DRAFT

MURPHY CREEK
EXISTING CONDITIONS
URBAN STREAM ASSESSMENT PROCEDURE

Prepared for:
The City of Aurora
Aurora, Colorado
and
The Mile High Flood District
Lakewood, Colorado

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1.0 SUMMARY

1.1 Project Background

Wright Water Engineers, Inc. (WWE) has prepared this report to summarize the evaluation of the **existing conditions** of a portion of Murphy Creek in Aurora, Colorado, bounded by East Mississippi Avenue to the south and E-470 to the west (Study Area) as shown on Figure 1. WWE has prepared this report on behalf of Trammell Crow Company, which is currently planning on developing the land adjacent to the Study Area, outside of the Murphy Creek floodplain. Following multiple coordination meetings with the City of Aurora (City) and the Mile High Flood District (MHFD) concerning Murphy Creek, it was requested that an Adaptive Management Plan be developed for the Study Area along with initial, targeted improvements to the creek if deemed necessary. As a first step towards the development of the Adaptive Management Plan, the City and the MHFD identified a need to assess the existing conditions of Murphy Creek through the Study Area using the MHFD's Urban Stream Assessment Procedure (USAP). This approach was discussed and agreed upon during a meeting on March 4, 2024.

Figure 1. Vicinity Map (Aerial Imagery from Google Earth)

1.2 Methodology

The Urban Stream Framework is a relatively new approach to stream management that the MHFD has adopted which places emphasis on the context of stream systems. MHFD has developed the USAP as a tool to help define this context. The existing conditions USAP completed for Murphy

Creek is based upon a draft memorandum, 'Urban Stream Assessment Procedure: Overview and Interim User Guidelines', provided by MHFD dated August 8, 2023, and authored by Brian Murphy, PhD, PE of River Works Ltd (Brian Murphy, 2023). The USAP methodology and analysis for Murphy Creek follows the guidelines and methods outlined in this memorandum as well as an Excel workbook also provided by MHFD, 'MHFD Stream Assessment Procedure V15'.

The USAP considers five elements for assessing stream conditions: 1) community values, 2) hydrology, 3) hydraulics, 4) geomorphology, and 5) vegetation. Each element includes several relevant metrics. Because not all metrics are pertinent for this Study Area, WWE coordinated with the City and the MHFD to identify the metrics applicable to this analysis. This report provides a high-level summary of the methods and findings of the USAP for the evaluation of these metrics.

As shown on the USAP scoring map in Appendix 1, Murphy Creek was subdivided into five reaches based on changes in stream character. Each reach was assessed on the identified metrics. Based upon the metric scoring, a functional rating was assigned for each element. A weight was also assigned to each element prior to aggregating the scoring to assign a functional rating for each reach. The following fractional weight was assigned to each element: 10% for community values, 20% for hydrology and hydraulics, and 25% for geomorphology and vegetation.

1.3 Results

The USAP scores the condition of the creek based on four assessment levels (from worst to best): 'not functional', 'partly functional', 'functional', and 'fully functional'. The scoring for each element, and thus the aggregate scoring for each reach, indicated that existing conditions of Murphy Creek through the Study Area were either 'functional' or 'partly functional'. The cumulative analysis of any one reach did not find that any of the reaches were 'fully functional' or 'not functional', while some individual reach metrics might score 'fully functional' or 'not functional'. A summary of the scoring is included on the map in Appendix 1. The USAP worksheets developed by MHFD are provided in Appendix 2 and also outline the assigned scoring for each metric by reach.

The condition of the creek is indicative of the historical changes in land use both upstream and within the Study Area. Generally speaking, the changes in land use have fragmented reaches of Murphy Creek with roadway crossings and altered the hydrologic regime of the creek. Changes in hydrology have impacted the creek hydraulics, geomorphology, and vegetation through the Study Area as the creek has incised in response to these stressors. The creek continues to evolve towards a state of dynamic equilibrium as sloughing banks have given rise to the development of baseflow channel within the greater creek dimension.

1.4 Next Steps

As this USAP evaluated the existing conditions of Murphy Creek, potential future responses to development within the Study Area and upstream were not considered though they could be under a future phase. It is anticipated that the planned development alone would have minimal impact on USAP scoring because the latest plan does not encroach upon the Murphy Creek floodplain.

Given that the USAP is a relatively new tool used by the MHFD to describe the context of stream systems, the use and application of these results will need to be coordinated with the City and the MHFD to identify the next steps for managing the Study Area. The existing conditions USAP could be used as a baseline for monitoring Murphy Creek or to identify potential locations for spot improvements, if necessary.

2.0 COMMUNITY VALUES

2.1 Natural Space Opportunities

To evaluate natural space opportunities for the studied Murphy Creek reaches, WWE examined the Study Area along with regions both upstream and downstream. Although the immediate surroundings of Murphy Creek remain predominantly rural, recent development has introduced trail systems and stream access points in the region. Within the Study Area, there is potential for the introduction of trail systems and waterway access. Opportunities for regional trail connectivity along Murphy Creek are limited by the E-470 corridor immediately downstream of the Study Area. Still, there are localized opportunities within the Study Area to create access points to Murphy Creek that could increase the community's engagement with the natural environment and provide recreational benefits.

2.1.1 Reaches 1, 2, 3, 4, and 5

To assess the recreational potential of the Study Area, WWE coordinated with the City of Aurora's Parks, Recreation, and Open Space department (PROS) to understand if there are any existing plans for recreational improvements through the Study Area. PROS indicated that while there are currently no planning documents that address the Study Area, the City generally recognizes the need to provide for park and open space acreage along Murphy Creek as the corridor develops. PROS further recognized that the E-470 tollway is an obvious obstacle to regional trail connectivity.

As the current development plan preserves the Murphy Creek floodplain, there are opportunities to provide local access to natural spaces. Use of these access points may be limited by trail connectivity constraints and lack of residential housing immediately adjacent to the Study Area. Consequently, this resulted in a 'functional' score for natural space opportunities. Given the regional scale of these natural space opportunities, all reaches were assigned the same score.

3.0 HYDROLOGY

3.1 Flow Regime Change

Historical aerial imagery was used to evaluate changes in flow regime throughout the Murphy Creek Study Area (Appendix 3). Overall, minimal development has occurred immediately adjacent to the Study Area, and no in-channel diversions or structures have been introduced. The hydrograph progression remains consistent with anticipated increases in flood and baseflows across the region due to historical land use changes. However, a culvert constructed under State Highway 30 has rerouted a historically south-to-north-flowing western tributary (referred to as Murphy Creek West in "The Murphy Creek and Tributaries Major Drainageway Plan Baseline Hydrology Report" prepared by Merrick and Company [2023] [Drainageway Plan]). The culvert diverts this flow eastward under the highway into Murphy Creek. This modification has likely influenced the flow dynamics and patterns within the creek downstream of the rerouted outfall.

3.1.1 Reaches 1, 2, and 3

The flow regime of these reaches changed from their historical condition when the construction of a culvert under State Highway 30 rerouted Murphy Creek West to confluence with Murphy Creek upstream of its historical confluence. This created a slightly modified hydrograph progression and resulted in a 'functional' score for the three downstream reaches (Reaches 1, 2, and 3).

3.1.2 Reaches 4 and 5

The flow regime changes of these reaches were given a score of 'fully functional' as there are little to no alterations of natural runoff processes and no in-channel structures within the Study Area. Flows have increased from historical conditions, but the hydrograph progression is consistent with the anticipated modifications resultant of upstream development.

3.2 Rate and Magnitude

Evaluation of the rate and magnitude of changes in flow was based on both historical and existing flow data. The 2-, 5-, 10-, 25-, 50-, 100-, and 500-year peak flow rates were compared for both historical and existing conditions to assess the functionality of this metric. Existing peak flow values were sourced from the Drainageway Plan (Merrick and Company, 2023). While historical peak flow values were not part of the Drainageway Plan, they were provided by MHFD and derived from the same model as that developed for the existing conditions. A summary of the historical and existing conditions peak flow rates is included in Appendix 4.

3.2.1 Reaches 1, 2, 3, 4, and 5

Significant increases in peak flow values were observed, particularly for the 2-, 5-, and 10-year low flow events, where increases exceeded 1000%. For the 100-year major storm event, peak flow increases were closer to 20%. WWE's scoring of this metric considered both major and minor peak flow events. Because rainfall-runoff models, such as that used for the Drainageway Plan, have been developed to provide greater accuracy for larger events, greater emphasis was placed on the major storm events. As such, all five reaches were scored as 'partly functional'.

3.3 Volume

Evaluation of the flow volume was based on both historical and existing flow data. The 2-, 5-, 10-, 25-, 50-, 100-, and 500-year volumes were compared for both historical and existing conditions to assess the functionality of this metric. Existing volumes were sourced from the Drainageway Plan. While historical volumes were not part of the Drainageway Plan, they were provided by MHFD and derived from the same model as that developed for the existing conditions. A summary of the historical and existing conditions flow volumes is included in Appendix 4.

3.3.1 Reaches 1, 2, 3, 4, and 5

Significant increases in runoff volumes were observed, particularly for the 2-, 5-, and 10-year low flow events, where increases exceeded 1000%. For the 100-year major storm event, peak flow increases were closer to 20%. WWE's scoring of this metric considered both major and minor events. Because rainfall-runoff models, such as that used for the Drainageway Plan, have been developed to provide greater accuracy for larger events, greater emphasis was placed on the major storm events. As such, all five reaches were scored as 'partly functional'.

4.0 HYDRAULICS

4.1 Riverscape (Channel and Floodplain Capacity)

The evaluation of channel and floodplain capacity examines the hydraulic characteristics of the floodplain and any potential encroachments. The existing floodplain is currently undeveloped. While several roads border the Study Area, they do not encroach upon the floodplain. The existing topography reveals what appears to be an area of fill upstream of E-470 that does encroach upon the floodplain. However, the fill area is well-vegetated and not discernable in historical aerial images. Major flood flow depths and velocities outside the channel are relatively low, as the floodplain is wide and slopes gradually downstream.

4.1.1 Reaches 1 and 2

Reaches 1 and 2 scored as 'functional' because the stream channel and floodplain are able to convey the major storm event (i.e., the 100-year event). There appears to be an old fill area that does encroach upon the floodplain. This feature is situated just upstream of the E-470 corridor and creates a backwater effect through the Study Area. For these reasons, Reaches 1 and 2 scored as 'functional', rather than 'fully functional'.

4.1.2 Reaches 3, 4, and 5

These reaches scored as 'fully functional' due to the absence of floodplain encroachment, the channel and floodplain's ability to convey major storm events, and the large width and shallow slope of the floodplain.

4.2 Floodplain Connectivity Ratio

The floodplain connectivity ratio was evaluated using the Valley Bottom Extraction Tool (VBET) (Gilbert et al., 2016), which generates a delineation of the estimated valley bottom polygon (see Appendix 5). The frequency upon which this area is inundated was then evaluated using the existing conditions two-dimensional hydraulic model for Murphy Creek. The scoring for this metric assesses how frequently the floodplain is inundated at "moderate intervals." For this evaluation, "moderate intervals" was defined as the 10-year event. Generally, the Study Area has high banks that prevent the floodplain outside the main channel from being inundated during events less than or equal to the 10-year event. This results in a floodplain that is infrequently inundated compared to the potential floodplain area identified by the VBET tool and led to a 'not functional' score.

4.2.1 Reaches 1, 2, 3, 4, and 5

Based on the hydraulic modeling, the 10-year event predominantly remains within the channel with minimal floodplain inundation. When compared to the estimated valley bottom, the 10-year event inundates less than 30% of this area, resulting in a score of 'not functional' for all reaches.

4.3 Entrenchment Ratio

The entrenchment ratio is a quantitative metric calculated by taking the ratio of the width of the flood-prone area to the surface width of the bankfull channel. The bankfull channel limits were estimated using field indicators and hydraulic modeling. WWE found that the inundation boundary produced at 70% of the 2-year flow rate correlated well with the limits of the observed bankfull channel; therefore, this flow rate was used to approximate bankfull for the purposes of this analysis. Representative cross sections were taken for each reach, measuring the surface width of the bankfull channel and the surface width at twice the bankfull channel depth. The entrenchment ratio was then calculated for each reach, and the reaches were scored based on the value of this ratio (see Appendix 6).

4.3.1 Reach 1

Using 70% of the 2-year event as the bankfull flow rate, WWE compared this bankfull channel surface width to twice the bankfull channel depth surface width for Reach 1. For Reach 1, the entrenchment ratio was 1.5, resulting in a score of 'partly functional'. Due to the realignment of Murphy Creek and aggradation resultant of the construction of E-470, this reach features a wider bankfull channel than the dimension observed elsewhere in the Study Area, resulting in the relatively lower score.

4.3.2 Reaches 2, 3, 4, and 5

Using 70% of the 2-year event as the bankfull flow rate, WWE compared this bankfull channel surface width to twice the bankfull channel depth surface width for Reaches 2, 3, 4, and 5. For these reaches, the entrenchment ratio was greater than 2.5, resulting in a score of 'fully functional'.

5.0 GEOMORPHOLOGY

5.1 Sediment Transport Capacity

The sediment transport capacity of each reach was assessed using the Capacity Supply Ratio (CSR) (Stroth et al., 2017). The CSR compares the sediment transport capacity, or effectiveness, of the study reach to the reach immediately upstream. By comparing the sediment transport capacity between two reaches, trends in local erosion and sedimentation can be estimated. To estimate the sediment transport capacity of each reach, the following information is needed: 1) a Flow Duration Curve (FDC), 2) bed material size, and 3) an estimate of the creek dimension. CSR documentation is provided as Appendix 7.

WWE completed a regional gage analysis utilizing the web-based hydrologic tools on eRAMS (the Environmental Resource Assessment and Management System [STRATA, 2024]). FDCs were developed for several gages within the same hydrophysiographic region as Murphy Creek. The

FDCs for each gage were normalized by drainage area, averaged, and then scaled to the Study Area to create an estimate FDC for Murphy Creek.

Bed material samples were collected for each reach to estimate the bed material gradation. The samples were taken at a location that was generally representative of the entire reach. A sieve analysis was completed by GROUND Engineering Consultants, Inc. for each of the collected samples to provide a material gradation. As WWE did not have access to the upstream property, it was assumed that the bed material gradation for Reach 5 was close to that of the upstream reach, and therefore Reach 5 was used to estimate the effectiveness of the reach upstream of the site.

Finally, WWE estimated the channel dimensions and slopes from field surveys previously conducted for the project. The dimensions were taken at a location that was generally representative of the larger reach; however, variability within each reach was observed.

With these inputs, the effectiveness of each reach was estimated and compared to that of the reach upstream to calculate the CSR and ultimately assess the sediment transport capacity of each reach. See Appendix 7 for documentation of the FDC, sieve analysis, and effectiveness calculated for each reach.

5.1.1 Reach 1

This reach has similar sediment capacity to that of the upstream reach; however, the downstream E-470 culverts somewhat disrupt continuity in the sediment transport process. WWE is not aware of these culverts requiring extensive or consistent maintenance. Therefore, Reach 1 was determined to be ‘functional’.

5.1.2 Reaches 2 and 4

This reach features finer material than that of the reach upstream, indicating that it is depositional. Minimal maintenance would be required to maintain functionality. Therefore, Reaches 2 and 4 were determined to be ‘functional’.

5.1.3 Reach 3

This reach features larger bed material than that of the downstream reaches, suggesting that it may be supply limited. Although this reach may tend to be erosional, no significant headcuts were observed and minimal maintenance would be required to maintain its current function. Therefore, Reach 3 was determined to be ‘functional’.

5.1.4 Reach 5

This reach features larger bed material than that of the downstream reaches, suggesting that it may be supply limited. Multiple small headcuts were observed, although they are stabilized by existing vegetation, indicating that some maintenance may be required to limit future erosion. Therefore, Reach 5 was determined to be ‘partly functional’.

5.2 Channel Stability Index

The evaluation of the channel stability index metric is based on a number calculated using the Rapid Geomorphic Assessment (RGA) form. WWE utilized the RGA form from "Characterization of Suspended-Sediment Transport Conditions for Stable, 'Reference' Streams in Selected Ecoregions of EPA Region 8" (Klimetz, et al., 2009). This form assesses primary bed material, bank protection, incision, constriction, erosion, bank instability, vegetative cover, bank accretion, and the stage in channel evolution for each study reach. Each of these factors is assigned a score, which is then totaled on an individual reach basis to determine the reach's functionality. A detailed description of the scoring for each factor across the five reaches can be found in Appendix 8.

5.2.1 Reach 1

See the RGA form in the appendices for a score of each metric. This reach received a total score of 8.5, leading to a rating of 'fully functional'.

5.2.2 Reaches 2, 3, and 5

See the RGA forms in the appendices for a score of each metric. Reaches 2, 3, and 5 received total scores of 10.5, 13, and 15, respectively, leading to ratings of 'functional'.

5.2.3 Reach 4

See the RGA form in the appendices for a score of each metric. This reach received a total score of 23, leading to a rating of 'not functional'.

5.3 Channel Adjustments – Pattern

The channel pattern adjustments metric was evaluated by comparing the existing channel pattern to historical images dating back to 1965. In general, limited change has been observed in the Murphy Creek Study Area due to minimal development around the corridor and the absence of in-stream structures. The channel meanders through the Study Area, showing minor adjustments in its historical alignment. The most notable change in the historical channel pattern is at the downstream end, where the construction of E-470 and the associated culverts under the highway redirected the channel flow path to the north.

5.3.1 Reach 1

The construction of E-470 and a culvert under the highway realigned the historical flow path of the channel to the north, affecting roughly 50% of this reach. This is considered a moderate change to the channel pattern from historical condition and led to a score of 'partly functional'.

5.3.2 Reaches 2, 4, and 5

These reaches show limited change in channel pattern when compared to their historical channel patterns, leading to a score of 'functional' for these three reaches.

5.3.3 Reach 3

Unlike the other reaches within the Study Area, Reach 3 is straight. While available historical aerial imagery shows it in its current alignment, the oldest photograph does not pre-date Highway 30. It is possible that Murphy Creek was realigned with the construction of this road but there is not readily available information to confirm that this is the case. As there is not hard evidence indicating that this reach has been realigned, it was scored as ‘functional’.

5.4 Channel Adjustments – Width

The channel width adjustments metric was evaluated by comparing the existing channel width to historical images dating back to 1965. In general, all reaches of Murphy Creek exhibit limited change in channel width, with variations of less than 15% from historical measurements. This stability is attributed to the minimal development in the surrounding corridor and the absence of in-stream structures. The consistent channel width across the Study Area leads to a ‘functional’ rating across all five reaches.

5.4.1 Reaches 1, 2, 3, 4, and 5

Based on historical imagery, all five reaches show limited changes, less than 15%, in channel width when compared to their historical channels. The consistent channel width across the Study Area leads to a ‘functional’ rating across all five reaches.

5.5 Channel Adjustments – Condition (SEM Stage)

The channel condition adjustments metric is based on the stage of each reach in the Stream Evolution Model (SEM) as outlined in “A Stream Evolution Model Integrating Habitat and Ecosystem Benefit” (Cluer and Thorne, 2014). Using topographic surveys and field assessments, WWE examined the active channel, bank stability, aggraded and slumped material, floodplain terraces, and critical bank height for each reach to determine its SEM stage. All reaches were classified into either stage 4, stage 5, or stage 6, with the commonality among these stages being that degradation is the dominant process.

5.5.1 Reach 1

Reach 1 follows a braided channel pattern and falls into stage 6, the quasi-equilibrium SEM stage. Riparian plant communities are present and aggradation improves connectivity with and functionality of floodplain plants. Falling into the SEM stage 6 leads to a rating of ‘partly functional’.

5.5.2 Reaches 2, 3, and 5

Reaches 2 and 5 follow a meandering channel pattern and Reach 3 follows a relatively straight channel pattern. These three reaches fall into stage 5, the aggrading and widening SEM stage. Aggradation generates some bedforms and bars but the channel remains dysfunctional with regard to effective storage of sediment. The floodplain plant community remains generally isolated from the channel and channel widening may continue. Falling into the SEM stage 5 leads to a rating of ‘not functional’ for the three reaches.

5.5.3 Reach 4

Reach 4 follows a relatively straight channel pattern and falls into stage 4, the degradation and widening SEM stage. Sediment inputs from bank retreat initiate limited bedform and bank development, but mass failures eliminate stable banks and increase the extent of river cliffs that destroy riparian margins. Falling into the SEM stage 4 leads to a rating of ‘not functional’.

5.6 Channel Adjustments – Bed

The bed channel adjustments metric was determined based on topographic data and field assessments of each reach. WWE analyzed the topographic data to establish a hypothetical straight-grade thalweg, tying into the existing thalweg at the upstream end of Reach 5 and the downstream end of Reach 1. By comparing the surveyed thalweg to this straight-grade hypothetical thalweg, areas of aggradation and degradation were identified and quantified. Degradation was consistently observed across all reaches, with higher values, indicating a less functional stream, found in the upstream reaches. This was corroborated by WWE’s field survey, which noted several 1.5-foot to 2.0-foot headcuts in the active stream channel near the upstream end. In contrast, the downstream half of the Study Area generally exhibited more aggraded material, resulting in lower bed-level changes and a more functional stream score.

5.6.1 Reaches 1, 2, and 3

The three downstream reaches have more aggraded and slumped material in the channel when compared to the upstream reaches. Bed level changes of 0.5 foot to 1.0 foot were observed, leading to a rating of ‘functional’.

5.6.2 Reach 4

Reach 4 has the most significant channel degradation and incision, with bed level changes of greater than 2.0 feet when compared to a hypothetical straight-grade thalweg. This led to a rating of ‘not functional’ for this reach.

5.6.3 Reach 5

Reach 5 has moderate bed level changes, approximately 1.0 foot to 2.0 feet when compared to a hypothetical straight-grade thalweg, due to channel degradation and several headcuts. This led to a rating of ‘partly functional' for this reach.

6.0 VEGETATION

WWE assessed vegetation in the five reaches for nine different factors, summarized below. Appendix 9 provides images of vegetation in the Study Area, while Appendix 10 provides a photo log of the five reaches, including vegetation.

6.1 Clogging of Crossing Structures

The purpose of the crossing structures (bridges or culverts) clogging metric is to identify whether the structures are functioning as designed, without encroaching vegetation hindering the structure’s performance. A 'fully functional' structure, one without encroaching trees and shrubs clogging bridge or culvert openings, receives 3 points. A 'not functional' structure (with significant clogging) receives 0 points.

6.1.1 Reach 1

At Reach 1, the bridge opening functions operationally, but there are a significant number of cattails (*Typha* sp.) present near and around the bridge opening. Due to the cattail presence and potential for future clogging, Reach 1 received a score of 1.5 points.

6.1.2 Reaches 2, 3, and 4

No crossing structures exist in Reaches 2, 3, and 4 of the Study Area.

6.1.3 Reach 5

The bridge opening in Reach 5 functions similar to Reach 1, the cattails and other vegetation surrounding the bridge opening could lead to clogging of the structure in the future. Because of the proximity of vegetation to the bridge opening, Reach 5 received a score of 2 points.

6.2 Vegetation Along the Channel Banks and Proximal Floodplain

The vegetation along channel banks and floodplains metric compares the height of herbaceous vegetation as it relates to the flow. Non-functional vegetation would be tall, herbaceous plants that overreach the stream, dense willows on side slopes, or dense cattails within the channel bottom (receives 0 points). The primary vegetation satisfying this category within Reaches 1 through 5 is cattails within the channel bottom. A 'fully functional' system has short, herbaceous vegetation or tree seedlings, with higher flow than the vegetation height and would receive 3 points.

6.2.1 Reaches 1, 2, and 5

Reaches 1 and 2 received a score of 0 due to the presence of tall, herbaceous vegetation throughout the reaches. The vegetation is much higher than the average depth of flow in most places.

6.2.2 Reach 3

Reach 3 received a score of 1. In comparison to the other reaches, Reach 3 has open bank areas that lack tall vegetation. Over-reaching vegetation and willows are present; however, the average depth of flow equals the vegetation height and/or is 75% of the vegetation height.

6.2.3 Reach 4

Reach 4 has cattail population and tall vegetation growth. However, this vegetation is not as dense or tall as in Reaches 1, 2, and 5. Therefore, Reach 4 was given a score of 0.5.

6.3 Vegetation Vigor

Vegetation vigor is determined by the senescence, or degradation, visually shown in plants. This could be die-off, yellowing of leaves, or overall biological aging based on physical characteristics. 'Fully functional' reaches with 0 to 10% senescence receive 3 points.

6.3.1 Reaches 1, 2, 3, 4, and 5

The vegetation is fully functioning in all the evaluated reaches, with 0 to 10% senescence observed.

6.4 Bank Stability

Bank stability is the streambank's ability (based on the soil composition and vegetation present) to resist erosion via gravity and water. Vegetation communities and associated root systems can shield the bank from erosion while reducing the water velocity. In addition, roots can protect soil from gravity and high flow events. Bank stability is rated on a scale of 0 to 3 using the Greenline Bank Stability method provided in the United States Department of Agriculture 2000 report titled "Monitoring the Vegetation Resources in Riparian Areas" authored by Alma Winward (General Technical Report RMRS-GTR-47).

6.4.1 Reach 1

Most of Reach 1 is comprised of stable banks with woody vegetation; however, there is a large section of this reach that has collapsed. Therefore, Reach 1 was given a score of 1.75.

6.4.2 Reach 2

Reach 2 has groups of weedy herbaceous vegetation communities along the banks, with some upland plant communities above the banks. There are no woody communities rooted within the banks. Sections of the channel have high, steep, bank angles, and lack vegetation to support the unstable channel form. Reach 2 was given a score of 1.25.

6.4.3 Reaches 3 and 4

Reach 3 and 4 banks are primarily comprised of upland vegetation, both above and within the bank, without the support of woody vegetation. There are several sections of collapsed bank within these reaches due to unstable channel form and high, steep bank angles. Reaches 3 and 4 were given a score of 1.5.

6.4.4 Reach 5

Reach 5 has more willow species (*Salix* sp.) present to assist in bank stabilization. In addition, this reach has gradual banks compared to other, steeper reaches. Accordingly, Reach 5 was given a score of 2.

6.5 Native Riparian Vegetation Cover

The native riparian vegetation metric scores the amount of native species present within the riparian zone of the stream bank. Fully functioning riparian cover includes greater than 90% native riparian speciation and receives 3 points. Nonfunctional cover, with less than 50% native vegetation, receives 0 points.

6.5.1 Reaches 1, 3, and 4

Vegetation in Reaches 1, 3, and 4 is approximately 50 to 70% native, in addition to non-native or invasive species present. Some identified species include invasive spurge (*Euphorbia* sp.), cattails, and willows. Reaches 1, 3, and 4 received a score of 1.5.

6.5.2 Reach 2

Vegetation in Reach 2 is between 50 and 70% native, including spurge (not native), cattails, and willows. Reach 2 received a score of 1.25.

6.5.3 Reach 5

Vegetation in Reach 5 consists of approximately 70 to 90% native vegetation, although the average percentage is closer to 70% (i.e., the lower end of the range). Reach 5 received a score of 2.

6.6 Native Wetland Vegetation Cover

Wetlands are defined based on the hydrology, hydric soils, and hydric vegetation present in the Study Area. Native wetland vegetation can promote habitat, stabilize streambanks, provide flood protection, and improve water quality. Wetland species identified at Murphy Creek include, but are not limited to, cattails, common rush (*Juncus* sp.), and willows. Fully functioning native wetland speciation cover greater than 90% receives 3 points.

6.6.1 Reaches 1 and 5

Reaches 1 and 5 possess native wetland vegetation cover between 70 and 90%. These reaches were given a score of 2.

6.6.2 Reach 2

Native wetland vegetation cover in Reach 2 is between 50 and 60%. The cattails are not as prevalent in Reach 2 compared to Reaches 1 and 5, making the total score for Reach 2 slightly lower at 1.75.

6.6.3 Reach 3

Wetland vegetation cover and diversity is low in Reach 5, featuring more upland and noxious weed speciation. Reach 3 received a score of 1.

6.6.4 Reach 4

With native wetland vegetation cover of roughly 50%, Reach 4 was given a score of 1.5.

6.7 Noxious Weed Cover

Noxious weeds are plant species that may negatively impact native speciation by overpopulation, injure plants and/or animals, or degrade the natural ecosystem. A fully functioning system would possess less than 3% noxious weed and receive 3 points. A 'not functional' system would be inundated with noxious weeds, covering greater than 30% of the Study Area, and receive 0 points.

6.7.1 Reaches 1, 2, 3, and 4

Reaches 1, 2, 3, and 4 are functional, but possess noxious weed populations between 3 and 10%. Identified noxious weed species include spurge, mullein (*Verbascum* sp.), and thistle (*Cirsium* sp.). Reaches 1, 2, 3, and 4 therefore received a score of 2.

6.7.2 Reach 5

Reach 5 possesses noxious weed covering of roughly 10%. This reach had much less cover overall and received a score of 1.5.

6.8 Vegetation Community Mosaic

The Vegetation Community Mosaic metric is based on the number of plant communities present within the reach (upland, wetland, noxious, woody). A fully functioning mosaic would receive 3 points for three or more active communities.

6.8.1 Reaches 1, 2, 3, and 4

Reaches 1, 2, 3, and 4 receive a score of 2. A score of 2 is representative of identifying two to three plant communities within the reaches. Plant communities in these reaches include upland grass populations, cattails, noxious weed, and willows. Reaches 1, 2, 3, and 4 were given a score of 2.

6.8.2 Reach 5

Reach 5 possesses greater variety in the amount of vegetation communities present. Plant communities include upland grass, wetland, noxious weed, and woody speciation type. Reach 5 receives a score of 2.75.

6.9 Woody Species Recruitment

Woody species, or plants that produce wood as its hard stem, assist streambanks and riparian zones in bank support and stabilization. The primary woody species present at Murphy Creek is the willow. A fully functioning system would present multi-age recruitment of woody species (from seedlings, saplings, and whips) and would score 3 points. A non-functioning system would not possess any saplings but may have the substrate to support future woody speciation.

6.9.1 Reach 1

Reach 1 has a large group of willows, including saplings. Positive identification of saplings indicates functional wood speciation recruitment based on the scoring sheet, so Reach 1 received a score of 2.

6.9.2 Reaches 2 and 4

Reaches 2 and 4 are partly functional, possessing suitable substrate to promote woody species development and with seedlings present, but having no mature or adolescent saplings. Reaches 2 and 4 received a score of 1.

6.9.3 Reach 3

WWE identified only one sapling in Reach 3, but the primary development stage of woody species within the stretch is suitable substrate. Reach 3 received a score of 1.5

6.9.4 Reach 5

WWE positively identified multi-age development of woody species (primarily willows) in Reach 5, which was given a score of 3.

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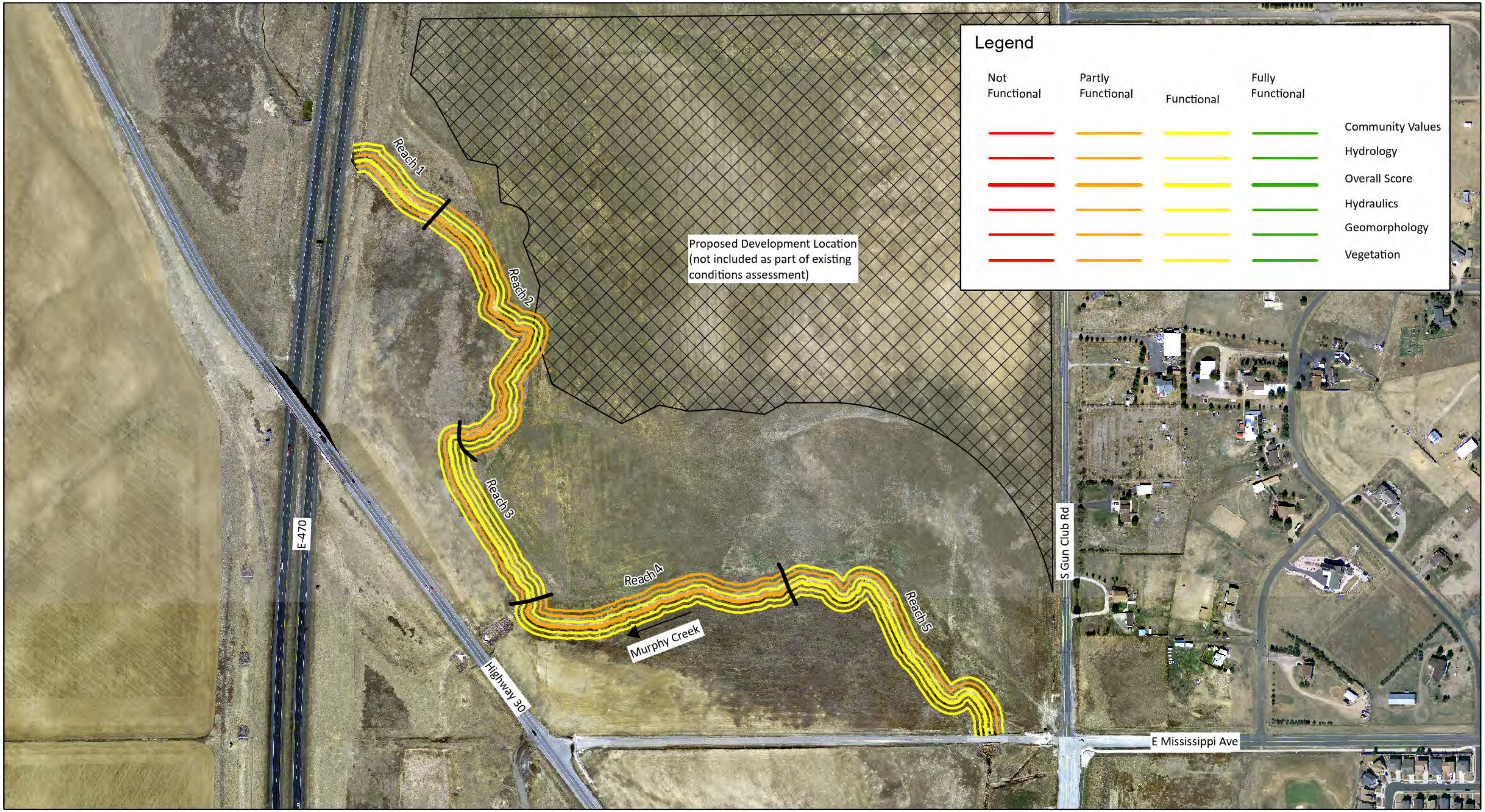
Appendix 1: USAP Summary Map



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WWE WRIGHT WATER ENGINEERS, INC.

AURORA, COLORADO

EXISTING CONDITIONS USAP SCORING

MURPHY CREEK

0 150 300 600 Feet

PROJECT NO 221-076.000

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FIGURE 1

Appendix 2: USAP Worksheets

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EXISTING CONDITIONS USAP SCORING MATRIX

ELEMENT	INDICATOR	METRIC	CODE	REACH 1	REACH 2	REACH 3	REACH 4	REACH 5
COMMUNITY VALUES	ACCESS TO NATURE	NATURAL SPACE OPPORTUNITIES	VN7a	2	2	2	2	2
			ACCESS TO NATURE - SUM	*2*	*2*	*2*	*2*	*2*
			HUMAN CONNECTION - SUM	*2*	*2*	*2*	*2*	*2*
HYDROLOGY	FLOW REGIME	FLOW REGIME CHANGE	HR1	2	2	2	3	3
		RATE/MAGNITUDE	HR2	1	1	1	1	1
		VOLUME	HR3	1	1	1	1	1
			FLOW REGIME - SUM	*4*	*4*	*4*	*5*	*5*
			HYDROLOGY- SUM	*4*	*4*	*4*	*5*	*5*
HYDRAULICS	FLOW CONVEYANCE	RIVERSCAPE CAPACITY	HyC1	2	2	3	3	3
			FLOW CONVEYANCE - SUM	*2*	*2*	*3*	*3*	*3*
	FLOODPLAIN CONNECTIVITY	FLOODPLAIN CONNECTIVITY RATIO	HyFC1	0	0	0	0	0
		ENTRENCHMENT RATIO (or OVERBANK RETURN INTERVAL)	HyFC2	1	3	3	3	3
			FLOODPLAIN CONNECTIVITY - SUM	*1*	*3*	*3*	*3*	*3*
			HYDRAULICS - SUM	*3*	*5*	*6*	*6*	*6*
GEOMORPHOLOGY	SEDIMENT REGIME	SEDIMENT TRANSPORT CAPACITY	GR5	2	2	2	2	1
			SEDIMENT REGIME - SUM	*2*	*2*	*2*	*2*	*1*
	STABILITY	CHANNEL STABILITY INDEX	GS4	3	2	2	0	2
			STABILITY - SUM	*3*	*2*	*2*	*0*	*2*
	MORPHOLOGY	CHANNEL ADJUSTMENTS-PATTERN	GM9	1	2	2	2	2
		CHANNEL ADJUSTMENTS-WIDTH	GM10	2	2	2	2	2
		CHANNEL ADJUSTMENTS-SEM STAGE	GM11	1	0	0	0	0
		CHANNEL ADJUSTMENTS-BED LEVEL CHANGE	GM12	2	2	2	0	1
			MORPHOLOGY - SUM	*6*	*6*	*6*	*4*	*5*
			GEOMORPHOLOGY - SUM	*11*	*10*	*10*	*6*	*8*
VEGETATION	FLOW CONVEYANCE	CLOGGING OF CROSSING STRUCTURES	VC6	1.5	-	-	-	2
		VEGETATION ALONG THE CHANNEL BANKS AND FLOODPLAIN	VC9	0	0	1	0.5	0
			FLOW CONVEYANCE - SUM	*1.5*	*0*	*1*	*0.5*	*2*
	DYNAMIC STABILITY	VEGETATION VIGOR	VS7	3	3	3	3	3
		BANK STABILITY	VS9	1.75	1.25	1.5	1.5	2
		NATIVE RIPARIAN VEGETATION COVER	VS10	1.5	1.25	1.5	1.5	2
		NATIVE WETLAND VEGETATION COVER	VS11	2	1.75	1	1.5	2
			DYNAMIC STABILITY - SUM	*8.25*	*7.25*	*7*	*7.5*	*9*
	RESILIENCY	NOXIOUS WEED COVER	VR9	2	2	2	2	1.5
			RESILIENCY - SUM	*2*	*2*	*2*	*2*	*1.5*
	ADAPTABILITY	VEGETATION COMMUNITY MOSIAC	VA7	2	2	2	2	2.75
		WOODY SPECIES RECRUITMENT	VA8	2	1	1.5	1	3
			VEGETATION - SUM	*4*	*3*	*3.5*	*3*	*5.75*
			VEGETATION - SUM	*16*	*12.25*	*13.5*	*13*	*18.25*

*metrics not evaluated are not shown in this table

LEGEND	
0	NOT FUNCTIONAL
1	PARTLY FUNCTIONAL
2	FUNCTIONAL
3	FULLY FUNCTIONAL

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USAP SCORING MATRIX ELEMENT WEIGHTING BREAKDOWN

Give greatest weight to 'master variables'

ELEMENT WEIGHTING	
COMMUNITY VALUES	*10%*
HYDROLOGY	*20%*
HYDRAULICS	*20%*
GEOMORPHOLOGY	*25%*
VEGETATION	*25%*
SUM	*100%*

Element weighting may be adjusted. Sum must equal 100.

		REACH 1	REACH 2	REACH 3	REACH 4	REACH 5
OVERALL						
TOTAL SCORE (0-100):		*54.7*	*49.9*	*53.3*	*47.2*	*59.2*
COMMUNITY VALUES						
TOTAL SCORE (0-100):		*66.7*	*66.7*	*66.7*	*66.7*	*66.7*
COMMUNITY VALUES INDICATORS	ACCESS TO NATURE	66.7	66.7	66.7	66.7	66.7
HYDROLOGY						
TOTAL SCORE (0-100):		*44.4*	*44.4*	*44.4*	*55.6*	*55.6*
HYDROLOGY INDICATORS	FLOW REGIME	44.4	44.4	44.4	55.6	55.6
HYDRAULICS						
TOTAL SCORE (0-100):		*33.3*	*55.6*	*66.7*	*66.7*	*66.7*
HYDRAULICS INDICATORS	FLOW CONVEYANCE	66.7	66.7	100.0	100.0	100.0
	FLOODPLAIN CONNECTIVITY	16.7	50.0	50.0	50.0	50.0
GEOMORPHOLOGY						
TOTAL SCORE (0-100):		*61.1*	*55.6*	*55.6*	*33.3*	*44.4*
GEOMORPHOLOGY INDICATORS	SEDIMENT REGIME	66.7	66.7	66.7	66.7	33.3
	STABILITY	100.0	66.7	66.7	0.0	66.7
	MORPHOLOGY	50.0	50.0	50.0	33.3	41.7
VEGETATION						
TOTAL SCORE (0-100):		*58.3*	*45.4*	*50.0*	*48.1*	*67.6*
VEGETATION INDICATORS	FLOW CONVEYANCE	25.0	0.0	33.3	16.7	33.3
	DYNAMIC STABILITY	68.8	60.4	58.3	62.5	75.0
	RESILIENCY	66.7	66.7	66.7	66.7	50.0
	ADAPTABILITY	66.7	50.0	58.3	50.0	95.8

*TOTAL SCORE IS A WEIGHTED AVERAGE OF THE NUMBER OF METRICS PER INDICATOR

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MURPHY CREEK REACH 1

Element	Scale	Indicator	Description	Metrics	Measurement (definition)	Assessment Method	Analysis	Metric Code	Functional characteristics (and/or maintenance requirements)	Score Level of Function (and/or maintenance)	Score
Community Values	Watershed	Access to Nature	Presence of/Easy access to green spaces, natural areas, parks, trails, and waterways	Natural space opportunities	Mapped locations of proposed parks and open space, vacant lands, natural land cover, riparian corridor	Identify natural space opportunities based on land use and cover characteristics, schools, community gardens, and potential for certified backyard wildlife habitat areas.	Remote sensing–GIS, Trust for Public Land Metro DNA data	VN2	(A) Very high opportunities within the watershed to provide access to natural spaces (B) High opportunities within the watershed to provide access to natural spaces (C) Moderate opportunities within the watershed to provide access to natural spaces (D) Low to no opportunities within the watershed to provide access to natural spaces	Very high (3 points) High (2 points) Moderate (1 point) Low or no opportunities (0 points)	2
Hydrology	Corridor	Flow Regime	The shape and size of stream channels, the distribution of vegetation, and the stability of channel bed and banks are all largely determined by the interaction between the flow regime and local geology and landform.	Flow regime change	Evaluation of changes in flow regime along the stream corridor under existing conditions, including anthropogenic impacts such as diversions, groundwater wells, and unnatural inflow	Evaluation of changes in flow regime (quantitative). In absence of available data, the assessment is based on field survey to identify locations along the corridor where the flow regime changes (qualitative)	Hydrological data and/or modelling such as stream gage analysis or hydrograph flow-routing	HR1	(A) Fully functional: downstream hydrograph progression is consistent with anticipated increases in flood flows, based on upstream contributing area. No alterations of natural runoff processes and no in-channel structures (no stressors). (B) Functional: downstream hydrograph progression is slightly modified due to limited alterations of natural runoff processes and in-channel structures (minimal stressors). (C) Partly functional: downstream hydrograph progression is moderately modified due to multiple alterations of natural runoff processes and in-channel structures (multiple stressors). (D) Not functional: downstream hydrograph progression is significantly modified due to multiple alterations of natural runoff processes and in-channel structures (multiple stressors).	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	2
	Reach	Flow Regime	Ability of stream to meet intent of the Master Plan and adjust to modified flow conditions and high functioning lower maintenance streams Determine flow regime for the following conditions: - Future land use - Existing land use - Historical condition - MP condition	Rate/magnitude	Evaluation of the pattern of peaks in the hydrograph and deviation of annual net peak flow discharge to understand impacts geomorphologically relevant thresholds (evaluate base flow, Active channel flow (average annual flow), 2-year, 5-year, 10-year, 50-year, and 100-year)	Evaluation of flow rate and magnitude between historical, existing, and future conditions (quantitative). Master Plan Data and/or Hydrograph flow-routing for existing and future land use from hydrologic model; stream gage analysis for historical and existing conditions, if gage data is available	Hydrological data, desktop analysis, and/or modelling (CUHP and EPA-SWMM)	HR2	(A) Fully functional: magnitude and duration of annual discharge peaks closely resembles optimal hydrograph. Net change of existing condition value compared to baseline (natural) condition value less than 10% of the flow magnitude. (B) Functional: hydrograph has a natural seasonal pattern, but peaks are attenuated, elevated, extended, or shortened. Net change of existing condition value compared to baseline (natural) condition value between 10% and 20% of the flow magnitude. (C) Partly functional: disrupted seasonal hydrograph patterns and/or departure from natural peak flow magnitude. Net change of existing condition value compared to baseline (natural) condition value between 20% and 40% of the flow magnitude. (D) Not functional: disrupted seasonal hydrograph patterns and/or departure from natural peak flow magnitude. Net change of existing condition value compared to baseline (natural) condition value, more than 40% of the flow magnitude.	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	1
				Volume	The total volume metric rates the net annual change in water volume caused by anthropogenic uses as a percentage of natural flows.	Analysis of total volume between historical, existing, and future conditions (quantitative).	Hydrological data, desktop analysis, and/or modelling	HR3	(A) Fully functional: net change of existing condition value compared to baseline (natural) condition value less than 10% of the total annual volume. (B) Functional: net change of existing condition value compared to baseline (natural) condition value between 10% and 20% of the total annual volume. (C) Partly functional: net change of existing condition value compared to baseline (natural) condition value between 20% and 40% of the total annual volume. (D) Not functional: net change of existing condition value compared to baseline (natural) condition value more than 40% of the total annual volume.	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	1
Hydraulics	Reach	Flow Conveyance	Ensure project provides level of service indicated in MP. As a public safety issue, velocity and/or depth of a stream should not reach dangerous levels.	Riverscape (channel and floodplain) capacity	Evaluation of the capacity and space available for a riverscape (channel and floodplain) to convey the full spectrum of flows.	Measurement of hydraulic characteristics such as capacity, flow area, depth, velocity (quantitative)	Hydraulic model and/or Remote sensing–GIS	HyC1	(A) Fully functional: no encroachment; stream channel and floodplain can convey >1% AEP flood. (B) Functional: negligible presence of encroachment; stream channel and floodplain can convey >2% AEP flood. (C) Partly functional: presence of structures within floodplain; stream channel and floodplain can convey >10% AEP flood (D) Not functional: significant encroachment of structures in the floodplain; stream channel and floodplain can convey <10% AEP flood	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	2
		Floodplain Connectivity	The degree to which water inundates and hydrates the adjacent corridor. It is a measure of the extent and frequency with which flows interact with the channel and floodplain to create a characteristic pattern of land saturation or inundation.	Floodplain connectivity ratio	Presence of a modern floodplain and hillslope–stream corridor connectivity presence and length of elements of disconnection (e.g., roads) within a buffer 50-m wide for each river side	Measurement of width and longitudinal length (quantitative); identification/ checking of modern floodplain (qualitative)	Remote sensing–GIS using Valley Bottom Extraction Tool (see Gilbert et al. 2016); Digital Elevation Models (DEM), stream networks, valley slopes, height above the drainage network (HAND), and upstream contributing area.	HyFC1	(A) Fully functional: floodplains can be extensively and frequently inundated with only minor historic or existing impairments (80%-100%) (B) Functional: floodplains can be fully inundated at moderate intervals or show mild impacts and/or modifications to the floodplain and/or channel (50%-80%). (C) Partly functional: floodplains can be partially inundated at moderate intervals or show mild impacts and/or modifications to the floodplain and/or channel (30%-50%). (D) Not functional: floodplains are rarely or infrequently inundated by flood flows or have incurred severe and/or irreversible impairments or modifications, usually by heavy anthropogenic impacts (0%-30%).	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	0
				Entrenchment ratio (or overbank return interval)	Vertical containment of the stream described as the ratio of the width of the flood-prone area to the surface width of the bankfull channel (flows > Q2 overtop low flow channel)	Identification and measurement of bankfull stage and flood-prone width (quantitative)	Remote sensing-GIS and field survey; hydraulic model	HyFC2	(A) Fully functional: minimally entrenched; entrenchment ratio is >2.5 for single thread partly confined or laterally unconfined river type. (B) Functional: slightly entrenched; entrenchment ratio is >2.2 for single thread partly confined or laterally unconfined river type. (C) Partly functional: moderately entrenched; entrenchment ratio is >1.4 and <2.2 for single thread partly confined or laterally unconfined river type. (D) Not functional: significantly entrenched; entrenchment ratio is <1.4 for single thread partly confined or laterally unconfined river type.	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	1
Geomorphology	Reach	Sediment Regime	Trends of erosion and sedimentation, local zones of erosion (within channel)	Sediment transport capacity	Bed-material load transported through the river reach by a sequence of flows over an extended time period divided by the bed-material load transported into the reach by the same sequence of flows over the same time period (Soar and Thorne 2001)	Supply or capacity limited using capacity supply ratio (CSR)	Modelling/analysis (CSR)	GR5	(A) Fully functional: the amount of sediment transported through the reach is self-sustainable with no management or maintenance required. Limited, if any, impediments to sediment delivery or transport is present throughout the reach. CSR = 1. (B) Functional: impediments to sediment transport may exist, but they are either insignificant or they impact sediment transport from only a small portion of the overall contributing reach or corridor. Minor stressors are present and minimal maintenance is required to maintain functionality. CSR > 1 (C) Partly functional: major impediments to sediment transport exist, but these impediments either pass a portion of the sediment downstream or block sediment from less than half of the contributing area. Stressors significantly alter sediment transport and extensive or consistent active maintenance is required. CSR > 1 (D) Not functional: severe impediments to sediment transport are present and impact most or all of the reach. Sediment transport through the reach is severely altered to a level that results in an inability to support functional processes. CSR > 1	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	2
		Stability	Patterns, levels, and rates of dynamic processes (erosion, deposition, and migration) stream considering its landscape setting, including lateral migration and bank stability.	Channel stability index	Channel-stability ranking scheme following the Rapid Geomorphic Assessment (RGA) sensu Simon and Downs (1995) and Vermont (https://dec.vermont.gov/watershed/rivers/river-corridor-and-floodplain-protection/geomorphic-assessment)	Identification and measurement of bed material, bed/bank protection, degree of incision, degree of constriction, bank erosion, bank instability, bank accretion (quantitative)	Remote sensing and/or field survey	GS4	(A) Fully functional: RGA score < 10 (B) Functional: RGA score between 10 and 15 (C) Partly functional: RGA score between 15 and 20 (D) Not functional: RGA score >20	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	3
		Morphology	Replicate natural stream processes to extent possible to provide resiliency and minimize maintenance. The channel geometry is self-sustaining under natural channel processes and requires little to no maintenance.	Channel adjustments - pattern	Adjustments in channel pattern	Changes in channel pattern based on historical channel thalweg and bank lines (quantitative)	Remote sensing (GIS)	GM9	(A) Fully functional: absence of changes in channel pattern from a historical reference point. (B) Functional: limited change to a similar channel pattern from a historical reference point. (C) Partly functional: moderate change to a similar channel pattern from a historical reference point. (D) Not functional: change to a different channel pattern from a historical reference point.	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	1
				Channel adjustments - width	Adjustments in channel width	Changes in channel width based on historical bankfull/active channel widths (quantitative)	Remote sensing (GIS)	GM10	(A) Fully functional: no change compared to a historical reference point (B) Functional: limited changes (≤15%) from a historical reference point (C) Partly functional: moderate changes (15 to 35%) from a historical reference point. (D) Not functional: intense changes (>35%) from a historical reference point.	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	2
				Channel adjustments - condition (SEM stage)	Linking the evolutionary stage and trajectory of stream adjustment to hydrogeomorphic attributes (following Cluer and Thorne, 2014)	Evidence of stream evolution stage (qualitative)	Feld survey of cross sections (if available) from onsite data collection; field observations	GM11	(A) Fully functional: pre-disturbance, dynamically meta-stable riverscape featuring historical natural planform connected to a frequently inundated floodplain that supports riparian vegetation (Qsin ≥ Qsout; h<<hc); SEM Stages 0 and 8 (B) Functional: dynamically stable and laterally active channel within a floodplain complex (Qsin ≥ Qsout; h<<hc); SEM Stages 1 and 7 (C) Partly functional: quasi-equilibrium channel with two-stage cross-section featuring regime channel inset within larger, degraded channel (Qsin ~ Qsout; h<hc); SEM Stage 6 (D) Not functional: incising with unstable, retreating banks and abandoned floodplain (Qsin < Qsout; h>hc) or bed rising, aggrading, widening channel with unstable banks (Qsin ~ Qsout; h<hc); SEM Stages 2, 3, 3s, 4, 4-3, and 5	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	1
				Channel adjustments - bed	Bed-level adjustments	Evidence of incision or aggradation (qualitative/quantitative)	Cross sections/ longitudinal profiles (if available); field survey	GM12	(A) Fully functional: negligible bed-level changes (≤0.5 ft) (B) Functional: limited bed-level changes (0.5 to 1 ft) (C) Partly functional: moderate bed-level changes (1 to 2 ft) (D) Not functional: intense bed-level changes (>2 ft)	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	2
Vegetation	Reach	Flow Conveyance	Vegetation density and structure do not impede flood conveyance	Clogging of crossing structures	Clogging of channel spanning crossing structures such as bridges and culverts via encroaching trees and shrubs.	Evidence of vegetation clogging openings to bridges and culverts (qualitative)	Field survey	VC6	(A) Fully functional: encroaching trees and shrubs do not clog bridge or culvert openings. (B) Functional: minimal clogging of bridge or culvert openings by encroaching trees and shrubs. (C) Partly functional: moderate clogging of bridge or culvert openings by encroaching trees and shrubs. (D) Not functional: significant clogging of bridge or culvert openings by encroaching trees and shrubs.	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	1.5
				Vegetation along the channel banks and proximal floodplain	Vegetation composition, density, and height	Visual observation (either quantitative using transects or qualitative with meandering survey)	Field survey	VC9	(A) Fully functional: short herbaceous vegetation or tree seedlings (average depth of flow is at least 2x vegetation height) (B) Functional: short herbaceous vegetation (average depth of flow is 1-2x vegetation height) OR low density willows on bank slopes (C) Partly functional: medium height herbaceous vegetation (average depth of flow = vegetation height) OR moderately dense willows on side slopes (D) Not functional: taller herbaceous vegetation (average depth of flow< 1/2 vegetation height) OR dense willows on side slopes OR dense cattails in channel bottom	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	0
		Dynamic Stability	Riparian vegetation extends from stream edges to overbank areas (i.e., floodfringe) and stabilizes soil during flood events	Vegetation vigor	Percent vegetation senescence (stress or age induced dieback)	Visual observation of plant senescence in vegetation communities in study reach quantitatively (transects) or in meandering survey	Ffeld observations	VS7	(A) Fully functional: 0-10% senescence (B) Functional: 10-30% senescence (C) Partly functional: 30-75% senescence (D) Not functional: >75% senescence	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	3
				Bank Stability	Bank stability index based on dominant vegetation along channel banks	Visual observation of vegetation composition and cover along channel banks and assignment of index value from Winward 2000 and BLM MIM Ratings	Field survey	VS9	(A) Fully functional: Greenline Stability between 7.5 and 10 (B) Functional: Greenline Stability between 5 and 7.5 (C) Partly functional: Greenline Stability between 2.5 and 5.0 (D) Not functional: Greenline stability from 0 to 2.5	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	1.75
				Native riparian vegetation cover	Relative cover of native plant species in all community types present in the riparian corridor	Identification and visual estimation of percent cover of all herbs, shrubs, and trees	Field survey	VS10	(A) Fully functional: percent cover of native vegetation > 90% (B) Functional: percent cover of native vegetation 70-90% (C) Partly functional: percent cover of native vegetation 50-70% (D) Not functional: percent cover of native vegetation <50%	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	1.5
				Native wetland vegetation cover	Relative cover of native plant species in wetland community only	Identification and measurement of extent and percent cover of herbs, shrubs, and trees	Field survey	VS11	(A) Fully functional: percent cover of native vegetation > 90% (B) Functional: percent cover of native vegetation 70-90% (C) Partly functional: percent cover of native vegetation 50-70% (D) Not functional: percent cover of native vegetation <50%	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	2
		Resiliency	Vegetation communities are able to maintain functioning in response to disturbance	Noxious weed cover	Absolute cover of noxious weeds in the riparian corridor	Visual estimation of state listed noxious weed cover in riparian corridor	Field survey	VR9	(A) Fully functional: noxious weeds cover < 3% (B) Functional: noxious weed cover 3-10% (C) Partly functional: noxious weed cover 10-30% (D) Not functional: noxious weed cover > 30%	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	2
		Adaptability	Vegetation communities are able to adapt to changes in hydrology due to climate change or development	Vegetation community mosaic	Number of plant communities present in the riparian corridor	Visual estimation of the number of different plant communities present from the channel to the edge of the riparian corridor (ex. wetland herb, wetland shrub, riparian herb, riparian shrub, upland)	Field observations	VA7	(A) Fully functional: ≥3 plant communities present (B) Functional: 2-3 plant communities present (C) Partly functional: 1-2 plant communities present (D) Not functional: 0-1 plant communities present	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	2
				Woody species recruitment	Presence of recruitement for native woody species	Visual estimation of age of native riparian tree and shrub recruits (seedling, sapling, whips)	Field survey	VA8	(A) Fully functional: multi-age recruitement (seedlings, saplings, whips) (B) Functional: saplings or whips present (C) Partly functional: suitable substrate present AND seedlings present (D) Not functional: no seedlings but substrate present	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	2

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MURPHY CREEK REACH 2

Element	Scale	Indicator	Description	Metrics	Measurement (definition)	Assessment Method	Analysis	Metric Code	Functional characteristics (and/or maintenance requirements)	Score Level of Function (and/or maintenance)	Score
Community Values	Watershed	Access to Nature	Presence of/Easy access to green spaces, natural areas, parks, trails, and waterways	Natural space opportunities	Mapped locations of proposed parks and open space, vacant lands, natural land cover, riparian corridor	Identify natural space opportunities based on land use and cover characteristics, schools, community gardens, and potential for certified backyard wildlife habitat areas.	Remote sensing–GIS, Trust for Public Land Metro DNA data	VN2	(A) Very high opportunities within the watershed to provide access to natural spaces (B) High opportunities within the watershed to provide access to natural spaces (C) Moderate opportunities within the watershed to provide access to natural spaces (D) Low to no opportunities within the watershed to provide access to natural spaces	Very high (3 points) High (2 points) Moderate (1 point) Low or no opportunities (0 points)	2
Hydrology	Corridor	Flow Regime	The shape and size of stream channels, the distribution of vegetation, and the stability of channel bed and banks are all largely determined by the interaction between the flow regime and local geology and landform.	Flow regime change	Evaluation of changes in flow regime along the stream corridor under existing conditions, including anthropogenic impacts such as diversions, groundwater wells, and unnatural inflow	Evaluation of changes in flow regime (quantitative). In absence of available data, the assessment is based on field survey to identify locations along the corridor where the flow regime changes (qualitative)	Hydrological data and/or modelling such as stream gage analysis or hydrograph flow-routing	HR1	(A) Fully functional: downstream hydrograph progression is consistent with anticipated increases in flood flows, based on upstream contributing area. No alterations of natural runoff processes and no in-channel structures (no stressors). (B) Functional: downstream hydrograph progression is slightly modified due to limited alterations of natural runoff processes and in-channel structures (minimal stressors). (C) Partly functional: downstream hydrograph progression is moderately modified due to multiple alterations of natural runoff processes and in-channel structures (multiple stressors). (D) Not functional: downstream hydrograph progression is significantly modified due to multiple alterations of natural runoff processes and in-channel structures (multiple stressors).	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	2
	Reach	Flow Regime	Ability of stream to meet intent of the Master Plan and adjust to modified flow conditions and high functioning lower maintenance streams Determine flow regime for the following conditions: - Future land use - Existing land use - Historical condition - MP condition	Rate/magnitude	Evaluation of the pattern of peaks in the hydrograph and deviation of annual net peak flow discharge to understand impacts geomorphologically relevant thresholds (evaluate base flow, Active channel flow (average annual flow), 2-year, 5-year, 10-year, 50-year, and 100-year)	Evaluation of flow rate and magnitude between historical, existing, and future conditions (quantitative). Master Plan Data and/or Hydrograph flow-routing for existing and future land use from hydrologic model; stream gage analysis for historical and existing conditions, if gage data is available	Hydrological data, desktop analysis, and/or modelling (CUHP and EPA-SWMM)	HR2	(A) Fully functional: magnitude and duration of annual discharge peaks closely resembles optimal hydrograph. Net change of existing condition value compared to baseline (natural) condition value less than 10% of the flow magnitude. (B) Functional: hydrograph has a natural seasonal pattern, but peaks are attenuated, elevated, extended, or shortened. Net change of existing condition value compared to baseline (natural) condition value between 10% and 20% of the flow magnitude. (C) Partly functional: disrupted seasonal hydrograph patterns and/or departure from natural peak flow magnitude. Net change of existing condition value compared to baseline (natural) condition value between 20% and 40% of the flow magnitude. (D) Not functional: disrupted seasonal hydrograph patterns and/or	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	1
				Volume	The total volume metric rates the net annual change in water volume caused by anthropogenic uses as a percentage of natural flows.	Analysis of total volume between historical, existing, and future conditions (quantitative).	Hydrological data, desktop analysis, and/or modelling	HR3	(A) Fully functional: net change of existing condition value compared to baseline (natural) condition value less than 10% of the total annual volume. (B) Functional: net change of existing condition value compared to baseline (natural) condition value between 10% and 20% of the total annual volume. (C) Partly functional: net change of existing condition value compared to baseline (natural) condition value between 20% and 40% of the total annual volume. (D) Not functional: net change of existing condition value compared to baseline (natural) condition value more than 40% of the total annual volume.	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	1
Hydraulics	Reach	Flow Conveyance	Ensure project provides level of service indicated in MP. As a public safety issue, velocity and/or depth of a stream should not reach dangerous levels.	Riverscape (channel and floodplain) capacity	Evaluation of the capacity and space available for a riverscape (channel and floodplain) to convey the full spectrum of flows.	Measurement of hydraulic characteristics such as capacity, flow area, depth, velocity (quantitative)	Hydraulic model and/or Remote sensing–GIS	HyC1	(A) Fully functional: no encroachment; stream channel and floodplain can convey >1% AEP flood. (B) Functional: negligible presence of encroachment; stream channel and floodplain can convey >2% AEP flood. (C) Partly functional: presence of structures within floodplain; stream channel and floodplain can convey >10% AEP flood (D) Not functional: significant encroachment of structures in the floodplain; stream channel and floodplain can convey <10% AEP flood	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	2
		Floodplain Connectivity	The degree to which water inundates and hydrates the adjacent corridor. It is a measure of the extent and frequency with which flows interact with the channel and floodplain to create a characteristic pattern of land saturation or inundation.	Floodplain connectivity ratio	Presence of a modern floodplain and hillslope–stream corridor connectivity presence and length of elements of disconnection (e.g., roads) within a buffer 50-m wide for each river side	Measurement of width and longitudinal length (quantitative); identification/ checking of modern floodplain (qualitative)	Remote sensing–GIS using Valley Bottom Extraction Tool (see Gilbert et al. 2016); Digital Elevation Models (DEM), stream networks, valley slopes, height above the drainage network (HAND), and upstream contributing area.	HyFC1	(A) Fully functional: floodplains can be extensively and frequently inundated with only minor historic or existing impairments (80%-100%) (B) Functional: floodplains can be fully inundated at moderate intervals or show mild impacts and/or modifications to the floodplain and/or channel (50%-80%). (C) Partly functional: floodplains can be partially inundated at moderate intervals or show mild impacts and/or modifications to the floodplain and/or channel (30%-50%). (D) Not functional: floodplains are rarely or infrequently inundated by flood flows or have incurred severe and/or irreversible impairments or modifications, usually by heavy anthropogenic impacts (0%-30%).	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	0
				Entrenchment ratio (or overbank return interval)	Vertical containment of the stream described as the ratio of the width of the flood-prone area to the surface width of the bankfull channel (flows > Q2 overtop low flow channel)	Identification and measurement of bankfull stage and flood-prone width (quantitative)	Remote sensing-GIS and field survey; hydraulic model	HyFC2	(A) Fully functional: minimally entrenched; entrenchment ratio is >2.5 for single thread partly confined or laterally unconfined river type. (B) Functional: slightly entrenched; entrenchment ratio is >2.2 for single thread partly confined or laterally unconfined river type. (C) Partly functional: moderately entrenched; entrenchment ratio is >1.4 and <2.2 for single thread partly confined or laterally unconfined river type. (D) Not functional: significantly entrenched; entrenchment ratio is <1.4 for single thread partly confined or laterally unconfined river type.	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	3
Geomorphology	Reach	Sediment Regime	Trends of erosion and sedimentation, local zones of erosion (within channel)	Sediment transport capacity	Bed-material load transported through the river reach by a sequence of flows over an extended time period divided by the bed-material load transported into the reach by the same sequence of flows over the same time period (Soar and Thorne 2001)	Supply or capacity limited using capacity supply ratio (CSR)	Modelling/analysis (CSR)	GR5	(A) Fully functional: the amount of sediment transported through the reach is self-sustainable with no management or maintenance required. Limited, if any, impediments to sediment delivery or transport is present throughout the reach. CSR = 1. (B) Functional: impediments to sediment transport may exist, but they are either insignificant or they impact sediment transport from only a small portion of the overall contributing reach or corridor. Minor stressors are present and minimal maintenance is required to maintain functionality. CSR > 1 (C) Partly functional: major impediments to sediment transport exist, but these impediments either pass a portion of the sediment downstream or block sediment from less than half of the contributing area. Stressors significantly alter sediment transport and extensive or consistent active maintenance is required. CSR > 1 (D) Not functional: severe impediments to sediment transport are present and impact most or all of the reach. Sediment transport through the reach is severely altered to a level that results in an inability to support functional processes. CSR > 1	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	2
		Stability	Patterns, levels, and rates of dynamic processes (erosion, deposition, and migration) stream considering its landscape setting, including lateral migration and bank stability.	Channel stability index	Channel-stability ranking scheme following the Rapid Geomorphic Assessment (RGA) sensu Simon and Downs (1995) and Vermont (https://dec.vermont.gov/watershed/rivers/river-corridor-and-floodplain-protection/geomorphic-assessment)	Identification and measurement of bed material, bed/bank protection, degree of incision, degree of constriction, bank erosion, bank instability, bank accretion (quantitative)	Remote sensing and/or field survey	GS4	(A) Fully functional: RGA score < 10 (B) Functional: RGA score between 10 and 15 (C) Partly functional: RGA score between 15 and 20 (D) Not functional: RGA score >20	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	2
		Morphology	Replicate natural stream processes to extent possible to provide resiliency and minimize maintenance. The channel geometry is self-sustaining under natural channel processes and requires little to no maintenance.	Channel adjustments - pattern	Adjustments in channel pattern	Changes in channel pattern based on historical channel thalweg and bank lines (quantitative)	Remote sensing (GIS)	GM9	(A) Fully functional: absence of changes in channel pattern from a historical reference point. (B) Functional: limited change to a similar channel pattern from a historical reference point. (C) Partly functional: moderate change to a similar channel pattern from a historical reference point. (D) Not functional: change to a different channel pattern from a historical reference point.	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	2
				Channel adjustments - width	Adjustments in channel width	Changes in channel width based on historical bankfull/active channel widths (quantitative)	Remote sensing (GIS)	GM10	(A) Fully functional: no change compared to a historical reference point (B) Functional: limited changes (≤15%) from a historical reference point (C) Partly functional: moderate changes (15 to 35%) from a historical reference point. (D) Not functional: intense changes (>35%) from a historical reference point.	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	2
				Channel adjustments - condition (SEM stage)	Linking the evolutionary stage and trajectory of stream adjustment to hydrogeomorphic attributes (following Cluer and Thorne, 2014)	Evidence of stream evolution stage (qualitative)	Feld survey of cross sections (if available) from onsite data collection; field observations	GM11	(A) Fully functional: pre-disturbance, dynamically meta-stable riverscape featuring historical natural planform connected to a frequently inundated floodplain that supports riparian vegetation (Qsin ≥ Qsout; h<<hc); SEM Stages 0 and 8 (B) Functional: dynamically stable and laterally active channel within a floodplain complex (Qsin ≥ Qsout; h<<hc); SEM Stages 1 and 7 (C) Partly functional: quasi-equilibrium channel with two-stage cross-section featuring regime channel inset within larger, degraded channel (Qsin ~ Qsout; h<hc); SEM Stage 6 (D) Not functional: incising with unstable, retreating banks and abandoned floodplain (Qsin < Qsout; h>hc) or bed rising, aggrading, widening channel with unstable banks (Qsin ~ Qsout; h<hc); SEM Stages 2, 3, 3s, 4, 4-3, and 5	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	0
				Channel adjustments - bed	Bed-level adjustments	Evidence of incision or aggradation (qualitative/quantitative)	Cross sections/ longitudinal profiles (if available); field survey	GM12	(A) Fully functional: negligible bed-level changes (≤0.5 ft) (B) Functional: limited bed-level changes (0.5 to 1 ft) (C) Partly functional: moderate bed-level changes (1 to 2 ft) (D) Not functional: intense bed-level changes (>2 ft)	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	2
Vegetation	Reach	Flow Conveyance	Vegetation density and structure do not impede flood conveyance	Clogging of crossing structures	Clogging of channel spanning crossing structures such as bridges and culverts via encroaching trees and shrubs.	Evidence of vegetation clogging openings to bridges and culverts (qualitative)	Field survey	VC6	(A) Fully functional: encroaching trees and shrubs do not clog bridge or culvert openings. (B) Functional: minimal clogging of bridge or culvert openings by encroaching trees and shrubs. (C) Partly functional: moderate clogging of bridge or culvert openings by encroaching trees and shrubs. (D) Not functional: significant clogging of bridge or culvert openings by encroaching trees and shrubs.	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	N/A
				Vegetation along the channel banks and proximal floodplain	Vegetation composition, density, and height	Visual observation (either quanitative using transects or qualitive with meandering survey)	Field survey	VC9	(A) Fully functional: short herbaceous vegetation or tree seedlings (average depth of flow is at least 2x vegetation height) (B) Functional: short herbaceous vegetation (average depth of flow is 1-2x vegetation height) OR low density willows on bank slopes (C) Partly functional: medium height herbaceous vegetation (average depth of flow = vegetation height) OR moderately dense willows on side slopes (D) Not functional: taller herbaceous vegetation (average depth of flow< 1/2 vegetation height) OR dense willows on side slopes OR dense cattails in channel bottom	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	0
		Dynamic Stability	Riparian vegetation extends from stream edges to overbank areas (i.e., floodfringe) and stabilizes soil during flood events	Vegetation vigor	Percent vegetation senescence (stress or age induced dieback)	Visual observation of plant senescence in vegetation communities in study reach quantitatively (transects) or in meandering survey	Ffeld observations	VS7	(A) Fully functional: 0-10% senescence (B) Functional: 10-30% senescence (C) Partly functional: 30-75% senescence (D) Not functional: >75% senescence	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	3
				Bank Stability	Bank stability index based on dominant vegetation along channel banks	Visual observation of vegetation composition and cover along channel banks and assignment of index value from Winward 2000 and BLM MIM Ratings	Field survey	VS9	(A) Fully functional: Greenline Stability between 7.5 and 10 (B) Functional: Greenline Stability between 5 and 7.5 (C) Partly functional: Greenline Stability between 2.5 and 5.0 (D) Not functional: Greenline stability from 0 to 2.5	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	1.25
				Native riparian vegetation cover	Relative cover of native plant species in all community types present in the riparian corridor	Identification and visual estimation of percent cover of all herbs, shrubs, and trees	Field survey	VS10	(A) Fully functional: percent cover of native vegetation > 90% (B) Functional: percent cover of native vegetation 70-90% (C) Partly functional: percent cover of native vegetation 50-70% (D) Not functional: percent cover of native vegetation <50%	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	1.25
				Native wetland vegetation cover	Relative cover of native plant species in wetland community only	Identification and measurement of extent and percent cover of herbs, shrubs, and trees	Field survey	VS11	(A) Fully functional: percent cover of native vegetation > 90% (B) Functional: percent cover of native vegetation 70-90% (C) Partly functional: percent cover of native vegetation 50-70% (D) Not functional: percent cover of native vegetation <50%	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	1.75
		Resiliency	Vegetation communities are able to maintain functioning in response to disturbance	Noxious weed cover	Absolute cover of noxious weeds in the riparian corridor	Visual estimation of state listed noxious weed cover in riparian corridor	Field survey	VR9	(A) Fully functional: noxious weeds cover < 3% (B) Functional: noxious weed cover 3-10% (C) Partly functional: noxious weed cover 10-30% (D) Not functional: noxious weed cover > 30%	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	2
		Adaptability	Vegetation communities are able to adapt to changes in hydrology due to climate change or development	Vegetation community mosaic	Number of plant communities present in the riparian corridor	Visual estimation of the number of different plant communities present from the channel to the edge of the riparian corridor (ex. wetland herb, wetland shrub, riparian herb, riparian shrub, upland)	Field observations	VA7	(A) Fully functional: ≥3 plant communities present (B) Functional: 2-3 plant communities present (C) Partly functional: 1-2 plant communities present (D) Not functional: 0-1 plant communities present	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	2
				Woody species recruitment	Presence of recruitement for native woody species	Visual estimation of age of native riparian tree and shrub recruits (seedling, sapling, whips)	Field survey	VA8	(A) Fully functional: multi-age recruitement (seedlings, saplings, whips) (B) Functional: saplings or whips present (C) Partly functional: suitable substrate present AND seedlings present (D) Not functional: no seedlings but substrate present	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	1

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MURPHY CREEK REACH 3

Element	Scale	Indicator	Description	Metrics	Measurement (definition)	Assessment Method	Analysis	Metric Code	Functional characteristics (and/or maintenance requirements)	Score Level of Function (and/or maintenance)	Score
Community Values	Watershed	Access to Nature	Presence of/Easy access to green spaces, natural areas, parks, trails, and waterways	Natural space opportunities	Mapped locations of proposed parks and open space, vacant lands, natural land cover, riparian corridor	Identify natural space opportunities based on land use and cover characteristics, schools, community gardens, and potential for certified backyard wildlife habitat areas.	Remote sensing–GIS, Trust for Public Land Metro DNA data	VN2	(A) Very high opportunities within the watershed to provide access to natural spaces (B) High opportunities within the watershed to provide access to natural spaces (C) Moderate opportunities within the watershed to provide access to natural spaces (D) Low to no opportunities within the watershed to provide access to natural spaces	Very high (3 points) High (2 points) Moderate (1 point) Low or no opportunities (0 points)	2
Hydrology	Corridor	Flow Regime	The shape and size of stream channels, the distribution of vegetation, and the stability of channel bed and banks are all largely determined by the interaction between the flow regime and local geology and landform.	Flow regime change	Evaluation of changes in flow regime along the stream corridor under existing conditions, including anthropogenic impacts such as diversions, groundwater wells, and unnatural inflow	Evaluation of changes in flow regime (quantitative). In absence of available data, the assessment is based on field survey to identify locations along the corridor where the flow regime changes (qualitative)	Hydrological data and/or modelling such as stream gage analysis or hydrograph flow-routing	HR1	(A) Fully functional: downstream hydrograph progression is consistent with anticipated increases in flood flows, based on upstream contributing area. No alterations of natural runoff processes and no in-channel structures (no stressors). (B) Functional: downstream hydrograph progression is slightly modified due to limited alterations of natural runoff processes and in-channel structures (minimal stressors). (C) Partly functional: downstream hydrograph progression is moderately modified due to multiple alterations of natural runoff processes and in-channel structures (multiple stressors). (D) Not functional: downstream hydrograph progression is significantly modified due to multiple alterations of natural runoff processes and in-channel structures (multiple stressors).	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	2
	Reach	Flow Regime	Ability of stream to meet intent of the Master Plan and adjust to modified flow conditions and high functioning lower maintenance streams Determine flow regime for the following conditions: - Future land use - Existing land use - Historical condition - MP condition	Rate/magnitude	Evaluation of the pattern of peaks in the hydrograph and deviation of annual net peak flow discharge to understand impacts geomorphologically relevant thresholds (evaluate base flow, Active channel flow (average annual flow), 2-year, 5-year, 10-year, 50-year, and 100-year)	Evaluation of flow rate and magnitude between historical, existing, and future conditions (quantitative). Master Plan Data and/or Hydrograph flow-routing for existing and future land use from hydrologic model; stream gage analysis for historical and existing conditions, if gage data is available	Hydrological data, desktop analysis, and/or modelling (CUHP and EPA-SWMM)	HR2	(A) Fully functional: magnitude and duration of annual discharge peaks closely resembles optimal hydrograph. Net change of existing condition value compared to baseline (natural) condition value less than 10% of the flow magnitude. (B) Functional: hydrograph has a natural seasonal pattern, but peaks are attenuated, elevated, extended, or shortened. Net change of existing condition value compared to baseline (natural) condition value between 10% and 20% of the flow magnitude. (C) Partly functional: disrupted seasonal hydrograph patterns and/or departure from natural peak flow magnitude. Net change of existing condition value compared to baseline (natural) condition value between 20% and 40% of the flow magnitude. (D) Not functional: disrupted seasonal hydrograph patterns and/or departure from natural peak flow magnitude. Net change of existing condition value compared to baseline (natural) condition value, more than 40% of the flow magnitude.	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	1
				Volume	The total volume metric rates the net annual change in water volume caused by anthropogenic uses as a percentage of natural flows.	Analysis of total volume between historical, existing, and future conditions (quantitative).	Hydrological data, desktop analysis, and/or modelling	HR3	(A) Fully functional: net change of existing condition value compared to baseline (natural) condition value less than 10% of the total annual volume. (B) Functional: net change of existing condition value compared to baseline (natural) condition value between 10% and 20% of the total annual volume. (C) Partly functional: net change of existing condition value compared to baseline (natural) condition value between 20% and 40% of the total annual volume. (D) Not functional: net change of existing condition value compared to baseline (natural) condition value more than 40% of the total annual volume.	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	1
Hydraulics	Reach	Flow Conveyance	Ensure project provides level of service indicated in MP. As a public safety issue, velocity and/or depth of a stream should not reach dangerous levels.	Riverscape (channel and floodplain) capacity	Evaluation of the capacity and space available for a riverscape (channel and floodplain) to convey the full spectrum of flows.	Measurement of hydraulic characteristics such as capacity, flow area, depth, velocity (quantitative)	Hydraulic model and/or Remote sensing–GIS	HyC1	(A) Fully functional: no encroachment; stream channel and floodplain can convey >1% AEP flood. (B) Functional: negligible presence of encroachment; stream channel and floodplain can convey >2% AEP flood. (C) Partly functional: presence of structures within floodplain; stream channel and floodplain can convey >10% AEP flood (D) Not functional: significant encroachment of structures in the floodplain; stream channel and floodplain can convey <10% AEP flood	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	3
		Floodplain Connectivity	The degree to which water inundates and hydrates the adjacent corridor. It is a measure of the extent and frequency with which flows interact with the channel and floodplain to create a characteristic pattern of land saturation or inundation.	Floodplain connectivity ratio	Presence of a modern floodplain and hillslope–stream corridor connectivity presence and length of elements of disconnection (e.g., roads) within a buffer 50-m wide for each river side	Measurement of width and longitudinal length (quantitative); identification/ checking of modern floodplain (qualitative)	Remote sensing–GIS using Valley Bottom Extraction Tool (see Gilbert et al. 2016); Digital Elevation Models (DEM), stream networks, valley slopes, height above the drainage network (HAND), and upstream contributing area.	HyFC1	(A) Fully functional: floodplains can be extensively and frequently inundated with only minor historic or existing impairments (80%-100%) (B) Functional: floodplains can be fully inundated at moderate intervals or show mild impacts and/or modifications to the floodplain and/or channel (50%-80%). (C) Partly functional: floodplains can be partially inundated at moderate intervals or show mild impacts and/or modifications to the floodplain and/or channel (30%-50%). (D) Not functional: floodplains are rarely or infrequently inundated by flood flows or have incurred severe and/or irreversible impairments or modifications, usually by heavy anthropogenic impacts (0%-30%).	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	0
				Entrenchment ratio (or overbank return interval)	Vertical containment of the stream described as the ratio of the width of the flood-prone area to the surface width of the bankfull channel (flows > Q2 overtop low flow channel)	Identification and measurement of bankfull stage and flood-prone width (quantitative)	Remote sensing-GIS and field survey; hydraulic model	HyFC2	(A) Fully functional: minimally entrenched; entrenchment ratio is >2.5 for single thread partly confined or laterally unconfined river type. (B) Functional: slightly entrenched; entrenchment ratio is >2.2 for single thread partly confined or laterally unconfined river type. (C) Partly functional: moderately entrenched; entrenchment ratio is >1.4 and <2.2 for single thread partly confined or laterally unconfined river type. (D) Not functional: significantly entrenched; entrenchment ratio is <1.4 for single thread partly confined or laterally unconfined river type.	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	3
Geomorphology	Reach	Sediment Regime	Trends of erosion and sedimentation, local zones of erosion (within channel)	Sediment transport capacity	Bed-material load transported through the river reach by a sequence of flows over an extended time period divided by the bed-material load transported into the reach by the same sequence of flows over the same time period (Soar and Thorne 2001)	Supply or capacity limited using capacity supply ratio (CSR)	Modelling/analysis (CSR)	GR5	(A) Fully functional: the amount of sediment transported through the reach is self-sustainable with no management or maintenance required. Limited, if any, impediments to sediment delivery or transport is present throughout the reach. CSR = 1. (B) Functional: impediments to sediment transport may exist, but they are either insignificant or they impact sediment transport from only a small portion of the overall contributing reach or corridor. Minor stressors are present and minimal maintenance is required to maintain functionality. CSR > 1 (C) Partly functional: major impediments to sediment transport exist, but these impediments either pass a portion of the sediment downstream or block sediment from less than half of the contributing area. Stressors significantly alter sediment transport and extensive or consistent active maintenance is required. CSR > 1 (D) Not functional: severe impediments to sediment transport are present and impact most or all of the reach. Sediment transport through the reach is severely altered to a level that results in an inability to support functional processes. CSR > 1	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	2
		Stability	Patterns, levels, and rates of dynamic processes (erosion, deposition, and migration) stream considering its landscape setting, including lateral migration and bank stability.	Channel stability index	Channel-stability ranking scheme following the Rapid Geomorphic Assessment (RGA) sensu Simon and Downs (1995) and Vermont (https://dec.vermont.gov/watershed/rivers/river-corridor-and-floodplain-protection/geomorphic-assessment)	Identification and measurement of bed material, bed/bank protection, degree of incision, degree of constriction, bank erosion, bank instability, bank accretion (quantitative)	Remote sensing and/or field survey	GS4	(A) Fully functional: RGA score < 10 (B) Functional: RGA score between 10 and 15 (C) Partly functional: RGA score between 15 and 20 (D) Not functional: RGA score >20	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	2
		Morphology	Replicate natural stream processes to extent possible to provide resiliency and minimize maintenance. The channel geometry is self-sustaining under natural channel processes and requires little to no maintenance.	Channel adjustments - pattern	Adjustments in channel pattern	Changes in channel pattern based on historical channel thalweg and bank lines (quantitative)	Remote sensing (GIS)	GM9	(A) Fully functional: absence of changes in channel pattern from a historical reference point. (B) Functional: limited change to a similar channel pattern from a historical reference point. (C) Partly functional: moderate change to a similar channel pattern from a historical reference point. (D) Not functional: change to a different channel pattern from a historical reference point.	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	2
				Channel adjustments - width	Adjustments in channel width	Changes in channel width based on historical bankfull/active channel widths (quantitative)	Remote sensing (GIS)	GM10	(A) Fully functional: no change compared to a historical reference point (B) Functional: limited changes (≤15%) from a historical reference point (C) Partly functional: moderate changes (15 to 35%) from a historical reference point. (D) Not functional: intense changes (>35%) from a historical reference point.	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	2
				Channel adjustments - condition (SEM stage)	Linking the evolutionary stage and trajectory of stream adjustment to hydrogeomorphic attributes (following Cluer and Thorne, 2014)	Evidence of stream evolution stage (qualitative)	Feld survey of cross sections (if available) from onsite data collection; field observations	GM11	(A) Fully functional: pre-disturbance, dynamically meta-stable riverscape featuring historical natural planform connected to a frequently inundated floodplain that supports riparian vegetation (Qsin ≥ Qsout; h<<hc); SEM Stages 0 and 8 (B) Functional: dynamically stable and laterally active channel within a floodplain complex (Qsin ≥ Qsout; h<<hc); SEM Stages 1 and 7 (C) Partly functional: quasi-equilibrium channel with two-stage cross-section featuring regime channel inset within larger, degraded channel (Qsin ~ Qsout; h<hc); SEM Stage 6 (D) Not functional: incising with unstable, retreating banks and abandoned floodplain (Qsin < Qsout; h>hc) or bed rising, aggrading, widening channel with unstable banks (Qsin ~ Qsout; h<hc); SEM Stages 2, 3, 3s, 4, 4-3, and 5	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	0
				Channel adjustments - bed	Bed-level adjustments	Evidence of incision or aggradation (qualitative/quantitative)	Cross sections/ longitudinal profiles (if available); field survey	GM12	(A) Fully functional: negligible bed-level changes (≤0.5 ft) (B) Functional: limited bed-level changes (0.5 to 1 ft) (C) Partly functional: moderate bed-level changes (1 to 2 ft) (D) Not functional: intense bed-level changes (>2 ft)	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	2
Vegetation	Reach	Flow Conveyance	Vegetation density and structure do not impede flood conveyance	Clogging of crossing structures	Clogging of channel spanning crossing structures such as bridges and culverts via encroaching trees and shrubs.	Evidence of vegetation clogging openings to bridges and culverts (qualitative)	Field survey	VC6	(A) Fully functional: encroaching trees and shrubs do not clog bridge or culvert openings. (B) Functional: minimal clogging of bridge or culvert openings by encroaching trees and shrubs. (C) Partly functional: moderate clogging of bridge or culvert openings by encroaching trees and shrubs. (D) Not functional: significant clogging of bridge or culvert openings by encroaching trees and shrubs.	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	N/A
				Vegetation along the channel banks and proximal floodplain	Vegetation composition, density, and height	Visual observation (either quanitative using transects or qualitative with meandering survey)	Field survey	VC9	(A) Fully functional: short herbaceous vegetation or tree seedlings (average depth of flow is at least 2x vegetation height) (B) Functional: short herbaceous vegetation (average depth of flow is 1-2x vegetation height) OR low density willows on bank slopes (C) Partly functional: medium height herbaceous vegetation (average depth of flow = vegetation height) OR moderately dense willows on side slopes (D) Not functional: taller herbaceous vegetation (average depth of flow< 1/2 vegetation height) OR dense willows on side slopes OR dense cattails in channel bottom	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	1
		Dynamic Stability	Riparian vegetation extends from stream edges to overbank areas (i.e., floodfringe) and stabilizes soil during flood events	Vegetation vigor	Percent vegetation senescence (stress or age induced dieback)	Visual observation of plant senescence in vegetation communities in study reach quantitatively (transects) or in meandering survey	Ffeld observations	VS7	(A) Fully functional: 0-10% senescence (B) Functional: 10-30% senescence (C) Partly functional: 30-75% senescence (D) Not functional: >75% senescence	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	3
				Bank Stability	Bank stability index based on dominant vegetation along channel banks	Visual observation of vegetation composition and cover along channel banks and assignment of index value from Winward 2000 and BLM MIM Ratings	Field survey	VS9	(A) Fully functional: Greenline Stability between 7.5 and 10 (B) Functional: Greenline Stability between 5 and 7.5 (C) Partly functional: Greenline Stability between 2.5 and 5.0 (D) Not functional: Greenline stability from 0 to 2.5	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	1.5
				Native riparian vegetation cover	Relative cover of native plant species in all community types present in the riparian corridor	Identification and visual estimation of percent cover of all herbs, shrubs, and trees	Field survey	VS10	(A) Fully functional: percent cover of native vegetation > 90% (B) Functional: percent cover of native vegetation 70-90% (C) Partly functional: percent cover of native vegetation 50-70% (D) Not functional: percent cover of native vegetation <50%	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	1.5
				Native wetland vegetation cover	Relative cover of native plant species in wetland community only	Identification and measurement of extent and percent cover of herbs, shrubs, and trees	Field survey	VS11	(A) Fully functional: percent cover of native vegetation > 90% (B) Functional: percent cover of native vegetation 70-90% (C) Partly functional: percent cover of native vegetation 50-70% (D) Not functional: percent cover of native vegetation <50%	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	1
		Resiliency	Vegetation communities are able to maintain functioning in response to disturbance	Noxious weed cover	Absolute cover of noxious weeds in the riparian corridor	Visual estimation of state listed noxious weed cover in riparian corridor	Field survey	VR9	(A) Fully functional: noxious weeds cover < 3% (B) Functional: noxious weed cover 3-10% (C) Partly functional: noxious weed cover 10-30% (D) Not functional: noxious weed cover > 30%	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	2
		Adaptability	Vegetation communities are able to adapt to changes in hydrology due to climate change or development	Vegetation community mosaic	Number of plant communities present in the riparian corridor	Visual estimation of the number of different plant communities present from the channel to the edge of the riparian corridor (ex. wetland herb, wetland shrub, riparian herb, riparian shrub, upland)	Field observations	VA7	(A) Fully functional: ≥3 plant communities present (B) Functional: 2-3 plant communities present (C) Partly functional: 1-2 plant communities present (D) Not functional: 0-1 plant communities present	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	2
				Woody species recruitment	Presence of recruitement for native woody species	Visual estimation of age of native riparian tree and shrub recruits (seedling, sapling, whips)	Field survey	VA8	(A) Fully functional: multi-age recruitement (seedlings, saplings, whips) (B) Functional: saplings or whips present (C) Partly functional: suitable substrate present AND seedlings present (D) Not functional: no seedlings but substrate present	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	1.5

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MURPHY CREEK REACH 4

Element	Scale	Indicator	Description	Metrics	Measurement (definition)	Assessment Method	Analysis	Metric Code	Functional characteristics (and/or maintenance requirements)	Score Level of Function (and/or maintenance)	Score
Community Values	Watershed	Access to Nature	Presence of/Easy access to green spaces, natural areas, parks, trails, and waterways	Natural space opportunities	Mapped locations of proposed parks and open space, vacant lands, natural land cover, riparian corridor	Identify natural space opportunities based on land use and cover characteristics, schools, community gardens, and potential for certified backyard wildlife habitat areas.	Remote sensing–GIS, Trust for Public Land Metro DNA data	VN2	(A) Very high opportunities within the watershed to provide access to natural spaces (B) High opportunities within the watershed to provide access to natural spaces (C) Moderate opportunities within the watershed to provide access to natural spaces (D) Low to no opportunities within the watershed to provide access to natural spaces	Very high (3 points) High (2 points) Moderate (1 point) Low or no opportunities (0 points)	2
Hydrology	Corridor	Flow Regime	The shape and size of stream channels, the distribution of vegetation, and the stability of channel bed and banks are all largely determined by the interaction between the flow regime and local geology and landform.	Flow regime change	Evaluation of changes in flow regime along the stream corridor under existing conditions, including anthropogenic impacts such as diversions, groundwater wells, and unnatural inflow	Evaluation of changes in flow regime (quantitative). In absence of available data, the assessment is based on field survey to identify locations along the corridor where the flow regime changes (qualitative)	Hydrological data and/or modelling such as stream gage analysis or hydrograph flow-routing	HR1	(A) Fully functional: downstream hydrograph progression is consistent with anticipated increases in flood flows, based on upstream contributing area. No alterations of natural runoff processes and no in-channel structures (no stressors). (B) Functional: downstream hydrograph progression is slightly modified due to limited alterations of natural runoff processes and in-channel structures (minimal stressors). (C) Partly functional: downstream hydrograph progression is moderately modified due to multiple alterations of natural runoff processes and in-channel structures (multiple stressors). (D) Not functional: downstream hydrograph progression is significantly modified due to multiple alterations of natural runoff processes and in-channel structures (multiple stressors).	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	3
	Reach	Flow Regime	Ability of stream to meet intent of the Master Plan and adjust to modified flow conditions and high functioning lower maintenance streams Determine flow regime for the following conditions: - Future land use - Existing land use - Historical condition - MP condition	Rate/magnitude	Evaluation of the pattern of peaks in the hydrograph and deviation of annual net peak flow discharge to understand impacts geomorphologically relevant thresholds (evaluate base flow, Active channel flow (average annual flow), 2-year, 5-year, 10-year, 50-year, and 100-year)	Evaluation of flow rate and magnitude between historical, existing, and future conditions (quantitative). Master Plan Data and/or Hydrograph flow-routing for existing and future land use from hydrologic model; stream gage analysis for historical and existing conditions, if gage data is available	Hydrological data, desktop analysis, and/or modelling (CUHP and EPA-SWMM)	HR2	(A) Fully functional: magnitude and duration of annual discharge peaks closely resembles optimal hydrograph. Net change of existing condition value compared to baseline (natural) condition value less than 10% of the flow magnitude. (B) Functional: hydrograph has a natural seasonal pattern, but peaks are attenuated, elevated, extended, or shortened. Net change of existing condition value compared to baseline (natural) condition value between 10% and 20% of the flow magnitude. (C) Partly functional: disrupted seasonal hydrograph patterns and/or departure from natural peak flow magnitude. Net change of existing condition value compared to baseline (natural) condition value between 20% and 40% of the flow magnitude. (D) Not functional: disrupted seasonal hydrograph patterns and/or departure from natural peak flow magnitude. Net change of existing condition value compared to baseline (natural) condition value, more than 40% of the flow magnitude.	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	1
				Volume	The total volume metric rates the net annual change in water volume caused by anthropogenic uses as a percentage of natural flows.	Analysis of total volume between historical, existing, and future conditions (quantitative).	Hydrological data, desktop analysis, and/or modelling	HR3	(A) Fully functional: net change of existing condition value compared to baseline (natural) condition value less than 10% of the total annual volume. (B) Functional: net change of existing condition value compared to baseline (natural) condition value between 10% and 20% of the total annual volume. (C) Partly functional: net change of existing condition value compared to baseline (natural) condition value between 20% and 40% of the total annual volume. (D) Not functional: net change of existing condition value compared to baseline (natural) condition value more than 40% of the total annual volume.	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	1
Hydraulics	Reach	Flow Conveyance	Ensure project provides level of service indicated in MP. As a public safety issue, velocity and/or depth of a stream should not reach dangerous levels.	Riverscape (channel and floodplain) capacity	Evaluation of the capacity and space available for a riverscape (channel and floodplain) to convey the full spectrum of flows.	Measurement of hydraulic characteristics such as capacity, flow area, depth, velocity (quantitative)	Hydraulic model and/or Remote sensing–GIS	HyC1	(A) Fully functional: no encroachment; stream channel and floodplain can convey >1% AEP flood. (B) Functional: negligible presence of encroachment; stream channel and floodplain can convey >2% AEP flood. (C) Partly functional: presence of structures within floodplain; stream channel and floodplain can convey >10% AEP flood (D) Not functional: significant encroachment of structures in the floodplain; stream channel and floodplain can convey <10% AEP flood	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	3
		Floodplain Connectivity	The degree to which water inundates and hydrates the adjacent corridor. It is a measure of the extent and frequency with which flows interact with the channel and floodplain to create a characteristic pattern of land saturation or inundation.	Floodplain connectivity ratio	Presence of a modern floodplain and hillslope–stream corridor connectivity presence and length of elements of disconnection (e.g., roads) within a buffer 50-m wide for each river side	Measurement of width and longitudinal length (quantitative); identification/ checking of modern floodplain (qualitative)	Remote sensing–GIS using Valley Bottom Extraction Tool (see Gilbert et al. 2016); Digital Elevation Models (DEM), stream networks, valley slopes, height above the drainage network (HAND), and upstream contributing area.	HyFC1	(A) Fully functional: floodplains can be extensively and frequently inundated with only minor historic or existing impairments (80%-100%) (B) Functional: floodplains can be fully inundated at moderate intervals or show mild impacts and/or modifications to the floodplain and/or channel (50%-80%). (C) Partly functional: floodplains can be partially inundated at moderate intervals or show mild impacts and/or modifications to the floodplain and/or channel (30%-50%). (D) Not functional: floodplains are rarely or infrequently inundated by flood flows or have incurred severe and/or irreversible impairments or modifications, usually by heavy anthropogenic impacts (0%-30%).	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	0
				Entrenchment ratio (or overbank return interval)	Vertical containment of the stream described as the ratio of the width of the flood-prone area to the surface width of the bankfull channel (flows > Q2 overtop low flow channel)	Identification and measurement of bankfull stage and flood-prone width (quantitative)	Remote sensing-GIS and field survey; hydraulic model	HyFC2	(A) Fully functional: minimally entrenched; entrenchment ratio is >2.5 for single thread partly confined or laterally unconfined river type. (B) Functional: slightly entrenched; entrenchment ratio is >2.2 for single thread partly confined or laterally unconfined river type. (C) Partly functional: moderately entrenched; entrenchment ratio is >1.4 and <2.2 for single thread partly confined or laterally unconfined river type. (D) Not functional: significantly entrenched; entrenchment ratio is <1.4 for single thread partly confined or laterally unconfined river type.	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	3
Geomorphology	Reach	Sediment Regime	Trends of erosion and sedimentation, local zones of erosion (within channel)	Sediment transport capacity	Bed-material load transported through the river reach by a sequence of flows over an extended time period divided by the bed-material load transported into the reach by the same sequence of flows over the same time period (Soar and Thorne 2001)	Supply or capacity limited using capacity supply ratio (CSR)	Modelling/analysis (CSR)	GR5	(A) Fully functional: the amount of sediment transported through the reach is self-sustainable with no management or maintenance required. Limited, if any, impediments to sediment delivery or transport is present throughout the reach. CSR = 1. (B) Functional: impediments to sediment transport may exist, but they are either insignificant or they impact sediment transport from only a small portion of the overall contributing reach or corridor. Minor stressors are present and minimal maintenance is required to maintain functionality. CSR > 1 (C) Partly functional: major impediments to sediment transport exist, but these impediments either pass a portion of the sediment downstream or block sediment from less than half of the contributing area. Stressors significantly alter sediment transport and extensive or consistent active maintenance is required. CSR > 1 (D) Not functional: severe impediments to sediment transport are present and impact most or all of the reach. Sediment transport through the reach is severely altered to a level that results in an inability to support functional processes. CSR > 1	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	2
		Stability	Patterns, levels, and rates of dynamic processes (erosion, deposition, and migration) stream considering its landscape setting, including lateral migration and bank stability.	Channel stability index	Channel-stability ranking scheme following the Rapid Geomorphic Assessment (RGA) sensu Simon and Downs (1995) and Vermont (https://dec.vermont.gov/watershed/rivers/river-corridor-and-floodplain-protection/geomorphic-assessment)	Identification and measurement of bed material, bed/bank protection, degree of incision, degree of constriction, bank erosion, bank instability, bank accretion (quantitative)	Remote sensing and/or field survey	GS4	(A) Fully functional: RGA score < 10 (B) Functional: RGA score between 10 and 15 (C) Partly functional: RGA score between 15 and 20 (D) Not functional: RGA score >20	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	0
		Morphology	Replicate natural stream processes to extent possible to provide resiliency and minimize maintenance. The channel geometry is self-sustaining under natural channel processes and requires little to no maintenance.	Channel adjustments - pattern	Adjustments in channel pattern	Changes in channel pattern based on historical channel thalweg and bank lines (quantitative)	Remote sensing (GIS)	GM9	(A) Fully functional: absence of changes in channel pattern from a historical reference point. (B) Functional: limited change to a similar channel pattern from a historical reference point. (C) Partly functional: moderate change to a similar channel pattern from a historical reference point. (D) Not functional: change to a different channel pattern from a historical reference point.	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	2
				Channel adjustments - width	Adjustments in channel width	Changes in channel width based on historical bankfull/active channel widths (quantitative)	Remote sensing (GIS)	GM10	(A) Fully functional: no change compared to a historical reference point (B) Functional: limited changes (≤15%) from a historical reference point (C) Partly functional: moderate changes (15 to 35%) from a historical reference point. (D) Not functional: intense changes (>35%) from a historical reference point.	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	2
				Channel adjustments - condition (SEM stage)	Linking the evolutionary stage and trajectory of stream adjustment to hydrogeomorphic attributes (following Cluer and Thorne, 2014)	Evidence of stream evolution stage (qualitative)	Feld survey of cross sections (if available) from onsite data collection; field observations	GM11	(A) Fully functional: pre-disturbance, dynamically meta-stable riverscape featuring historical natural planform connected to a frequently inundated floodplain that supports riparian vegetation (Qsin ≥ Qsout; h<<hc); SEM Stages 0 and 8 (B) Functional: dynamically stable and laterally active channel within a floodplain complex (Qsin ≥ Qsout; h<<hc); SEM Stages 1 and 7 (C) Partly functional: quasi-equilibrium channel with two-stage cross-section featuring regime channel inset within larger, degraded channel (Qsin ~ Qsout; h<hc); SEM Stage 6 (D) Not functional: incising with unstable, retreating banks and abandoned floodplain (Qsin < Qsout; h>hc) or bed rising, aggrading, widening channel with unstable banks (Qsin ~ Qsout; h<hc); SEM Stages 2, 3, 3s, 4, 4-3, and 5	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	0
				Channel adjustments - bed	Bed-level adjustments	Evidence of incision or aggradation (qualitative/quantitative)	Cross sections/ longitudinal profiles (if available); field survey	GM12	(A) Fully functional: negligible bed-level changes (≤0.5 ft) (B) Functional: limited bed-level changes (0.5 to 1 ft) (C) Partly functional: moderate bed-level changes (1 to 2 ft) (D) Not functional: intense bed-level changes (>2 ft)	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	0
Vegetation	Reach	Flow Conveyance	Vegetation density and structure do not impede flood conveyance	Clogging of crossing structures	Clogging of channel spanning crossing structures such as bridges and culverts via encroaching trees and shrubs.	Evidence of vegetation clogging openings to bridges and culverts (qualitative)	Field survey	VC6	(A) Fully functional: encroaching trees and shrubs do not clog bridge or culvert openings. (B) Functional: minimal clogging of bridge or culvert openings by encroaching trees and shrubs. (C) Partly functional: moderate clogging of bridge or culvert openings by encroaching trees and shrubs. (D) Not functional: significant clogging of bridge or culvert openings by encroaching trees and shrubs.	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	N/A
				Vegetation along the channel banks and proximal floodplain	Vegetation composition, density, and height	Visual observation (either quantitative using transects or qualitative with meandering survey)	Field survey	VC9	(A) Fully functional: short herbaceous vegetation or tree seedlings (average depth of flow is at least 2x vegetation height) (B) Functional: short herbaceous vegetation (average depth of flow is 1-2x vegetation height) OR low density willows on bank slopes (C) Partly functional: medium height herbaceous vegetation (average depth of flow = vegetation height) OR moderately dense willows on side slopes (D) Not functional: taller herbaceous vegetation (average depth of flow< 1/2 vegetation height) OR dense willows on side slopes OR dense cattails in channel bottom	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	0.5
		Dynamic Stability	Riparian vegetation extends from stream edges to overbank areas (i.e., floodfringe) and stabilizes soil during flood events	Vegetation vigor	Percent vegetation senescence (stress or age induced dieback)	Visual observation of plant senescence in vegetation communities in study reach quantitatively (transects) or in meandering survey	Ffeld observations	VS7	(A) Fully functional: 0-10% senescence (B) Functional: 10-30% senescence (C) Partly functional: 30-75% senescence (D) Not functional: >75% senescence	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	3
				Bank Stability	Bank stability index based on dominant vegetation along channel banks	Visual observation of vegetation composition and cover along channel banks and assignment of index value from Winward 2000 and BLM MIM Ratings	Field survey	VS9	(A) Fully functional: Greenline Stability between 7.5 and 10 (B) Functional: Greenline Stability between 5 and 7.5 (C) Partly functional: Greenline Stability between 2.5 and 5.0 (D) Not functional: Greenline stability from 0 to 2.5	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	1.5
				Native riparian vegetation cover	Relative cover of native plant species in all community types present in the riparian corridor	Identification and visual estimation of percent cover of all herbs, shrubs, and trees	Field survey	VS10	(A) Fully functional: percent cover of native vegetation > 90% (B) Functional: percent cover of native vegetation 70-90% (C) Partly functional: percent cover of native vegetation 50-70% (D) Not functional: percent cover of native vegetation <50%	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	1.5
				Native wetland vegetation cover	Relative cover of native plant species in wetland community only	Identification and measurement of extent and percent cover of herbs, shrubs, and trees	Field survey	VS11	(A) Fully functional: percent cover of native vegetation > 90% (B) Functional: percent cover of native vegetation 70-90% (C) Partly functional: percent cover of native vegetation 50-70% (D) Not functional: percent cover of native vegetation <50%	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	1.5
		Resiliency	Vegetation communities are able to maintain functioning in response to disturbance	Noxious weed cover	Absolute cover of noxious weeds in the riparian corridor	Visual estimation of state listed noxious weed cover in riparian corridor	Field survey	VR9	(A) Fully functional: noxious weeds cover < 3% (B) Functional: noxious weed cover 3-10% (C) Partly functional: noxious weed cover 10-30% (D) Not functional: noxious weed cover > 30%	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	2
		Adaptability	Vegetation communities are able to adapt to changes in hydrology due to climate change or development	Vegetation community mosaic	Number of plant communities present in the riparian corridor	Visual estimation of the number of different plant communities present from the channel to the edge of the riparian corridor (ex. wetland herb, wetland shrub, riparian herb, riparian shrub, upland)	Field observations	VA7	(A) Fully functional: ≥3 plant communities present (B) Functional: 2-3 plant communities present (C) Partly functional: 1-2 plant communities present (D) Not functional: 0-1 plant communities present	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	2
				Woody species recruitment	Presence of recruitement for native woody species	Visual estimation of age of native riparian tree and shrub recruits (seedling, sapling, whips)	Field survey	VA8	(A) Fully functional: multi-age recruitement (seedlings, saplings, whips) (B) Functional: saplings or whips present (C) Partly functional: suitable substrate present AND seedlings present (D) Not functional: no seedlings but substrate present	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	1

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MURPHY CREEK REACH 5

Element	Scale	Indicator	Description	Metrics	Measurement (definition)	Assessment Method	Analysis	Metric Code	Functional characteristics (and/or maintenance requirements)	Score Level of Function (and/or maintenance)	Score
Community Values	Watershed	Access to Nature	Presence of/Easy access to green spaces, natural areas, parks, trails, and waterways	Natural space opportunities	Mapped locations of proposed parks and open space, vacant lands, natural land cover, riparian corridor	Identify natural space opportunities based on land use and cover characteristics, schools, community gardens, and potential for certified backyard wildlife habitat areas.	Remote sensing–GIS, Trust for Public Land Metro DNA data	VN2	(A) Very high opportunities within the watershed to provide access to natural spaces (B) High opportunities within the watershed to provide access to natural spaces (C) Moderate opportunities within the watershed to provide access to natural spaces (D) Low to no opportunities within the watershed to provide access to natural spaces	Very high (3 points) High (2 points) Moderate (1 point) Low or no opportunities (0 points)	2
Hydrology	Corridor	Flow Regime	The shape and size of stream channels, the distribution of vegetation, and the stability of channel bed and banks are all largely determined by the interaction between the flow regime and local geology and landform.	Flow regime change	Evaluation of changes in flow regime along the stream corridor under existing conditions, including anthropogenic impacts such as diversions, groundwater wells, and unnatural inflow	Evaluation of changes in flow regime (quantitative). In absence of available data, the assessment is based on field survey to identify locations along the corridor where the flow regime changes (qualitative)	Hydrological data and/or modelling such as stream gage analysis or hydrograph flow-routing	HR1	(A) Fully functional: downstream hydrograph progression is consistent with anticipated increases in flood flows, based on upstream contributing area. No alterations of natural runoff processes and no in-channel structures (no stressors). (B) Functional: downstream hydrograph progression is slightly modified due to limited alterations of natural runoff processes and in-channel structures (minimal stressors). (C) Partly functional: downstream hydrograph progression is moderately modified due to multiple alterations of natural runoff processes and in-channel structures (multiple stressors). (D) Not functional: downstream hydrograph progression is significantly modified due to multiple alterations of natural runoff processes and in-channel structures (multiple stressors).	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	3
	Reach	Flow Regime	Ability of stream to meet intent of the Master Plan and adjust to modified flow conditions and high functioning lower maintenance streams Determine flow regime for the following conditions: - Future land use - Existing land use - Historical condition - MP condition	Rate/magnitude	Evaluation of the pattern of peaks in the hydrograph and deviation of annual net peak flow discharge to understand impacts geomorphologically relevant thresholds (evaluate base flow, Active channel flow (average annual flow), 2-year, 5-year, 10-year, 50-year, and 100-year)	Evaluation of flow rate and magnitude between historical, existing, and future conditions (quantitative). Master Plan Data and/or Hydrograph flow-routing for existing and future land use from hydrologic model; stream gage analysis for historical and existing conditions, if gage data is available	Hydrological data, desktop analysis, and/or modelling (CUHP and EPA-SWMM)	HR2	(A) Fully functional: magnitude and duration of annual discharge peaks closely resembles optimal hydrograph. Net change of existing condition value compared to baseline (natural) condition value less than 10% of the flow magnitude. (B) Functional: hydrograph has a natural seasonal pattern, but peaks are attenuated, elevated, extended, or shortened. Net change of existing condition value compared to baseline (natural) condition value between 10% and 20% of the flow magnitude. (C) Partly functional: disrupted seasonal hydrograph patterns and/or departure from natural peak flow magnitude. Net change of existing condition value compared to baseline (natural) condition value between 20% and 40% of the flow magnitude. (D) Not functional: disrupted seasonal hydrograph patterns and/or departure from natural peak flow magnitude. Net change of existing condition value compared to baseline (natural) condition value, more than 40% of the flow magnitude.	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	1
				Volume	The total volume metric rates the net annual change in water volume caused by anthropogenic uses as a percentage of natural flows.	Analysis of total volume between historical, existing, and future conditions (quantitative).	Hydrological data, desktop analysis, and/or modelling	HR3	(A) Fully functional: net change of existing condition value compared to baseline (natural) condition value less than 10% of the total annual volume. (B) Functional: net change of existing condition value compared to baseline (natural) condition value between 10% and 20% of the total annual volume. (C) Partly functional: net change of existing condition value compared to baseline (natural) condition value between 20% and 40% of the total annual volume. (D) Not functional: net change of existing condition value compared to baseline (natural) condition value more than 40% of the total annual volume.	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	1
Hydraulics	Reach	Flow Conveyance	Ensure project provides level of service indicated in MP. As a public safety issue, velocity and/or depth of a stream should not reach dangerous levels.	Riverscape (channel and floodplain) capacity	Evaluation of the capacity and space available for a riverscape (channel and floodplain) to convey the full spectrum of flows.	Measurement of hydraulic characteristics such as capacity, flow area, depth, velocity (quantitative)	Hydraulic model and/or Remote sensing–GIS	HyC1	(A) Fully functional: no encroachment; stream channel and floodplain can convey >1% AEP flood. (B) Functional: negligible presence of encroachment; stream channel and floodplain can convey >2% AEP flood. (C) Partly functional: presence of structures within floodplain; stream channel and floodplain can convey >10% AEP flood (D) Not functional: significant encroachment of structures in the floodplain; stream channel and floodplain can convey <10% AEP flood	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	3
		Floodplain Connectivity	The degree to which water inundates and hydrates the adjacent corridor. It is a measure of the extent and frequency with which flows interact with the channel and floodplain to create a characteristic pattern of land saturation or inundation.	Floodplain connectivity ratio	Presence of a modern floodplain and hillslope–stream corridor connectivity presence and length of elements of disconnection (e.g., roads) within a buffer 50-m wide for each river side	Measurement of width and longitudinal length (quantitative); identification/ checking of modern floodplain (qualitative)	Remote sensing–GIS using Valley Bottom Extraction Tool (see Gilbert et al. 2016); Digital Elevation Models (DEM), stream networks, valley slopes, height above the drainage network (HAND), and upstream contributing area.	HyFC1	(A) Fully functional: floodplains can be extensively and frequently inundated with only minor historic or existing impairments (80%-100%) (B) Functional: floodplains can be fully inundated at moderate intervals or show mild impacts and/or modifications to the floodplain and/or channel (50%-80%). (C) Partly functional: floodplains can be partially inundated at moderate intervals or show mild impacts and/or modifications to the floodplain and/or channel (30%-50%). (D) Not functional: floodplains are rarely or infrequently inundated by flood flows or have incurred severe and/or irreversible impairments or modifications, usually by heavy anthropogenic impacts (0%-30%).	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	0
				Entrenchment ratio (or overbank return interval)	Vertical containment of the stream described as the ratio of the width of the flood-prone area to the surface width of the bankfull channel (flows > Q2 overtop low flow channel)	Identification and measurement of bankfull stage and flood-prone width (quantitative)	Remote sensing-GIS and field survey; hydraulic model	HyFC2	(A) Fully functional: minimally entrenched; entrenchment ratio is >2.5 for single thread partly confined or laterally unconfined river type. (B) Functional: slightly entrenched; entrenchment ratio is >2.2 for single thread partly confined or laterally unconfined river type. (C) Partly functional: moderately entrenched; entrenchment ratio is >1.4 and <2.2 for single thread partly confined or laterally unconfined river type. (D) Not functional: significantly entrenched; entrenchment ratio is <1.4 for single thread partly confined or laterally unconfined river type.	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	3
Geomorphology	Reach	Sediment Regime	Trends of erosion and sedimentation, local zones of erosion (within channel)	Sediment transport capacity	Bed-material load transported through the river reach by a sequence of flows over an extended time period divided by the bed-material load transported into the reach by the same sequence of flows over the same time period (Soar and Thorne 2001)	Supply or capacity limited using capacity supply ratio (CSR)	Modelling/analysis (CSR)	GR5	(A) Fully functional: the amount of sediment transported through the reach is self-sustainable with no management or maintenance required. Limited, if any, impediments to sediment delivery or transport is present throughout the reach. CSR = 1. (B) Functional: impediments to sediment transport may exist, but they are either insignificant or they impact sediment transport from only a small portion of the overall contributing reach or corridor. Minor stressors are present and minimal maintenance is required to maintain functionality. CSR > 1 (C) Partly functional: major impediments to sediment transport exist, but these impediments either pass a portion of the sediment downstream or block sediment from less than half of the contributing area. Stressors significantly alter sediment transport and extensive or consistent active maintenance is required. CSR > 1 (D) Not functional: severe impediments to sediment transport are present and impact most or all of the reach. Sediment transport through the reach is severely altered to a level that results in an inability to support functional processes. CSR > 1	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	1
		Stability	Patterns, levels, and rates of dynamic processes (erosion, deposition, and migration) stream considering its landscape setting, including lateral migration and bank stability.	Channel stability index	Channel-stability ranking scheme following the Rapid Geomorphic Assessment (RGA) sensu Simon and Downs (1995) and Vermont (https://dec.vermont.gov/watershed/rivers/river-corridor-and-floodplain-protection/geomorphic-assessment)	Identification and measurement of bed material, bed/bank protection, degree of incision, degree of constriction, bank erosion, bank instability, bank accretion (quantitative)	Remote sensing and/or field survey	GS4	(A) Fully functional: RGA score < 10 (B) Functional: RGA score between 10 and 15 (C) Partly functional: RGA score between 15 and 20 (D) Not functional: RGA score >20	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	2
		Morphology	Replicate natural stream processes to extent possible to provide resiliency and minimize maintenance. The channel geometry is self-sustaining under natural channel processes and requires little to no maintenance.	Channel adjustments - pattern	Adjustments in channel pattern	Changes in channel pattern based on historical channel thalweg and bank lines (quantitative)	Remote sensing (GIS)	GM9	(A) Fully functional: absence of changes in channel pattern from a historical reference point. (B) Functional: limited change to a similar channel pattern from a historical reference point. (C) Partly functional: moderate change to a similar channel pattern from a historical reference point. (D) Not functional: change to a different channel pattern from a historical reference point.	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	2
				Channel adjustments - width	Adjustments in channel width	Changes in channel width based on historical bankfull/active channel widths (quantitative)	Remote sensing (GIS)	GM10	(A) Fully functional: no change compared to a historical reference point (B) Functional: limited changes (≤15%) from a historical reference point (C) Partly functional: moderate changes (15 to 35%) from a historical reference point. (D) Not functional: intense changes (>35%) from a historical reference point.	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	2
				Channel adjustments - condition (SEM stage)	Linking the evolutionary stage and trajectory of stream adjustment to hydrogeomorphic attributes (following Cluer and Thorne, 2014)	Evidence of stream evolution stage (qualitative)	Feld survey of cross sections (if available) from onsite data collection; field observations	GM11	(A) Fully functional: pre-disturbance, dynamically meta-stable riverscape featuring historical natural planform connected to a frequently inundated floodplain that supports riparian vegetation (Qsin ≥ Qsout; h<<hc); SEM Stages 0 and 8 (B) Functional: dynamically stable and laterally active channel within a floodplain complex (Qsin ≥ Qsout; h<<hc); SEM Stages 1 and 7 (C) Partly functional: quasi-equilibrium channel with two-stage cross-section featuring regime channel inset within larger, degraded channel (Qsin ~ Qsout; h<hc); SEM Stage 6 (D) Not functional: incising with unstable, retreating banks and abandoned floodplain (Qsin < Qsout; h>hc) or bed rising, aggrading, widening channel with unstable banks (Qsin ~ Qsout; h<hc); SEM Stages 2, 3, 3s, 4, 4-3, and 5	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	0
				Channel adjustments - bed	Bed-level adjustments	Evidence of incision or aggradation (qualitative/quantitative)	Cross sections/ longitudinal profiles (if available); field survey	GM12	(A) Fully functional: negligible bed-level changes (≤0.5 ft) (B) Functional: limited bed-level changes (0.5 to 1 ft) (C) Partly functional: moderate bed-level changes (1 to 2 ft) (D) Not functional: intense bed-level changes (>2 ft)	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	1
Vegetation	Reach	Flow Conveyance	Vegetation density and structure do not impede flood conveyance	Clogging of crossing structures	Clogging of channel spanning crossing structures such as bridges and culverts via encroaching trees and shrubs.	Evidence of vegetation clogging openings to bridges and culverts (qualitative)	Field survey	VC6	(A) Fully functional: encroaching trees and shrubs do not clog bridge or culvert openings. (B) Functional: minimal clogging of bridge or culvert openings by encroaching trees and shrubs. (C) Partly functional: moderate clogging of bridge or culvert openings by encroaching trees and shrubs. (D) Not functional: significant clogging of bridge or culvert openings by encroaching trees and shrubs.	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	2
				Vegetation along the channel banks and proximal floodplain	Vegetation composition, density, and height	Visual observation (either quanitative using transects or qualitative with meandering survey)	Field survey	VC9	(A) Fully functional: short herbaceous vegetation or tree seedlings (average depth of flow is at least 2x vegetation height) (B) Functional: short herbaceous vegetation (average depth of flow is 1-2x vegetation height) OR low density willows on bank slopes (C) Partly functional: medium height herbaceous vegetation (average depth of flow = vegetation height) OR moderately dense willows on side slopes (D) Not functional: taller herbaceous vegetation (average depth of flow< 1/2 vegetation height) OR dense willows on side slopes OR dense cattails in channel bottom	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	0
		Dynamic Stability	Riparian vegetation extends from stream edges to overbank areas (i.e., floodfringe) and stabilizes soil during flood events	Vegetation vigor	Percent vegetation senescence (stress or age induced dieback)	Visual observation of plant senescence in vegetation communities in study reach quantitatively (transects) or in meandering survey	Ffeld observations	VS7	(A) Fully functional: 0-10% senescence (B) Functional: 10-30% senescence (C) Partly functional: 30-75% senescence (D) Not functional: >75% senescence	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	3
				Bank Stability	Bank stability index based on dominant vegetation along channel banks	Visual observation of vegetation composition and cover along channel banks and assignment of index value from Winward 2000 and BLM MIM Ratings	Field survey	VS9	(A) Fully functional: Greenline Stability between 7.5 and 10 (B) Functional: Greenline Stability between 5 and 7.5 (C) Partly functional: Greenline Stability between 2.5 and 5.0 (D) Not functional: Greenline stability from 0 to 2.5	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	2
				Native riparian vegetation cover	Relative cover of native plant species in all community types present in the riparian corridor	Identification and visual estimation of percent cover of all herbs, shrubs, and trees	Field survey	VS10	(A) Fully functional: percent cover of native vegetation > 90% (B) Functional: percent cover of native vegetation 70-90% (C) Partly functional: percent cover of native vegetation 50-70% (D) Not functional: percent cover of native vegetation <50%	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	2
				Native wetland vegetation cover	Relative cover of native plant species in wetland community only	Identification and measurement of extent and percent cover of herbs, shrubs, and trees	Field survey	VS11	(A) Fully functional: percent cover of native vegetation > 90% (B) Functional: percent cover of native vegetation 70-90% (C) Partly functional: percent cover of native vegetation 50-70% (D) Not functional: percent cover of native vegetation <50%	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	2
		Resiliency	Vegetation communities are able to maintain functioning in response to disturbance	Noxious weed cover	Absolute cover of noxious weeds in the riparian corridor	Visual estimation of state listed noxious weed cover in riparian corridor	Field survey	VR9	(A) Fully functional: noxious weeds cover < 3% (B) Functional: noxious weed cover 3-10% (C) Partly functional: noxious weed cover 10-30% (D) Not functional: noxious weed cover > 30%	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	1.5
		Adaptability	Vegetation communities are able to adapt to changes in hydrology due to climate change or development	Vegetation community mosaic	Number of plant communities present in the riparian corridor	Visual estimation of the number of different plant communities present from the channel to the edge of the riparian corridor (ex. wetland herb, wetland shrub, riparian herb, riparian shrub, upland)	Field observations	VA7	(A) Fully functional: ≥3 plant communities present (B) Functional: 2-3 plant communities present (C) Partly functional: 1-2 plant communities present (D) Not functional: 0-1 plant communities present	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	2.75
				Woody species recruitment	Presence of recruitement for native woody species	Visual estimation of age of native riparian tree and shrub recruits (seedling, sapling, whips)	Field survey	VA8	(A) Fully functional: multi-age recruitement (seedlings, saplings, whips) (B) Functional: saplings or whips present (C) Partly functional: suitable substrate present AND seedlings present (D) Not functional: no seedlings but substrate present	Fully functional (3 points) Functional (2 points) Partly functional (1 point) Not functional (0 points)	3

Appendix 3: Historical Aerial Imagery

Path: G:\WWE\221-076\000\GIS\01_mxd\HistAerialEval\HistAerialEval.aprx

WWE
WRIGHT WATER
ENGINEERS, INC.

AURORA, COLORADO

2024 - HISTORICAL AERIAL EVALUATION

MURPHY CREEK

0 150 300 600
Feet

PROJECT NO
221-076.000

DRAFT

FIGURE
1

Path: G:\WWE\221-076\000\GIS\01_mxd\HistAerialEval\HistAerialEval.aprx

WWE WRIGHT WATER ENGINEERS, INC.

AURORA, COLORADO

2002 - HISTORICAL AERIAL EVALUATION

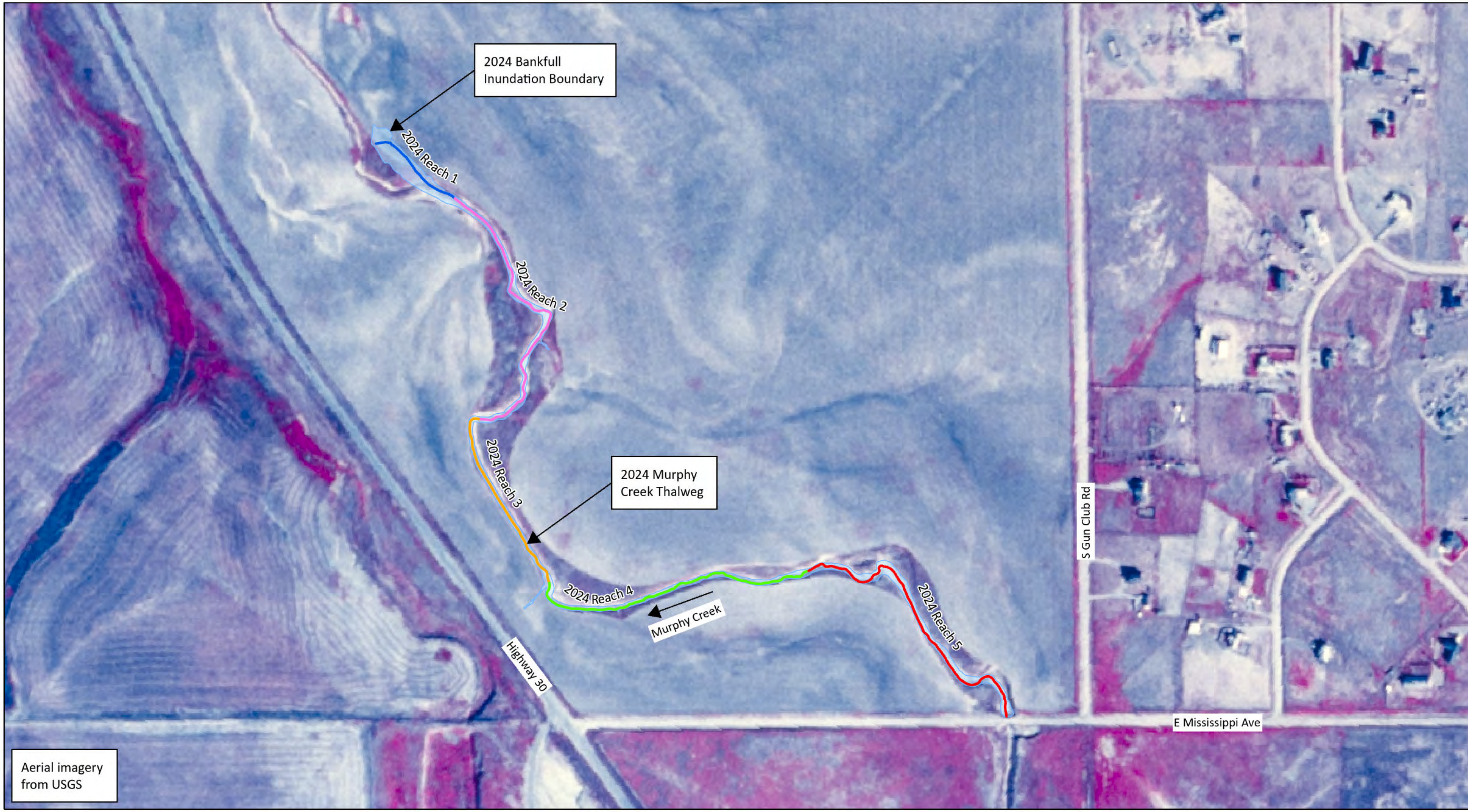
MURPHY CREEK

0 150 300 600 Feet

PROJECT NO 221-076.000

DRAFT

FIGURE 2



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WWE
WRIGHT WATER ENGINEERS, INC.

AURORA, COLORADO

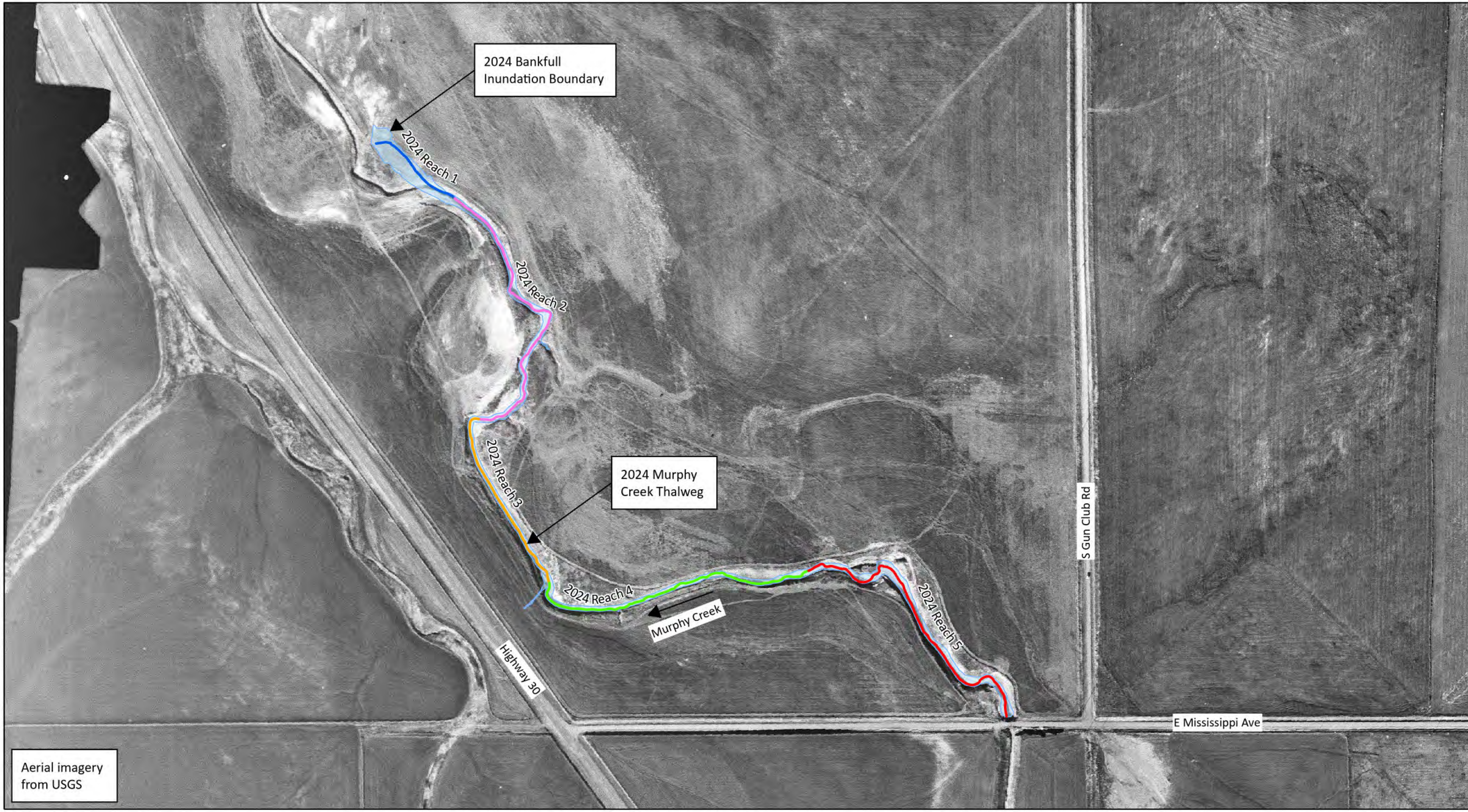
1984 - HISTORICAL AERIAL EVALUATION

MURPHY CREEK

PROJECT NO
221-076.000

DRAFT

FIGURE
3



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WWE WRIGHT WATER ENGINEERS, INC.

AURORA, COLORADO

1965 - HISTORICAL AERIAL EVALUATION

MURPHY CREEK

0 150 300 600 Feet

PROJECT NO 221-076.000

DRAFT

FIGURE 4

Appendix 4: Hydrology Summary Tables

DRAFT

MURPHY CREEK

EXISTING CONDITIONS URBAN STREAM ASSESSMENT PROCEDURE

HYDROLOGY SUMMARY TABLES

PEAK FLOW RATES

Location	Design Point[1]	Historical Conditions Peak Flow Rates [cfs]						
		2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	500-Year
At Mississippi Ave	1100	3	12	22	1295	2028	2760	5265
At Confluence with Eastern Unnamed Tributary	1050	3	12	22	1298	2074	2840	5384
At E-470	1040	3	12	22	1299	2077	2864	5419

Location	Design Point[1]	Existing Conditions Peak Flow Rates [cfs]						
		2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	500-Year
At Mississippi Ave	1100	201	320	492	1792	2453	3258	5704
At Confluence with Eastern Unnamed Tributary	1050	199	319	491	1829	2502	3399	5867
At E-470	1040	199	319	491	1835	2514	3424	5893

Location	Design Point[1]	Increase in Peak Flow Rates Between Existing and Historical Conditions [%]						
		2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	500-Year
At Mississippi Ave	1100	6700%	2667%	2236%	138%	121%	118%	108%
At Confluence with Eastern Unnamed Tributary	1050	6633%	2658%	2232%	141%	121%	120%	109%
At E-470	1040	6633%	2658%	2232%	141%	121%	120%	109%

Note:

1. Historical and existing conditions peak flow rates were referenced from the Murphy Creek and Tributaries Major Drainageway Plan Baseline Hydrology Report prepared by Merrick & Company (2023). While historical peak flow values were not part of the Drainageway Plan, they were provided by MHFD and derived from the same model as that developed for the existing conditions.

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MURPHY CREEK

EXISTING CONDITIONS URBAN STREAM ASSESSMENT PROCEDURE

HYDROLOGY SUMMARY TABLES

FLOW VOLUMES

Location	Design Point[1]	Historical Conditions Flow Volumes [ac-ft]						
		2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	500-Year
At Mississippi Ave	1100	1	6	10	341	497	709	1166
At Confluence with Eastern Unnamed Tributary	1050	1	6	11	368	537	761	1255
At E-470	1040	2	6	11	374	546	776	1277

Location	Design Point[1]	Existing Conditions Flow Volumes [ac-ft]						
		2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	500-Year
At Mississippi Ave	1100	69	105	155	482	645	850	1317
At Confluence with Eastern Unnamed Tributary	1050	69	106	157	510	684	905	1409
At E-470	1040	69	106	157	519	697	921	1433

Location	Design Point[1]	Increase in Flow Volumes Between Existing and Historical Conditions [%]						
		2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	500-Year
At Mississippi Ave	1100	6940%	1755%	1547%	141%	130%	120%	113%
At Confluence with Eastern Unnamed Tributary	1050	6910%	1760%	1423%	138%	127%	119%	112%
At E-470	1040	3455%	1760%	1423%	139%	128%	119%	112%

Note:

1. Historical and existing conditions peak flow rates were referenced from the Murphy Creek and Tributaries Major Drainageway Plan Baseline Hydrology Report prepared by Merrick & Company (2023). While historical peak flow values were not part of the Drainageway Plan, they were provided by MHFD and derived from the same model as that developed for the existing conditions.

Appendix 5: Valley Bottom Extraction Tool

Reach #	Reach Length (ft)	VBET Area (ft^2)	VBET TW (ft)	10-yr Area (ft^2)	10-yr TW (ft)	10-yr vs VBET TW (%)
1	369.0	139,685	379	35,721	97	26%
2	1,145.8	480,870	420	92,934	81	19%
3	707.5	355,469	502	64,241	91	18%
4	1,078.4	769,062	713	75,079	70	10%
5	1,138.5	856,875	753	184,190	162	21%

*TW indicates Top Width

PLAN

120 0 120 240 FT

NORTH

DRAFT
WORK IN PROGRESS

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GLENWOOD SPRINGS, CO 81602
(970)945-7755 FAX(970)945-9210

VALLEY BOTTOM EXTRACTION TOOL FIGURE

MURPHY CREEK URBAN STREAM ASSESSMENT PROCEDURE
AURORA, COLORADO

NOTES:

1. 10-YEAR INUNDATION BOUNDARY CREATED BY HEC-RAS 2D MODEL.
2. VBET POLYGONS PROVIDED BY BRIAN MURPHY, PHD, P.E.
3. TOPOGRAPHIC SURVEY PROVIDED BY ENGINEERING SERVICE COMPANY.

WWE JOB NUMBER:
221-076.000

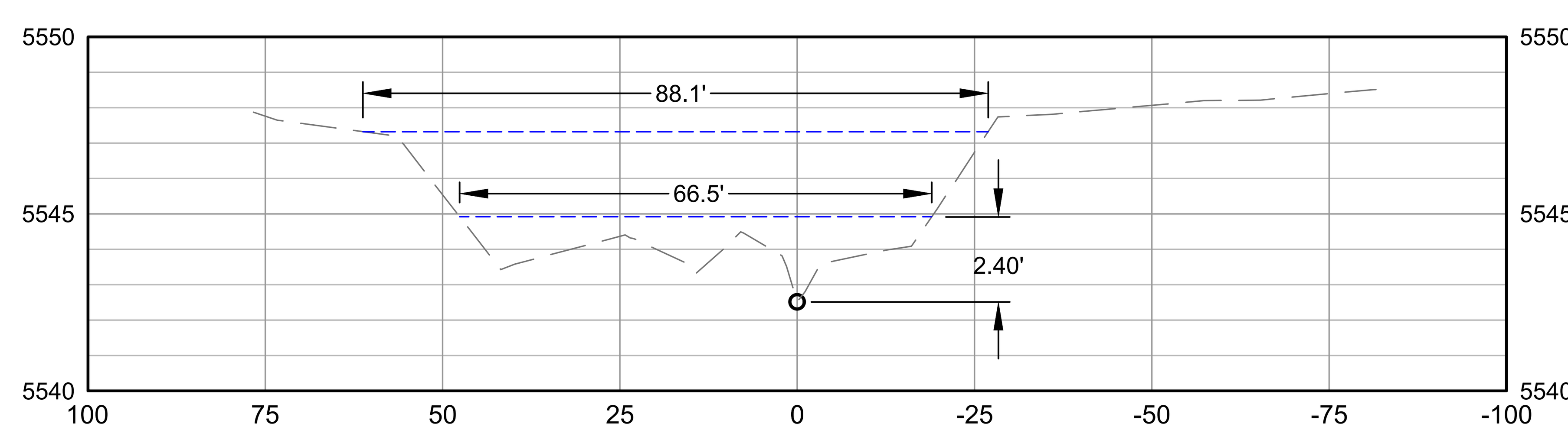
FIGURE 1

Appendix 6: Typical Sections

PLAN

30 0 30 60 FT

NORTH



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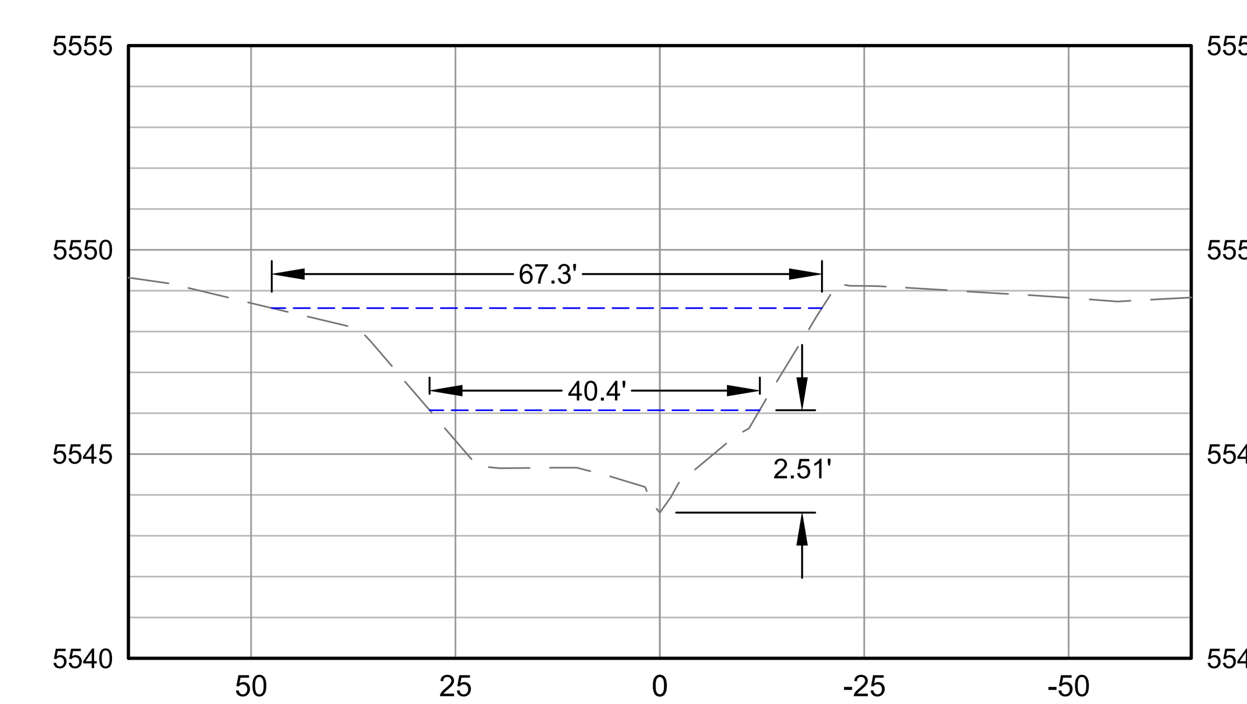

STA: 8+14

Reach #	Station	Bankfull Depth (ft)	Bankfull Width (ft)	Bankfull Width @ 2X Bankfull Depth (ft)	Entrenchment Ratio	Average Entrenchment Ratio for Reach	USAP Score
1	7+00	2.40	66.5	88.1	1.32	1.50	1
	8+14	2.51	40.4	67.3	1.67		

SECTION

20 0 20 40 FT
HORIZONTAL

4 0 4 8 FT
VERTICAL

DRAFT
WORK IN PROGRESS

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ENTRENCHMENT RATIO REACH 1

MURPHY CREEK URBAN STREAM ASSESSMENT PROCEDURE
AURORA, COLORADO

NOTES:

1. BANKFULL INUNDATION BOUNDARY CREATED BY HEC-RAS 2D MODEL.
2. BANKFULL FLOW ESTIMATED AS 70% OF 2-YEAR DISCHARGE BASED ON MHFD'S USDCM. THIS ESTIMATE WAS VERIFIED IN THE FIELD BY APPROXIMATING THE BANKFULL CHANNEL WIDTH AND DEPTH.
3. TOPOGRAPHIC SURVEY PROVIDED BY ENGINEERING SERVICE COMPANY.

WWE JOB NUMBER:
221-076.000

FIGURE 1

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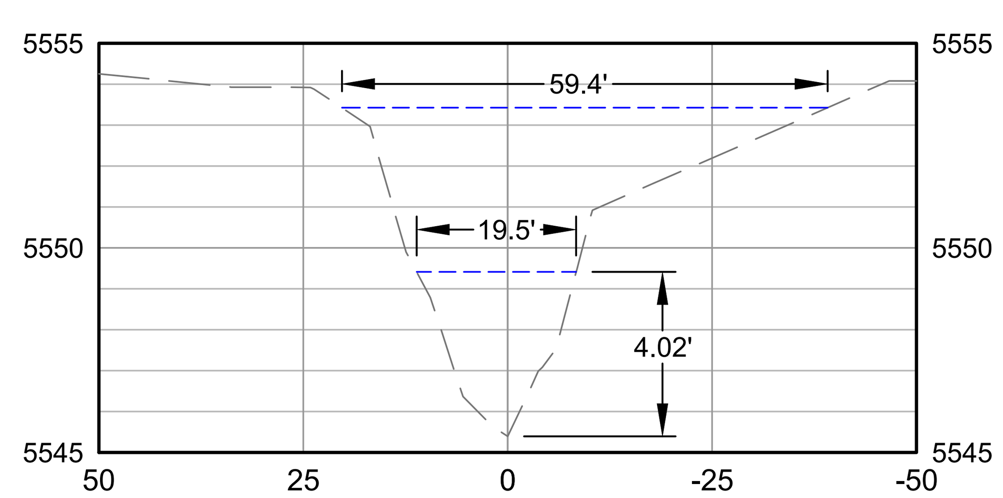
PLAN

40 0 40 80 FT

NORTH



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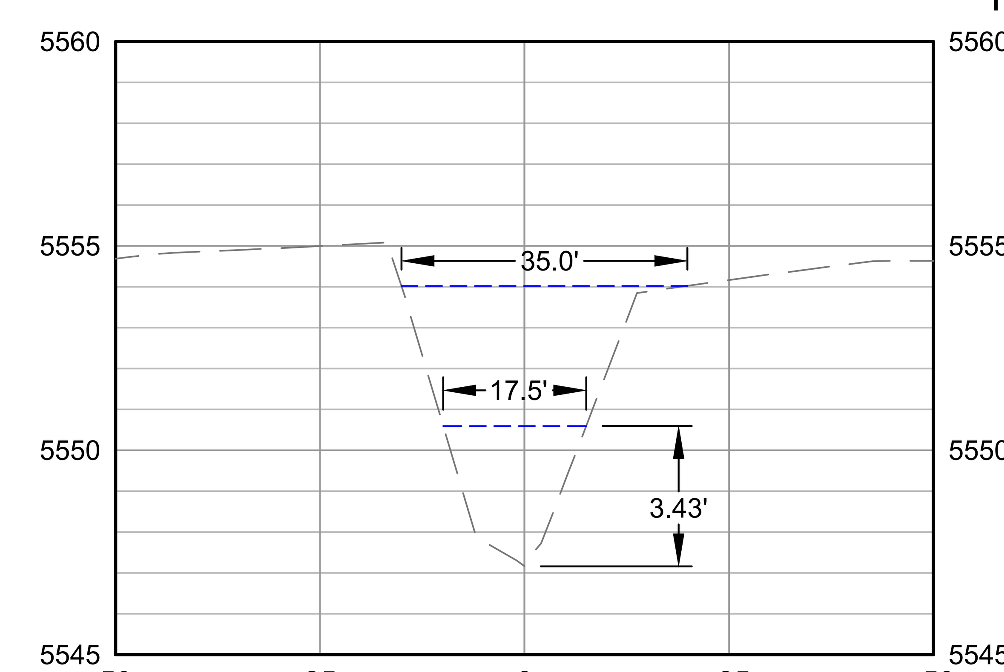

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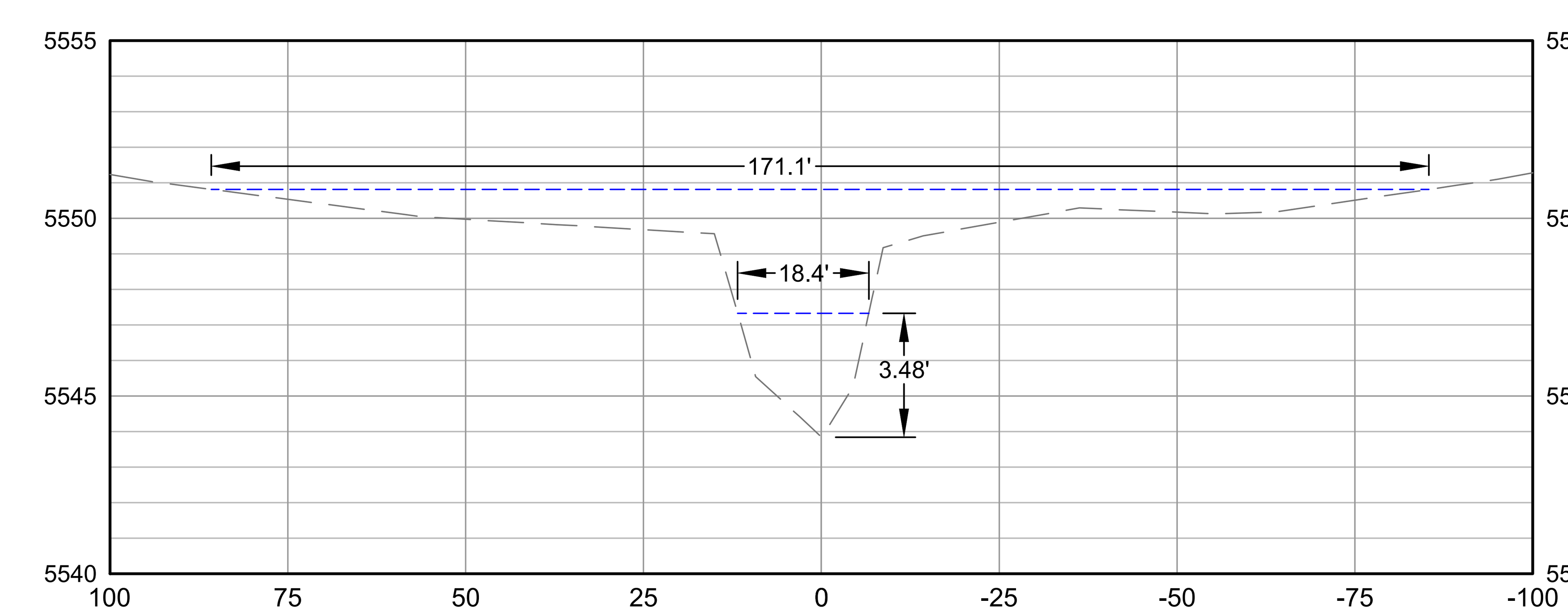

STA: 10+00

Reach #	Station	Bankfull Depth (ft)	Bankfull Width (ft)	Bankfull Width @ 2X Bankfull Depth (ft)	Entrenchment Ratio	Average Entrenchment Ratio for Reach	USAP Score
2	10+00	3.48	18.4	171.1	9.29	4.78	3
	13+50	4.02	19.5	59.4	3.05		
	16+40	3.43	17.5	35.0	2.00		

SECTION

20 0 20 40 FT
HORIZONTAL

4 0 4 8 FT
VERTICAL

DRAFT
WORK IN PROGRESS

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GLENWOOD SPRINGS, CO 81602
(970)945-7755 FAX(970)945-9210

ENTRENCHMENT RATIO REACH 2

MURPHY CREEK URBAN STREAM ASSESSMENT PROCEDURE
AURORA, COLORADO

NOTES:

1. BANKFULL INUNDATION BOUNDARY CREATED BY HEC-RAS 2D MODEL.
2. BANKFULL FLOW ESTIMATED AS 70% OF 2-YEAR DISCHARGE BASED ON MHFD'S USDCM. THIS ESTIMATE WAS VERIFIED IN THE FIELD BY APPROXIMATING THE BANKFULL CHANNEL WIDTH AND DEPTH.
3. TOPOGRAPHIC SURVEY PROVIDED BY ENGINEERING SERVICE COMPANY.

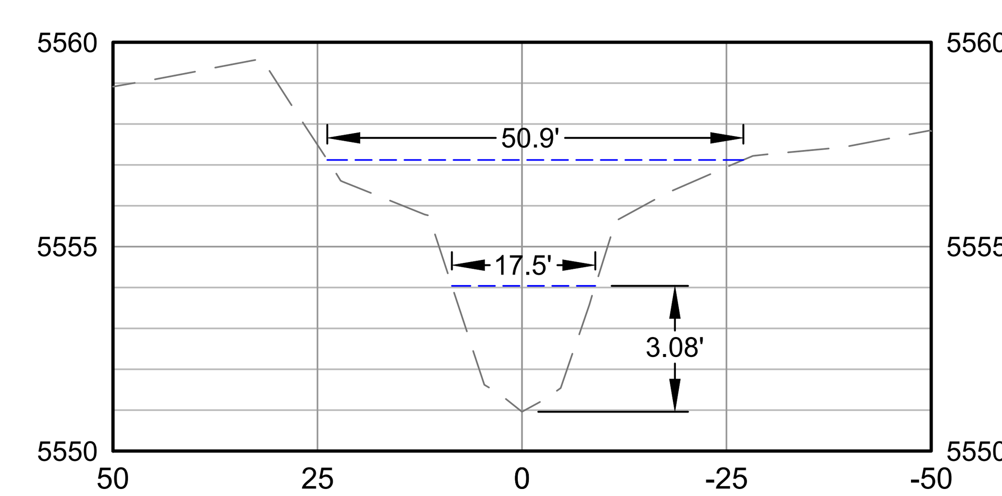
WWE JOB NUMBER:
221-076.000

FIGURE 2

PLAN

40 0 40 80 FT

NORTH



STA: 23+00

Reach #	Station	Bankfull Depth (ft)	Bankfull Width (ft)	Bankfull Width @ 2X Bankfull Depth (ft)	Entrenchment Ratio	Average Entrenchment Ratio for Reach	USAP Score
3	23+00	3.08	17.5	50.9	2.90	2.90	3

SECTION

20 0 20 40 FT HORIZONTAL

4 0 4 8 FT VERTICAL

DRAFT
WORK IN PROGRESS

WWE
WRIGHT WATER ENGINEERS, INC.
818 COLORADO AVE. P.O. BOX 219
GLENWOOD SPRINGS, CO 81602
(970)945-7755 FAX(970)945-9210

ENTRENCHMENT RATIO REACH 3

MURPHY CREEK URBAN STREAM ASSESSMENT PROCEDURE
AURORA, COLORADO

NOTES:

1. BANKFULL INUNDATION BOUNDARY CREATED BY HEC-RAS 2D MODEL.
2. BANKFULL FLOW ESTIMATED AS 70% OF 2-YEAR DISCHARGE BASED ON MHFD'S USDCM. THIS ESTIMATE WAS VERIFIED IN THE FIELD BY APPROXIMATING THE BANKFULL CHANNEL WIDTH AND DEPTH.
3. TOPOGRAPHIC SURVEY PROVIDED BY ENGINEERING SERVICE COMPANY.

WWE JOB NUMBER:
221-076.000

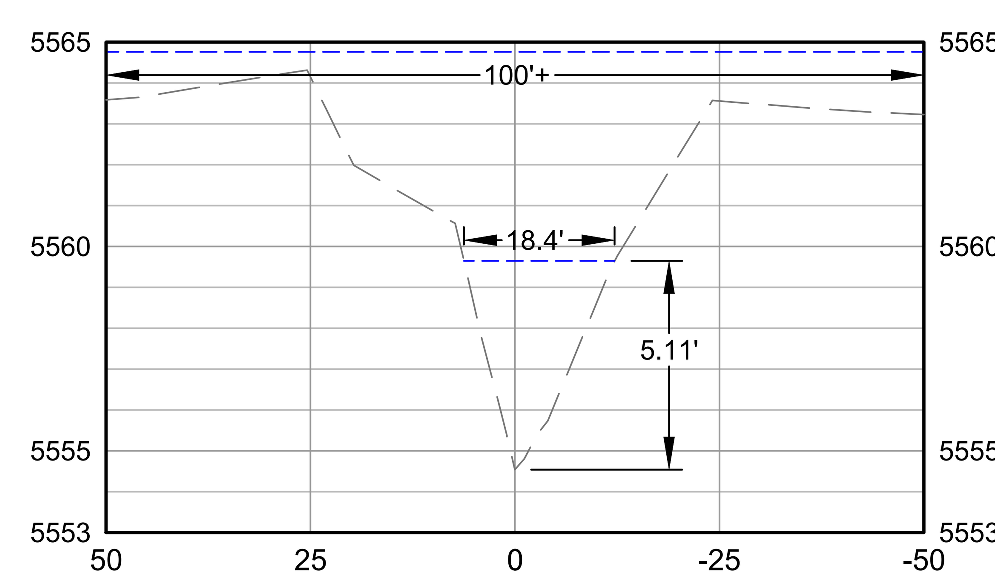
FIGURE 3

Plot Date/Time: 07/15/2024, 04:40:33 PM: G:\WWE\221-076\000\CAD\01_DWGS\TSXX - TYPICAL SECTIONS.DWG-REACH 3

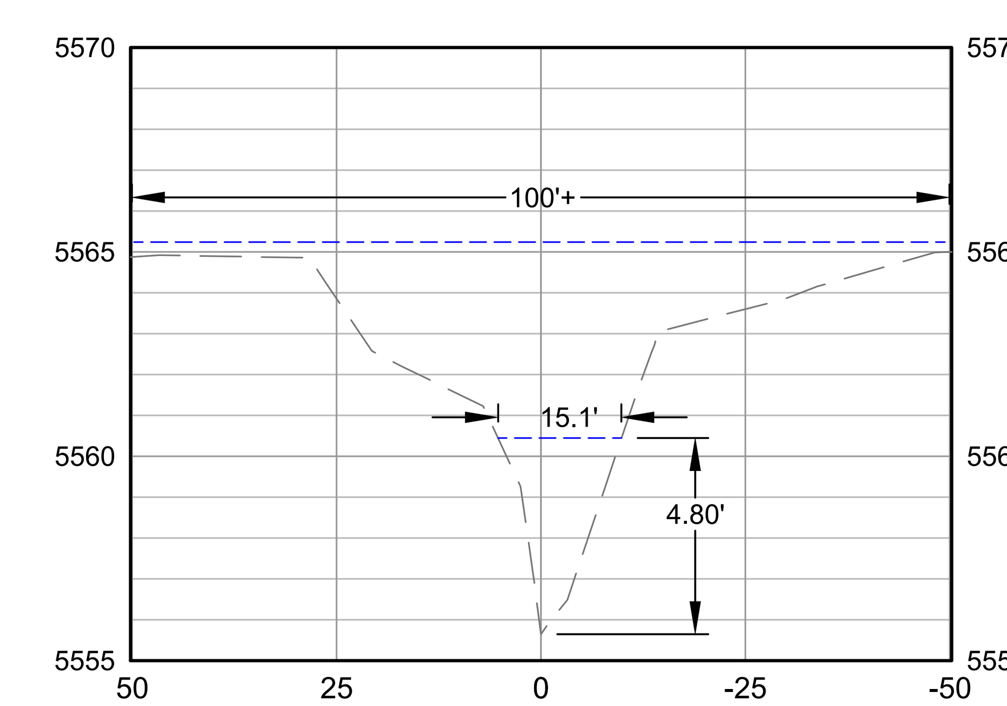
PLAN

40 0 40 80 FT

NORTH



STA: 32+40



STA: 34+00

Reach #	Station	Bankfull Depth (ft)	Bankfull Width (ft)	Bankfull Width @ 2X Bankfull Depth (ft)	Entrenchment Ratio	Average Entrenchment Ratio for Reach	USAP Score
4	32+40	5.11	18.4	100+	5.43	6.02	3
	34+00	4.80	15.1	100+	6.62		

SECTION

20 0 20 40 FT
HORIZONTAL

4 0 4 8 FT
VERTICAL

DRAFT
WORK IN PROGRESS

WWE
WRIGHT WATER ENGINEERS, INC.
818 COLORADO AVE. P.O. BOX 219
GLENWOOD SPRINGS, CO 81602
(970)945-7755 FAX(970)945-9210

ENTRENCHMENT RATIO REACH 4

MURPHY CREEK URBAN STREAM ASSESSMENT PROCEDURE
AURORA, COLORADO

NOTES:

1. BANKFULL INUNDATION BOUNDARY CREATED BY HEC-RAS 2D MODEL.
2. BANKFULL FLOW ESTIMATED AS 70% OF 2-YEAR DISCHARGE BASED ON MHFD'S USDCM. THIS ESTIMATE WAS VERIFIED IN THE FIELD BY APPROXIMATING THE BANKFULL CHANNEL WIDTH AND DEPTH.
3. TOPOGRAPHIC SURVEY PROVIDED BY ENGINEERING SERVICE COMPANY.

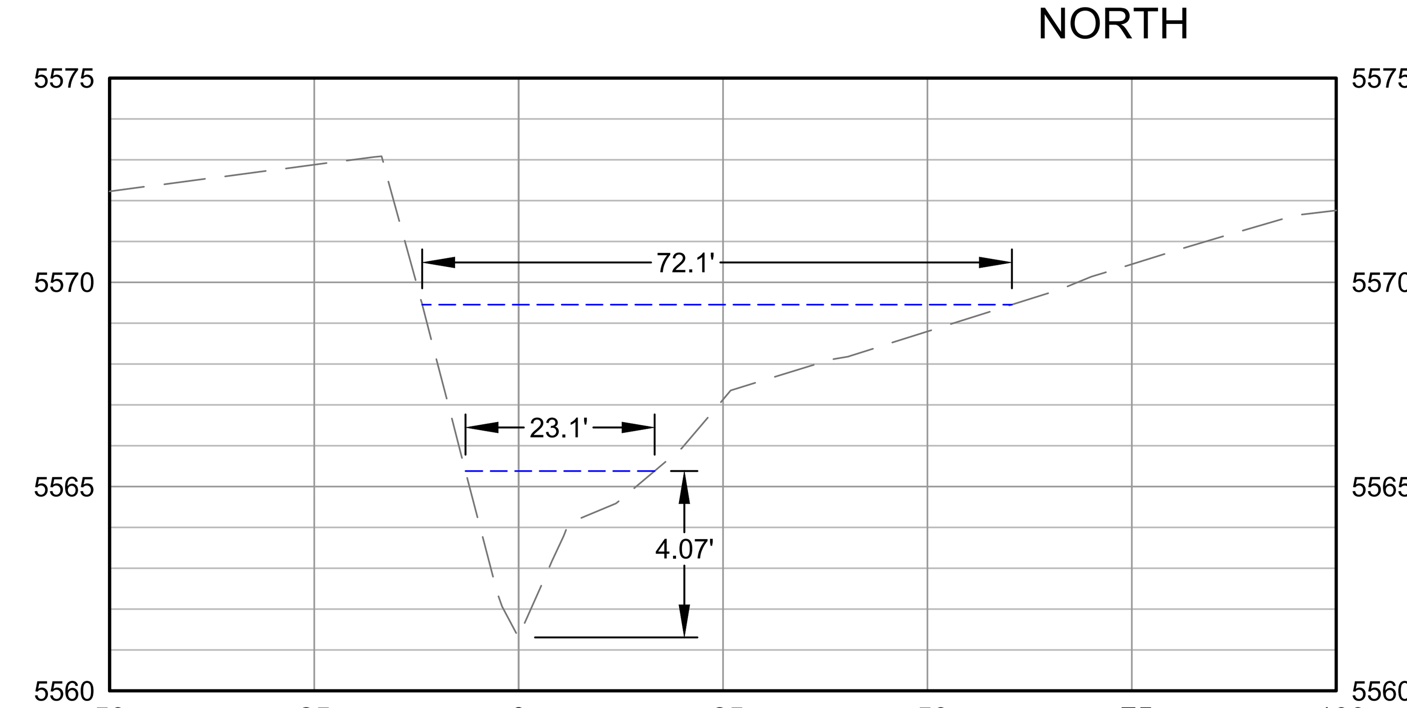
WWE JOB NUMBER:
221-076.000

FIGURE 4

PLAN

40 0 40 80 FT

NORTH



STA: 44+00

SECTION

20 0 20 40 FT
HORIZONTAL

4 0 4 8 FT
VERTICAL

Reach #	Station	Bankfull Depth (ft)	Bankfull Width (ft)	Bankfull Width @ 2X Bankfull Depth (ft)	Entrenchment Ratio	Average Entrenchment Ratio for Reach	USAP Score
5	44+00	4.07	23.1	72.1	3.12	3.12	3

DRAFT
WORK IN PROGRESS

WWE
WRIGHT WATER ENGINEERS, INC.
818 COLORADO AVE. P.O. BOX 219
GLENWOOD SPRINGS, CO 81602
(970)945-7755 FAX(970)945-9210

ENTRENCHMENT RATIO REACH 5

MURPHY CREEK URBAN STREAM ASSESSMENT PROCEDURE
AURORA, COLORADO

NOTES:

1. BANKFULL INUNDATION BOUNDARY CREATED BY HEC-RAS 2D MODEL.
2. BANKFULL FLOW ESTIMATED AS 70% OF 2-YEAR DISCHARGE BASED ON MHFD'S USDCM. THIS ESTIMATE WAS VERIFIED IN THE FIELD BY APPROXIMATING THE BANKFULL CHANNEL WIDTH AND DEPTH.
3. TOPOGRAPHIC SURVEY PROVIDED BY ENGINEERING SERVICE COMPANY.

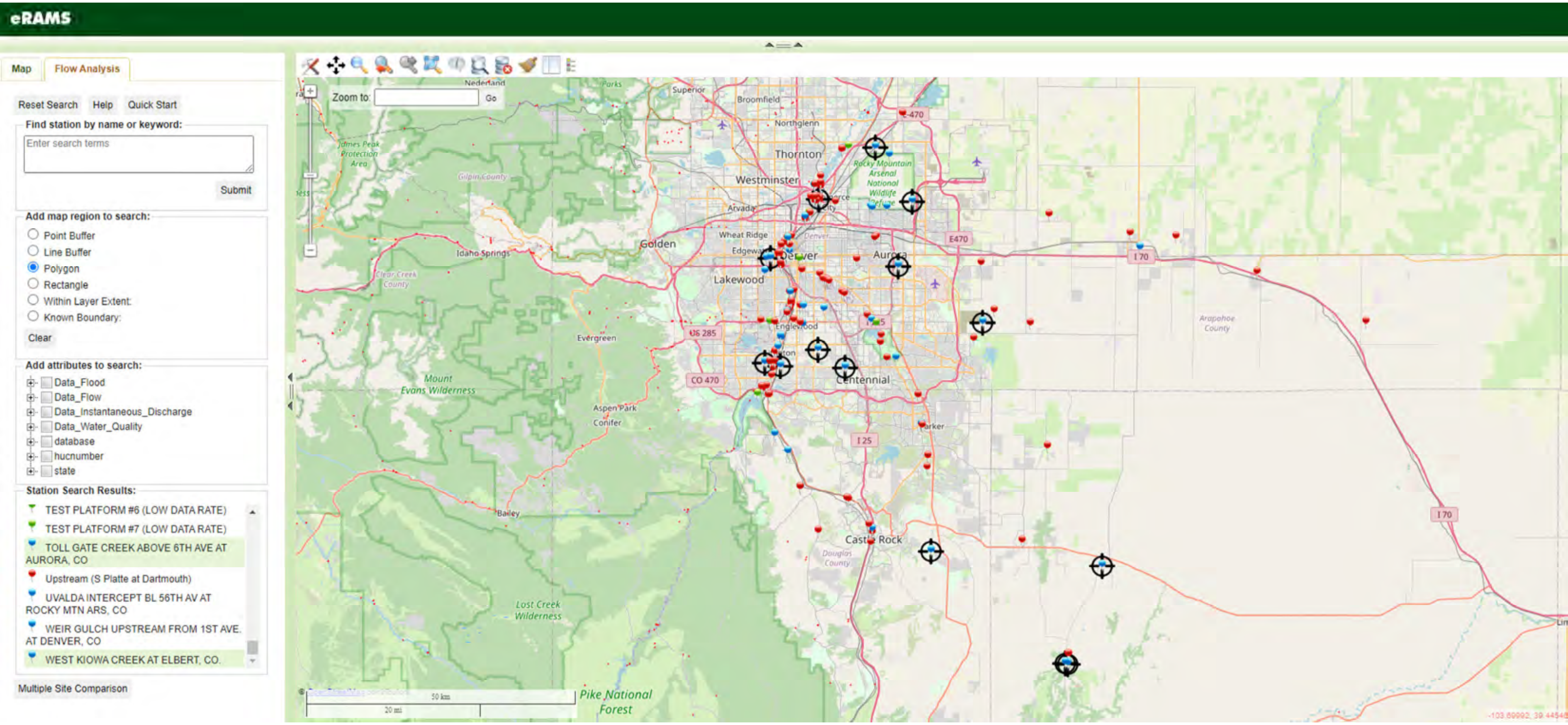
WWE JOB NUMBER:
221-076.000

FIGURE 5

Plot Date/Time: 07/15/2024, 04:41:21 PM; G:\WWE\221-076\000\CAD\01_DWGS\TSXX - TYPICAL SECTIONS.DWG-REACH 5

Appendix 7: CSR Documentation

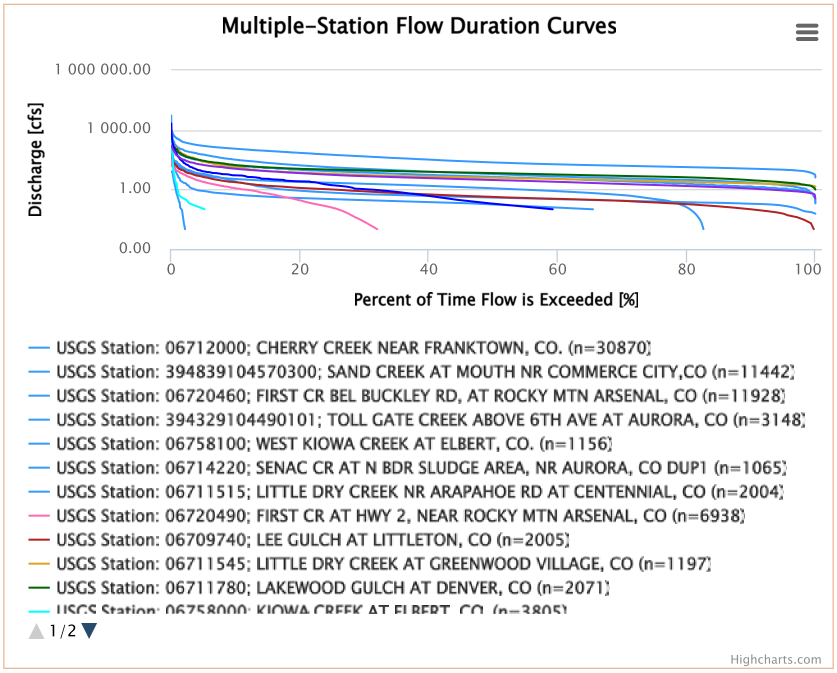
Murphy Creek USAP:
Flow Duration Curve
Selected Gage Locations (eRAMS)



Murphy Creek USAP: Flow Duration Curve eRAMS Results

Flow Duration Curve Results:

A flow duration curve (FDC) is the ranked graphing of river flows on a scale of percent exceedance. For example a flow value associated with the flow interval of 15% means that particular flow value is met o exceeded only 15% of the time. This graph is meant to give a quick overview of the flow ranges, variability, and probability of flows of a river segment during the different flow periods of a river; which are High from 0 to 10 percent flow interval, Moist Conditions 10-40, Mid-Range Flows 40-60, Dry Conditions 60-90, and Low Flows 90-100 (Cleland 2003).



Analysis Summary:

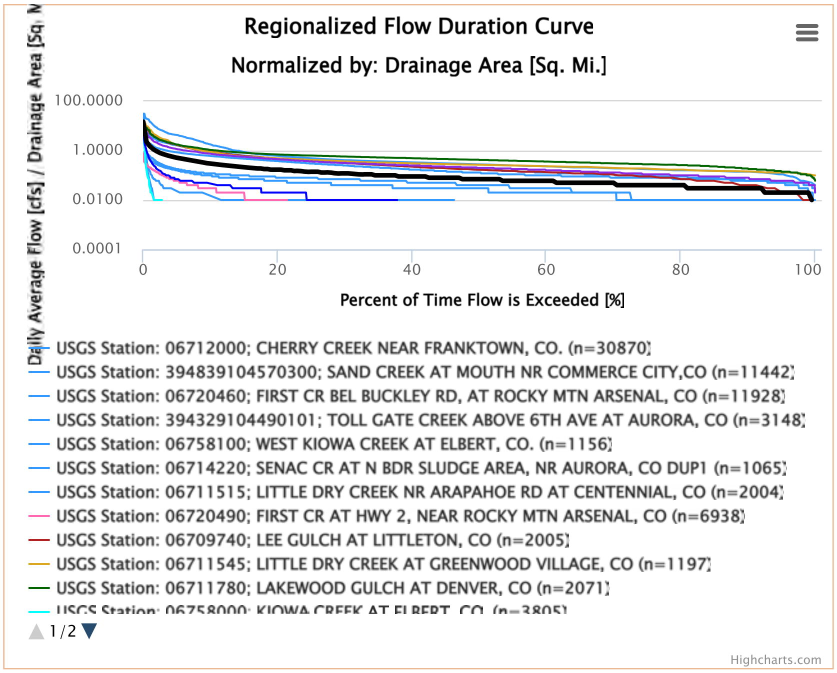
	USGS 06709910;	USGS 06758200;	USGS 06758000;	USGS 06711780;	USGS 06711545;	USGS 06709740;	USGS 06720490;	USGS 06711515;	USGS 06714220;	USGS 06758100;	USGS 394329104490101;	US 0672
General												
- Total Observations:	2564	3652	3805	2071	1197	2005	6938	2004	1065	1156	3148	11928
- Start Date:	2013-05-23	1955-10-01	1955-05-01	2013-04-01	1994-06-22	2013-06-06	1991-10-01	2013-06-07	1989-08-01	1962-08-01	2012-03-01	1991-01
- End Date:	2024-05-28	1965-09-29	1965-09-29	2024-05-28	1997-09-30	2024-05-28	2010-09-29	2024-05-28	1993-09-30	1965-09-29	2024-05-28	2024-28
- Units:	cfs	cfs	cfs	cfs	cfs	cfs	cfs	cfs	cfs	cfs	cfs	cfs

FDC Exceedance Summary

Exceedance Percentile	USGS; 06709910	USGS; 06758200	USGS; 06758000	USGS; 06711780	USGS; 06711545	USGS; 06709740	USGS 067204
%	Flow (cfs)	Flow (cfs)	Flow (cfs)	Flow (cfs)	Flow (cfs)	Flow (cfs)	Flow (c
99	0.675	0.002	0.001	1.604	1.606	0.023	0.0
95	0.893	0.012	0.005	2.266	1.839	0.061	0.0
90	1.116	0.025	0.011	2.911	2.024	0.099	0.001
75	1.67	0.061	0.026	4.424	2.671	0.223	0.003
50	2.99	0.194	0.053	6.673	3.885	0.423	0.007
25	5.41	1.594	0.079	9.931	6.121	1.0	0.123
10	11.032	5.135	0.095	16.795	12.887	2.315	1.151
5	17.14	8.168	0.109	27.835	25.037	4.178	2.404
1	49.68	48.48	0.995	87.303	106.03	12.388	8.614

Regional Flow Duration Curve:

A regional flow duration curve (FDC) is an averaging of multiple FDCs from a number of gauges in a particular geographic region which exhibits similar traits (climate, geology, etc.). There are a number of wa regionalize a flow duration curve given gauge data (statistical regression, parametric fitting, or graphical methods (Castellarin et al., 2004)). The method used here is a graphical method similar to that used b Smakhtin et al. (2000) in which each individual gauge's flow duration curve is normalized based on a metric like drainage area, long-term averge flow, or another flow metric like Q2 or bankfull discharge. The normalized flow duration curves are then averaged together (using their period length as a weighting factor as described by Niadas (2005)) to determine a regionalized FDC. Then for an ungaged basin in the geographic region, if the normalizing metric is estimated it can be combined with the regional FDC for an estimate of the FDC at the unguaged site.



Re-Run Regional Flow Duration Curve

If after running the regional flow duration curve, you notice one or more stations do not seem to fit the trends of the other normalized flow duration curves, you can re-run the analysis. Select the stations belo wish to keep and click the re-run button to re-evaulate the regional flow duration curve using only the selected stations.

Stations To Include in Regional Flow Duration Curve Calculation

- [x] USGS Station: 06712000; CHERRY CREEK NEAR FRANKTOWN, CO. (n=30870)
- [x] USGS Station: 394839104570300; SAND CREEK AT MOUTH NR COMMERCE CITY,CO (n=11442)
- [x] USGS Station: 06720460; FIRST CR BEL BUCKLEY RD, AT ROCKY MTN ARSENAL, CO (n=11928)
- [x] USGS Station: 394329104490101; TOLL GATE CREEK ABOVE 6TH AVE AT AURORA, CO (n=3148)
- [x] USGS Station: 06758100; WEST KIOWA CREEK AT ELBERT, CO. (n=1156)
- [x] USGS Station: 06714220; SENAC CR AT N BDR SLUDGE AREA, NR AURORA, CO DUP1 (n=1065)
- [x] USGS Station: 06711515; LITTLE DRY CREEK NR ARAPAHOE RD AT CENTENNIAL, CO (n=2004)
- [x] USGS Station: 06720490; FIRST CR AT HWY 2, NEAR ROCKY MTN ARSENAL, CO (n=6938)
- [x] USGS Station: 06709740; LEE GULCH AT LITTLETON, CO (n=2005)
- [x] USGS Station: 06711545; LITTLE DRY CREEK AT GREENWOOD VILLAGE, CO (n=1197)
- [x] USGS Station: 06711780; LAKEWOOD GULCH AT DENVER, CO (n=2071)
- [x] USGS Station: 06758000; KIOWA CREEK AT ELBERT, CO. (n=3805)
- [x] USGS Station: 06758200; KIOWA CREEK AT KIOWA, CO. (n=3652)
- [x] USGS Station: 06709910; DUTCH CR AT PLATTE CANYON DRIVE NEAR LITTLETON, CO (n=2564)

Re-Run Regional Flow Duration Curve

Normalized FDC Exceedance Summary

Exceedance Percentile	Regional FDC	USGS; 06709910	USGS; 06758200	USGS; 06758000	USGS; 06711780	USGS; 06711545	USGS; 0670974(
%	cfs/Sq. Mi.	cfs/Sq. Mi.	cfs/Sq. Mi.	cfs/Sq. Mi.	cfs/Sq. Mi.	cfs/Sq. Mi.	cfs/Sq. Mi.
99	0.015	0.046	0.0	0.0	0.102	0.112	0.009
95	0.022	0.061	0.0	0.0	0.144	0.128	0.024
90	0.027	0.076	0.0	0.0	0.185	0.141	0.039
75	0.04	0.114	0.001	0.001	0.282	0.186	0.089
50	0.07	0.203	0.002	0.002	0.425	0.27	0.169
25	0.14	0.368	0.014	0.003	0.633	0.425	0.4
10	0.302	0.75	0.044	0.003	1.07	0.895	0.926
5	0.52	1.166	0.071	0.004	1.773	1.739	1.671

Exceedance Percentile	Regional FDC	USGS; 06709910	USGS; 06758200	USGS; 06758000	USGS; 06711780	USGS; 06711545	USGS; 0670974(
%	cfs/Sq. Mi.	cfs/Sq. Mi.	cfs/Sq. Mi.	cfs/Sq. Mi.	cfs/Sq. Mi.	cfs/Sq. Mi.	cfs/Sq. Mi.
1	1.51	3.38	0.42	0.035	5.561	7.363	4.955
Drainage Area [Sq. Mi.]	--	14.7	115.4	28.6	15.7	14.4	2.5

Comments:

Add comments before printing report...

References:

Castellarin, A., G. Galeati, L. Brandimarte, A. Montanari, and A. Brath. 2004. Regional Flow-Duration Curves: Reliability for Ungauged Basins. *Advances in Water Resources*. 27:953-965.

Cleland, B. R. November 2003. TMDL Development from the 'Bottom Up' Part III: Duration Curves and Wet-Weather Assessments. National TMDL Science and Policy 2003.

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Hirsch, Robert M., Dennis R. Helsel, Timothy A. Cohn, and Edward J. Gilroy. 1993. "Chapter 17: Statistical Analysis of Hydrologic Data." *The McGraw Hill Handbook of Hydrology.* D. R. Maidment, ed., McGra
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Niadas, I.A. 2005. Regional Flow Duration Curve Estimation in Small Ungauged Catchments using Instantaneous Flow Measurements and a Censored Data Approach. *Journal of Hydrology.* 314:48-66.

Smakhtin, V.U. 2000. Low Flow Hydrology: A Review. *Journal of Hydrology*. 240:147-186.

Disclaimer:

GROUND ENGINEERING

Client: Drake Ludwig
Wright Water Engineers
818 East Colorado Avenue
Denver, CO 80210

Wright Water Engineers

Report Date:	Jun 20, 2024	Work Order No.:	24-1210.SoilSampling.0001; ver: 1
Work Order Date:	Jun 14, 2024	Reviewed by:	Evan Kuhn

Soil/Aggregate Laboratory Summary

General Location:	Delivered samples 1-5	Logged-in by:	Evan Kuhn

Client: Drake Ludwig
Wright Water Engineers
818 East Colorado Avenue
Denver, CO 80210

GROUND ENGINEERING

Wright Water Engineers

Report Date:	Jun 20, 2024	Work Order No.:	24-1210.SoilSampling.0001; ver: 1
Work Order Date:	Jun 14, 2024	Reviewed by:	Evan Kuhn

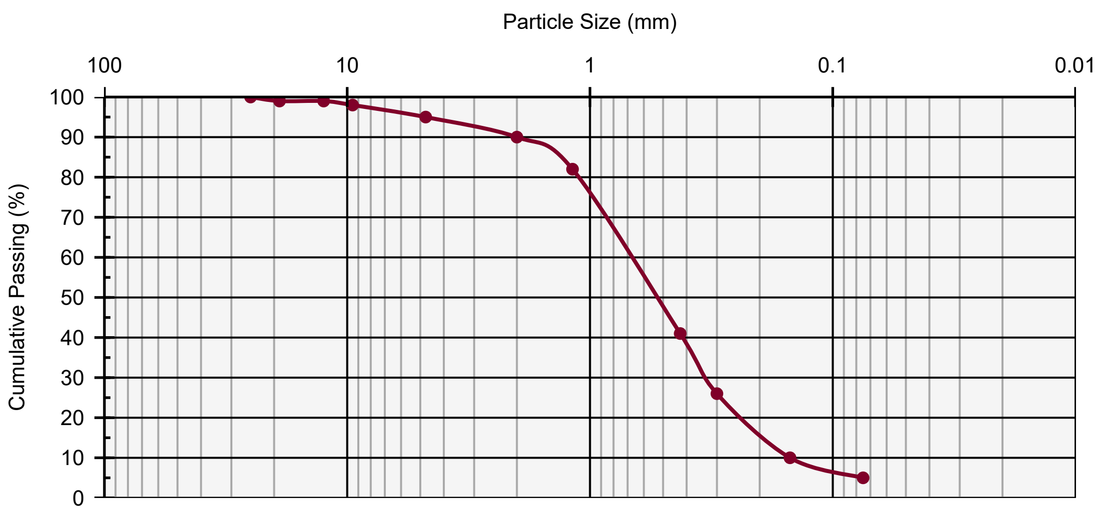
Soil/Aggregate Laboratory Summary

Sample No.:	1
Dropped Off By:	Client *Sampling may not be in accordance with reported method.
Sampling Method:	ASTM D75 / AASHTO T2 / CDOT CP30
Sample Location:	Sample 1
Lab ID:	Soil18995

Atterberg Limits (ASTM D4318) and Classification (ASTM D2487 & AASHTO M145)

Method	Liquid Limit		Plastic Limit		Plasticity Index		Classification	
	Value	Spec.	Value	Spec.	Value	Spec.	USCS	AASHTO
Single Point	-	-	NP	-	NP	-	SP-SM	A-1-b (0)

Soil Gradation (ASTM D6913)



Coarse Gradation				Fine Gradation			
Sieve Size	Particle Size (mm)	Cumulative Passing (%)	Specified (%)	Sieve Size	Particle Size (mm)	Cumulative Passing (%)	Specified (%)
6 in	150	-	-	No. 4	4.75	95	-
5 in	125	-	-	No. 8	2.36	-	-
4 in	100	-	-	No. 10	2.00	90	-
3 in	75	-	-	No. 16	1.18	82	-
2.5 in	63	-	-	No. 20	0.85	-	-
2 in	50	-	-	No. 30	0.60	-	-
1.5 in	37.5	-	-	No. 40	0.425	41	-
1 in	25.0	100	-	No. 50	0.300	26	-
3/4 in	19.0	99	-	No. 60	0.250	-	-
1/2 in	12.5	99	-	No. 100	0.150	10	-
3/8 in	9.5	98	-	No. 140	0.090	-	-
No. 4	4.75	95	-	No. 200	0.075	5	-

Client: Drake Ludwig
Wright Water Engineers
818 East Colorado Avenue
Denver, CO 80210

Wright Water Engineers

Report Date:	Jun 20, 2024	Work Order No.:	24-1210.SoilSampling.0001; ver: 1
Work Order Date:	Jun 14, 2024	Reviewed by:	Evan Kuhn

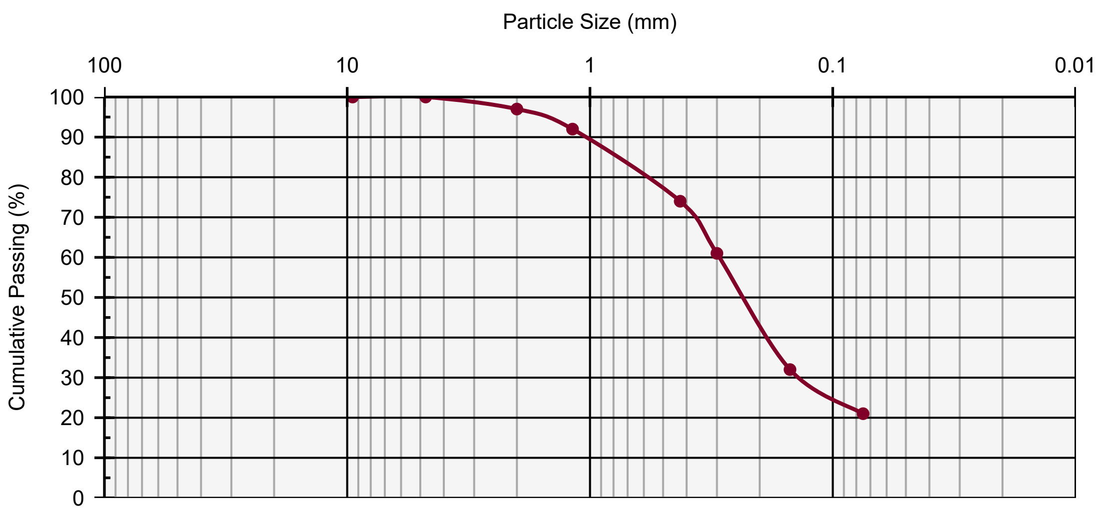
Soil/Aggregate Laboratory Summary

Sample No.: 2
Dropped Off By: Client *Sampling may not be in accordance with reported method.
Sampling Method: ASTM D75 / AASHTO T2 / CDOT CP30
Sample Location: Sample 2
Lab ID: Soil18996

Atterberg Limits (ASTM D4318) and Classification (ASTM D2487 & AASHTO M145)

Method	Liquid Limit		Plastic Limit		Plasticity Index		Classification	
	Value	Spec.	Value	Spec.	Value	Spec.	USCS	AASHTO
Single Point	31	-	23	-	8	-	SC	A-2-4 (0)

Soil Gradation (ASTM D6913)



Coarse Gradation				Fine Gradation			
Sieve Size	Particle Size (mm)	Cumulative Passing (%)	Specified (%)	Sieve Size	Particle Size (mm)	Cumulative Passing (%)	Specified (%)
6 in	150	-	-	No. 4	4.75	100	-
5 in	125	-	-	No. 8	2.36	-	-
4 in	100	-	-	No. 10	2.00	97	-
3 in	75	-	-	No. 16	1.18	92	-
2.5 in	63	-	-	No. 20	0.85	-	-
2 in	50	-	-	No. 30	0.60	-	-
1.5 in	37.5	-	-	No. 40	0.425	74	-
1 in	25.0	-	-	No. 50	0.300	61	-
3/4 in	19.0	-	-	No. 60	0.250	-	-
1/2 in	12.5	-	-	No. 100	0.150	32	-
3/8 in	9.5	100	-	No. 140	0.090	-	-
No. 4	4.75	100	-	No. 200	0.075	21	-

Wright Water Engineers

Report Date:	Jun 20, 2024	*Work Order No.:*	24-1210.SoilSampling.0001; ver: 1
Work Order Date:	Jun 14, 2024	*Reviewed by:*	Evan Kuhn

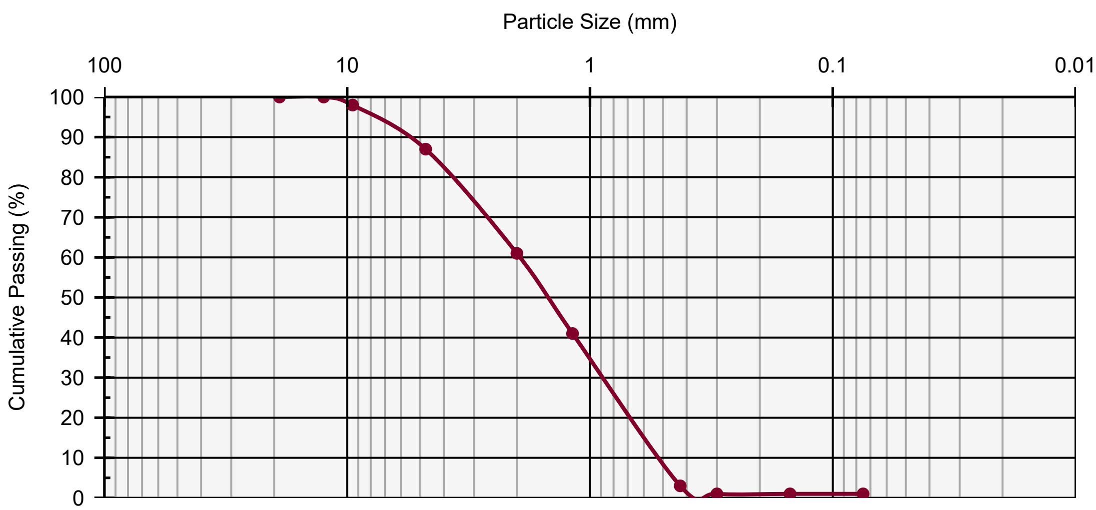
Soil/Aggregate Laboratory Summary

Sample No.: 3
Dropped Off By: Client *Sampling may not be in accordance with reported method.
Sampling Method: ASTM D75 / AASHTO T2 / CDOT CP30
Sample Location: Sample 3
Lab ID: Soil18997

Atterberg Limits (ASTM D4318) and Classification (ASTM D2487 & AASHTO M145)

Method	Liquid Limit		Plastic Limit		Plasticity Index		Classification	
	Value	Spec.	Value	Spec.	Value	Spec.	USCS	AASHTO
Single Point	-	-	NP	-	NP	-	SP	A-1-b (0)

Soil Gradation (ASTM D6913)



Coarse Gradation				Fine Gradation			
Sieve Size	Particle Size (mm)	Cumulative Passing (%)	Specified (%)	Sieve Size	Particle Size (mm)	Cumulative Passing (%)	Specified (%)
6 in	150	-	-	No. 4	4.75	87	-
5 in	125	-	-	No. 8	2.36	-	-
4 in	100	-	-	No. 10	2.00	61	-
3 in	75	-	-	No. 16	1.18	41	-
2.5 in	63	-	-	No. 20	0.85	-	-
2 in	50	-	-	No. 30	0.60	-	-
1.5 in	37.5	-	-	No. 40	0.425	3	-
1 in	25.0	-	-	No. 50	0.300	1	-
3/4 in	19.0	100	-	No. 60	0.250	-	-
1/2 in	12.5	100	-	No. 100	0.150	1	-
3/8 in	9.5	98	-	No. 140	0.090	-	-
No. 4	4.75	87	-	No. 200	0.075	1	-

Client: Drake Ludwig
Wright Water Engineers
818 East Colorado Avenue
Denver, CO 80210

Wright Water Engineers

Report Date:	Jun 20, 2024	Work Order No.:	24-1210.SoilSampling.0001; ver: 1
Work Order Date:	Jun 14, 2024	Reviewed by:	Evan Kuhn

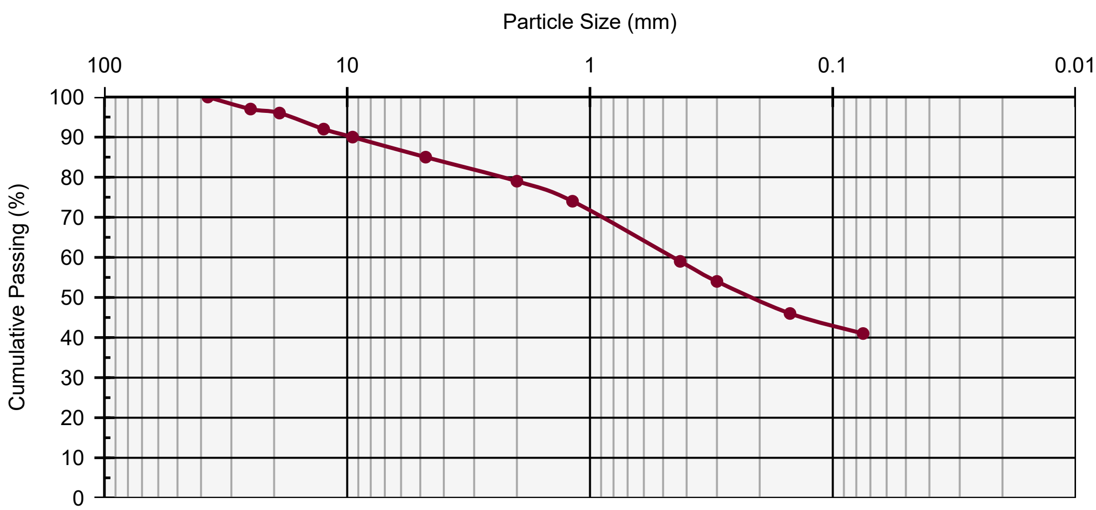
Soil/Aggregate Laboratory Summary

Sample No.:	4
Dropped Off By:	Client *Sampling may not be in accordance with reported method.
Sampling Method:	ASTM D75 / AASHTO T2 / CDOT CP30
Sample Location:	Sample 4
Lab ID:	Soil18998

Atterberg Limits (ASTM D4318) and Classification (ASTM D2487 & AASHTO M145)

Method	Liquid Limit		Plastic Limit		Plasticity Index		Classification	
	Value	Spec.	Value	Spec.	Value	Spec.	USCS	AASHTO
Single Point	31	-	22	-	9	-	(SC)g	A-4 (1)

Soil Gradation (ASTM D6913)



Coarse Gradation				Fine Gradation			
Sieve Size	Particle Size (mm)	Cumulative Passing (%)	Specified (%)	Sieve Size	Particle Size (mm)	Cumulative Passing (%)	Specified (%)
6 in	150	-	-	No. 4	4.75	85	-
5 in	125	-	-	No. 8	2.36	-	-
4 in	100	-	-	No. 10	2.00	79	-
3 in	75	-	-	No. 16	1.18	74	-
2.5 in	63	-	-	No. 20	0.85	-	-
2 in	50	-	-	No. 30	0.60	-	-
1.5 in	37.5	100	-	No. 40	0.425	59	-
1 in	25.0	97	-	No. 50	0.300	54	-
3/4 in	19.0	96	-	No. 60	0.250	-	-
1/2 in	12.5	92	-	No. 100	0.150	46	-
3/8 in	9.5	90	-	No. 140	0.090	-	-
No. 4	4.75	85	-	No. 200	0.075	41	-

Client: Drake Ludwig
Wright Water Engineers
818 East Colorado Avenue
Denver, CO 80210

Wright Water Engineers

Report Date:	Jun 20, 2024	Work Order No.:	24-1210.SoilSampling.0001; ver: 1
Work Order Date:	Jun 14, 2024	Reviewed by:	Evan Kuhn

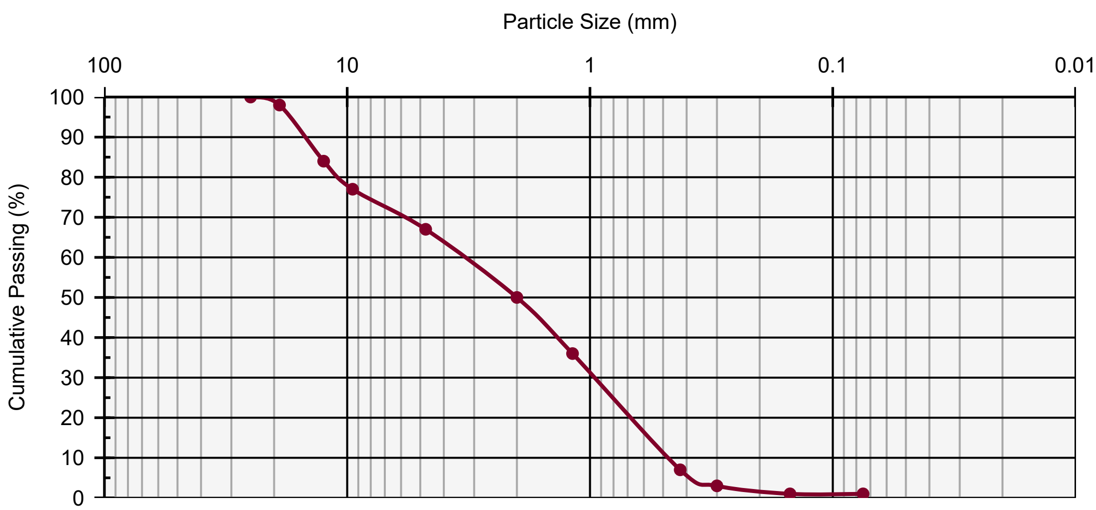
Soil/Aggregate Laboratory Summary

Sample No.:	5
Dropped Off By:	Client *Sampling may not be in accordance with reported method.
Sampling Method:	ASTM D75 / AASHTO T2 / CDOT CP30
Sample Location:	Sample 5
Lab ID:	Soil18999

Atterberg Limits (ASTM D4318) and Classification (ASTM D2487 & AASHTO M145)

Method	Liquid Limit		Plastic Limit		Plasticity Index		Classification	
	Value	Spec.	Value	Spec.	Value	Spec.	USCS	AASHTO
Single Point	-	-	NP	-	NP	-	(SP)g	A-1-a (0)

Soil Gradation (ASTM D6913)



Coarse Gradation				Fine Gradation			
Sieve Size	Particle Size (mm)	Cumulative Passing (%)	Specified (%)	Sieve Size	Particle Size (mm)	Cumulative Passing (%)	Specified (%)
6 in	150	-	-	No. 4	4.75	67	-
5 in	125	-	-	No. 8	2.36	-	-
4 in	100	-	-	No. 10	2.00	50	-
3 in	75	-	-	No. 16	1.18	36	-
2.5 in	63	-	-	No. 20	0.85	-	-
2 in	50	-	-	No. 30	0.60	-	-
1.5 in	37.5	-	-	No. 40	0.425	7	-
1 in	25.0	100	-	No. 50	0.300	3	-
3/4 in	19.0	98	-	No. 60	0.250	-	-
1/2 in	12.5	84	-	No. 100	0.150	1	-
3/8 in	9.5	77	-	No. 140	0.090	-	-
No. 4	4.75	67	-	No. 200	0.075	1	-

Murphy Creek USAP:
Reach 1 Effectiveness (tons/day)

Supply Reach:

Inputs For Supply Reach		
Main Channel		
Bottom Width	60	ft
Bank Height	4.5	ft
Bank Angle	3.5	H:V
Slope	0.0065	ft/ft
Right Bank (n)	0.04	
Left Bank (n)	0.04	
Grain Size		
D16	0.2	mm
D50	0.52	mm
D84	0.95	mm
Floodplain		
Floodplain Angle	70	H:V
Floodplain (n)	0.035	

Tab Guidance

** Required Inputs*

(-) Auto-updated values

Supply Reach Results											
Hydrology		Hydraulics							Concentration (ppm)	Sediment Yield (tons/day)	Effectiveness (tons/day)
Discharge (cfs)	Probability	Depth (ft)	Over Bank (T/F)	R (ft)	Area (ft2)	Velocity (ft/s)	n Bed	Regime			
0.1	0.005000	0.07	FALSE	0.07	4.24	0.03	0.023	Upper	0.0000	0.00	0.00
0.2	0.005000	0.07	FALSE	0.07	4.24	0.04	0.023	Upper	0.0000	0.00	0.00
0.2	0.020000	0.07	FALSE	0.07	4.24	0.05	0.023	Upper	0.0000	0.00	0.00
0.2	0.020000	0.07	FALSE	0.07	4.24	0.05	0.023	Upper	0.0000	0.00	0.00
0.3	0.050000	0.07	FALSE	0.07	4.24	0.06	0.023	Upper	0.0000	0.00	0.00
0.3	0.050000	0.07	FALSE	0.07	4.24	0.07	0.023	Upper	0.0000	0.00	0.00
0.4	0.050000	0.07	FALSE	0.07	4.24	0.08	0.023	Upper	0.0000	0.00	0.00
0.4	0.050000	0.07	FALSE	0.07	4.24	0.10	0.023	Upper	0.0000	0.00	0.00
0.5	0.050000	0.07	FALSE	0.07	4.24	0.11	0.023	Upper	0.0000	0.00	0.00
0.5	0.050000	0.07	FALSE	0.07	4.24	0.12	0.023	Upper	0.0000	0.00	0.00
0.6	0.050000	0.07	FALSE	0.07	4.24	0.13	0.023	Upper	0.0000	0.00	0.00
0.6	0.050000	0.07	FALSE	0.07	4.24	0.15	0.023	Upper	0.0000	0.00	0.00
0.7	0.050000	0.07	FALSE	0.07	4.24	0.17	0.023	Upper	0.0000	0.00	0.00
0.8	0.050000	0.07	FALSE	0.07	4.24	0.19	0.023	Upper	0.0000	0.00	0.00
0.9	0.050000	0.07	FALSE	0.07	4.24	0.21	0.023	Upper	0.0000	0.00	0.00
1.0	0.050000	0.07	FALSE	0.07	4.24	0.24	0.023	Upper	0.0000	0.00	0.00
1.2	0.050000	0.07	FALSE	0.07	4.24	0.28	0.023	Upper	0.0000	0.00	0.00
1.4	0.050000	0.07	FALSE	0.07	4.24	0.33	0.023	Upper	0.0000	0.00	0.00
1.7	0.050000	0.07	FALSE	0.07	4.24	0.40	0.023	Upper	0.0000	0.00	0.00
2.1	0.050000	0.07	FALSE	0.07	4.24	0.50	0.023	Upper	11.1487	0.06	0.00
3.0	0.050000	0.07	FALSE	0.07	4.24	0.71	0.023	Upper	101.4349	0.83	0.04
5.2	0.050000	0.07	FALSE	0.07	4.24	1.23	0.023	Upper	702.2931	9.86	0.49
7.3	0.020000	0.07	FALSE	0.07	4.24	1.72	0.023	Upper	1769.2923	34.74	0.69
15.1	0.020000	0.14	FALSE	0.14	8.51	1.78	0.024	Upper	1536.7219	62.71	1.25
22.5	0.005000	0.13	FALSE	0.14	8.51	2.65	0.024	Upper	4098.1119	249.49	1.25
										Total	**3.73**

Murphy Creek USAP:
Reach 2 Effectiveness (tons/day)

Supply Reach:

Inputs For Supply Reach		
Main Channel		
Bottom Width	8	ft
Bank Height	6	ft
Bank Angle	1.7	H:V
Slope	0.0046	ft/ft
Right Bank (n)	0.04	
Left Bank (n)	0.04	
Grain Size		
D16	0.05	mm
D50	0.24	mm
D84	0.7	mm
Floodplain		
Floodplain Angle	70	H:V
Floodplain (n)	0.035	

Tab Guidance

** Required Inputs*

(-) Auto-updated values

Supply Reach Results											
Hydrology		Hydraulics							Concentration (ppm)	Sediment Yield (tons/day)	Effectiveness (tons/day)
Discharge (cfs)	Probability	Depth (ft)	Over Bank (T/F)	R (ft)	Area (ft2)	Velocity (ft/s)	n Bed	Regime			
0.1	0.005000	0.05	FALSE	0.05	0.38	0.35	0.021	Lower	2.1211	0.00	0.00
0.2	0.005000	0.05	FALSE	0.05	0.38	0.40	0.021	Lower	11.6516	0.00	0.00
0.2	0.020000	0.05	FALSE	0.05	0.38	0.51	0.021	Lower	59.0587	0.03	0.00
0.2	0.020000	0.05	FALSE	0.05	0.38	0.58	0.021	Lower	114.2056	0.07	0.00
0.3	0.050000	0.09	FALSE	0.09	0.76	0.35	0.023	Lower	1.9424	0.00	0.00
0.3	0.050000	0.09	FALSE	0.09	0.76	0.41	0.023	Lower	11.1212	0.01	0.00
0.4	0.050000	0.09	FALSE	0.09	0.76	0.47	0.023	Lower	29.2461	0.03	0.00
0.4	0.050000	0.09	FALSE	0.09	0.76	0.53	0.023	Lower	57.8834	0.06	0.00
0.5	0.050000	0.09	FALSE	0.09	0.76	0.59	0.023	Lower	98.7572	0.12	0.01
0.5	0.050000	0.09	FALSE	0.09	0.76	0.66	0.023	Lower	154.3715	0.21	0.01
0.6	0.050000	0.09	FALSE	0.09	0.76	0.73	0.023	Lower	220.9571	0.33	0.02
0.6	0.050000	0.09	FALSE	0.09	0.76	0.82	0.023	Lower	317.5314	0.54	0.03
0.7	0.050000	0.09	FALSE	0.09	0.76	0.92	0.023	Lower	460.8008	0.88	0.04
0.8	0.050000	0.09	FALSE	0.09	0.76	1.03	0.023	Lower	650.9955	1.39	0.07
0.9	0.050000	0.14	FALSE	0.14	1.16	0.78	0.024	Lower	235.0218	0.57	0.03
1.0	0.050000	0.14	FALSE	0.14	1.16	0.89	0.024	Lower	361.1486	1.00	0.05
1.2	0.050000	0.14	FALSE	0.14	1.16	1.03	0.024	Lower	558.0074	1.79	0.09
1.4	0.050000	0.13	FALSE	0.14	1.16	1.21	0.024	Lower	879.8194	3.33	0.17
1.7	0.050000	0.18	FALSE	0.18	1.56	1.08	0.025	Lower	582.5787	2.65	0.13
2.1	0.050000	0.18	FALSE	0.18	1.56	1.37	0.025	Lower	1109.0890	6.39	0.32
3.0	0.050000	0.27	FALSE	0.26	2.38	1.27	0.027	Lower	784.8755	6.40	0.32
5.2	0.050000	0.36	FALSE	0.34	3.24	1.61	0.028	Lower	1312.0749	18.42	0.92
7.3	0.020000	0.45	FALSE	0.42	4.12	1.76	0.029	Transitional	1531.6972	30.08	0.60
15.1	0.020000	0.72	FALSE	0.63	6.96	2.17	0.030	Transitional	2139.9912	87.33	1.75
22.5	0.005000	0.89	FALSE	0.77	8.99	2.51	0.031	Transitional	2764.2768	168.29	0.84
										Total	**5.40**

Murphy Creek USAP:
Reach 3 Effectiveness (tons/day)

Supply Reach:

Inputs For Supply Reach		
Main Channel		
Bottom Width	9	ft
Bank Height	4	ft
Bank Angle	1.7	H:V
Slope	0.0049	ft/ft
Right Bank (n)	0.04	
Left Bank (n)	0.04	
Grain Size		
D16	0.55	mm
D50	1.6	mm
D84	4.1	mm
Floodplain		
Floodplain Angle	70	H:V
Floodplain (n)	0.035	

Tab Guidance

** Required Inputs*
(-) Auto-updated values

Supply Reach Results											
Hydrology		Hydraulics							Concentration (ppm)	Sediment Yield (tons/day)	Effectiveness (tons/day)
Discharge (cfs)	Probability	Depth (ft)	Over Bank (T/F)	R (ft)	Area (ft2)	Velocity (ft/s)	n Bed	Regime			
0.1	0.005000	0.06	FALSE	0.06	0.57	0.23	0.022	Lower	0.0000	0.00	0.00
0.2	0.005000	0.06	FALSE	0.06	0.57	0.27	0.022	Lower	0.0000	0.00	0.00
0.2	0.020000	0.06	FALSE	0.06	0.57	0.34	0.022	Lower	0.0000	0.00	0.00
0.2	0.020000	0.06	FALSE	0.06	0.57	0.39	0.022	Lower	0.0000	0.00	0.00
0.3	0.050000	0.06	FALSE	0.06	0.57	0.47	0.022	Lower	0.0000	0.00	0.00
0.3	0.050000	0.06	FALSE	0.06	0.57	0.55	0.022	Lower	0.0000	0.00	0.00
0.4	0.050000	0.06	FALSE	0.06	0.57	0.63	0.022	Lower	0.0000	0.00	0.00
0.4	0.050000	0.06	FALSE	0.06	0.57	0.71	0.022	Lower	0.0000	0.00	0.00
0.5	0.050000	0.06	FALSE	0.06	0.57	0.80	0.022	Lower	0.0215	0.00	0.00
0.5	0.050000	0.06	FALSE	0.06	0.57	0.89	0.022	Lower	4.5870	0.01	0.00
0.6	0.050000	0.06	FALSE	0.06	0.57	0.98	0.022	Lower	16.6396	0.03	0.00
0.6	0.050000	0.09	FALSE	0.09	0.86	0.73	0.023	Lower	0.0000	0.00	0.00
0.7	0.050000	0.12	FALSE	0.12	1.15	0.61	0.024	Lower	0.0000	0.00	0.00
0.8	0.050000	0.12	FALSE	0.12	1.15	0.69	0.024	Lower	0.0000	0.00	0.00
0.9	0.050000	0.12	FALSE	0.12	1.15	0.78	0.024	Lower	0.0000	0.00	0.00
1.0	0.050000	0.12	FALSE	0.12	1.15	0.89	0.024	Lower	3.7179	0.01	0.00
1.2	0.050000	0.12	FALSE	0.12	1.15	1.03	0.024	Lower	20.5669	0.07	0.00
1.4	0.050000	0.12	FALSE	0.12	1.15	1.22	0.024	Lower	62.7600	0.24	0.01
1.7	0.050000	0.18	FALSE	0.18	1.75	0.96	0.026	Lower	9.1285	0.04	0.00
2.1	0.050000	0.18	FALSE	0.18	1.75	1.22	0.026	Lower	55.9661	0.32	0.02
3.0	0.050000	0.24	FALSE	0.24	2.36	1.28	0.027	Lower	65.7480	0.54	0.03
5.2	0.050000	0.29	FALSE	0.29	2.98	1.75	0.027	Lower	230.6314	3.24	0.16
7.3	0.020000	0.42	FALSE	0.40	4.26	1.71	0.029	Lower	187.8803	3.69	0.07
15.1	0.020000	0.66	FALSE	0.60	6.99	2.16	0.030	Lower	360.3698	14.71	0.29
22.5	0.005000	0.84	FALSE	0.74	9.18	2.46	0.032	Lower	489.3130	29.79	0.15
										Total	**0.74**

Murphy Creek USAP:
Reach 4 Effectiveness (tons/day)

Supply Reach:

Inputs For Supply Reach		
Main Channel		
Bottom Width	4	ft
Bank Height	5	ft
Bank Angle	1.4	H:V
Slope	0.0054	ft/ft
Right Bank (n)	0.04	
Left Bank (n)	0.04	
Grain Size		
D16	0.001	mm
D50	0.22	mm
D84	4	mm
Floodplain		
Floodplain Angle	70	H:V
Floodplain (n)	0.035	

Tab Guidance

** Required Inputs*

(-) Auto-updated values

Supply Reach Results											
Hydrology		Hydraulics							Concentration (ppm)	Sediment Yield (tons/day)	Effectiveness (tons/day)
Discharge (cfs)	Probability	Depth (ft)	Over Bank (T/F)	R (ft)	Area (ft2)	Velocity (ft/s)	n Bed	Regime			
0.1	0.005000	0.08	FALSE	0.08	0.32	0.41	0.036	Lower	76.8150	0.03	0.00
0.2	0.005000	0.08	FALSE	0.08	0.32	0.47	0.036	Lower	121.8111	0.05	0.00
0.2	0.020000	0.08	FALSE	0.08	0.32	0.60	0.036	Lower	257.1193	0.13	0.00
0.2	0.020000	0.08	FALSE	0.08	0.32	0.69	0.036	Lower	382.8231	0.23	0.00
0.3	0.050000	0.12	FALSE	0.11	0.49	0.55	0.038	Lower	178.3661	0.13	0.01
0.3	0.050000	0.12	FALSE	0.11	0.49	0.64	0.038	Lower	272.2262	0.23	0.01
0.4	0.050000	0.16	FALSE	0.15	0.66	0.54	0.040	Lower	149.9187	0.14	0.01
0.4	0.050000	0.16	FALSE	0.15	0.66	0.61	0.040	Lower	218.3209	0.24	0.01
0.5	0.050000	0.16	FALSE	0.15	0.66	0.69	0.039	Lower	305.0031	0.37	0.02
0.5	0.050000	0.15	FALSE	0.15	0.66	0.77	0.039	Lower	413.8334	0.57	0.03
0.6	0.050000	0.15	FALSE	0.15	0.66	0.85	0.039	Lower	537.0785	0.81	0.04
0.6	0.050000	0.20	FALSE	0.18	0.83	0.75	0.041	Lower	353.8343	0.60	0.03
0.7	0.050000	0.19	FALSE	0.18	0.83	0.84	0.041	Lower	484.8060	0.92	0.05
0.8	0.050000	0.24	FALSE	0.21	1.01	0.78	0.042	Lower	369.9845	0.79	0.04
0.9	0.050000	0.23	FALSE	0.21	1.01	0.89	0.042	Lower	519.4011	1.26	0.06
1.0	0.050000	0.23	FALSE	0.21	1.01	1.01	0.042	Lower	728.5973	2.02	0.10
1.2	0.050000	0.27	FALSE	0.24	1.20	0.99	0.043	Lower	654.3621	2.10	0.11
1.4	0.050000	0.32	FALSE	0.27	1.39	1.01	0.043	Lower	650.2460	2.46	0.12
1.7	0.050000	0.36	FALSE	0.30	1.58	1.07	0.044	Lower	711.9138	3.24	0.16
2.1	0.050000	0.39	FALSE	0.33	1.78	1.20	0.045	Lower	916.7879	5.28	0.26
3.0	0.050000	0.53	FALSE	0.42	2.39	1.26	0.047	Lower	934.1827	7.62	0.38
5.2	0.050000	0.75	FALSE	0.55	3.50	1.48	0.049	Lower	1206.0750	16.93	0.85
7.3	0.020000	0.95	FALSE	0.64	4.47	1.63	0.051	Transitional	1376.7740	27.04	0.54
15.1	0.020000	1.52	FALSE	0.89	7.48	2.02	0.054	Transitional	1904.6664	77.73	1.55
22.5	0.005000	2.08	FALSE	1.07	10.33	2.18	0.056	Transitional	2032.4851	123.74	0.62
										Total	**5.01**

Murphy Creek USAP:
Reach 5 Effectiveness (tons/day)

Supply Reach:

Inputs For Supply Reach		
Main Channel		
Bottom Width	4	ft
Bank Height	5	ft
Bank Angle	3	H:V
Slope	0.0066	ft/ft
Right Bank (n)	0.04	
Left Bank (n)	0.04	
Grain Size		
D16	0.6	mm
D50	2	mm
D84	12.5	mm
Floodplain		
Floodplain Angle	70	H:V
Floodplain (n)	0.035	

Tab Guidance

** Required Inputs*

(-) Auto-updated values

Supply Reach Results											
Hydrology		Hydraulics							Concentration (ppm)	Sediment Yield (tons/day)	Effectiveness (tons/day)
Discharge (cfs)	Probability	Depth (ft)	Over Bank (T/F)	R (ft)	Area (ft2)	Velocity (ft/s)	n Bed	Regime			
0.1	0.005000	0.08	FALSE	0.07	0.33	0.40	0.029	Upper	0.0000	0.00	0.00
0.2	0.005000	0.08	FALSE	0.07	0.33	0.46	0.029	Upper	0.0000	0.00	0.00
0.2	0.020000	0.08	FALSE	0.07	0.33	0.58	0.029	Upper	0.0000	0.00	0.00
0.2	0.020000	0.08	FALSE	0.07	0.33	0.67	0.029	Upper	0.0000	0.00	0.00
0.3	0.050000	0.07	FALSE	0.07	0.33	0.82	0.029	Upper	0.0468	0.00	0.00
0.3	0.050000	0.07	FALSE	0.07	0.33	0.94	0.029	Upper	8.0938	0.01	0.00
0.4	0.050000	0.07	FALSE	0.07	0.33	1.08	0.029	Upper	32.0679	0.03	0.00
0.4	0.050000	0.07	FALSE	0.07	0.33	1.22	0.029	Upper	75.4321	0.08	0.00
0.5	0.050000	0.06	FALSE	0.07	0.33	1.37	0.029	Upper	142.3380	0.17	0.01
0.5	0.050000	0.11	FALSE	0.11	0.51	1.00	0.030	Upper	13.6484	0.02	0.00
0.6	0.050000	0.11	FALSE	0.11	0.51	1.10	0.030	Upper	32.6084	0.05	0.00
0.6	0.050000	0.10	FALSE	0.11	0.51	1.22	0.030	Upper	66.6989	0.11	0.01
0.7	0.050000	0.10	FALSE	0.11	0.51	1.38	0.029	Upper	126.1185	0.24	0.01
0.8	0.050000	0.15	FALSE	0.14	0.70	1.13	0.030	Upper	36.3382	0.08	0.00
0.9	0.050000	0.14	FALSE	0.14	0.70	1.29	0.030	Upper	80.1561	0.19	0.01
1.0	0.050000	0.13	FALSE	0.14	0.70	1.47	0.030	Upper	154.8953	0.43	0.02
1.2	0.050000	0.18	FALSE	0.17	0.90	1.33	0.031	Upper	86.6055	0.28	0.01
1.4	0.050000	0.17	FALSE	0.17	0.90	1.56	0.030	Upper	184.8788	0.70	0.03
1.7	0.050000	0.21	FALSE	0.20	1.10	1.53	0.031	Upper	155.6011	0.71	0.04
2.1	0.050000	0.24	FALSE	0.23	1.32	1.62	0.031	Upper	187.1526	1.08	0.05
3.0	0.050000	0.26	FALSE	0.26	1.54	1.96	0.031	Upper	366.2064	2.99	0.15
5.2	0.050000	0.34	FALSE	0.34	2.27	2.29	0.032	Upper	548.3352	7.70	0.38
7.3	0.020000	0.47	FALSE	0.41	3.08	2.36	0.033	Upper	540.5547	10.61	0.21
15.1	0.020000	0.73	FALSE	0.58	5.30	2.85	0.034	Upper	809.4808	33.04	0.66
22.5	0.005000	0.93	FALSE	0.69	7.16	3.15	0.034	Upper	977.1751	59.49	0.30
										Total	**1.91**

Murphy Creek USAP:
Upstream Reach Effectiveness (tons/day)

Supply Reach:

Inputs For Supply Reach		
Main Channel		
Bottom Width	15	ft
Bank Height	10	ft
Bank Angle	3	H:V
Slope	0.0055	ft/ft
Right Bank (n)	0.04	
Left Bank (n)	0.04	
Grain Size		
D16	0.6	mm
D50	2	mm
D84	12.5	mm
Floodplain		
Floodplain Angle	70	H:V
Floodplain (n)	0.035	

Tab Guidance

** Required Inputs*

(-) Auto-updated values

Supply Reach Results											
Hydrology		Hydraulics							Concentration (ppm)	Sediment Yield (tons/day)	Effectiveness (tons/day)
Discharge (cfs)	Probability	Depth (ft)	Over Bank (T/F)	R (ft)	Area (ft2)	Velocity (ft/s)	n Bed	Regime			
0.1	0.005000	0.08	FALSE	0.08	1.19	0.11	0.025	Lower	0.0000	0.00	0.00
0.2	0.005000	0.08	FALSE	0.08	1.19	0.13	0.025	Lower	0.0000	0.00	0.00
0.2	0.020000	0.08	FALSE	0.08	1.19	0.16	0.025	Lower	0.0000	0.00	0.00
0.2	0.020000	0.08	FALSE	0.08	1.19	0.19	0.025	Lower	0.0000	0.00	0.00
0.3	0.050000	0.08	FALSE	0.08	1.19	0.23	0.025	Lower	0.0000	0.00	0.00
0.3	0.050000	0.08	FALSE	0.08	1.19	0.26	0.025	Lower	0.0000	0.00	0.00
0.4	0.050000	0.08	FALSE	0.08	1.19	0.30	0.025	Lower	0.0000	0.00	0.00
0.4	0.050000	0.08	FALSE	0.08	1.19	0.34	0.025	Lower	0.0000	0.00	0.00
0.5	0.050000	0.08	FALSE	0.08	1.19	0.38	0.025	Lower	0.0000	0.00	0.00
0.5	0.050000	0.08	FALSE	0.08	1.19	0.43	0.025	Lower	0.0000	0.00	0.00
0.6	0.050000	0.08	FALSE	0.08	1.19	0.47	0.025	Lower	0.0000	0.00	0.00
0.6	0.050000	0.08	FALSE	0.08	1.19	0.52	0.025	Lower	0.0000	0.00	0.00
0.7	0.050000	0.08	FALSE	0.08	1.19	0.59	0.025	Lower	0.0000	0.00	0.00
0.8	0.050000	0.08	FALSE	0.08	1.19	0.66	0.025	Lower	0.0000	0.00	0.00
0.9	0.050000	0.08	FALSE	0.08	1.19	0.76	0.025	Lower	0.0000	0.00	0.00
1.0	0.050000	0.08	FALSE	0.08	1.19	0.86	0.025	Lower	0.5494	0.00	0.00
1.2	0.050000	0.08	FALSE	0.08	1.19	1.00	0.025	Lower	11.4600	0.04	0.00
1.4	0.050000	0.12	FALSE	0.11	1.80	0.78	0.027	Lower	0.0000	0.00	0.00
1.7	0.050000	0.12	FALSE	0.11	1.80	0.94	0.027	Lower	3.9953	0.02	0.00
2.1	0.050000	0.16	FALSE	0.15	2.42	0.88	0.028	Lower	0.9699	0.01	0.00
3.0	0.050000	0.15	FALSE	0.15	2.42	1.25	0.028	Lower	53.2593	0.43	0.02
5.2	0.050000	0.23	FALSE	0.22	3.68	1.41	0.029	Lower	88.9354	1.25	0.06
7.3	0.020000	0.31	FALSE	0.29	4.98	1.46	0.030	Lower	93.9320	1.84	0.04
15.1	0.020000	0.45	FALSE	0.43	7.69	1.97	0.032	Lower	263.4297	10.75	0.22
22.5	0.005000	0.61	FALSE	0.56	10.55	2.14	0.033	Lower	315.1565	19.19	0.10
										Total	**0.44**

Appendix 8: Rapid Geomorphic Assessment

DRAFT

CHANNEL-STABILITY RANKING SCHEME

River Murphy Creek Site Identifier Reach 1

Date 6/3/2024 Time Mid-day Crew DTL/NBS Samples Taken ____

Pictures (circle) U/S D/S X-section Slope ____ Pattern: Meandering / Straight / Braided (circled)

							Score
1. Primary bed material							
	Bedrock	Boulder/Cobble		Gravel	Sand	Silt Clay	
	0	1		2	3	4	3
2. Bed/bank protection							
	Yes	No	(with)	1 bank protected	2 banks		
	0	1		2	3		1
3. Degree of incision (Relative elevation of "normal" low water; floodplain/terrace @ 100%)							
	0-10%	11-25%	26-50%	51-75%	76-100%		
	4	3	2	1	0		3
4. Degree of constriction (Relative decrease in top-bank width from up to downstream)							
	0-10%	11-25%	26-50%	51-75%	76-100%		
	0	1	2	3	4		0
5. Stream bank erosion (Each bank)							
	None	Fluvial	Mass wasting (failures)				
Left	0	1	2				0
Right	0	1	2				0
6. Stream bank instability (Percent of each bank failing)							
	0-10%	11-25%	26-50%	51-75%	76-100%		
Left	0	0.5	1	1.5	2		0
Right	0	0.5	1	1.5	2		0
7. Established riparian woody-vegetative cover (Each bank)							
	0-10%	11-25%	26-50%	51-75%	76-100%		
Left	2	1.5	1	0.5	0		0
Right	2	1.5	1	0.5	0		0
8. Occurrence of bank accretion (Percent of each bank with fluvial deposition)							
	0-10%	11-25%	26-50%	51-75%	76-100%		
Left	2	1.5	1	0.5	0		0
Right	2	1.5	1	0.5	0		0
9. Stage of channel evolution							
	I	II	III	IV	V	VI	
	0	1	2	4	3	1.5	1.5

Figure 11 – Channel stability ranking scheme used to conduct rapid geomorphic assessments (RGAs). The channel stability index is the sum of the values obtained for the nine criterion.

Total: 8.5

DRAFT

CHANNEL-STABILITY RANKING SCHEME

River Murphy Creek Site Identifier Reach 2

Date 6/3/2024 Time Mid-day Crew DTL/NBS Samples Taken ______

Pictures (circle) U/S D/S X-section Slope ______ Pattern: (Meandering — circled) Straight Braided

Criterion							Score
1. Primary bed material							
	Bedrock	Boulder/Cobble		Gravel	Sand	Silt Clay	
	0	1		2	3	4	3
2. Bed/bank protection							
	Yes	No	(with)	1 bank protected	2 banks		
	0	1		2	3		1
3. Degree of incision (Relative elevation of "normal" low water; floodplain/terrace @ 100%)							
	0-10%	11-25%	26-50%	51-75%	76-100%		
	4	3	2	1	0		3
4. Degree of constriction (Relative decrease in top-bank width from up to downstream)							
	0-10%	11-25%	26-50%	51-75%	76-100%		
	0	1	2	3	4		0
5. Stream bank erosion (Each bank)							
	None	Fluvial	Mass wasting (failures)				
Left	0	1	2				0
Right	0	1	2				0
6. Stream bank instability (Percent of each bank failing)							
	0-10%	11-25%	26-50%	51-75%	76-100%		
Left	0	0.5	1	1.5	2		0
Right	0	0.5	1	1.5	2		0.5
7. Established riparian woody-vegetative cover (Each bank)							
	0-10%	11-25%	26-50%	51-75%	76-100%		
Left	2	1.5	1	0.5	0		0
Right	2	1.5	1	0.5	0		0
8. Occurrence of bank accretion (Percent of each bank with fluvial deposition)							
	0-10%	11-25%	26-50%	51-75%	76-100%		
Left	2	1.5	1	0.5	0		0
Right	2	1.5	1	0.5	0		0
9. Stage of channel evolution							
	I	II	III	IV	V	VI	
	0	1	2	4	3	1.5	3

Figure 11 – Channel stability ranking scheme used to conduct rapid geomorphic assessments (RGAs). The channel stability index is the sum of the values obtained for the nine criterion.

Total: 10.5

DRAFT

CHANNEL-STABILITY RANKING SCHEME

River Murphy Creek Site Identifier Reach 3

Date 6/3/2024 Time Mid-day Crew DTL/NBS Samples Taken ____

Pictures (circle) U/S D/S X-section Slope ____ Pattern: Meandering / **(Straight)** / Braided

1. Primary bed material

	Bedrock	Boulder/Cobble	Gravel	Sand	Silt Clay	
	0	1	2	3	4	3

2. Bed/bank protection

	Yes	No	(with)	1 bank protected	2 banks	
	0	1		2	3	1

3. Degree of incision (Relative elevation of "normal" low water; floodplain/terrace @ 100%)

	0-10%	11-25%	26-50%	51-75%	76-100%	
	4	3	2	1	0	4

4. Degree of constriction (Relative decrease in top-bank width from up to downstream)

	0-10%	11-25%	26-50%	51-75%	76-100%	
	0	1	2	3	4	0

5. Stream bank erosion (Each bank)

	None	Fluvial	Mass wasting (failures)	
Left	0	1	2	0
Right	0	1	2	0

6. Stream bank instability (Percent of each bank failing)

	0-10%	11-25%	26-50%	51-75%	76-100%	
Left	0	0.5	1	1.5	2	1
Right	0	0.5	1	1.5	2	1

7. Established riparian woody-vegetative cover (Each bank)

	0-10%	11-25%	26-50%	51-75%	76-100%	
Left	2	1.5	1	0.5	0	0
Right	2	1.5	1	0.5	0	0

8. Occurrence of bank accretion (Percent of each bank with fluvial deposition)

	0-10%	11-25%	26-50%	51-75%	76-100%	
Left	2	1.5	1	0.5	0	0
Right	2	1.5	1	0.5	0	0

9. Stage of channel evolution

	I	II	III	IV	V	VI	
	0	1	2	4	3	1.5	3

Figure 11 – Channel stability ranking scheme used to conduct rapid geomorphic assessments (RGAs). The channel stability index is the sum of the values obtained for the nine criterion.

Total: 13

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CHANNEL-STABILITY RANKING SCHEME

River Murphy Creek Site Identifier Reach 4

Date 6/3/2024 Time Mid-day Crew DTL/NBS Samples Taken ______

Pictures (circle) U/S D/S X-section Slope ______ Pattern: Meandering / **(Straight)** / Braided

Criterion							Score
1. Primary bed material							
	Bedrock	Boulder/Cobble		Gravel	Sand	Silt Clay	
	0	1		2	3	4	3
2. Bed/bank protection							
	Yes	No	(with)	1 bank protected	2 banks		
	0	1		2	3		1
3. Degree of incision (Relative elevation of "normal" low water; floodplain/terrace @ 100%)							
	0-10%	11-25%	26-50%	51-75%	76-100%		
	4	3	2	1	0		3
4. Degree of constriction (Relative decrease in top-bank width from up to downstream)							
	0-10%	11-25%	26-50%	51-75%	76-100%		
	0	1	2	3	4		0
5. Stream bank erosion (Each bank)							
	None	Fluvial	Mass wasting (failures)				
Left	0	1	2				2
Right	0	1	2				2
6. Stream bank instability (Percent of each bank failing)							
	0-10%	11-25%	26-50%	51-75%	76-100%		
Left	0	0.5	1	1.5	2		1.5
Right	0	0.5	1	1.5	2		1.5
7. Established riparian woody-vegetative cover (Each bank)							
	0-10%	11-25%	26-50%	51-75%	76-100%		
Left	2	1.5	1	0.5	0		1
Right	2	1.5	1	0.5	0		1
8. Occurrence of bank accretion (Percent of each bank with fluvial deposition)							
	0-10%	11-25%	26-50%	51-75%	76-100%		
Left	2	1.5	1	0.5	0		1.5
Right	2	1.5	1	0.5	0		1.5
9. Stage of channel evolution							
	I	II	III	IV	V	VI	
	0	1	2	4	3	1.5	4

Figure 11 – Channel stability ranking scheme used to conduct rapid geomorphic assessments (RGAs). The channel stability index is the sum of the values obtained for the nine criterion.

Total: 23

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CHANNEL-STABILITY RANKING SCHEME

River Murphy Creek Site Identifier Reach 5

Date 6/3/2024 Time Mid-day Crew DTL/NBS Samples Taken ____

Pictures (circle) U/S D/S X-section Slope ____ Pattern: (Meandering — circled) Straight Braided

							Score
1. Primary bed material							
	Bedrock	Boulder/Cobble		Gravel	Sand	Silt Clay	
	0	1		2	3	4	3
2. Bed/bank protection							
	Yes	No	(with)	1 bank protected	2 banks		
	0	1		2	3		1
3. Degree of incision (Relative elevation of "normal" low water; floodplain/terrace @ 100%)							
	0-10%	11-25%	26-50%	51-75%	76-100%		
	4	3	2	1	0		3
4. Degree of constriction (Relative decrease in top-bank width from up to downstream)							
	0-10%	11-25%	26-50%	51-75%	76-100%		
	0	1	2	3	4		2
5. Stream bank erosion (Each bank)							
	None	Fluvial	Mass wasting (failures)				
Left	0	1	2				0
Right	0	1	2				0
6. Stream bank instability (Percent of each bank failing)							
	0-10%	11-25%	26-50%	51-75%	76-100%		
Left	0	0.5	1	1.5	2		0.5
Right	0	0.5	1	1.5	2		0.5
7. Established riparian woody-vegetative cover (Each bank)							
	0-10%	11-25%	26-50%	51-75%	76-100%		
Left	2	1.5	1	0.5	0		0
Right	2	1.5	1	0.5	0		0
8. Occurrence of bank accretion (Percent of each bank with fluvial deposition)							
	0-10%	11-25%	26-50%	51-75%	76-100%		
Left	2	1.5	1	0.5	0		1
Right	2	1.5	1	0.5	0		1
9. Stage of channel evolution							
	I	II	III	IV	V	VI	
	0	1	2	4	3	1.5	3

Figure 11 – Channel stability ranking scheme used to conduct rapid geomorphic assessments (RGAs). The channel stability index is the sum of the values obtained for the nine criterion.

Total: 15

4.2.3 Channel-Stability Index

A scheme that assesses nine unique criteria was used to record observations of field conditions during RGAs (Figure 11). Each criterion was ranked from zero to four and all values summed to provide an index of relative channel stability. The higher the number the greater the instability: sites with values greater than 20 exhibit considerable instability; stable sites generally rank 10 or less. Intermediate values denote reaches of moderate instability. However, rankings are not weighted, thus a site ranked 20 is not twice as unstable as a site ranked 10. The process of filling out the form enables the final decision of 'Stage of Channel Evolution'.

Characterizing Channel Geomorphology

1. Primary bed material

Bedrock	The parent material that underlies all other material. In some cases this becomes exposed at the surface. Bedrock can be recognized by appearing as large slabs of rock, parts of which may be covered by other surficial material.
Boulder/Cobble	All rocks greater than 64 mm median diameter.
Gravel	All particles with a median diameter between 64.0 – 2.00 mm
Sand	All Particles with a median diameter between 2.00 – 0.062 mm
Silt Clay	All fine particles with a median diameter of less than 0.062 mm
	Grain size classification given by Knighton (1998) p. 107.

2. Bed/bank protection

Yes	Mark if the channel bed is artificially protected, such as with rip rap or concrete.
No	Mark if the channel bed is not artificially protected and is composed of natural material.
1 bank protected	Mark if one bank is artificially protected, such as with rip rap or concrete.
2 banks	Mark if two banks are artificially protected.

3. Degree of incision (Relative elevation of "normal" low water)

Assume top-bank elevation represents the 100% elevation and the thalweg represents 0% elevation, select the relative elevation of "normal" low water.

4. Degree of constriction (Relative decrease in top-bank width from up to downstream)

Often only found where obstructions or artificial protection are present within the channel. Taking the reach length into consideration, channel width at the upstream and downstream parts of the constriction are measured and the relative difference calculated.

5. Stream bank erosion (Each bank)

The dominant form of bank erosion is marked separately for each bank, left and right, facing in a downstream direction.

If the reach is a meandering reach, the banks are viewed in terms of 'Inside, Outside' as opposed to 'Left, Right' (appropriate for questions 5-8). Inside bank, being the inner bank of the meander, if the stream bends to the left as you face downstream, this would be the left bank. Outside bank, being the outer bank, on your right as you face downstream in a stream meandering left.

None	No erosion
Fluvial	Fluvial processes (i.e. undercutting of the bank toe), cause erosion.
Mass Wasting	Mass movement of large amounts of material from the bank is the method of bank erosion. Often characterized by high, steep banks with shear bank faces. Debris at the bank toe appears to have fallen from higher up in the bank face. Includes, rotational slip failures and block failures.

6. Stream bank instability (Percent of each bank failing)
   If the bank exhibits mass wasting, mark percentage of bank with failures over the length of the reach. If more than 50% failures are marked, the dominant process is mass wasting (see question 5).

7. Established riparian woody-vegetative cover (Each bank)
   Riparian vegetative cover refers to perennial vegetation that grows on the streambanks. This was originally defined as including only trees and shrubs but was revised to include perennial grasses.

8. Occurrence of bank accretion (Percent of each bank with fluvial deposition)
   The percentage of the reach length with fluvial deposition of material (often sand, also includes fines and gravels) is marked.

9. Stage of channel evolution
   Stages of channel evolution are given by Simon and Hupp, 1986 (see diagram below). All of the above questions help lead to an answer to this question. Refer to previously determined criterion for guidance. See Table 5 for guidelines of features often found with each stage of channel evolution.

Total Score Total up the responses to the 9 questions.

4.2.4 Stages of Channel Evolution

The channel evolution framework set out by Simon and Hupp (1986) is used by TMDL practitioners to assess the stability of a channel reach (Figure 12; Table 5). With stages of channel evolution tied to discrete channel processes and not strictly to specific channel shapes, they have been successfully used to describe systematic channel-adjustment processes over time and space in diverse environments, subject to various disturbances such as stream response to: channelization in the Southeast US Coastal Plain (Simon, 1994); volcanic eruptions in the Cascade Mountains (Simon, 1999); and dams in Tuscany, Italy (Rinaldi and Simon, 1998). Because the stages of channel evolution represent shifts in dominant channel processes, they are systematically related to suspended-sediment and bed-material discharge (Simon, 1989b; Kuhnle and Simon, 2000), fish-community structure, rates of channel widening (Simon and Hupp, 1992), and the density and distribution of woody-riparian vegetation (Hupp, 1992).

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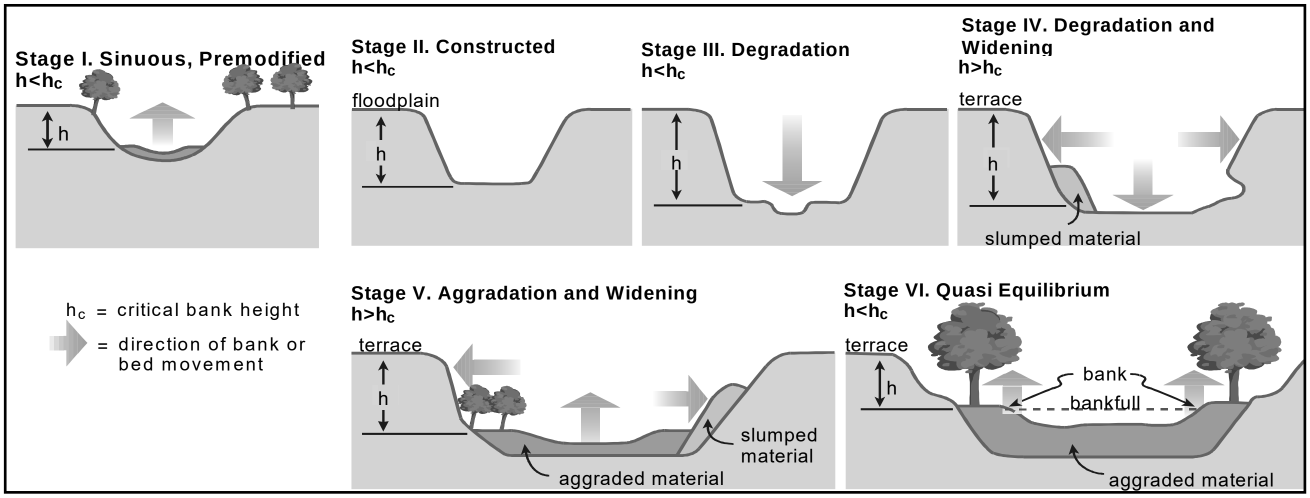


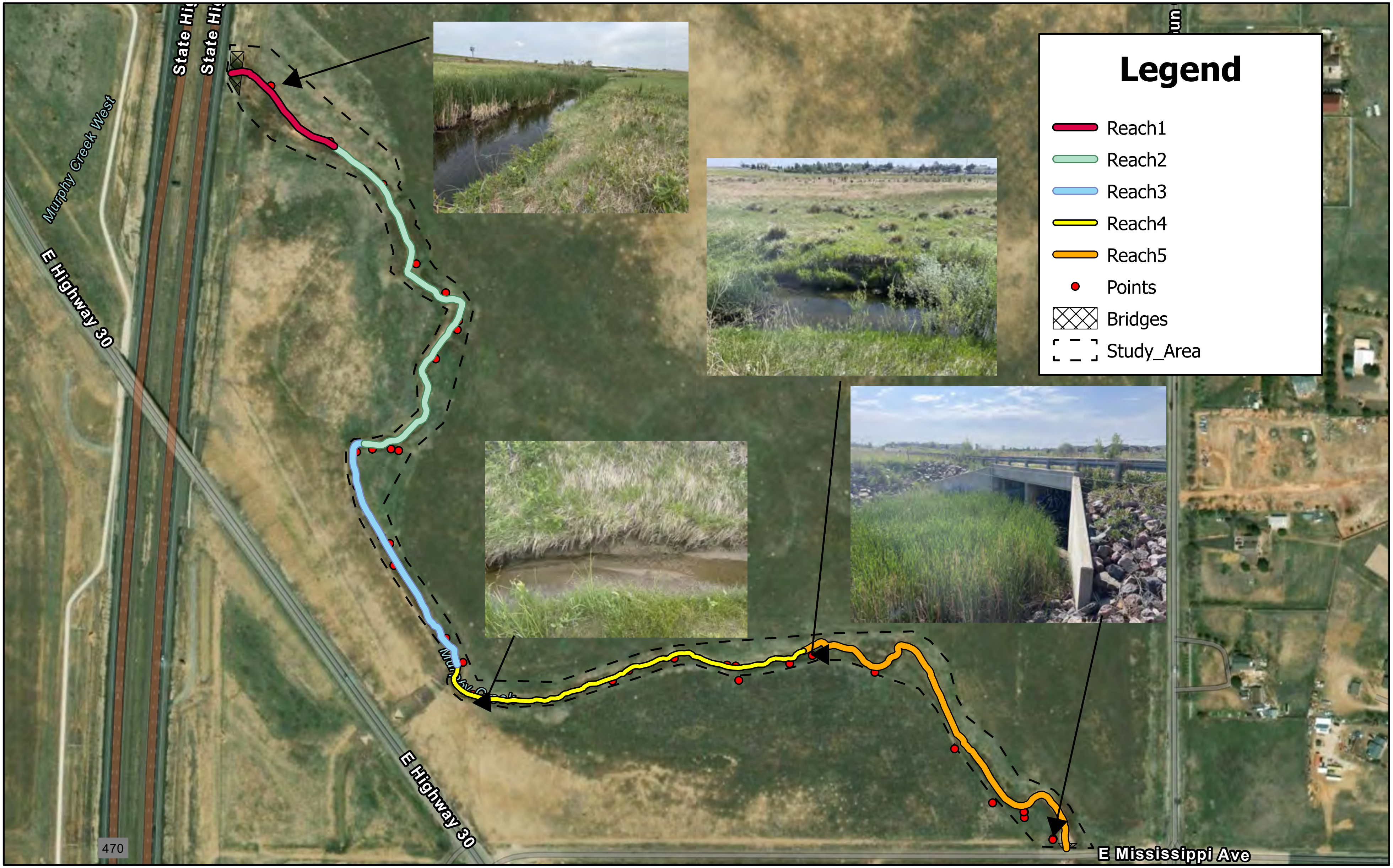
Figure 12 – Six stages of channel evolution from Simon and Hupp (1986) and Simon (1989a) identifying Stages I and VI as 'reference' channel conditions (See Table 5 for explanation of stages).

Table 5 – Summary of conditions to be expected at each stage of channel evolution.

Stage	Descriptive Summary
I	*Pre-modified* – Stable bank conditions, no mass wasting, small, low angle bank slopes. Established woody vegetation, convex upper bank, concave lower bank.
II	*Constructed* – Artificial reshaping of existing banks. Vegetation often removed, banks steepened, heightened and made linear.
III	*Degradation* – Lowering of channel bed and consequent increase of bank heights. Incision without widening. Bank toe material removed causing an increase in bank angle.
IV	*Threshold* – Degradation and basal erosion. Incision and active channel widening. Mass wasting from banks because bank heights exceed the critical conditions (geotechnical strength) of the bank material. Leaning and fallen vegetation. Vertical face may be present.
V	*Aggradation* – Deposition of material on bed, often sand. Widening of channel through bank retreat; no incision. Concave bank profile. Filed material re-worked and deposited. May see floodplain terraces. Channel follows a meandering course.
VI	*Restabilization* – Reduction in bank heights, aggradation of the channel bed. Deposition on the upper bank therefore visibly buried vegetation. Convex shape. May see floodplain terraces.

An advantage of a process-based channel-evolution scheme for use in TMDL development is that Stages I and VI represent true 'reference' conditions. In some cases, such as in the Midwestern United States where land clearing activities near the turn of the 20th Century caused massive changes in rainfall-runoff relations and land use, channels are unlikely to recover to Stage I, pre-modified conditions. Stage VI, a re-stabilized condition, is a much more likely target under present regional land use and altered hydrologic regimes (Simon and Rinaldi, 2000) and can be used as a 'reference' condition. Stage VI streams can be characterized as a 'channel-within-a-channel', where the previous floodplain surface is less frequently inundated and can be described as a terrace. This morphology is typical of recovering and re-stabilized stream systems following incision. In pristine areas, where disturbances have not occurred or where they are far less severe, Stage I conditions can be appropriate as a reference.

Appendix 9: Vegetation Exhibit



Path: G:\WWE\221-076\000\GIS\02_data\CET_Working\MyProject4\MyProject4.aprx

WRIGHT WATER ENGINEERS, INC.

ARAPAHOE/AURORA, COLORADO

VEGETATION STUDY

MURPHY CREEK STREAM RESTORATION

N W E S

0 250 500 ft

PROJECT NO. 221-076.000

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FIGURE 1

Appendix 10: Photo Log

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Reach 1 Site Photos: May 2024

Photograph 1

Photograph 2

Photograph 3

Photograph 4

Photographs taken by Wright Water Engineers, Inc.

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Reach 1 Site Photos: June 2024

Photograph 5

Photograph 6

Photographs taken by Wright Water Engineers, Inc.

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Reach 2 Site Photos: May 2024

Photograph 7

Photograph 8

Photograph 9

Photograph 10

Photographs taken by Wright Water Engineers, Inc.

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Reach 2 Site Photos: June 2024

Photograph 11

Photograph 12

Photograph 13

Photograph 14

Photographs taken by Wright Water Engineers, Inc.

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Reach 3 Site Photos: May 2024

Photograph 15

Photograph 16

Photograph 17

Photograph 18

Photographs taken by Wright Water Engineers, Inc.

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Reach 3 Site Photos: June 2024

Photograph 19

Photograph 20

Photograph 21

Photograph 22

Photographs taken by Wright Water Engineers, Inc.

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Reach 4 Site Photos: May 2024

Photograph 23

Photograph 24

Photograph 25

Photograph 26

Photographs taken by Wright Water Engineers, Inc.

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Reach 4 Site Photos: June 2024

Photograph 27

Photograph 28

Photograph 29

Photograph 30

Photographs taken by Wright Water Engineers, Inc.

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Reach 5 Site Photos: May 2024

Photograph 31

Photograph 32

Photograph 33

Photograph 34

Photographs taken by Wright Water Engineers, Inc.

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Reach 5 Site Photos: June 2024


Photograph 35


Photograph 36


Photograph 37


Photograph 38

Photographs taken by Wright Water Engineers, Inc.

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Reach 5 Site Photos: June 2024

Photograph 39

Photograph 40

Photograph 41

Photograph 42

Photographs taken by Wright Water Engineers, Inc.

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