOG

Photo 1	
Date: 4/24/2024	
Description: Facing upstream viewing spillway of Ralston Creek over Croke Canal.	
Photo 2	
Date: 4/24/2024	
Description: Viewing downstream from gauging station towards segments 1A (River Left) and 1B (River Right). Sections begin immediately downstream of the riprap. .	

Photo 3	
Date: 4/24/2024	
Description: Facing downstream viewing segment 1A (left bank).	
Photo 4	
Date: 4/24/2024	
Description: Facing downstream viewing segment 1B (right bank)	

Photo 5	
Date: 4/24/2024	
Description: Facing downstream viewing segments 2A on left and 1B continued on right.	
Photo 6	
Date: 4/24/2024	
Description: Facing downstream viewing 3A.	

Photo 7	
Date: 4/24/2024	
Description: Facing downstream viewing 2B.	
Photo 8	
Date: 4/24/2024	
Description: Facing upstream viewing 4A on right and 3B on left. Note undercut on 4A which resulted in a HIGH BANCS rating while 3B resulted in a MODERATE rating.	

Photo 9	
Date: 4/24/2024	
Description: Facing upstream viewing 5A.	
Photo 10	
Date: 4/24/2024	
Description: Facing downstream viewing 5B.	

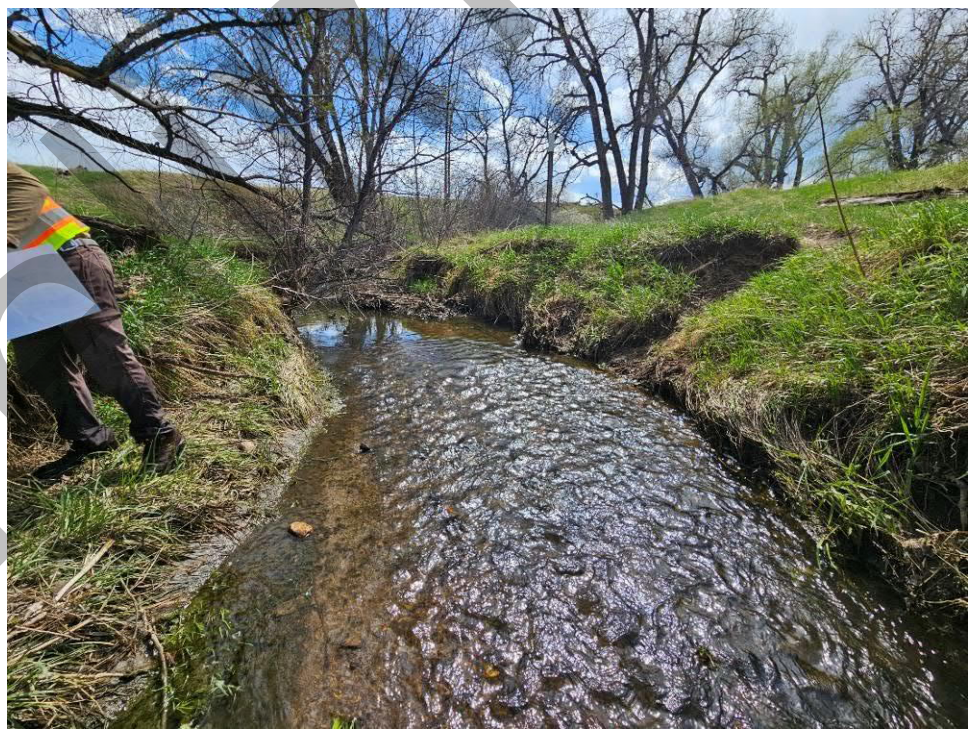
Photo 11	
Date: 4/24/2024	
Description: Facing downstream viewing segments 6A and 6B.	
Photo 12	
Date: 4/24/2024	
Description: Facing upstream viewing 7A on the right.	

Photo 13	
Date: 4/24/2024	
Description: Facing upstream viewing transition from 7A to 8A (right).	
Photo 14	
Date: 4/24/2024	
Description: Facing upstream viewing 9A (right) and 6B (left). Note undercut on 9A and bank collapse on 6B. 9A is trending towards collapsing.	

Photo 15	
Date: 4/24/2024	
Description: Facing upstream viewing the downstream end of 10A (right) and 6B (left)	
Photo 16	
Date: 4/24/2024	
Description: Facing downstream and viewing the terminus of the study reach.	

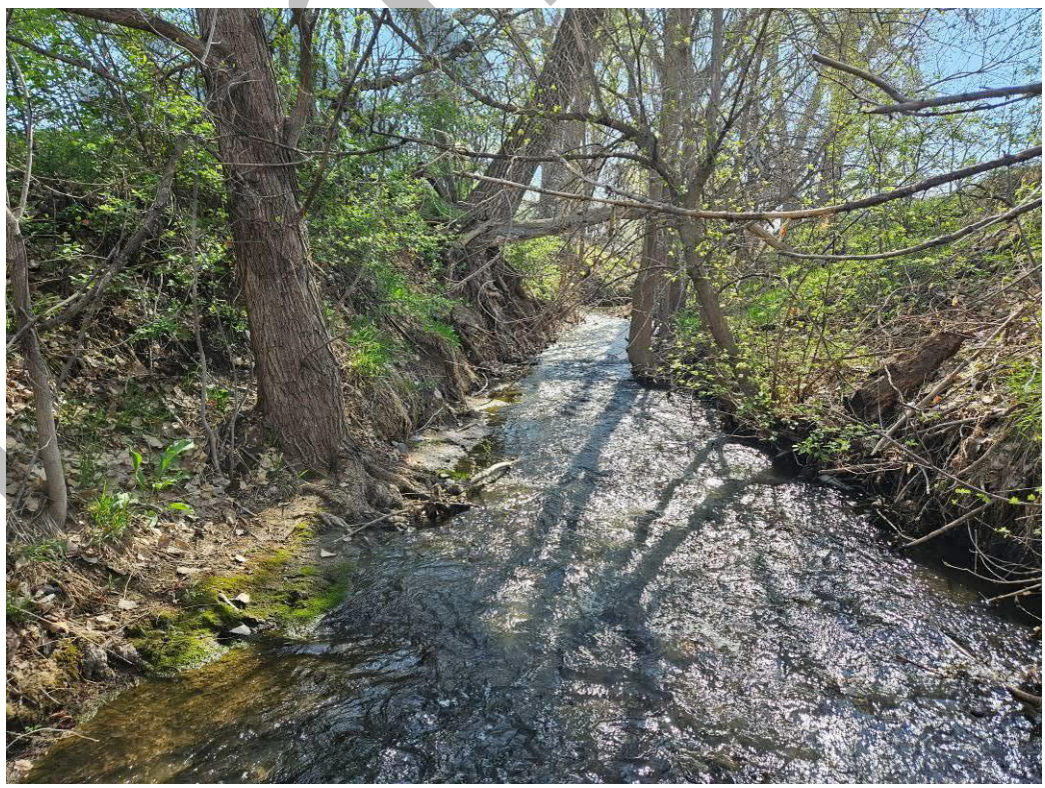
Photo 17	
Date: 4/25/2024	
Description: Facing towards Ralston Creek and the pedestrian bridge at the upstream end of the study reach. Viewing example of numerous mature riparian trees present.	
Photo 18	
Date: 4/25/2024	
Description: Viewing example of soil retention mature trees are providing despite poor bank height ratio, bank angle, and erodible sandy soils.	

Photo 19	
Date: 4/25/2024	
Description: Viewing eroded bank with dense root protection.	
Photo 20	
Date: 4/26/2024	
Description: Viewing specimen mature cottonwood tree.	

Photo 21	
Date: 4/25/2024	
Description: Viewing failing previous bank stabilization efforts due to vertical channel incision and undercutting the bank stabilization from channel confinement.	
Photo 22	
Date: 4/25/2024	
Description: Viewing reference reach section upstream from Croke Canal.	

APPENDIX C

BANCS DATA SUMMARY TABLE

Project Name	Ralston Creek								
Feature Feature I.D. (Bank., Headcut or Deposition I.D.)	Length, ft (Bank or deposition)	Height, ft (Bank or Headcut)	BEHI Rating	NBS Rating	Predicted Rate of Bank Erosion (ft/year)	Predicted Erosion Amount (ft^3/year)	Predicted Erosion Amount (tons/year)	Predicted Erosion Rate (tons/year/ft)	Comments
1A	102.9	12.5	High	High	1.00	1290.37	36.76	0.60	
2A	82.1	3.1	High	Low	0.40	101.80	2.90	0.06	
3A	78.3	11.0	High	High	1.00	861.30	24.54	0.53	
4A	343.3	2.0	High	Moderate	0.64	439.42	12.52	0.06	
5A	28.4	4.1	Very High	High	1.00	116.44	3.32	0.20	
6A	92.5	3.7	High	High	1.00	342.25	9.75	0.18	
7A	40.6	2.3	Moderate	Moderate	0.30	28.01	0.80	0.03	
8A	46.9	1.0	Low	Low	0.02	0.94	0.03	0.00	
9A	119.0	3.2	High	Moderate	0.64	243.71	6.94	0.10	
10A	114.3	2.0	Moderate	High	0.80	182.88	5.21	0.08	
1B	164.3	1.5	Moderate	Low	0.13	30.81	0.88	0.01	
2B	103.2	11.5	Very High	High	1.00	1186.80	33.81	0.55	
3B	244.2	2.9	Moderate	Moderate	0.30	212.45	6.05	0.04	
4B	123.8	3.0	High	High	1.00	371.40	10.58	0.14	
5B	40.4	3.7	High	Very High	1.75	261.59	7.45	0.31	
6B	388.5	3.4	Moderate	High	0.80	1056.72	30.11	0.13	
TOTAL OF ALL GRIDS	**2112.7**	**N/A**	**N/A**	**N/A**	**11.8**	**6726.9**	**191.6**	**3.0**	