MILE HIGH FLOOD DISTRICT

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To:	Laura Kroeger, Engineering Director
From:	Morgan Lynch, Mile High Flood District Watershed Manager Drew Beck, Matrix Design Group, Inc.
Date:	February 18, 2022
Subject:	**Stream Management Corridors**

Introduction

Stream Management Corridors (SMCs) have been defined throughout the Mile High Flood District (District) to protect and preserve urban stream corridors while also identifying an overall width that the stream may require to function. These corridors allow natural geomorphic processes to shape streams in ways that support High Functioning Lower Maintenance Streams (HFLMS) in increasingly urbanized settings. SMCs are beneficial for planning, safety, and ecological integrity. MHFD has provided this information as a planning tool for local communities to help guide land use changes in the watershed. SMCs are another beneficial tool for understanding the natural constraints of a stream system. When coupled with Fluvial Hazard Zone (FHZ) delineations Colorado Water Conservation Board (CWCB), 2020) and Federal Emergency Management Agency (FEMA)-regulated floodplains, SMCs become much more than representations of existing or predicted floodplain hazards; they become corridors that can accommodate flooding, allow for fluvial processes, and encourage natural stream geomorphic processes. SMCs have been defined for different spatial scales including Watershed Scale, Stream Corridor Scale, and Reach Scale (see **Figure 1**), linking the processes depending on the context of the information analyzed.

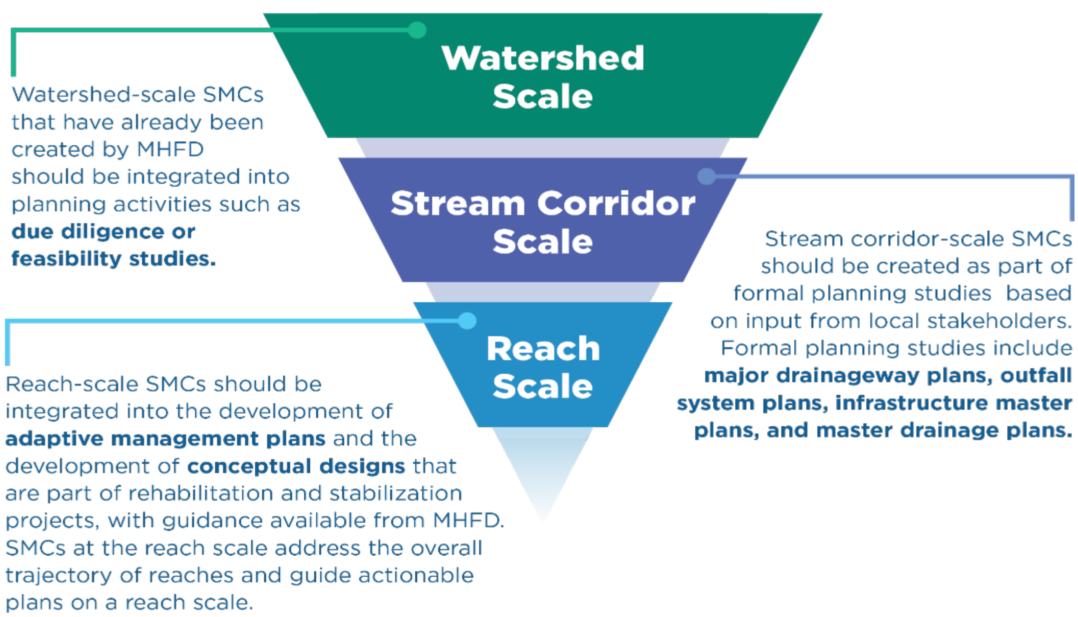


Figure 1. Stream Management Scales

SMC descriptions and guidance on development are defined in subsequent sections of this document. All SMCs currently defined by the District are available through the Stream Management Corridor Viewer (see **Figure 2**) on the District's website, www.mhfd.org/mapping.

Figure 2. Stream Management Corridor Viewer

Stream Management Corridors at the Watershed Scale

The District has developed an SMC for all streams within the District's Boundary with a focus on watersheds greater than 130 acres. The Watershed Scale is an area for broad characterization of existing streams using Geographic Information System (GIS)-based tools to create SMCs that guide planning activities. Stream processes and future trajectories are not directly defined at the Watershed Scale. The Watershed Scale SMCs are intended to be high level and are based on simplified methods, while identifying the general width that the stream may need to be fully functional or be restored to a functional condition.

SMCs were created for the District using a threshold planning approach based on each stream's shear stress. SMCs for streams that have a tributary area greater than 130 acres were established using an automated and simplified method using GIS. Several iterations were completed to understand the sensitivity of the stream management corridor based on valley slope and flow. Based on this sensitivity analysis, approximate widths were calculated by targeting 1 pound per square foot (lb/sf) shear stress or 4 lb/sf shear stress depending on the geographic location. The higher target values were used for the steeper, headwater streams located in the foothill or mountain regions of the District. Both target values were determined by using U.S. Department of Agriculture (USDA) Threshold Channel Designs, Part 654 (2007). Width was calculated using a simplified Manning's equation solving for width using slope and flow rate. Flow rates were calculated using a District-wide hydrology regression equation based on upstream drainage area (**Attachment 1**). Slopes were calculated from Light Detection and Ranging (LiDAR)-derived digital elevation models (DEMs) coupled with stream lengths that were identified with an automated GIS delineation. Once approximate widths were found that allowed for adequate floodplain shear stresses, these were buffered from the stream centerline to create the Watershed Scale SMCs.

In areas where the simplified approach resulted in unrealistic SMCs, a corridor was not defined. These areas shall be evaluated at the appropriate scale in future planning efforts.

Stream Management Corridors at the Stream Corridor Scale

The Watershed Scale simplified approach to defining SMCs develops stream corridors for planning purposes. This simplified approach does not consider site-specific characteristics. Additional refinement at this level is encouraged to ensure the context of the watershed and site-specific conditions are considered in the delineation. The District recommends mapping the SMC at a Stream Corridor Scale during development of a Major Drainageway Plan (MDP) with the local stakeholders to ensure the corridor will meet the goals and vision of all stakeholders. At the Stream Corridor Scale, watershed context and stakeholder feedback must be considered when determining the level of analysis needed to develop the SMC. The Stream Corridor Scale is defined by more refined GIS tools and desktop analysis. **Attachment 2** provides an example of how to utilize the Relative Elevation Model to complete a desktop analysis, as described in the *Colorado Fluvial Hazard Zone Delineation Protocol* (CWCB, 2020). The desktop analysis should be completed by a stream restoration specialist or fluvial geomorphologist. For undeveloped areas, a detailed analysis such as an FHZ analysis (CWCB, 2020) may be the appropriate tool to define the SMC. For additional information on how to define the SMC during the MDP process, please review the guidance for creating a Watershed Story (Enginuity, In Progress).

Stream Management Corridors at the Reach Scale

The Reach Scale SMC requires field visits, hydrologic studies, hydraulic studies, and geomorphic assessments. The overall goal of the Reach Scale SMC is to determine an evolutionary trajectory for the reach and evaluate the ability of the existing stream corridor to adapt to the future conditions. This understanding may be necessary when evaluating alternatives for stream improvements. The Reach Scale SMC builds upon the information developed for a Stream Corridor SMC by determining actionable work that has been identified as part of a planning process.

Stream bed material and stream geometry (size, bankfull depth, and bankfull width) should be collected during field visits, and an overall assessment of geomorphic and vegetative processes should be performed. A team of experts skilled in engineering, geomorphology, landscape architecture, and ecology will need to work collaboratively throughout the assessment to ensure the appropriate elements are considered. Following the field visit, hydrologic study, and hydraulic analysis, an Adaptive Management Plan can be developed to identify the stream corridor width necessary to preserve the existing stream stability. Alternatively, a Conceptual Design for rehabilitation or retrofitting could be created if the site-specific data indicate that the stream is on a trajectory toward instability. In both scenarios, the output will further refine the limits of the SMC.

Conclusion

While the hierarchy of the SMCs from Watershed Scale to Reach Scale gradually provides a more detailed SMC at each step, SMCs do not have to be completed in the order outlined. Each “scale” provides its own value. These SMCs also rely on the published FHZ protocols, which simplify the overall process. SMCs are a valuable tool for cities, counties, and the people living in them. They provide valuable information in addition to floodplain mapping and can help the District protect and preserve urban stream corridors.

References

Colorado Water Conservation Board (CWCB). 2020. *Colorado Fluvial Hazard Zone Delineation Protocol*. January.

Enginuity Engineering Solutions. In Progress. *Mile High Flood District Watershed Story*.

U.S. Department of Agriculture (USDA). 2007. Part 654 Stream Restoration Design National Engineering Handbook. *Chapter 8: Threshold Channel Design*.

Attachment 1

SMC Buffer Calculations for Auto-Generation

Memorandum

To: Shea Thomas, PE

From: Drew Beck, PE

Date: *revised* November 19, 2018

Subject: **Stream Management Corridor Buffer Calculations for Auto-Generation**

This memorandum describes the assumptions utilized to calculate the stream management corridor (SMC) buffer width for each segment of identified stream within the Urban Drainage Flood Control District (UDFCD). This process is broken up into three parts:

1. Rewrite Manning's Equation for rectangular channels.
2. Define the field calculator expression "Buffer_Calc" which uses Drainage Area and Average Slope to calculate SMC buffer width.
3. Apply the field calculator expressions for CFS and Top Width in the stream layer attribute table.

In addition, this memo summarizes the approach for developing the three fields required to use the buffer: cumulative drainage area, stream segment slope, and discharge.

Process for Calculating Stream Management Corridor Buffer Width

Part 1: Simplify and Rewrite Manning's Equation for rectangular channels

Note: Blue terms are for code simplification in the Field Calculator.

Even though the actual shape of the channel is trapezoidal we will assume a rectangular shape to simplify the calculations for the bottom width (b). This assumption is valid since the width is much larger (> 10 x depth) than the depth.

General Manning's Equation (English Units):

$$Q = \frac{1.49}{n} AR^{2/3} \sqrt{s}$$

Hydraulic radius (R) is:

$$R = \frac{A}{P}$$

For a rectangular shape channel hydraulic radius is where (b) is width and (y) is depth:

[1] nsolver is a sympy function that solves an equation for a specified variable. The sympy functions are standard in GIS.

$$R = \frac{by}{b + 2y}$$

For channels with a width that is much larger than depth (i.e. b> 10y), then hydraulic radius can be simplified to just depth (y)

$$R = y$$

Manning's Equation for a Rectangular channel with R=y (English Units):

$$Q = \frac{1.49}{n} yb\, y^{2/3} \sqrt{s}$$

Where:

Q = Discharge (cfs)

n = Manning's roughness (-)

y = Normal depth (ft)

b = Bottom width (ft)

s = Average channel slope (ft/ft)

1. **Isolate "b" on the left-hand side**

$$b = \frac{Q\, n}{1.49 y^{5/3} \sqrt{s}}$$

[1] nsolver is a sympy function that solves an equation for a specified variable. The sympy functions are standard in GIS.

Part 2: Define the Field Calculator Expression "Buffer_Calc"

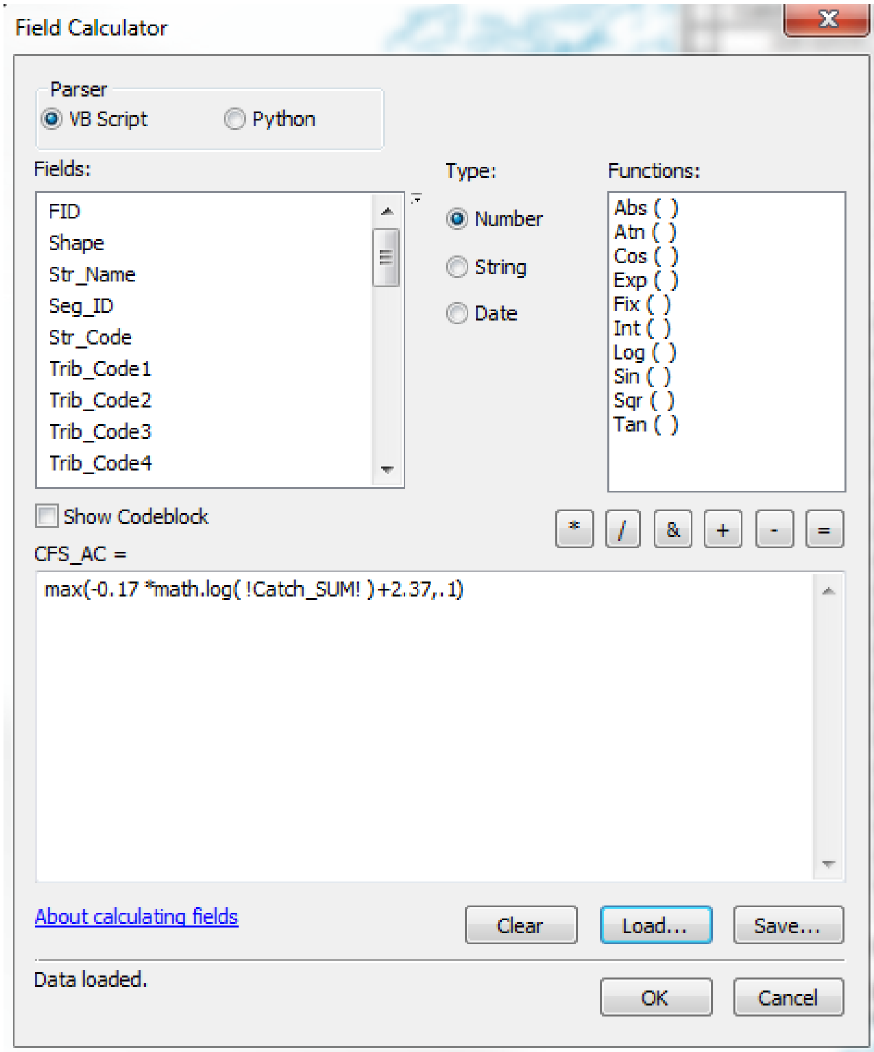
1. ***Open stream layer attribute table***
2. ***Ensure fields for average slope, drainage area, flow per acre assumption, and buffer width exist. Drainage area, flow per acre, and buffer width fields should be formatted as doubles.***
3. ***Right-click on the buffer width field and select "Field Calculator" > Select the "Python" parser > Select "Show Codeblock" > enter the following into the "Pre-Logic Script Code" box***

Pre-Logic Script Code:

```
from sympy import *


def Buffer_Calc(Drain_Area, Avg_Slope, CFS_per_AC):


 # Define unknown (b) and known variables

  b = Symbol('b')          # Defines bottom width variable for nsolver

  n = 0.045                # Manning's roughness

  m = 10                   # Sideslopes (m:1)

  Q = CFS_per_AC * Drain_Area     # Discharge (cfs), 1 cfs/acre * total drainage area in acres

  s = Avg_Slope            # Average channel slope (ft/ft) within immediate catchment

  y = 0.5/(62.4*s)             # Normal flow depth (ft) assuming 0.5 lb/sf shear stress


  # Rewrite Manning's equation

  b = (Q*n)/[1.49*y**(5/3)*s**(1/2)]


  # Use bottom width to calculate top width (top width = buffer distance)

  Top = b + (2*y*m)

  Top = round(Top,2)

  return Top
```

4. ***Calculate the CFS field with the flow expression***

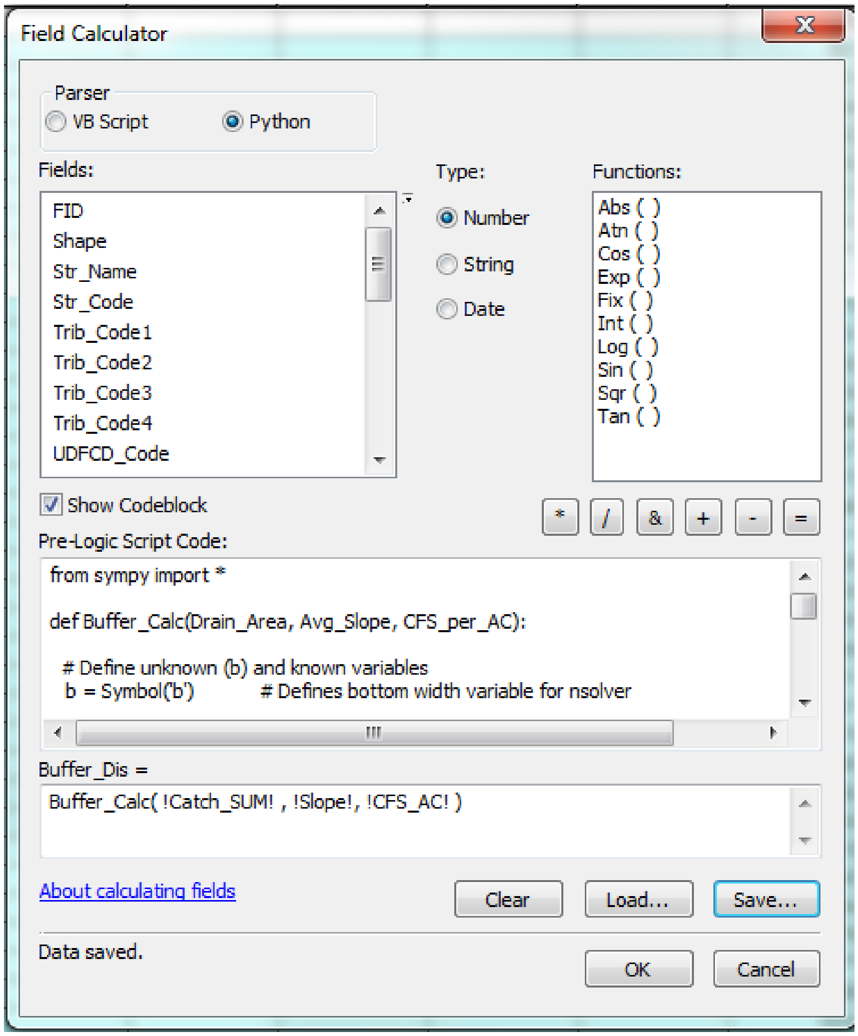
[1] nsolver is a sympy function that solves an equation for a specified variable. The sympy functions are standard in GIS.



5. ***Calculate the Drainage Area field to derive the Top Width***

6. ***The previous steps should look like the following screenshot:***

[1] nsolver is a sympy function that solves an equation for a specified variable. The sympy functions are standard in GIS.



Part 3: Apply the Field Calculator Expressions

Process for Developing the Field Inputs for Buffer Calculations

Slope

Slope was calculated by assigning a 'To' and 'From' elevation value to the start and end points of each individual stream segment. ET Geowizards was utilized in generating To and From Junctions. Elevations from the 2.5ft Digital Elevation Model were assigned to each point. The change in elevation between 2 points divided by the distance of their associated stream segment were used to calculate the slope in ArcGIS. In limited cases, adverse (negative) or unrealistically high slopes on short segments resulted from this calculation. For these instances, the slope was manually adjusted based on the average of the upstream and downstream slope along the same mainstem/ tributary.

[1] nsolver is a sympy function that solves an equation for a specified variable. The sympy functions are standard in GIS.

Cumulative Drainage Area

A Geometric Network was created and used as part of a model to correctly trace upstream accumulation. This began with ensuring there were an equal number of stream segments to catchments and associating the acreage of each catchment using a unique ID and a Table Join. Next, ET Geowizards was used to create middle points along each stream that would act as starting points or 'Flags' for the network. The model iterates through each flag, performing a trace upstream to find all accumulating records. Those records are selected, exported to a new layer, summed based on the acreage of each segment, and eventually joined back to the original Streams layer with a newly populated attribute.

Flow Per Acre Assumption

UDFCD compiled 100-year flows and associated drainage areas for several drainage basins to determine a general flow per acre assumption, as summarized in **Table 1**. Linear, logarithmic, and other trends were applied to the data (see **Figures 1** and **2**). All examined trends resulted in weak correlation (R-squared ≤ 0.4). The average flow per acre for the evaluated drainage basins is 1 cubic-feet per second/ acre, which is used as a baseline assumption. For large contributing areas, there appears to be a break in cfs per acre, which results in unrealistically large buffers along some of the major mainstem reaches. For these reaches, improved cfs per acre assumptions can be quantified using Major Drainageway Plans (MDPs) and other studies. A field and additional exponential trendline expression was generated for the dataset to adjust this assumption as necessary to ensure realistic SMC buffer widths.

[1] nsolver is a sympy function that solves an equation for a specified variable. The sympy functions are standard in GIS.

Table 1. Basis of Flow Per Acre Assumption

Drainage Basin	54th & Pecos	McKay Lake	Meadowood	Basin 4100	Willow (DougCo)	Senac	Weaver	Goldsmith	Second	Sulphur	BDC (ArapCo)	Bear Gulch
Study Date	2017	2018	2016	2018	2017	2014	2016	2018	2011	2017	2014	2014
DP	OF-0223	ML	Outfall	101	345	76	101	Outfall_Goldsmith		459	BDCOutfall	279
Drainage Area (ac)	286	740	1664	1691	2351	3066	4630	4954	4954	10835	12384	12800
Q100,future (cfs)	361	838	2206	1901	2131	4274	2386	2528	9454	5374	4651	13486
cfs/ac	1.26	1.13	1.33	1.12	0.91	1.39	0.52	0.51	1.91	0.50	0.38	1.05

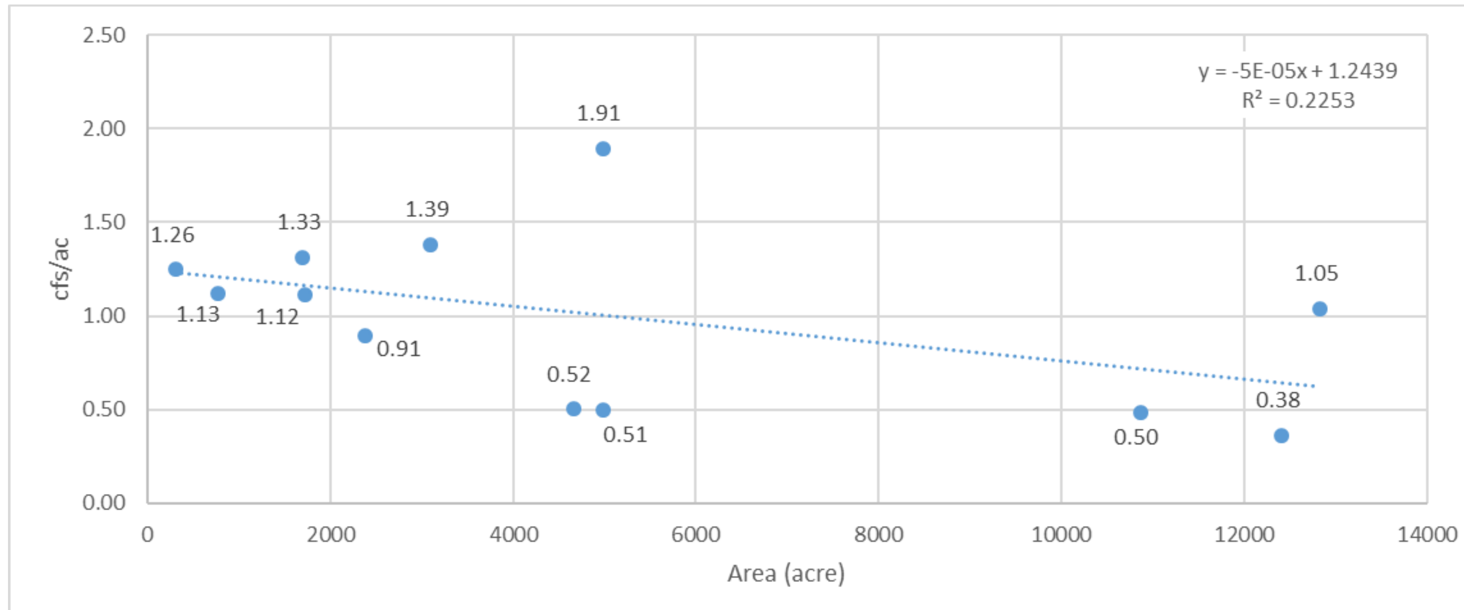


Figure 1. Linear Trendline

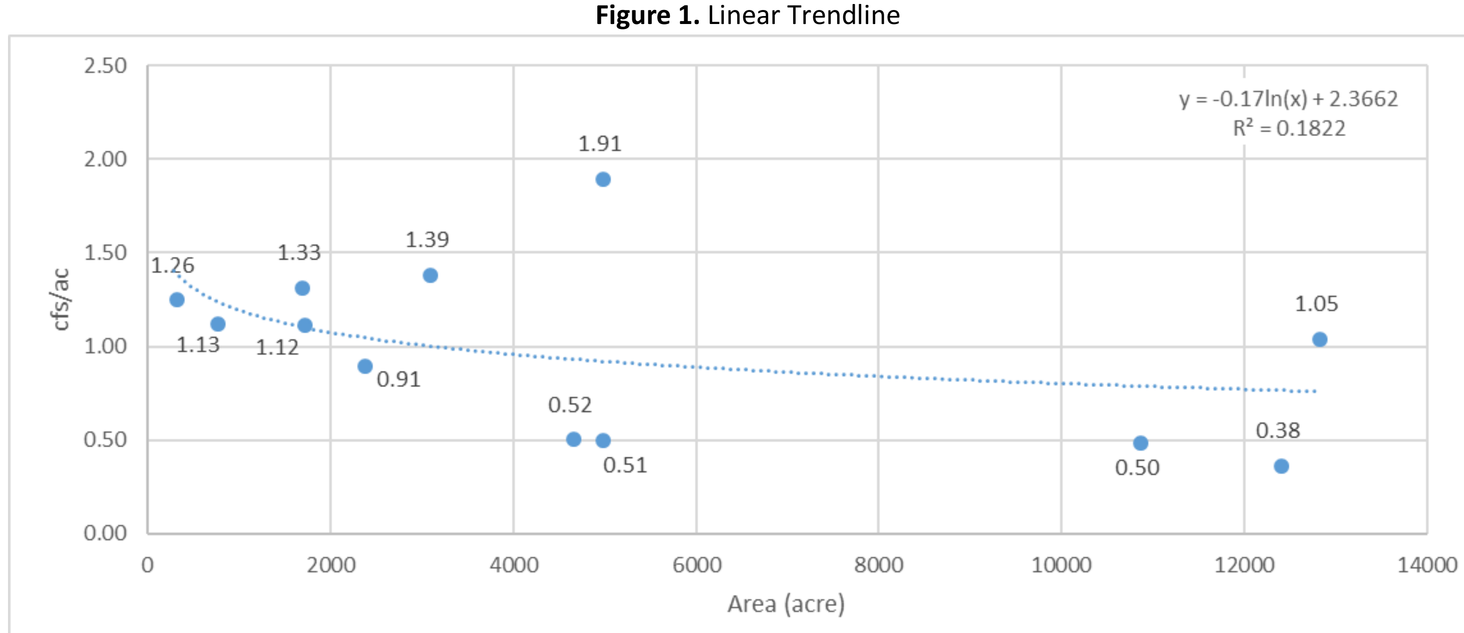


Figure 2. Logarithmic Trendline

[1] nsolver is a sympy function that solves an equation for a specified variable. The sympy functions are standard in GIS.

Attachment 2
Relative Elevation Model (REM) Best Practices and Observations

Relative Elevation Model (REM) Generation Best Practices and Observations – Coal Creek and Golden Area Stream Management Corridors (SMC)

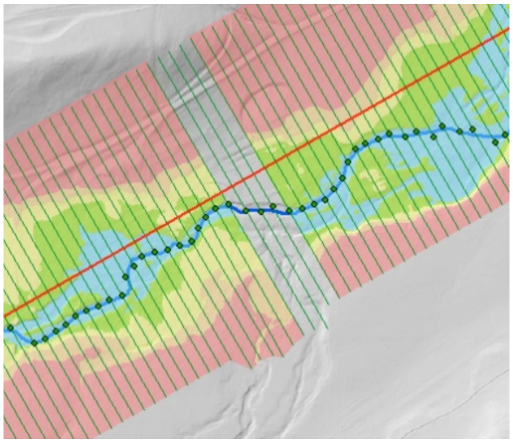
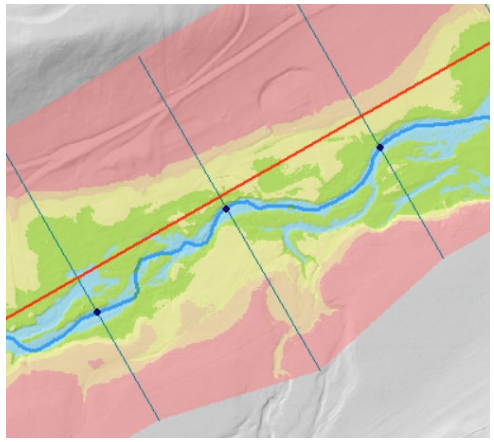
Cross-Section Generation Using the CWCB REM tool in ArcMap

In scenarios where HEC-RAS cross-sections are unavailable or if HEC-RAS cross-sections are not dense enough to provide the level of fidelity needed to produce valuable REMs, the CWCB REM tool for ArcMap can be used to generate cross-sections. Below are some lessons learned and noted best practices when developing cross-sections for REM development. REMs were developed for a section of Coal Creek between Coal Creek Canyon Rd. at the mouth of Coal Creek Canyon, to approximately Coal Creek Drive, one mile southwest of Superior. In addition, REMs for steep narrow reaches around the Golden area foothills were also developed.

Cross-sections generated for Coal Creek and Golden for REM production were developed off a general valley centerline to help prevent the intersection of cross-sections in highly sinuous stream channels, and to reduce the amount of manual cross-section manipulation. Appendix C of the Colorado Fluvial Hazard Zone Delineation Protocol (CWCB, 2020) was also used as a guide in cross-section and REM development.

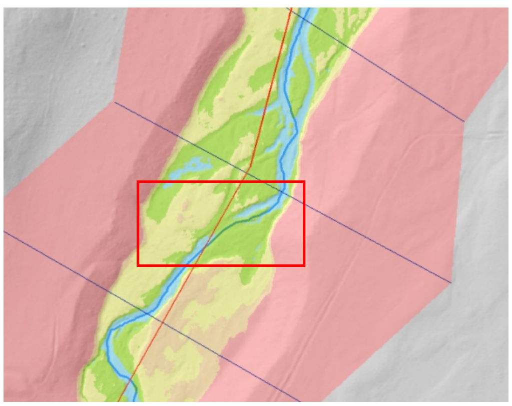
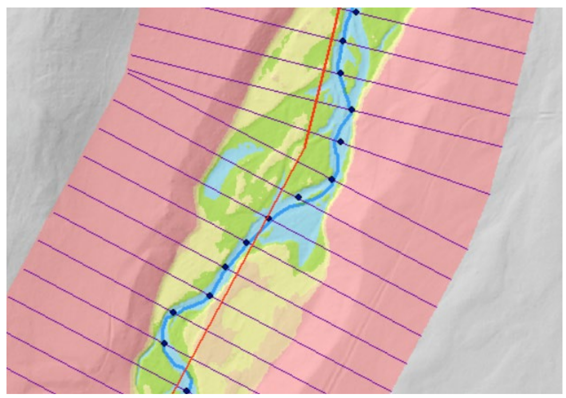
Cross section Spacing

- CWCB Appendix C suggests that cross-section spacing depends on the level of detail required by the user. Shorter cross-section spacing will yield a REM that captures more channel variation; however, it will require more effort to prevent the intersection of cross-sections.
    - A general valley centerline was used in the case of Coal Creek and Golden areas versus the stream thalweg to develop cross-sections. Using a general valley centerline helped prevent the intersection of cross-sections.
- An external review of the REM tool recommends drawing cross-sections with spacing approximately equal to the valley bottom width (valley wall to valley wall).
    - Despite the above recommendations, for the REM processing of Clear Creek, short spacing of cross-sections (50-100ft) derived from a valley centerline seemed to produce very useful REM's.
- Closer spacing (>50-100ft) can be afforded with the use of a valley centerline to derive cross-sections, while a wider spacing (approx. valley bottom width.) should be considered when using stream thalweg derived cross-sections, to help prevent the intersection of cross-sections and minimize manual cross-section manipulation.
    - Although not tested for Coal Creek and Golden area REMs, it would be useful to follow the Appendix C 'Output REM QA/QC' steps to validate which method produces the best REMs for use in FHZ delineations.
- Gaps in output REMs were identified at a cross-section spacing of 50ft. Gaps can be reduced by using larger cross-section spacings (~100ft spacing).

Left: 50ft cross-section spacing Right: 600ft (approx. valley wall width) Eliminates holes generated by REM tool. Minimal fidelity lost in REM quality. Gaps in output REM were also resolved with cross-sections spacing of 100ft.

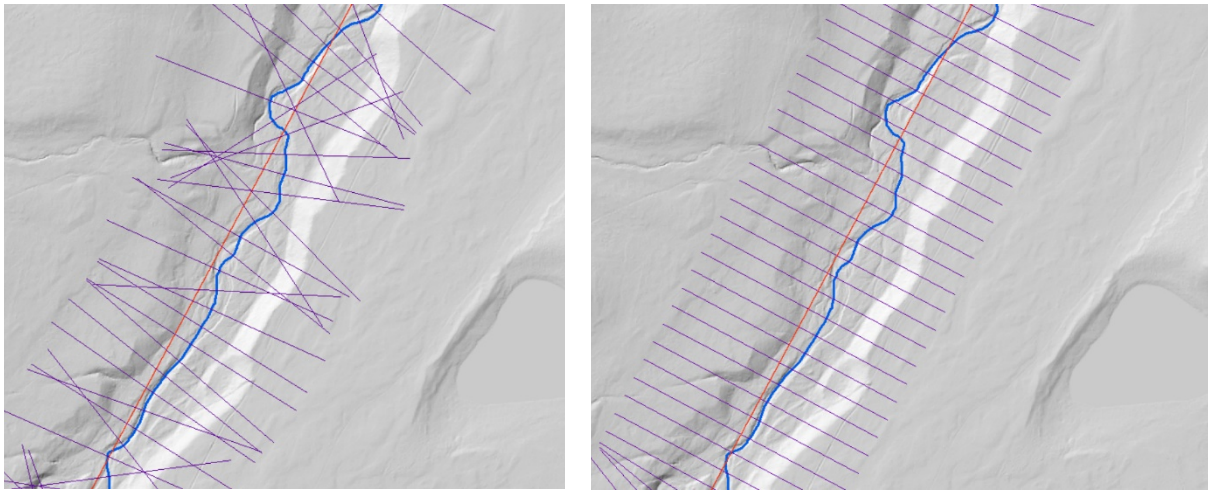
- Cross-section spacing of 100ft or more provide useful cross-sections without gaps in REM output.
- In several cases, using wider spaced cross-sections (600ft, approximate valley wall width), the output REM displayed disconnected stream channels where this may not actually exist, therefore closer spaced cross-sections (no closer than 50ft) seemed to capture highest level of detail without sacrificing processing time.
    - Once again, it would be useful to follow the Appendix C 'Output REM QA/QC' steps to validate the accuracy of the REMs developed from a valley centerline and at short cross-section spacings. (CWCB, 2020)

Left: 600ft cross-section spacing. Indicates potentially disconnected channel Right: 100ft cross-section spacing. Indicates more connected channel

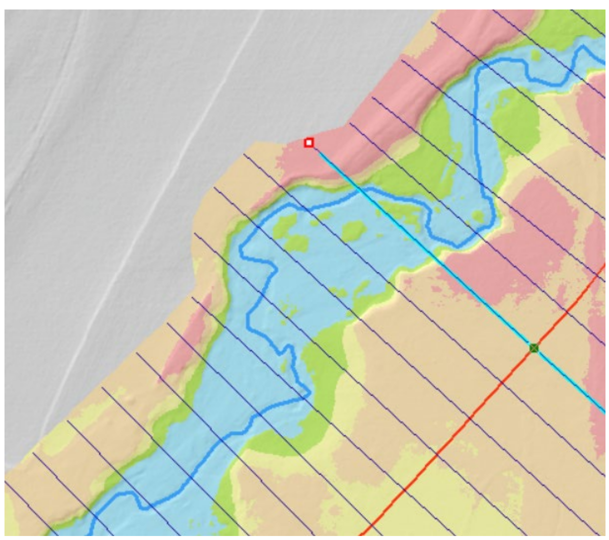
Manual Cross-Section Manipulation

- The use of a valley centerline for cross-section generation was found to be extremely usefully in producing dense cross-sections without excessive amounts of intersections and required less manual manipulation versus deriving cross-sections from the stream thalweg.
  - In almost all cases, manual manipulation (rotation, thinning, bending) of cross-sections generated by the REM tool was a necessary process to prevent intersecting cross-sections, and to accommodate very sinuous stream reaches.



Left: 100ft cross-section spacing derived from stream centerline. Right: 100ft cross-section spacing derived from valley centerline.

- In many cases, with cross-sections derived from a valley centerline, it will be necessary to extend a subset of cross-sections in order to capture the entire stream channel and valley margins.

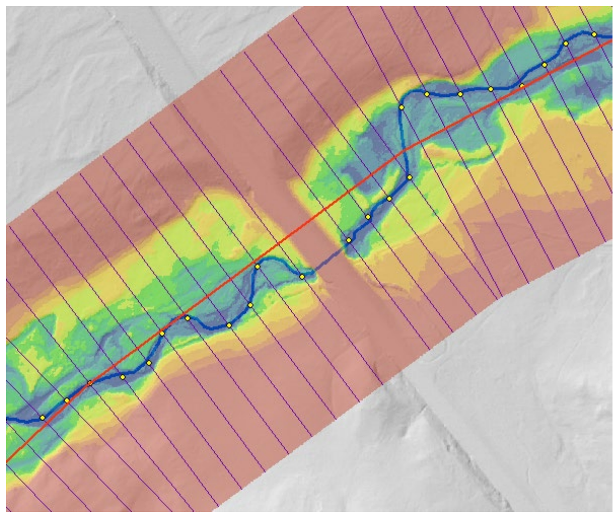


Extension of cross-sections to capture stream channel and valley margins

- Rotation of cross-sections to prevent intersections was often necessary. Generally, cross-sections should be drawn perpendicular to the channel centerline. Appendix C guidance mentions that cross-sections may need to be obliquely oriented to the channel line in very sinuous channels. (CWCB, 2020)

    - REMs developed with cross-sections obliquely oriented to channel line (usually the case with cross-sections derived from valley centerline) appear to be of good quality based on a qualitative comparison overlaid with a hillshade

- Cross-sections should be removed where they fall coincidentally with roadways, bridges or other human built crossings. This prevents the REM tool from obtaining the lowest channel elevation on the surface of the crossing, which would result in less accurate relative elevation outputs for this section.
    - An alternative to the manual removal of cross sections is to use DEMs that have been conditioned to account for false hydrologic barriers within the DEM, therefore enforcing proper drainage and realistic hydrologic connectivity, resulting in more realistic relative elevation outputs.



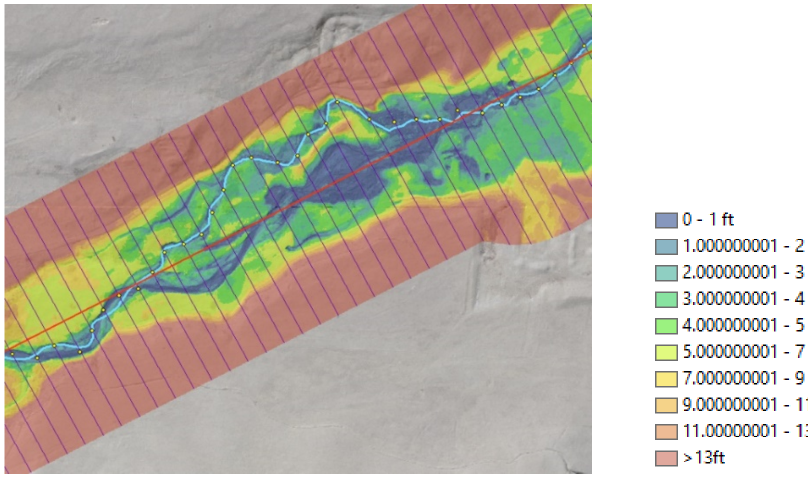
Example where a cross-section was removed to accomidate a culvert crossing.

Overall REM Interpretations and Fluvial Signature Identification

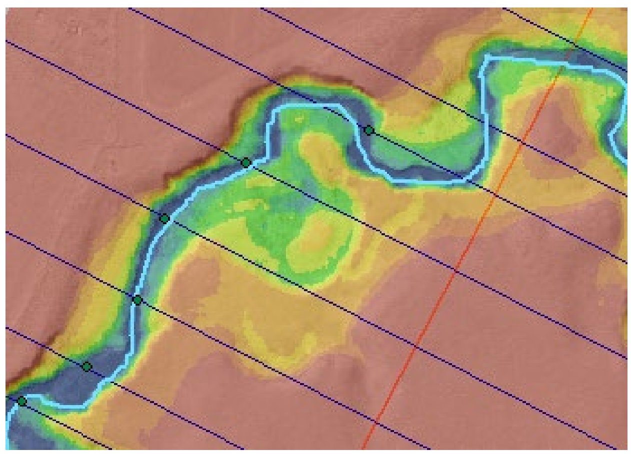
Coal Creek

All REMs for the Coal Creek and Golden area SMCs were generated using cross-sections that were derived from a general valley centerline at a cross-section spacing of 100ft (Coal Creek Corridor) and 50ft (Golden SMCs).

- REMs for Coal Creek were successful in identifying relict stream channels and reveal depositional areas. The detection of relict stream channels in this reach can assist mapping the Active Stream Corridor by indicating areas of potential future and past stream migration.

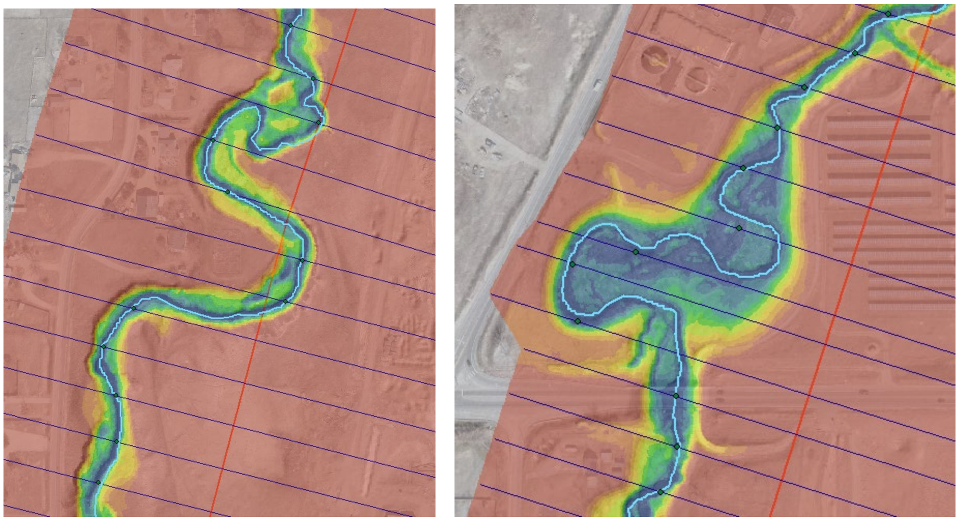


Relict stream channels and depositional features can be seen in the above REM of a portion of Coal Creek

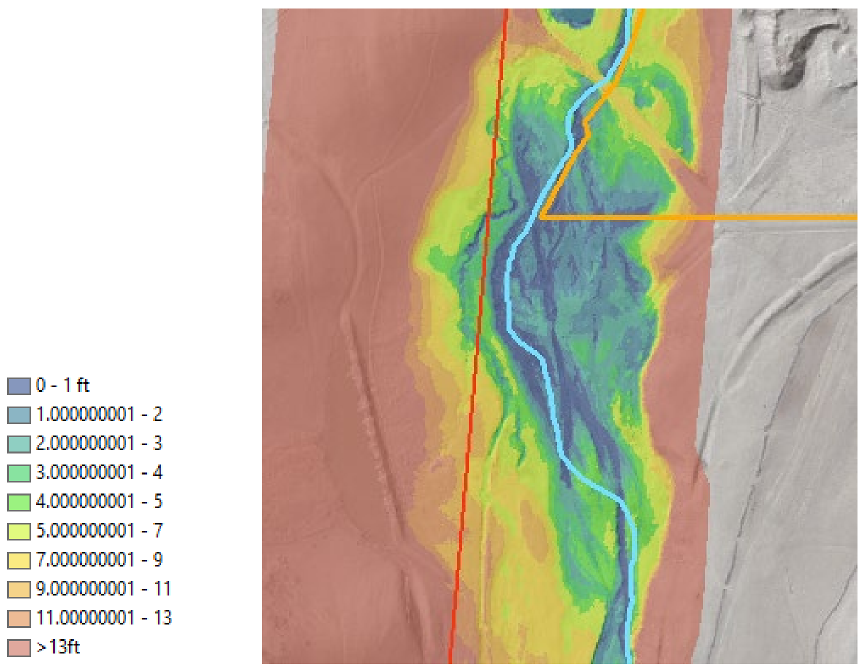


Relict oxbow can be seen in this confined reach of Caol Creek

- Confined corridors were also identified along Coal Creek and evidence of an incised stream or vertical erosion can be seen within the REM. The stream in this section of the reach is heavily confined by development on both sides of the corridor. Small abrupt changes in relative elevation can be seen.



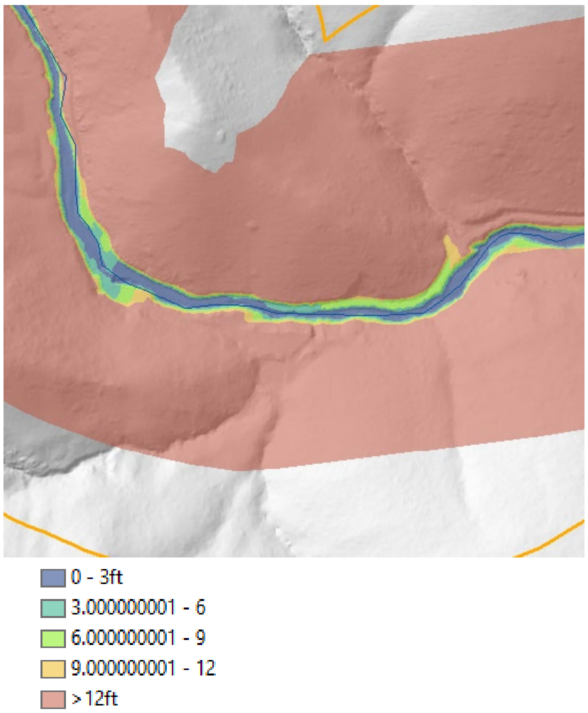
Example of extremely confined cooridor along Coal Creek with development influencing both sides of the cooridor.

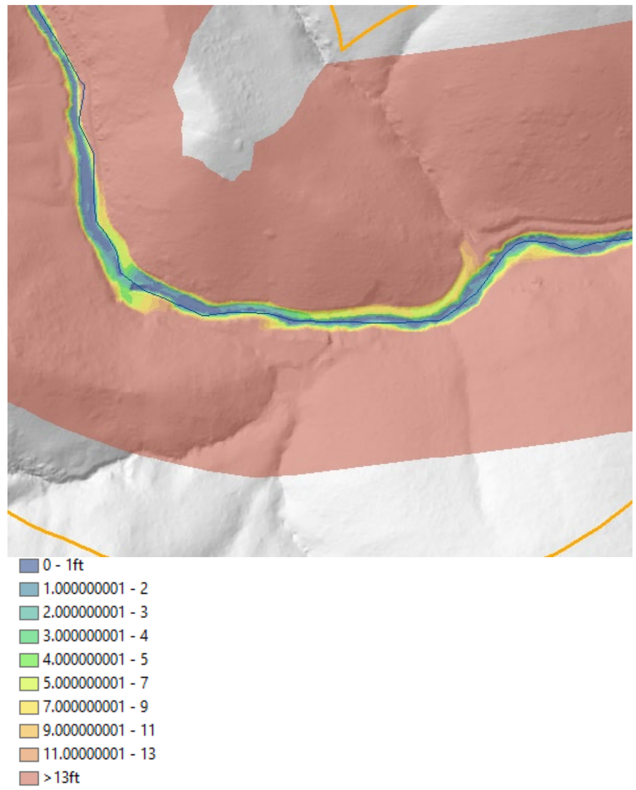


An area of gradual reletive elevation increases on both sides of Coal Creek

Golden – Steep and Narrow Stream Corridors

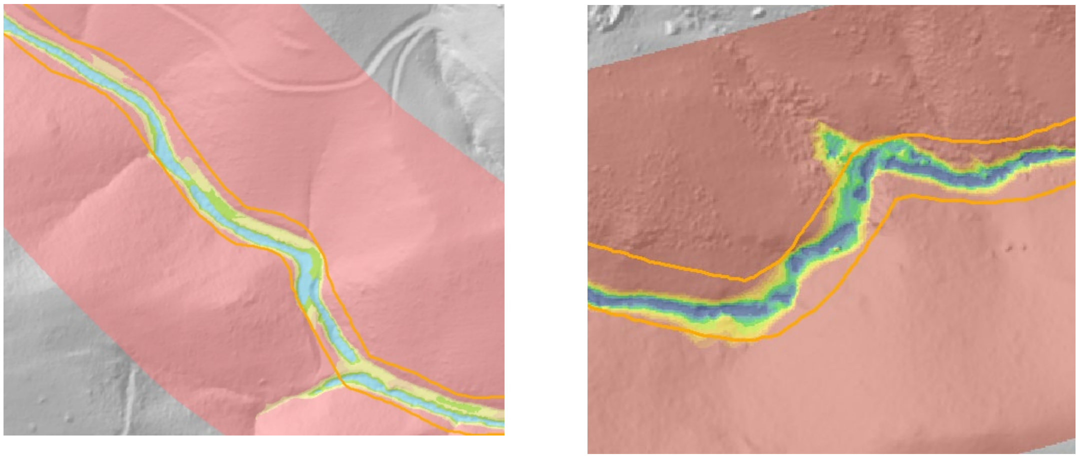
- In steep, narrow, stream corridors, the use of REMs was only marginally effective at identifying signs of small terracing and floodplain development. This is expected given the steep and narrow nature of the surrounding topography.
    - Classifying REMs at 1ft breaks and 3ft breaks did not change the visual interpretation of the REM or provide any additional insight to potential terracing in steep narrow corridors.
        - Typically, known bankfull heights can be used to set classification breaks for the REM.





Cressmans Gulch near Golden: Comparison of different classificaiton breaks for REM visualization and interpretation

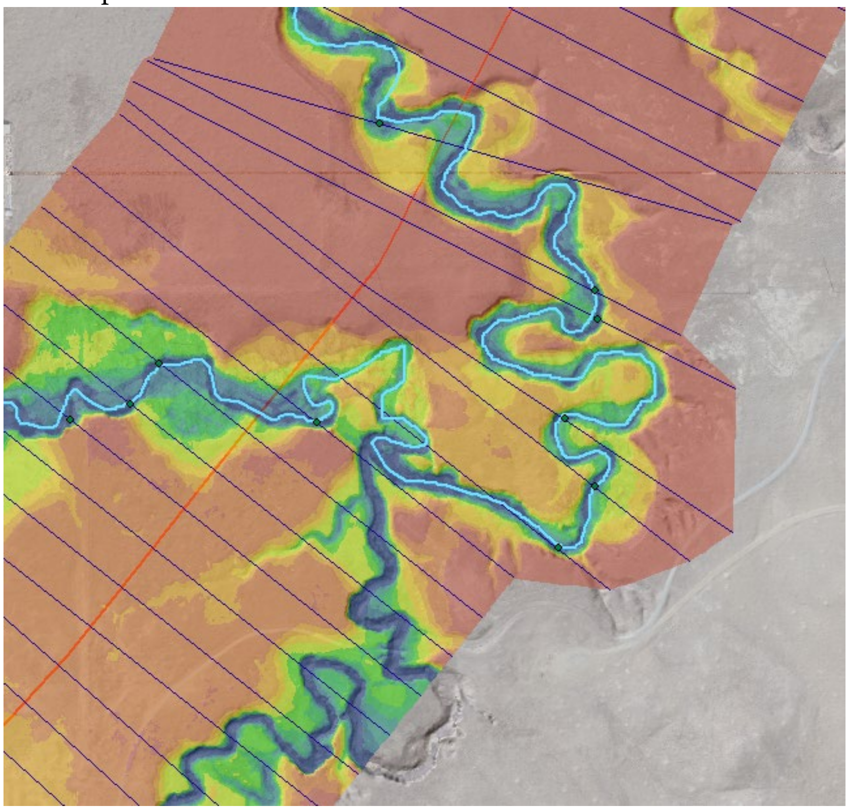
- Overall, across all the Golden area headwaters reaches where REMs were produced, the 50ft headwater protocol buffer (CWCB, 2020) largely conforms to the REM, and in some instances (Magpie Gulch, Indian Gulch), overestimates the extent of the stream channel. This suggests that using a 50ft buffer could be valid for Active Stream Corridor delineation.



Left: 50ft headwaters protocol buffer with REM of Halfile Gulch in Golden. Relatively close agreement. Right 50ft headwaters protocol buffer with REM of Magpie Gulch. Potential overestimation of ASC

REM Lessons Learned

- Using a valley centerline to generate cross-sections and to develop REMs appears to not yield acceptable results in extremely sinuous stream reaches, and in areas where there is a confluence of two reaches. In these scenarios, it is challenging to prevent the cross-sections of the valley centerline from intersecting the actual stream centerline in multiple places.
    - When the cross-section intersects the steam centerline multiple times, it appears the REM tool still grabs the lowest channel elevation of the intersections, however, the resulting REM does not appear to capture relative elevation correctly. This may likely be due to channel elevations not being properly extrapolated outward from the channel for proper interpolation.
        - Caution should be used when interpreting relative elevation in areas where the above scenario is true.
        - In these scenarios it may be useful to spend more time on manual cross-section manipulation.



An extremelly sinuous section of Coal Creek and a tributary. Cafeful interpretation of reletive elevation values shoud be used I these areas.

- If applicable, tributaries should be evaluated separately.
    - Appendix C also mentions that at confluences, cross-sections should cross each (primary reach and tributary) at the same absolute elevation. (CWCB, 2020)
- Overall, the use of a general valley centerline was effective at creating cross-sections with the "Generate Cross-Section" tool and yield highly useful REMs.

REM QA/QC

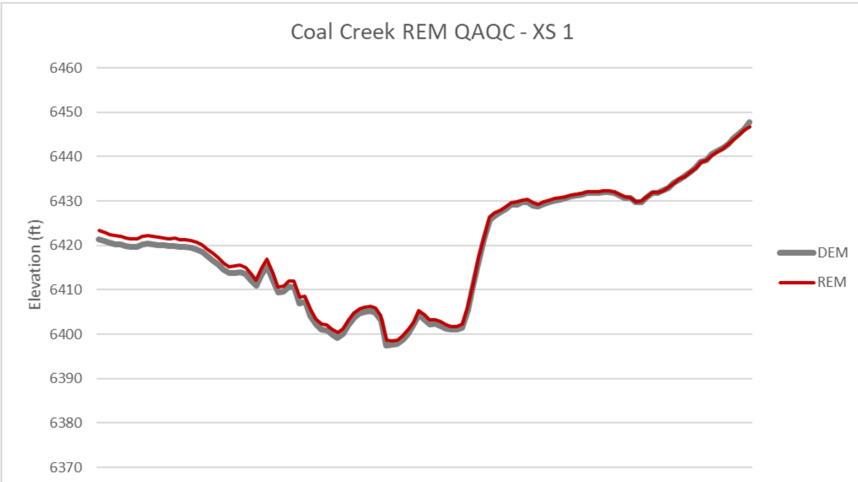
The following section summarizes the results of a QA/QC process followed to quantify and validate the quality of the REM generated from a valley centerline at a spacing of 100 ft. Since the development of REMs rely on the process of interpolation it is recommended that output REMs are validated and adequately represent the earth surface. The results below were completed using a QA/QC method outlined in Appendix C guidance published by CWCB (2020). The goal of the QA/QC process is to compare the deviation between the REM and the source DEM along a separate set of user defined cross-sections, here described as "QA/QC" cross-sections.

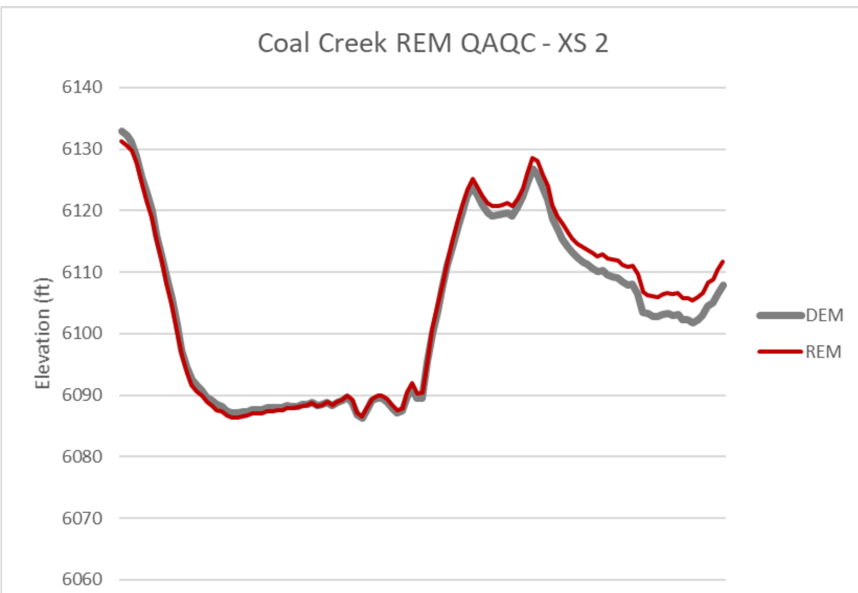
- Separate cross-sections independent from cross-sections used to generate the REM were created specifically for the QA/AC process. Five QA/QC cross-sections were created for the study reach along Coal Creek spanning the width of the REM.
- Absolute and relative elevations were extracted at 10-foot intervals along each QA/QC cross-section.
- REM and DEM minimum channel elevations were equalized by determining the z=0 lowest channel elevation and adding this value to the extracted relative elevation value. The lowest point shapefile created by the REM tool assisted in determining the z=0 point and associated absolute elevation.
- The absolute vertical distance between the extracted DEM and REM values were calculated by subtracting the equalized elevation value from the absolute (DEM) elevation value.
- The DEM and REM elevations extracted along the QA/QC cross-section were plotted to observe the variation between the two elevation surfaces (see figures below).
- For each QA/QC cross-section the Root Mean Square Error (RMSE), mean, median and 75th percentile was determined for the absolute vertical distance deviations between the DEM and REM values (see summary statistics below).
- XS 1, XS 2, XS 3, XS 4, XS 5 progress from furthest upstream to furthest downstream respectively.

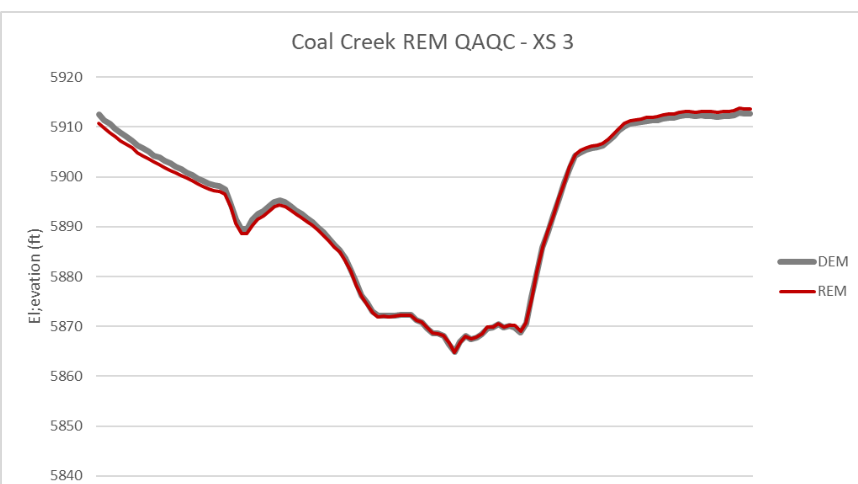
XS 1:		XS 2		XS 3		XS 4		XS 5	
RMSE	1.073682	RMSE	1.852881	RMSE	0.800138	RMSE	0.724589	RMSE	0.640134
Mean	-0.84959	Mean	-0.9296	Mean	0.223263	Mean	0.397669	Mean	-0.48526
Median	-0.91655	Median	-0.74132	Median	0.085628	Medain	0.388185	Median	-0.47092
75th Percentile	-0.31494	75th Percentile	0.514163	75th Percentile	0.926922	75th Percentile	0.935262	75th Percentile	-0.1554

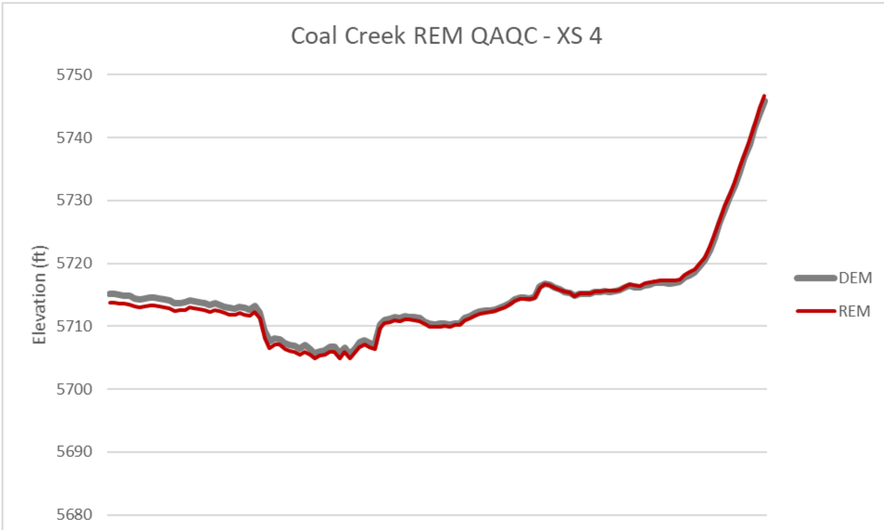
Statistic	Recommended Maximum Value[1]
Root Means Square of Absolute Value	0.75 feet
Mean and Median of Absolute Value	1.0 feet
75th Percentile of Absolute Value	1.25 feet

The summary statistics above demonstrate that most of the elevation samples across each QA/QC cross-section fall within the "Recommended Maximum Value" recommended by CWCB as an approximate industry standard threshold suggested for accurate FHZ mapping. The RMSE greater than the recommended maximum value of 0.75 feet in XS 1 and XS 2 can be explained by the deviation of the REM and DEM values at the valley wall, this is seen in the plots below for XS 1 and XS 2 (larger separation between DEM and REM lines). Since relative elevation at or above the valley walls is not usually of significant interest to the FHZ mapper, these variances can be accepted, as long as the relative elevation and absolute elevation variances are minimal within the channel, and in study areas where fluvial hazards are needed to be accurately visualized in the REM.


Coal Creek REM QAQC - XS 1
Elevation (ft)
6460
6450
6440
6430
6420
6410
6400
6390
6380
6370
DEM
REM


Coal Creek REM QAQC - XS 2
Elevation (ft)
6140
6130
6120
6110
6100
6090
6080
6070
6060
DEM
REM


Coal Creek REM QAQC - XS 3
El;evation (ft)
5920
5910
5900
5890
5880
5870
5860
5850
5840
DEM
REM



The REM QA/QC summary statistics and plots above demonstrate that a REM developed from cross-sections derived from a valley centerline and spaced at relatively close intervals (100 ft) produce REMs suitable for FHZ mapping. This validates the REMs developed for the study reach on Coal Creek and this QA/QC process should be applied to all REMs developed on any study reach to quantitatively measure the REM's suitability for stream management corridor mapping.