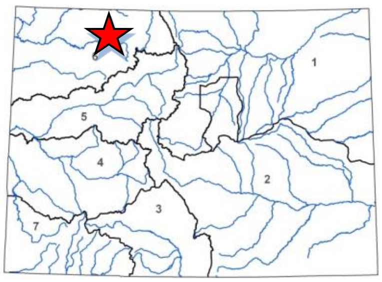
COLORADO
Colorado Water Conservation Board
Department of Natural Resources

Lower Elkhead Creek Restoration Project, Phase I
Trout Unlimited
January 2020 Board Meeting

Colorado Watershed Restoration Program Application



L O C A T I O N	
County/Counties:	Moffat & Routt
Drainage Basin:	Yampa

D E T A I L S	
Total Project Cost:	$1,464,000
Colorado Watershed Restoration Program Request:	$100,000
Recommended amount:	$100,000
Other CWCB Funding (pending WSRF):	$200,000
Other Funding Amount:	$1,139,000
Applicant Match:	$25,000
Project Type(s): Design and Construction	
Project Category(Categories): Watershed and Stream Restoration	
Measurable Result: 5 miles of channel restored	

Trout Unlimited (TU), in collaboration with Natural Resources Conservation Service (NRCS), will coordinate Phase 1 of a two-phased approach to restoring lower Elkhead Creek, an approximate 9-mile stretch of creek below Elkhead Reservoir that has experienced high to severe erosion and habitat degradation. Phase 1 of lower Elkhead Creek restoration will focus on the first five miles of creek directly downstream of the reservoir. For several years, TU and NRCS have worked to provide technical assistance to agricultural producers in the Phase 1 project area, including going out on site visits to identify resource concerns and priority sites along the creek, conducting visual stream health and wildlife habitat assessments, collecting survey data, and doing preliminary engineering design work. Technical assistance has also included conducting an extensive review of existing hydrology data, geomorphology reports and historical information pertaining to lower Elkhead Creek. Landowners on lower Elkhead Creek, with TU's assistance and facilitation, are currently in the process of forming a collective group that is centered around their shared concerns, issues, and visions for the creek.

The goals of Lower Elkhead Creek Restoration Project, Phase 1, are to 1) stabilize the creek channel, 2) increase system resiliency to flooding, drought, reservoir management and human activity, 3) provide tangible benefits to local agriculture and wildlife, 4) improve water temperature and water quality, and 5) support and maintain consumptive and non-consumptive water needs in the Yampa River Basin. This project aligns with priorities identified in multiple documents, including the 2014 Upper Yampa River State of the Watershed Report, the 2015 Yampa/White/Green Basin Implementation Plan, the 2015 Colorado Water Plan and the 2016 Upper Yampa River Watershed Plan. This project will further the goals and activities established in such documents for the Upper Yampa River and its watershed.

Project Objectives
- Continue to facilitate landowner meetings and formation of a collective group
- Conduct remaining field work necessary to construct projects
- Conduct remaining engineering and design work necessary to construct projects
- Complete NRCS planning necessary to apply for NRCS funding and to construct projects
- Assist producers with contracting procedures and procurement of project materials
- Implement restoration projects in the Phase 1 project area
- Monitor and assess pre- and post-project conditions and effectiveness of implemented construction techniques

Project Proposal Summary Sheet

Project Title: Lower Elkhead Creek Restoration Project, Phase 1
Project Location: refer to attached maps and project boundary coordinates
Grant Type: CWCB Colorado Watershed Restoration Program
Grant Request/Amount: $100,000
Cash Match Funding: CWCB WSRF funding: $200,000 (pending grant approvals)
Other funding: $1,045,000 ($65k secured, remaining funds pending grant awards, NRCS contracts and other 3rd party commitments)
In-Kind Match Funding: $119,000
Project Sponsor: Trout Unlimited
Project Contact: Kaitlyn Vaux, Yampa/White River Basin Project Coordinator
Address: PO Box 770610 Steamboat Springs, CO 80487
Email: kvaux@tu.org

Project Background and Description

Trout Unlimited (TU), in collaboration with Natural Resources Conservation Service (NRCS), will coordinate Phase 1 of a two-phased approach to restoring lower Elkhead Creek, an approximate 9-mile stretch of creek below Elkhead Reservoir that has experienced high to severe erosion and habitat degradation. Phase 1 of lower Elkhead Creek restoration will focus on the first five miles of creek directly downstream of the reservoir. For several years, TU and NRCS have worked to provide technical assistance to agricultural producers in the Phase 1 project area, including going out on site visits to identify resource concerns and priority sites along the creek, conducting visual stream health and wildlife habitat assessments, collecting survey data, and doing preliminary engineering design work. Technical assistance has also included conducting an extensive review of existing hydrology data, geomorphology reports and historical information pertaining to lower Elkhead Creek. Landowners on lower Elkhead Creek, with TU's assistance and facilitation, are currently in the process of forming a collective group that is centered around their shared concerns, issues, and visions for the creek.

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Project Objectives

Lower Elkhead Creek Restoration Project, Phase 1, objectives are to:
- Continue to facilitate landowner meetings and formation of a collective group
- Conduct remaining field work necessary to construct projects
- Conduct remaining engineering and design work necessary to construct projects
- Complete NRCS planning necessary to apply for NRCS funding and to construct projects
- Assist producers with contracting procedures and procurement of project materials
- Implement restoration projects in the Phase 1 project area
- Monitor and assess pre- and post-project conditions and effectiveness of implemented construction techniques

Project Tasks

Task 1

Description: Continue to help organize and facilitate landowner meetings.

Task 2

Description: Initiate pre-project monitoring efforts (e.g., water temperature loggers, riparian vegetation plots, soil moisture sensors, riparian monitoring wells, wildlife surveys, cross section surveys, bank erosion estimation, etc.)

Method/procedure: Temperature loggers and riparian monitoring wells will be purchased and installed at several points along the creek (at least three sites within the Phase 1 project area and one outside the project area) to capture any in-stream temperature fluctuations and changes in the water table between pre- and post-project implementation. Vegetation survey plots and photo point monitoring will also be set up to compare pre- and post-project riparian vegetation (e.g., diversity, abundance, survival rate, growth, etc.). Wildlife surveys (e.g., fish and invertebrates), cross section surveys and bank erosion estimates will also be done before and after construction.

Deliverable: TU will submit a pre-project summary of the Phase 1 project area, installation and setup of described monitoring efforts and initial data results.

Task 3

Description: Complete necessary [NRCS] field work, surveying and engineering to implement projects.

Task 4

Description: Complete [NRCS] project planning and contracting

Task 5

Description: Procurement of riparian plantings and other restoration materials

Method/procedure: For riparian vegetation, willow and cottonwood cuttings will be harvested from on-site locations in the spring and sent to the Colorado State Forest Service (CSFS) nursery to grow and develop root stock. The cuttings would then be collected and planted in the fall. Other riparian plants will be purchased directly from CSFS. Additional project materials (e.g., rock, erosion control blanket, stakes, vegetation cages, etc.) will be purchased through local companies and sources, based on competitive prices and quality.

Deliverable: TU will provide a report on the procurement of riparian vegetation and additional restoration materials, including how vegetation was collected/harvested, which species, what plants were purchased through CSFS, planting procedures, and post-planting care (e.g., watering, installing caging, etc.). The report will include photos and a timeline of Task 5 completion. The procurement of additional materials will be inventoried, and a report of what materials are purchased, quantities, and relative costs will be provided.

Task 6

Description: Secure contractors and initiate project construction.

Method/procedure: A contractor or contractors will be determined through a competitive bidding process and attempts to secure contractors with significant riverwork experience will be made. Site visits to the project area will be made in advance of bidding, if needed. Pre-construction meetings will be held between the contractor(s) and the lead project engineer prior to any on-the-ground work. Construction is expected to start in summer/early fall of each year, depending on contractor availability. The lead project engineer will be on site for the beginning of projects to ensure that construction occurs according to engineering designs.

Deliverable: TU will deliver a report on the project bidding process, who was selected and why, progress of construction and when sections are completed (including before and after photos).

Task 7
Description: Conduct post-project monitoring and evaluation

Method/procedure: TU will help to collect post-project data to directly compare with pre-project data. All monitoring data described in Task 2 will be collected after project completion.

Deliverable: TU will submit a summary of Phase 1 project completion and post-project monitoring data compared with initial monitoring results.

Reporting and Final Deliverable
TU will provide CWCB with a progress report every six months, beginning from the date of the executed contract. The progress report will describe the complete or partial completion of the tasks identified in the statement of work including a description of accomplishments, issues if any occurred, and any corrective actions taken. At completion of the project, TU will provide CWCB a final report that summarizes the project and documents how the project was completed.

The Lower Elkhead Creek Restoration Project, Phase 1, is expected to commence in the Summer of 2020 and continue for approximately three years (through 2023).

References

Brown, J. & L. Halliday. 2014. The Upper Yampa River 2014 State of the Watershed Report. Accessed from: https://steamboatsprings.net/DocumentCenter/View/16873/2014WatershedReport_V2_Interactivepdf

Amec & Hydros Consulting. 2015. Yampa/White/Green Basin Implementation Plan. Accessed from https://www.colorado.gov/pacific/sites/default/files/Yampa-WhiteBIP_Full.pdf

Colorado Water Conservation Board (CWCB). 2015. Colorado Water Plan. Accessed from: https://www.colorado.gov/pacific/cowaterplan/plan

Halliday, L. (Upper Yampa Watershed Group). 2016. Upper Yampa River Watershed Plan: Protecting and Managing Long Term Health. Accessed from: https://steamboatsprings.net/DocumentCenter/View/8714/Upper-Yampa-Watershed-Plan---May-2016?bidId=

Lower Elkhead Creek Restoration Project, Phase 1

Qualifications Evaluation

1. The lead project sponsor is Trout Unlimited. Trout Unlimited (TU) is working closely with the Natural Resources Conservation Service (NRCS) to assist agricultural producers on lower Elkhead Creek. The U.S. Fish and Wildlife Service (USFWS) Partners for Wildlife Program is also a stakeholder in Phase 1 of the lower Elkhead Creek restoration project and is providing technical and financial assistance. Other stakeholders include the Colorado River District and private landowners, and additional stakeholders are still to be determined (e.g., City of Craig, Tri-State Generation and Transmission Association, etc.)

2. In-kind services will come from the NRCS, TU and private landowners, in the form of engineering assistance, pre- and post-project monitoring and evaluation, and aspects of project implementation (e.g., fence-building, riparian plant harvesting and/or planting, etc.) Current pledged match contributions include those from the NRCS, TU, USWFS Partner for Wildlife Program, the Colorado River District and landowners. Additional contributions from other entities are still being discussed and to be determined.

Organizational Capacity

1. Trout Unlimited works nationwide to conserve, protect and restore coldwater fisheries and their watersheds, and partners with producers interested in improving agricultural operations and aquatic habitat. TU has had an on-the-ground presence in Northwest Colorado for nearly ten years, and projects to date have involved irrigation infrastructure improvements and efficiency upgrades, riparian habitat restoration, instream flow and habitat improvements, and the protection of native trout habitat. TU has collaborated and partnered with federal agencies (e.g., NRCS, Bureau of Land Management (BLM), U.S. Forest Service (USFS), U.S Fish and Wildlife Service (USFWS), U.S. Geological Service (USGS)), state agencies (e.g., Colorado Parks and Wildlife (CPW), Colorado State Forest Service (CSFS)) and local NGOs and groups (e.g., The Nature Conservancy, Colorado Cattleman's Agricultural Land Trust, Upper Yampa Watershed Group, River Network, Friends of the Yampa)).

2. Team Leads:

- **TU's Yampa-White Project Coordinator - Kaitlyn Vaux:** Kaitlyn is the Yampa-White Project Coordinator for Trout Unlimited and a partner biologist with NRCS. She has worked with landowners on lower Elkhead Creek for more than two years, has in-depth knowledge of the issues at hand and has secured funding for this project from other entities. Kaitlyn will serve as the grant and project manager, helping to oversee planning, construction and pre- and post-project monitoring. Time spent per week: 12 hours
- **NRCS District Conservationist - Kendall Smith:** Kendall is the NRCS District Conservationist (DC) for Moffat County, has extensive knowledge of NRCS procedures and has supported providing technical and financial assistance to landowners on lower Elkhead Creek. Kendall will assist with NRCS planning and contracting efforts. Time spent per week: 3 hours
- **NRCS Stream Restoration Engineer - TJ Burr, PE**: TJ is NRCS Colorado's Stream Restoration Specialist. TJ has worked as a civil engineer since graduating from the University of Wyoming in 1986, and for the past 10+ years has specialized in designing stream restoration projects. TJ has invested significant time and engineering assistance to landowners on lower Elkhead Creek and will continue to act as lead project engineer. Time spent per week: 10 hours
- **Lower Elkhead Creek Representative – TBD:** A landowner will be voted on by his/her neighbors to represent the collective group of lower Elkhead Creek landowners and be the lead

contact person regarding any information and decision-making pertaining to the Phase 1 project area and restoration work.

- **General Contractor(s) – TBD:** A contractor or contractors will be determined through a project bidding process, and attempts to secure contractors with significant riverwork experience will be made.

3. The project budget is based on material quantities and construction cost estimates computed by the lead project engineer, who has had more than ten years' experience designing and implementing NRCS stream restoration projects. To finetune project cost estimates, several preliminary designs of Phase 1 project work were provided to local contractors in summer 2018 to get estimates, which were comparable to those computed by the lead project engineer. For anticipated project timeline, please refer to the budget/timeline spreadsheet. All tasks identified to receive CWCB funding would take place after funding awards are announced and grants are contracted.

Proposal Effectiveness

1. The project team has used a wide array of background information to develop the proposed project. The lead project engineer has utilized reports (USGS, 1999 and 2011) that looked at Elkhead Creek meander migration rates as well as sediment and channel-geometry and estimated hydraulic conditions to determine the probable cause of accelerated streambed and streambank erosion on lower Elkhead Creek. Hydrology data from USGS stream gauges 09246500 and 09246200 (located on Elkhead Creek below and above Elkhead Reservoir, respectively) as well as StreamStats reports helped determine best restoration practices and engineering designs. In addition to those reports, the project team conducted visual stream health and wildlife habitat assessments, collected elevational survey data, reviewed soil reports, gathered anecdotal accounts of the creek from landowners and utilized other relevant historical information to best inform this project (please refer to the complete list of references provided in the attached *NRCS Design & Geomorphology Report, 2019*).

2. This project has multiple objectives and benefits and aligns with goals identified in the Upper Yampa River Watershed Plan, Yampa/White/Green Basin Implementation Plan and the Colorado Water Plan. The project will 1) restore threatened and imperiled plant communities, 2) support environmental non-consumptive water needs, 3) protect local agriculture and decreed pre-compact water rights for future water use, 4) promote long-term sustainability and resiliency of the Elkhead Creek ecosystem, and 5) maintain and improve watershed health. This project will also provide benefit to municipal and industrial (M&I) water released out of Elkhead Reservoir by stabilizing the conduit (i.e., lower Elkhead Creek) through which that water flows in order to get to its intended users.

3. The project will be implemented with the intent of mitigating bank instability and erosion, restoring the native riparian corridor, promoting floodplain connectivity and creating healthier working lands in the lower Elkhead Creek valley. The objectives of the project will be achieved by continuing to provide technical assistance to landowners on lower Elkhead Creek, determining best management practices and engineered options for active restoration efforts, and securing funding in order to move forward and implement projects.

Project monitoring will include pre- and post-project data collection in order to gauge restoration success. Monitoring will include the use of temperature loggers, photo point assessments, wildlife surveys, soil moisture sensors, cross-section surveys, bank erosion estimation, riparian monitoring wells, and visual stream health and wildlife habitat assessments. The data collected from these monitoring efforts will help measure the success of the proposed restoration actions and guide future riparian restoration applications.

Project Budget

Task	Description	Target Start Date*	Target Completion Date*	CWCB Funds**	Other Funding Cash***						Other Funding In-Kind	Total
					CPW	NRCS	TU and USFWS	Landowners	Colorado River District	TBD⸸		
1	Facilitate landowner meetings	Aug 2019	Jan 2020		-	-	-	-	-	-	$500 (TU)	$500
2	Pre-project monitoring	June 2020	July 2022	$5,000 (CWRP)	-	-	-	-	-	-	$1,500 (TU)	$6,500
3	Complete necessary field work, surveying and engineering	June 2020	Dec 2020	-	-	-	-	-	-	-	$100,000 (NRCS)	$100,000
4	Complete NRCS planning/contracting	Jan 2020	May 2021	-	-	-	-	-	-	-	$5,000 (NRCS)	$5,000
5	Procurement of project materials	June 2020	March 2023	$95,000 (CWRP) $150,000 (WSRF)	$150,000	-	$25,000	$65,000	$5,000	-	$2,500 (landowners)	$492,500
6	Implement project construction	Aug 2020	Oct 2023	$50,000 (WSRF)	-	$700,000 (NRCS)	-	-	-	$100,000	$7,500 (landowners)	$857,500
7	Post-project monitoring and evaluation	July 2021	Oct 2026	-	-	-	-	-	-	-	$2,000 (TU)	$2,000
	Totals			$300,000	$150,000	$700,000	$25,000	$65,000	$5,000	$100,000	$119,000	$1,464,000

* Project task start and end dates relating to NRCS contracts will depend upon NRCS funding that is available and secured in FY 2020 versus FY 2021. Different sections within the Phase 1 project area will likely be addressed in 2020, 2021 or 2022 depending on the timing of securing NRCS funding.

** Pending grant approvals

*** To date, $65,000 of Other Funding Cash have been secured ($5k from TU, $5k from USFWS, $45k from NRCS and $10k from landowners). Additional cash amounts are still pending.

⸸ e.g., City of Craig, Tri-State Generation and Transmission Association, Inc

CWRP = Colorado Watershed Restoration Program

WSRF = Water Supply Reserve Fund (Local and State)

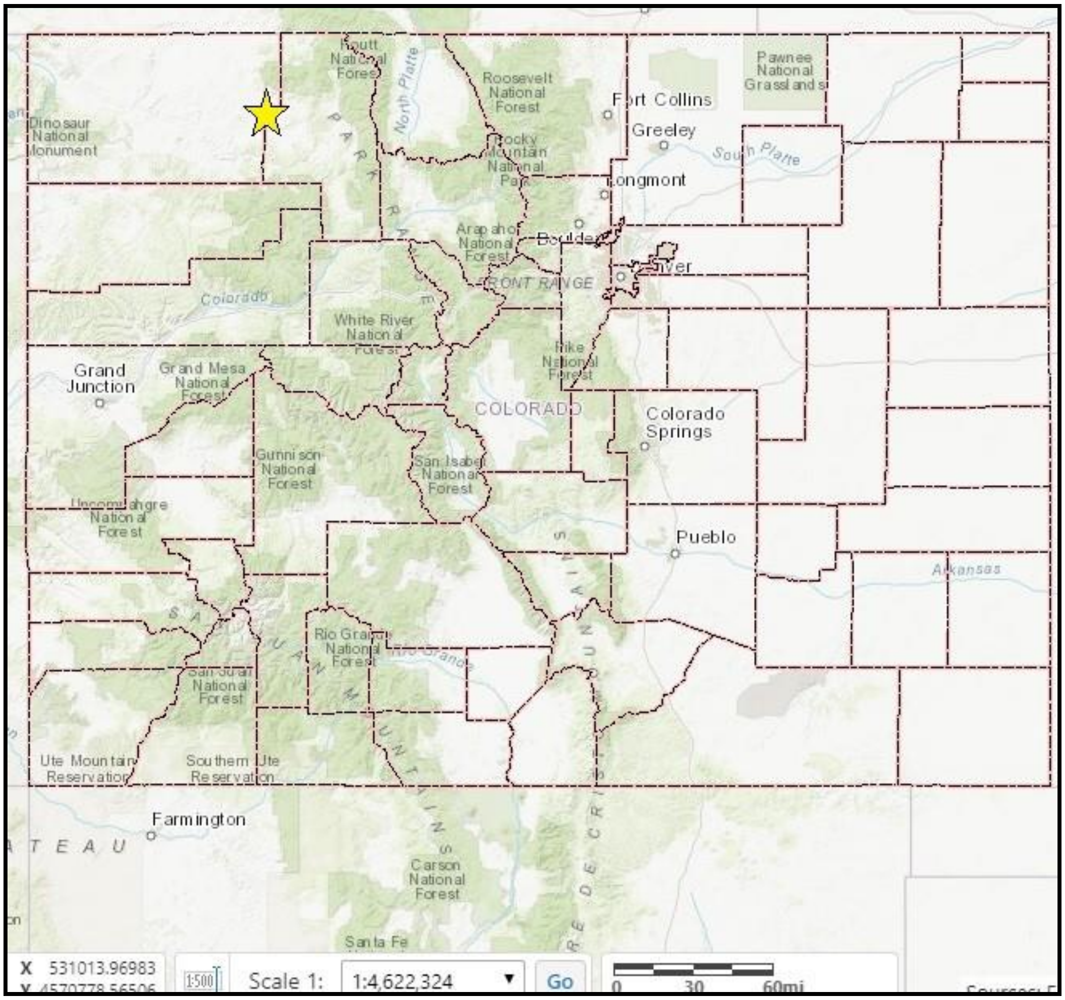


Photo 1. Location of Phase 1 project area within the state of Colorado.

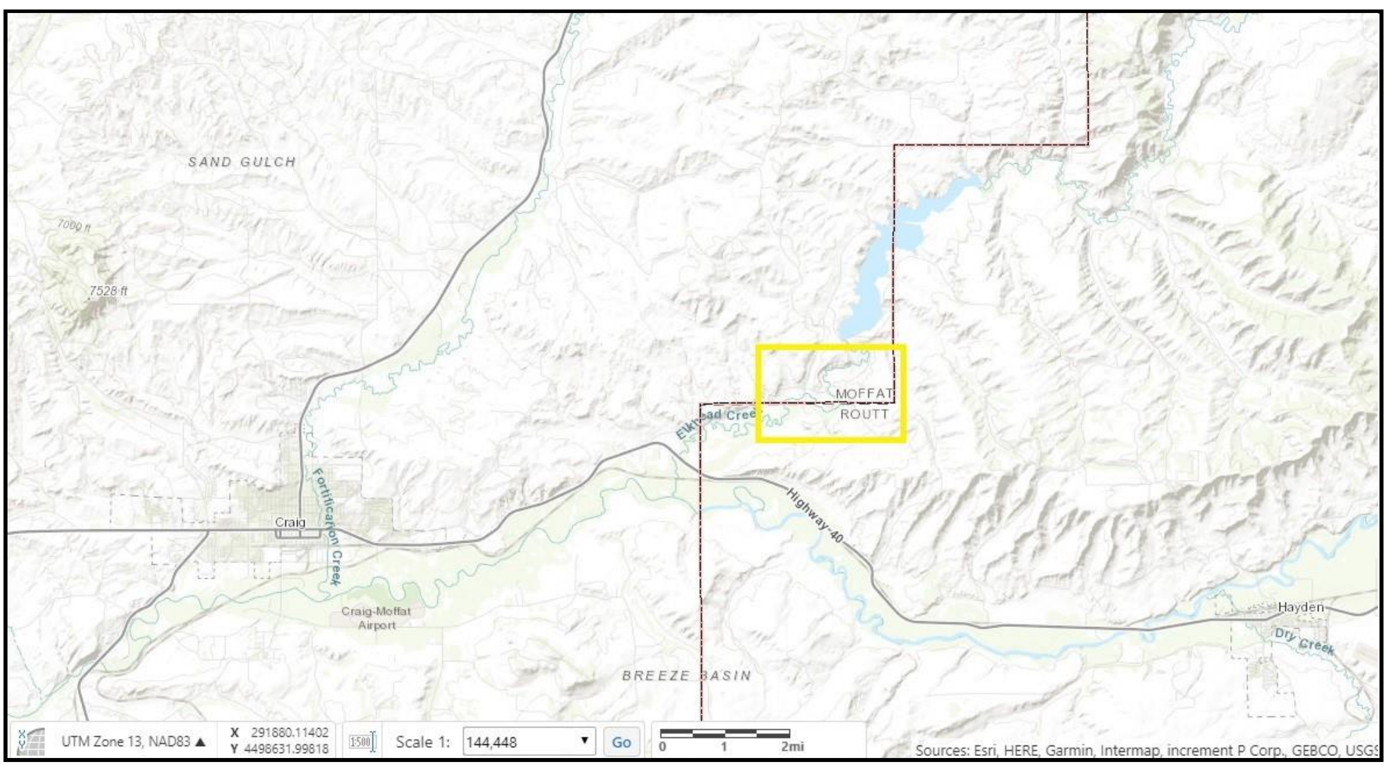


Photo 2. Location of Phase 1 project area, relative to the towns of Craig (Moffat County) and Hayden (Routt County), CO.

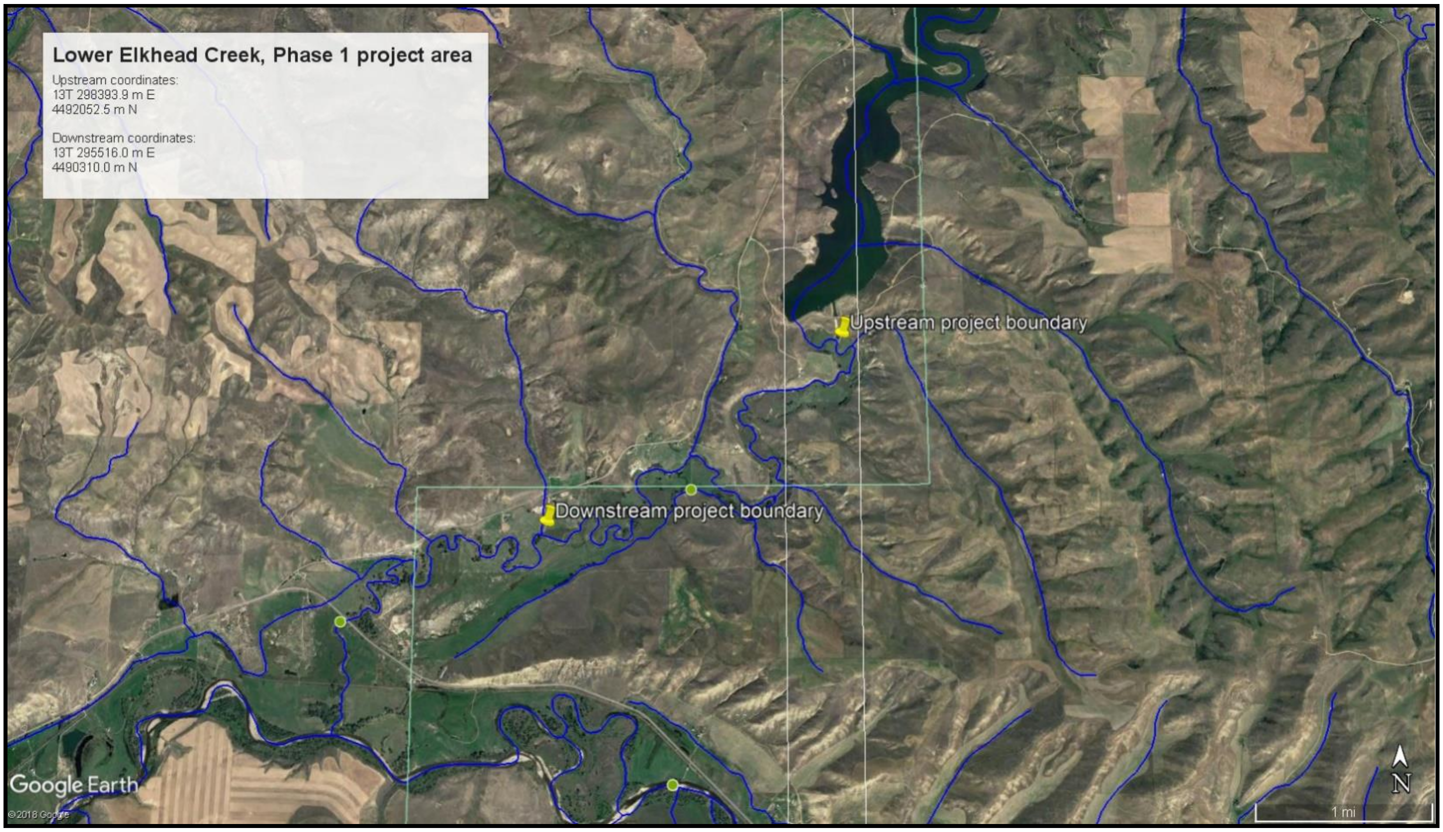
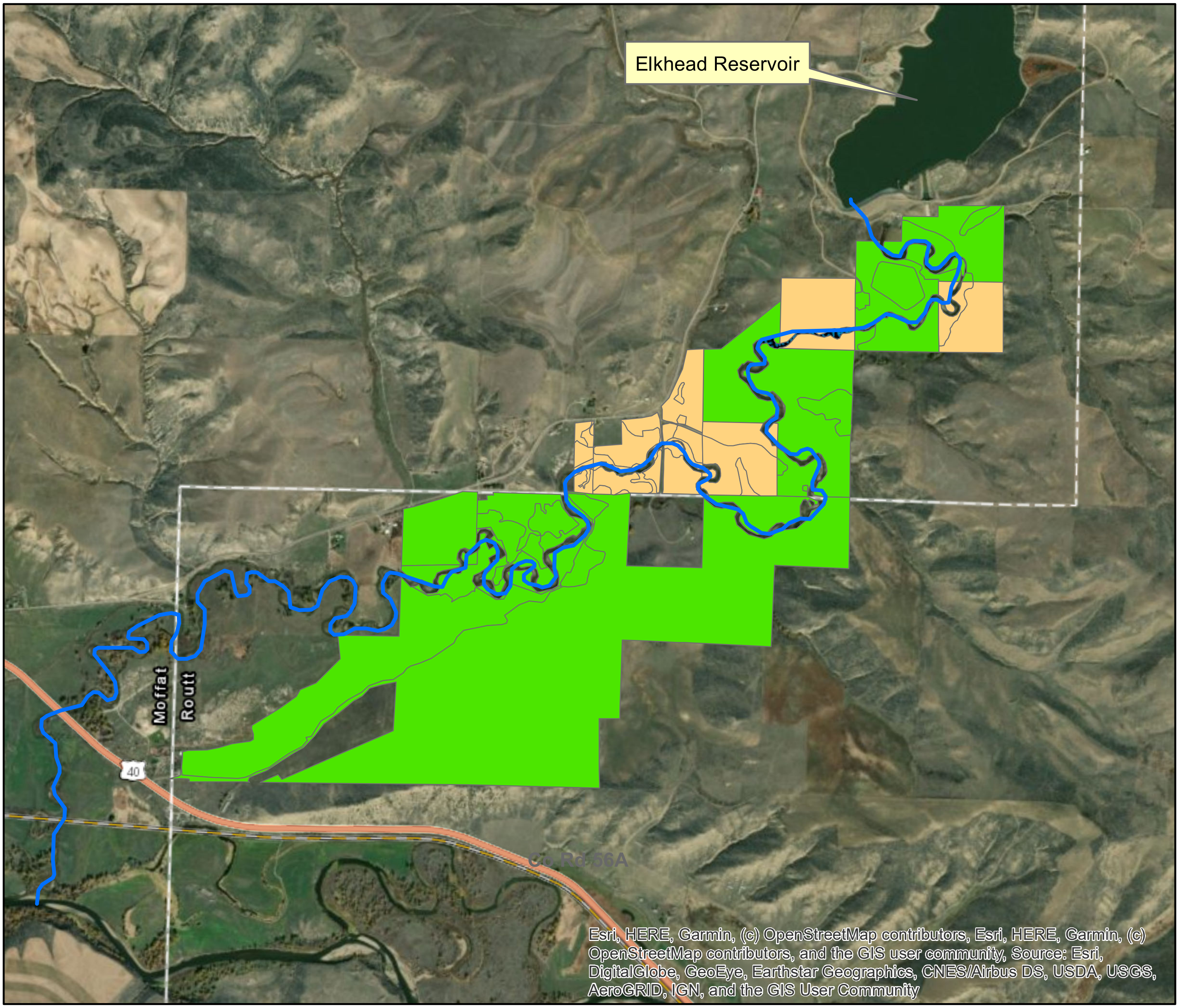


Photo 3. Upstream and downstream coordinates of the Phase 1 project area.

Lower Elkhead Creek Restoration Project
Phase 1

Date: 09/25/19
Counties: Moffat and Routt



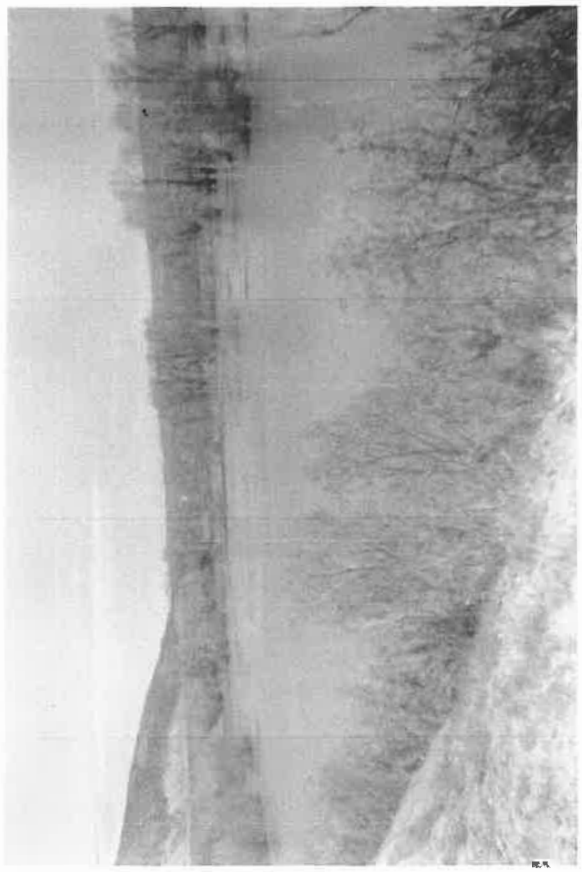
Legend

Surveyed
Unsurveyed
Elkhead Creek

N

0 0.25 0.5 1 Miles

Photos of lower Elkhead Creek taken in 1970 (pre-Elkhead Reservoir) by a landowner residing on the creek. Photos suggest high floodplain connectivity, frequent inundation, and presence of riparian vegetation.



Photos of lower Elkhead Creek taken in 1970 (pre-Elkhead Reservoir) by a landowner residing on the creek. Photos suggest high floodplain connectivity, frequent inundation, and presence of riparian vegetation.

Photos of lower Elkhead Creek in Spring 2018. Photos indicate excessive bank erosion and habitat degradation (photos were taken with permission from private landowners).

1. Steep vertical banks and floodplain disconnection.

2. Continued bank erosion and loss of bank stabilizing vegetation.

3. Looking upstream at the Elkhead Reservoir spillway and adjacent agricultural land.

4. Excessive erosion putting existing irrigation infrastructure at risk.

5. Location of where an irrigation pipeline used to cross the creek but was washed away.

Yampa-White-Green Basin Roundtable

Chris Sturm
Colorado Water Conservation Board
1313 Sherman St., Room 721
Denver, CO 80203

October 30, 2019

Dear Mr. Sturm,

I am writing on behalf of the Yampa/White/Green Basin Roundtable in support of the partnership effort to restore lower Elkhead Creek being undertaken by Trout Unlimited (TU), Natural Resources Conservation Service (NRCS), U.S. Fish & Wildlife Service (USFWS) and landowners residing on lower Elkhead Creek. The Yampa/White/Green Basin Roundtable is one of nine Basin Roundtables created in Colorado by the Colorado Water for the 21st Century Act (2006-HB-1177) to encourage locally-driven collaborative solutions to water issues in Colorado.

Lower Elkhead Creek has experienced severe erosion and habitat degradation, and the Phase 1 restoration project proposed by TU aims to address these issues through floodplain reconnection and riparian corridor reestablishment efforts. Floodplain access and riparian corridors are critical elements to a healthy river system, and they provide many ecological functions such as erosion control, water quality improvement and habitat provision for fish and other wildlife. Floodplains and riparian corridors are also natural water storage reservoirs and restoring these areas on lower Elkhead Creek would increase groundwater recharge, support low flow periods and help maintain non-consumptive benefits. The Basin Roundtable supports the proposed restoration efforts on lower Elkhead Creek not only because it will help address local community concerns but will contribute to improving watershed health and maintaining non-consumptive uses in the Colorado River Basin in general.

TU and NRCS have been working with concerned landowners on lower Elkhead Creek to assess individual creek reaches and seek solutions to address habitat degradation and ensure agricultural activities can continue. If funded, this restoration project would allow for the entirety of the Phase 1 project area and its issues to be addressed holistically and stakeholders to plan a comprehensive restoration effort with all landowners involved. The Basin Roundtable supports such efforts that, through community engagement and collaboration, generate benefits for local agriculture and watershed health.

I respectfully urge you to positively consider the Lower Elkhead Creek Restoration Project, Phase 1, and Trout Unlimited's application to the CWCB Watershed Restoration grant program and to provide funding for this project. Obtaining this grant will have a positive outcome for lower Elkhead Creek, landowners residing on the creek and the greater Craig community, and Northwest Colorado. The Yampa/White/Green Basin Roundtable will continue to support this project however it is able to.

With Gratitude,

Jackie Brown

Yampa White Green Basin Roundtable, Chair

United States Department of Agriculture

Natural Resources Conservation Service
[Craig] Service Center
[145 Commerce St.]
[Criag], CO [81625]

Lower Elkhead Creek Restoration: Letter of Support Project Summary

9/17/2019

Chris Sturm
Colorado Water Conservation Board
1313 Sherman St., Room 721, Denver, CO 80203

Dear Mr. Sturm,

The Natural Resources Conservation Service (NRCS) helps landowners to conserve working lands by helping people help the land. The NRCS has received request for assistance along Elkhead Creek for several years to address on going and worsening severe resource concerns. The primary resource concerns identified are bank erosion and habitat degradation. This has led to losses in prime agriculture production and access to water for historic irrigation practices.

Elkhead Creek is a large tributary to the Yampa River northeast of the town of Craig, with a drainage area of approximately 225 square miles. Since the late 19th century, Elkhead Creek's adjacent valley floor has been used for livestock grazing and hay production. Located downstream of Elkhead Reservoir, lower Elkhead Creek is a sediment-impoverished system and has experienced excessive bank erosion and channel incision. Water releases from the reservoir that help maintain minimum flows for endangered fish in the Yampa River alter lower Elkhead Creek's natural flow regime and result in sustained high flows. The creek's transition from a healthy floodplain-connected creek to an incised, disconnected one is evident by steep vertical banks, lack of a riparian corridor and a water table 3-5 feet lower than it historically used to be.

To date, NRCS has provided significant technical assistance and has committed $45,000 (as part of a 2019 EQIP contract) for bank stabilization/riparian restoration work on a section of lower Elkhead Creek. NRCS will continue to support future restoration actions that address identified resource concerns, and will continue to work with interested landowners residing on Elkhead Creek. Collaboration with additional project partners will further help address high priority sites along Elkhead Creek.

In cooperation with Trout Unlimited, NRCS is in full support of continuing assistance for the purpose of addressing identified resource concerns along Lower Elkhead Creek.

Respectfully,

Kendall A. Smith

Kendall Smith
District Conservationist

COLORADO RIVER DISTRICT
PROTECTING WESTERN COLORADO WATER SINCE 1937

October 1, 2019

Yampa/White/Green Basin Roundtable
c/o Colorado Water Conservation Board
1313 Sherman Street, Room 718
Denver, CO 80203

Dear Yampa/White/Green Roundtable Members:

I am writing this letter on behalf of the Colorado River District in support of the Lower Elkhead Creek Restoration Project being undertaken by Trout Unlimited (TU) on behalf of landowners residing on lower Elkhead Creek. Elkhead Creek has experienced erosion and habitat degradation and implementing solutions to restore the riparian area will improve the watershed health and enable agricultural in Lower Elkhead Creek to thrive.

As one of the Elkhead Reservoir partners at the upstream terminus of the project, the River District supports this project as neighbors in the basin. Furthermore, addressing this issue clearly fits the mission of the Colorado River District, to lead in the protection, conservation, use, and development of the water resources of the Colorado River basin for the welfare of the District. Accordingly, the River District has committed $5,000 of funding to the Lower Elkhead Creek Restoration Project.

Thank you for your leadership in addressing this pressing issue on Elkhead Creek.

Sincerely,

Andy Mueller
General Manager
amueller@crwcd.org

U.S. FISH & WILDLIFE SERVICE

DEPARTMENT OF THE INTERIOR

U.S. Fish and Wildlife Service

Partners for Fish & Wildlife

9/30/19

Dear Mr. Sturm,

As the NW Colorado Coordinator and Biologist for the Partners for Fish and Wildlife Program (PFW), it is my pleasure to support the Trout Unlimited Phase 1 Restoration Plan for Lower Elkhead Creek.

Working with private landowners on floodplain connection efforts that include the re-establishment of native riparian corridor and wildlife habitats are of particular interest.

The PFW Program has provided $5,000 in cost share to one of the landowners involved in the effort thus far. Our intention is to continue to assist the other private landowners in Phase 1 efforts as they progress.

I strongly support this effort, and hope that you identify and support this project as a priority for NW Colorado.

Bob

Bob Timberman
NW CO PFW Biologist
(970) 846-5139
bob_timberman@fws.gov

United States Department of Agriculture

Natural Resources Conservation Service
Denver Federal Center Bldg. 56, RM. 2604
P.O. Box 25426
Denver, CO 80225-0426

November 1, 2019

To:
Colorado Water Conservation Board
Attn: Chris Sturm
1313 Sherman St., Room 721
Denver, CO 80203

Subject: **Support for Trout Unlimited for Continuing Work in the Lower Elkhead Creek**

The NRCS supports Trout Unlimited's grant application to continue restoration work on the lower Elkhead Creek near Craig, Colorado. Trout Unlimited has been working with the NRCS and landowners on restoration work since April 2018. Our collaboration has produced stream restoration designs for four landowners, including the rancher who owns the most land that Elkhead Creek passes through. All of these landowners applied for and were accepted for assistance from the NRCS Environmental Quality Incentives Program (EQIP), but the out-of-pocket cost of the projects was too high for most of them.

We are taking a holistic approach to determining restoration work that benefits the entire river from the reservoir to the confluence with the Yampa River. Trout Unlimited completed baseline Stream Visual Assessments for the reaches we have permission to work on. Together, we completed detailed physical surveys of these reaches that include many cross sections and a longitudinal profile of the river. Our evaluation has included a look at the entire watershed along with an in-depth review of available historical documents and reports. More details and a list of references are included in the attached *Design & Geomorphology Report* (NRCS, 2019).

At some point in the past, Elkhead Creek incised by about four feet, which resulted in many adjustments that continue today. Lateral adjustment in the form of bank erosion is the most prevalent effect of the incision. The stream is in the process of establishing a new floodplain at the lower elevation.

There is still a lot of work to accomplish to enhance and stabilize Elkhead Creek. The NRCS will continue to support restoration efforts for Elkhead Creek through appropriate farm bill programs.

If you have any questions, please contact me at tee.burr@usda.gov.

Sincerely,

TJ BURR, PE
Stream Restoration Engineer

Cc: John Andrews, PE, NRCS State Conservation Engineer, Denver, CO
Francine Lheritier, NRCS Area Conservationist, Grand Junction, CO
Kendall Smith, District Conservationist, Craig, CO
Kaitlyn Vaux, Trout Unlimited/NRCS Partner, Steamboat Springs, CO

Atch: Design & Geomorphology Report, TJ Burr, NRCS-CO, 11/1/2019

Streambank Protection Project for

Elkhead Creek

Moffat & Routt Counties
Colorado

Prepared May 9, 2019; Revised: 11/1/2019
By TJ Burr

DESIGN & GEOMORPHOLOGY REPORT

United States Department of Agriculture
Natural Resources Conservation Service

UNITED STATES DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE

Denver, Colorado

Design & Geomorphology Report
Streambank Stabilization on Elkhead Creek

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Introduction and Background

The streambank protection projects for the three landowners, Hamilton, O'Neal, and Pankey are the first of several projects planned for the 9-mile reach between the Elkhead Reservoir and the Yampa River. Streambank erosion rates along Elkhead Creek are high to severe. Several landowners have applied for financial assistance via NRCS Environmental Quality Improvement Program (EQIP). The NRCS and Trout Unlimited are partnering on this project.

The residents and locals who have lived in the area for a long time say that the instability started after the construction of the dam project in 1974 and the enlargement in 2006.

Elkhead Reservoir History (Built in 1974; Enlarged in 2006)

Former capacity: 13,800 acre-feet
Enlarged capacity: 25,550 acre-feet
Cost to enlarge: $31 million
Old dam elevation: 6,378 feet
New dam elevation: 6,403 feet

https://www.coloradoriverdistrict.org/elkhead-reservoir/

Located 9-miles northeast of Craig, Colorado, and straddling the Moffat and Routt County line is one of northwest Colorado's premier flat-water recreational hot spots.

Elkhead Reservoir was originally **constructed in 1974** by Colorado Parks and Wildlife and the Yampa Participants, a consortium of power providers, as an earthen-fill dam with a total capacity of 13,700 acre feet of water for industrial and recreational use. Elkhead Reservoir is an on-stream reservoir on Elkhead Creek a major tributary of the Yampa River.

The watershed upstream of Elkhead drains a 205-square mile basin with a mean annual volume of 75,000 AF and peak flows of up to 2,500 cubic feet per second. The State of Colorado Water Quality Control Division currently classifies Elkhead Reservoir for the following uses Aquatic Life Cold I, Recreation E, Water Supply and Agricultural.

Problems

At some point, a disturbance or large flow caused the stream channel to downcut about 4 feet, as determined from field analysis and surveys. This was the second lowering of the streambed, but the first one was many years before the dam construction. This lowering disconnected the stream from the floodplain and created instability, especially in the banks. During the downcutting, the banks became steep and started eroding, which resulted in many nearly vertical banks with bare earth. The grade flattened. At the new gradient most of the stream power is transferred laterally causing migration of meanders. The channel is evolving and forming a new floodplain at the lowered elevation.

I haven't determined if the dam construction caused the channel incision but is a likely suspect. The reservoir had a major impact on sediment transport through Elk Creek. The sediment drops out in the reservoir, then the flow from the primary discharge pipe is essentially clear water. Without the sediment loading, clear water has more energy to transmit to the beds and banks of the channel.

As part of the stream evolution or during the history of settlement in the valley, cottonwood groves disappeared. There are still remnants of large cottonwood trees in places on the floodplain.

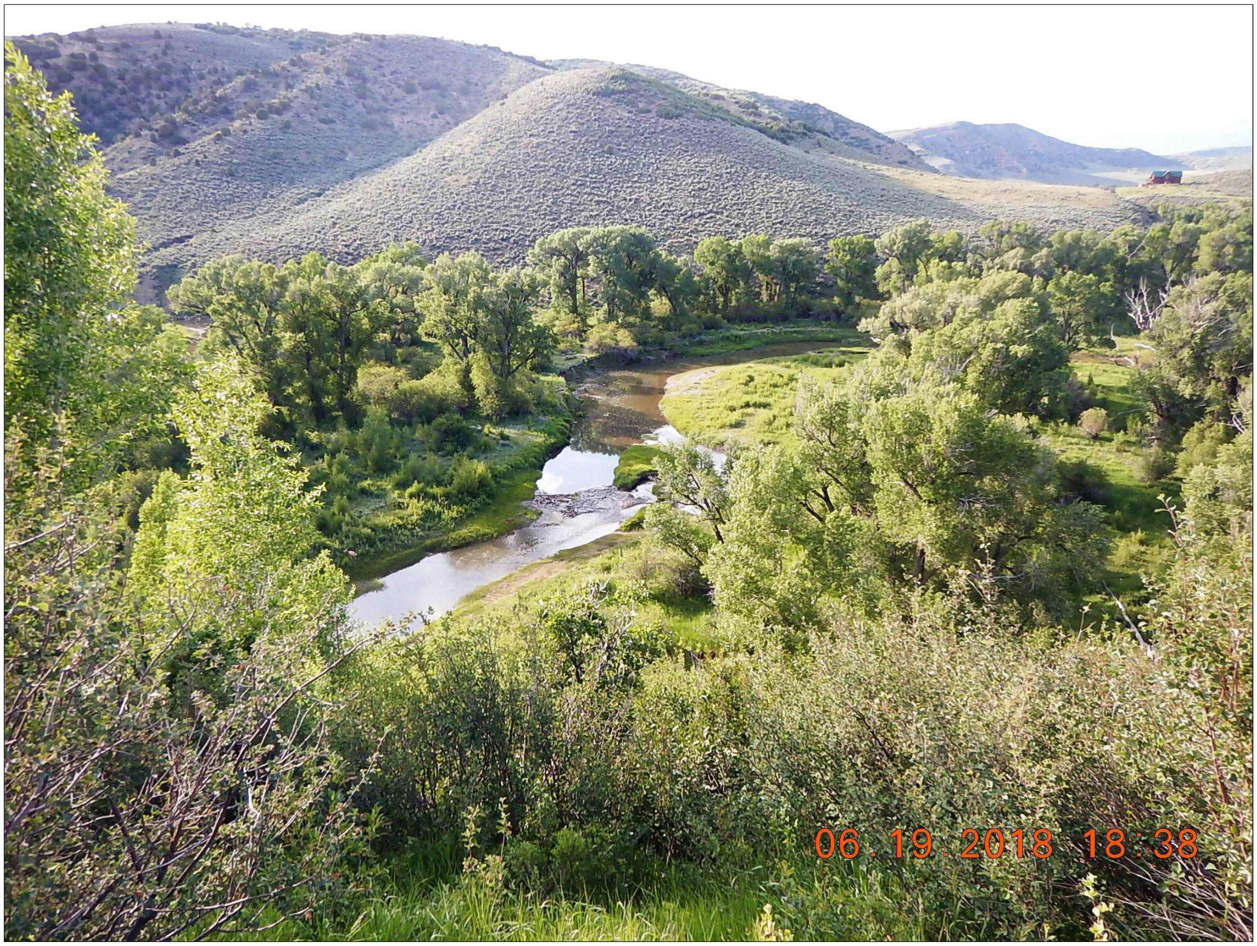


Photo 1: Cottonwood Trees on Elkhead Creek upstream of the reservoir (Photo by: TJ Burr, NRCS)

The USGS published the results of two studies that they conducted, one before and one after the reservoir enlargement project (See References). In their most recent study, concluding in 2009, they stated:

> The presence and operational characteristics of Elkhead Reservoir probably have had both mitigating and exacerbating effects on channel erosion downstream. However, reservoir effects on meander migration rates, if any, were not detectable in periods 3 (1978–93) and 4 (1994–2009). Other factors, such as characteristics of the flood-plain and channel sediments, the variability of climate and streamflow, land-use practices, and intentional manipulation of the channel also affect channel stability and meander migration rates.

Image 1: Aerial image showing the scarcity of cottonwood trees

I concur with the USGS reports but would give more consideration to the testimonies of long-term landowners along Elkhead Creek. One landowner stated that the adjusting stream channel after the dam was built caused trees to fall into the channel as banks eroded. Landowners have also said that the valley used to flood regularly, nearly every spring, but does not any longer. This supports that the incision caused the previous floodplain to be abandoned. Testimony from long-term landowners in the valley provide valuable details about the stability of Elkhead Creek.

As this is an ongoing project, I will continue collecting and analyzing field data as additional sites are added.

Factors that Influence the Stability of Elkhead Creek

- The sinuosity has increased since 1996, changing the stream centerline length from 9.33 to 10.0 miles (from dam outlet to confluence with the Yampa River). This has, in-turn, decreased the stream gradient.
- There has been a significant loss of vegetation partly due to land use and partly due to channel migration and erosion. The mature cottonwood groves that used to exist along Elkhead Creek are gone, except for a few small patches. I'm still looking for historical photos and aerial images to help determine when the vegetation disappeared.
- Decrease in sediment loading due to reservoir. Creates a short term increase in stream power, but additional sediment is added by bank erosion that starts a short distance downstream of the outlet.
- Impact to natural flow regime due to the attenuation of the reservoir.
- With the slope as flat as it is, additional channel incision isn't likely. The major changes will continue to be with lateral migration as the stream struggles to find an equilibrium.
- The loss of overhead canopy and shading has significantly changed the riparian corridor for plant and animal life.

- Bank instability is primarily due to the easily erodible alluvium material in the banks. These banks can be stabilized with shaping and vegetation.

Description of Proposed Project

The proposed project will improve streambank stability and improve water quality using the following methods: bank shaping, bioengineering, live stake planting, re-vegetation, riparian buffers, stabilized stream crossings, and a variety of streambank protection measures.

Natural on-site materials will be used for construction whenever possible. While stabilizing the banks it will be important to maintain the required cross section to convey the bankfull discharge.

The project will be implemented in phases as funding becomes available. The primary source of funding so far is through the NRCS Environmental Quality Improvement Program (EQIP). This funding requires landowners to share the cost and not all landowners can afford the improvements.

Ideally, we would complete the project sequentially from upstream to downstream along the entire lower reach as one comprehensive project.

Project Objectives

Priority Level 4

Dave Rosgen, PhD, defined four levels of stream restoration based on physical and economic constraints. A priority level 1 restoration is the most extensive type of restoration, such as raising a streambed elevation, changing the channel alignment and reconnecting a stream to a floodplain. A priority level 4 restoration involves minor stream work, such as stabilizing a stream in place to reduce bank erosion.

This is a priority level 4 project to stabilize the channel in place using in-stream structures, bank armoring, plantings, and bank shaping to decrease streambank erosion.

Primary Objective (Purpose)

The primary objective of this project is to reduce bank erosion for the entire project reach. Reducing the bank erosion has numerous secondary benefits as shown below. All of the landowners we are working with want to improve the riparian environment as much or more than protect their farmland. They realize the benefits of a stable, healthy stream.

Secondary Benefits

The following are anticipated secondary benefits from the proposed project:

1. Improved water quality through the reduction of sediment loading caused by bank erosion.
2. Enhanced riparian habitat through the addition of vegetation.
3. Fish habitat improvement from the vegetation and water quality improvements.
4. Reduced expenses for farmers and ranches who frequently have to replace their fences.
5. Reduction in the loss of fertile farmland.

Design Basis

Alternatives Considered

The following alternatives were considered for this project:

- The selected alternative is described in the Description of Proposed Project.
- The Do Nothing alternative was considered and dismissed. The landowners want to reduce bank erosion, stabilize the banks, and improve the habitat.
- Various alternatives were considered at individual work sites. The best alternatives were selected on a site-by-site basis. Nearly every method of streambank stabilization is being used across the full length of the project.
- Raising the streambed to reconnect the floodplain was considered and dismissed. The valley hydrology has adjusted to the new streambed elevation. The stream is naturally forming a new floodplain. Raising the streambed elevation would require dozens of channel spanning structures that would be expensive and difficult to maintain.
- Purchasing all of the valley properties and putting the land into a conservation trust. This would give the stream the space to meander back and forth to naturally adjust. This was dismissed as cost-prohibitive.

Design Criteria

The design is based on regime equations, and upstream and downstream cross-section data. The basic principles of fluid dynamics, physics, and standard engineering equations were used.

Project Risks, Challenges, and Uncertainty

- There is an inherent risk with any stream restoration project due to the complexities of natural river systems. This project is hydraulically designed for the bankfull discharge with the expectation that larger flows will overflow onto the floodplain.
- During construction the disturbed streambank is susceptible to damage, but the construction duration will be short to limit this exposure. To limit this risk, the specifications require the contractor to reasonably stabilize the site at the end of each work day.

- The restored streambank is also susceptible to any large flow events after construction, especially before the vegetation is well established.
- Invasive plant species are present at the project site.
- Deer browse has had a significant impact on previous riparian planting efforts and may pose a threat to riparian plantings and natural regeneration in the riparian area.
- A prolonged drought could adversely impact revegetation efforts.

Range of Natural Variability

Natural stream systems operate within a range of parameters while remaining stable. Streams adjust to a wide range of flows with the larger flows spreading out onto the floodplain. Streams move sediment, adjust according to sediment load, and flow variation.

A stream without natural variability is a channel with fixed sides and bottom.

References

Design references, programs, and criteria include the following:

1) *Stream Restoration Design*, Part 654, National Engineering Handbook, USDA NRCS, 2007.
2) *Watershed Assessment of River Stability and Sediment Supply* (WARSSS), Dave Rosgen, PG, PhD, 2006.
3) *RiverMorph 5.0 Hydraulics Program, RiverMorph, LLC, 2007.*
4) Conservation Practice Standards (CPS) used in part or entirety:
    a. Streambank & Shoreline Protection (580)
    b. Stream Crossing (578)
    c. Access Control (472)
    d. Critical Area Planting (342)
    e. Fence (382)
    f. Mulching (484) – Includes erosion control blankets
    g. Open Channel (582)
    h. Riparian Herbaceous Cover (390)
    i. Stream Habitat Improvement (395)
    j. Streambank & Shoreline Protection (580)
    k. Tree & Shrub Establishment (612)
5) *Applied River Morphology* by Dave Rosgen, 1996.
6) Survey Field Work by the NRCS & Trout Unlimited, March 28, 2014. Additional follow-up visits were also made. See Surveying & Site Analysis.

7) HEC-RAS Software, Current Version. US Army Corps of Engineers, Hydrologic Engineering Center.

8) Channel-Pattern and Cross-Section Changes in Selected Reaches of Elkhead Creek, Northwestern Colorado, 1938–2009, USGS, Elliott & Char, 2011.

9) Channel-Pattern Adjustments and Geomorphic Characteristics of Elkhead Creek, Colorado, 1937–97, USGS, Elliott & John G. Elliott and Stevan Gyetvai, 1999.

Watershed Assessment

Methodology

We used a variety of methods to assess the watershed conditions, including historical aerial photography, site visits, discussions with the landowner, review of regional hydrology data, review of other available mapping, published reports, lessons-learned, and a detailed survey using GPS equipment.

Major Disturbances within Watershed

Two of the known major disturbances in the watershed have been: 1) Changes in land use, i.e., conversion to agricultural use; and 2) The original construction and subsequent enlargement of the reservoir.

Surveying & Site Analysis

June 19-22, 2018 – First Survey Data by NRCS

Survey Data from June 19-22, 2018. Survey Leader: Vance Fulton assisted by TJ Burr.

Discharge from reservoir was about 5.5 cfs per July 2018 report.

Three sets of survey data:

Set 1, Steamboat Data Collector-Elkhead 6-19-18: Points BM 1, BM_1, **TBM 3**, TBM_3, 5-7, 45-735, 12000-12629, 14000 (TBM 3 Friday 6-22). TJ collected data points in the 11,000’s. [Edited to create points 1-4 for TBM shots. Saved as *.csv, comma delimited for inserting into Civil 3D] Kendall Smith obtained most of the 3-digit points, 400s, Total Points = **1,329**.

Set 2, elkhead2-6-19-18: Points BM_1 (TBM 1), 1000 - 1519, Kawcak site started with pt 1415. [Many of these points taken by TJ Burr] Total Points = 523.

Set 3, Craig Data Collector-Elkhead 6-20-18: Points 500 (TBM 2), **10000 – 11582** [points by TJ Burr] Total points = **841**.

Sets 1-3, total points = **2,693**.

Surveyed **Pankey Site 1** (at diversion) on morning of 6/21/2018. Kendall recorded survey points in the 400s. TJ’s points in low 11,000’s. I think **Jerry Magas** surveyed the 12,000’s.

Surveyed **Pankey Site 2** on afternoon of 6/21/2018. Vance and TJ.

Surveyed **Pankey Site 3** on morning of 6/22/2018. Vance and TJ. TJ started at point 11,200. Vance surveyed points in the 13,000's. Base station set at TBM 1, checked in with TBM 3.

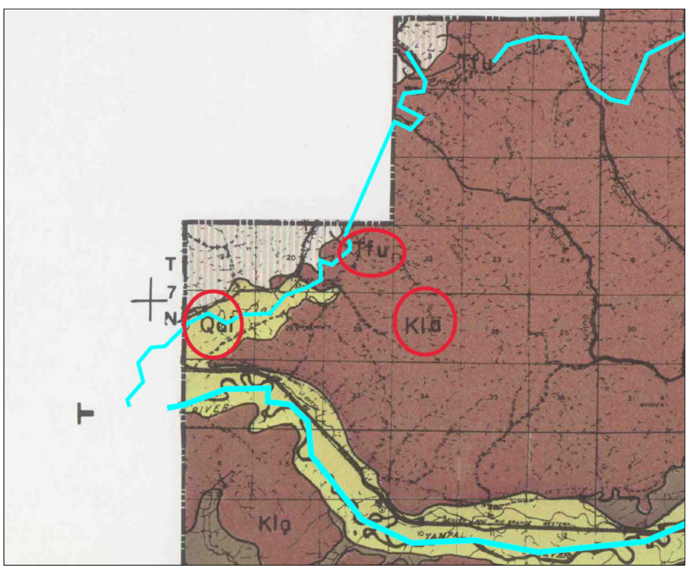
Hamilton Site, Vance surveyed this site on 9/12/2018. Points in 15,000s. total points = 521. After removing duplicate points, there were **221 points**. O'Neal survey points were included in the file.

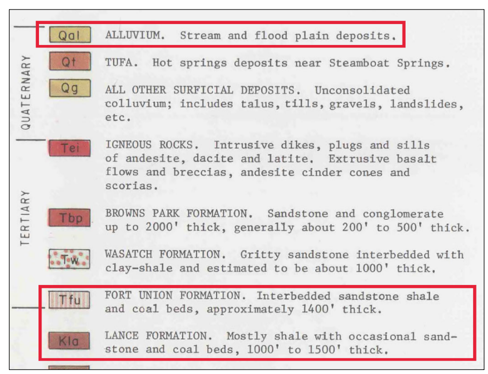
Total of all survey data = **2,914** points

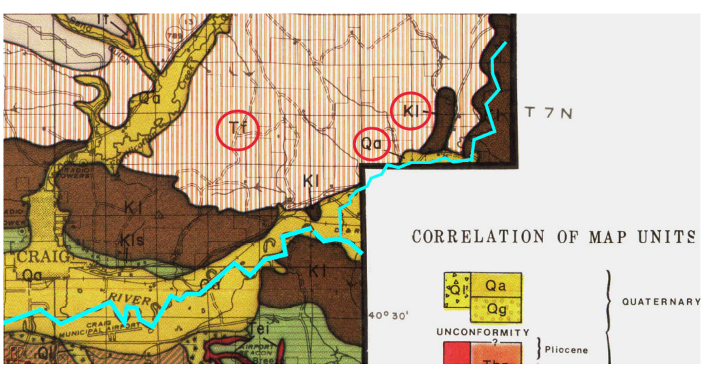
I also created points using interpolation between points to better define certain locations. I created **102** points and put an "*" at end of point descriptions.

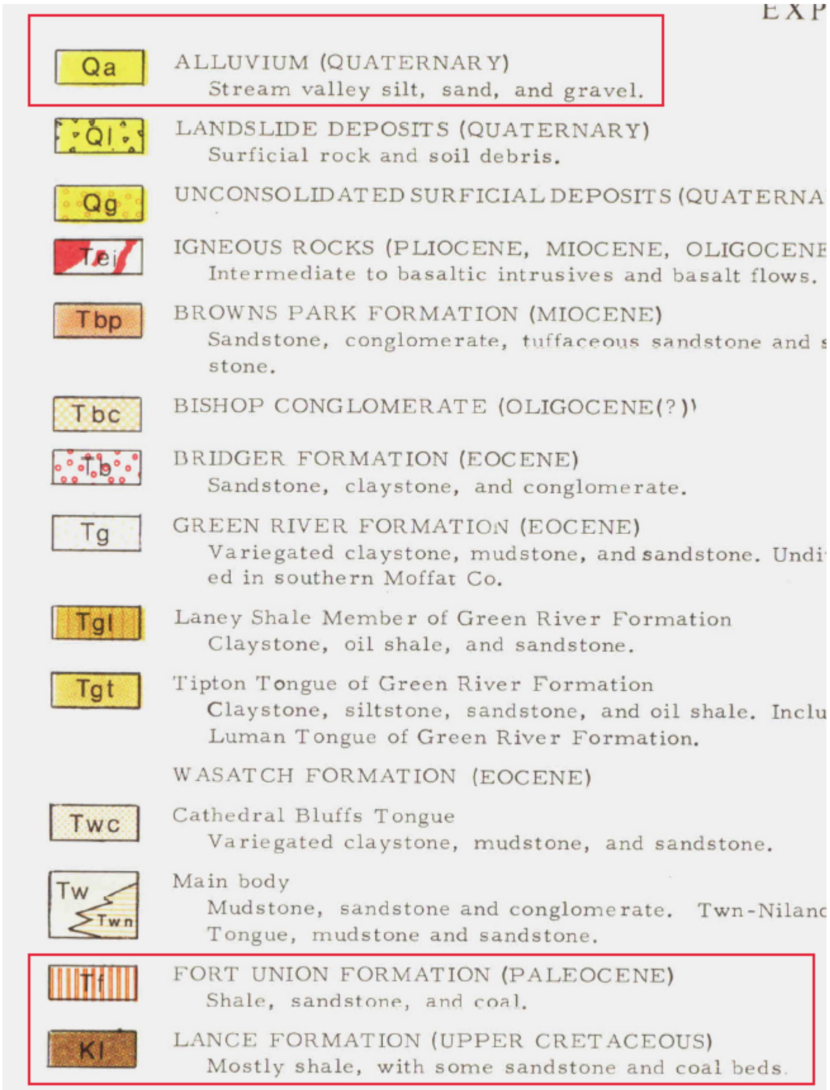
Geology

Our field observations confirm that most of the material the stream resides in is alluvial in nature. There were some locations with bedrock horizontal and vertical control, most commonly sandstone.









Streambed & Bank Materials

A representative sample of streambed material is shown in Figure 1: Streambed particle analysis. Two additional particle samples are also included below.

Data | Linear Graph | Bar Graph   Date: 06/19/2018

Size (mm)	TOT #	ITEM %	CUM %
0 - 0.062	11	11.00	11.00
0.062 - 0.125	3	3.00	14.00
0.125 - 0.25	11	11.00	25.00
0.25 - 0.50	15	15.00	40.00
0.50 - 1.0	0	0.00	40.00
1.0 - 2.0	0	0.00	40.00
2.0 - 4.0	0	0.00	40.00
4.0 - 5.7	0	0.00	40.00
5.7 - 8.0	1	1.00	41.00
8.0 - 11.3	0	0.00	41.00
11.3 - 16.0	2	2.00	43.00
16.0 - 22.6	4	4.00	47.00
22.6 - 32.0	11	11.00	58.00
32 - 45	15	15.00	73.00
45 - 64	18	18.00	91.00
64 - 90	8	8.00	99.00
90 - 128	1	1.00	100.00
128 - 180	0	0.00	100.00
180 - 256	0	0.00	100.00
256 - 362	0	0.00	100.00
362 - 512	0	0.00	100.00
512 - 1024	0	0.00	100.00
1024 - 2048	0	0.00	100.00
Bedrock	0	0.00	100.00

Particle Size Analysis

D16 (mm)	0.15
D35 (mm)	0.42
D50 (mm)	25.16
D84 (mm)	56.61
D95 (mm)	77
D100 (mm)	128
Silt/Clay (%)	11
Sand (%)	29
Gravel (%)	51
Cobble (%)	9
Boulder (%)	0
Bedrock (%)	0

Total Particles = 100

D50 25.16 mm

Figure 1: Streambed particle analysis from 10 transects at a representative riffle

Data | Linear Graph | Bar Graph   Date: 06/19/2018

Size (mm)	TOT #	ITEM %	CUM %
0 - 0.062	15	15.00	15.00
0.062 - 0.125	8	8.00	23.00
0.125 - 0.25	2	2.00	25.00
0.25 - 0.50	0	0.00	25.00
0.50 - 1.0	0	0.00	25.00
1.0 - 2.0	0	0.00	25.00
2.0 - 4.0	1	1.00	26.00
4.0 - 5.7	1	1.00	27.00
5.7 - 8.0	1	1.00	28.00
8.0 - 11.3	2	2.00	30.00
11.3 - 16.0	2	2.00	32.00
16.0 - 22.6	2	2.00	34.00
22.6 - 32.0	6	6.00	40.00
32 - 45	10	10.00	50.00
45 - 64	14	14.00	64.00
64 - 90	19	19.00	83.00
90 - 128	12	12.00	95.00
128 - 180	0	0.00	95.00
180 - 256	0	0.00	95.00
256 - 362	0	0.00	95.00
362 - 512	0	0.00	95.00
512 - 1024	5	5.00	100.00
1024 - 2048	0	0.00	100.00
Bedrock	0	0.00	100.00

Particle Size Analysis

D16 (mm)	0.07
D35 (mm)	24.17
D50 (mm)	45
D84 (mm)	93.17
D95 (mm)	128
D100 (mm)	1023.99
Silt/Clay (%)	15
Sand (%)	10
Gravel (%)	39
Cobble (%)	31
Boulder (%)	5
Bedrock (%)	0

Total Particles = 100

D50 45 mm

Figure 2: Particle analysis from riffle at cross section 470

Data | Linear Graph | Bar Graph   Date: 06/19/2018

Size (mm)	TOT #	ITEM %	CUM %
0 - 0.062	7	7.00	7.00
0.062 - 0.125	1	1.00	8.00
0.125 - 0.25	10	10.00	18.00
0.25 - 0.50	8	8.00	26.00
0.50 - 1.0	3	3.00	29.00
1.0 - 2.0	0	0.00	29.00
2.0 - 4.0	0	0.00	29.00
4.0 - 5.7	2	2.00	31.00
5.7 - 8.0	0	0.00	31.00
8.0 - 11.3	1	1.00	32.00
11.3 - 16.0	4	4.00	36.00
16.0 - 22.6	3	3.00	39.00
22.6 - 32.0	6	6.00	45.00
32 - 45	10	10.00	55.00
45 - 64	13	13.00	68.00
64 - 90	18	18.00	86.00
90 - 128	9	9.00	95.00
128 - 180	4	4.00	99.00
180 - 256	1	1.00	100.00
256 - 362	0	0.00	100.00
362 - 512	0	0.00	100.00
512 - 1024	0	0.00	100.00
1024 - 2048	0	0.00	100.00
Bedrock	0	0.00	100.00

Particle Size Analysis

D16 (mm)	0.23
D35 (mm)	14.83
D50 (mm)	38.5
D84 (mm)	87.11
D95 (mm)	128
D100 (mm)	255.99
Silt/Clay (%)	7
Sand (%)	22
Gravel (%)	39
Cobble (%)	32
Boulder (%)	0
Bedrock (%)	0

Total Particles = 100

D50 38.5 mm

Figure 3: Particle analysis from riffle at cross section 473

Image 2: Typical point bar material consisting of mostly gravel and cobble (TJ Burr, NRCS)

The streambanks consist of alluvial silts, sands, gravel, and cobble deposited throughout time. Most of the upper soil horizons consist of fine-grained sandy-loam material.

Image 3: Typical bank material and sloughing. Coarser material is found below the water level (TJ Burr, NRCS)

Aquatic Habitat Assessment Using SVAP2

The Stream Visual Assessment Protocol (SVAP2) is a national protocol that provides an initial evaluation of the overall condition of wadable streams, their riparian zones, and their instream habitats. The majority of the Nation’s streams and rivers are small, often with intermittent flows and, yet, they constitute a close multidimensional linkage between land and water management. These smaller streams and rivers are increasingly a focus of Natural Resources Conservation Service (NRCS) assistance to Landowners. This protocol was developed for relatively small streams, be they perennial or intermittent. Additional guidance and information about the SVAP is in the National Biology Handbook, Part 614, Subpart B, USDA NRCS, 2009.

The pre-project SVAP2 score sheet is included in the Appendix. The results indicate the stream “health” is in FAIR condition. We expect to uplift this condition with the proposed stream restoration work.

Hydrology

Natural Stream H&H

Hydrology and hydraulics for natural stream design follow the same engineering principles as traditional open channel design, but use a natural/irregular cross-section in lieu of the trapezoidal cross-section. Natural stream channel design also uses a variety of data to validate the hydraulic design, including gage data, regional curves, and field surveys. The field data trumps other less specific information because the field data represents actual conditions at the project site.

Precipitation

Precipitation frequency data is included in the Appendix.

Hydro-physiographic Province and Regional Curve

The project site watershed is in the *Mountain Region and Northwest* Physiographic Provinces of Colorado.

Fluvial Geomorphology

Rosgen Geomorphic Channel Design Methodology

The primary design reference for the hydraulic design of the typical channel cross-sections is the Rosgen Geomorphic Channel Design methodology as outlined in Chapter 11 of Part 654, Stream Restoration Design, National Engineering Handbook, August 2007. An outline of the 40-step procedural sequence starts on page 11-29. Not all steps are required for every project.

Reference Reach

We typically want to find and analyze a representative reference reach for the project. Intuitively, one would want to use the unregulated stream upstream of the reservoir. But, because of the influences of the reservoir on the downstream reach, that is not a good reference reach. There isn't a suitable reference reach for the lower reach of Elkhead Creek downstream of the reservoir.

Morphological Characteristics and Classification (B4c)

I used the Rosgen stream classification method to classify the stream type. There were some reaches that were C4 stream types, but overall the stream type is best described as a B4c. This was likely a C-stream that evolved into a B-stream due to the incision.

C-streams can be significantly altered and **rapidly destabilized** when the effects of imposed changes in bank stability, watershed condition, or flow regime are combined to exceed the channel stability threshold.

There are 147 morphological characteristics identified by Dave Rosgen, PhD (2010). The most pertinent of those parameters are included below. The key morphological characteristics (design parameters) are summarized in Table 1.

Table 1 - Morphological Characteristics

KEY GEOMORPHOLOGICAL CHARACTERISTICS			
Characteristic	**Existing**	**Design**	**Reference**
Valley Type		VIII(b)	
Valley Width, feet		1,140	
Stream Type		B4c	
Drainage Area, Square Miles		219	
Bankfull Discharge, cfs (Qbkf)		800	
Mean Velocity, ft/sec		3.2	
Bankfull Slope, ft/ft (S)		0.0017	
Bankfull Width, ft (Wbkf)		80	
Mean Depth, ft (dbkf)		3.10	
Width/Depth Ratio (W/D)		29	
Cross-Sectional Area, ft2 (Abkf)		248	
Maximum Depth (dmax)		5.00	
Width of Flood-Prone Area, ft (Wfpa)		123	
Entrenchment Ratio (Wfpa/Wbkf)		1.54	
Sinuosity (k) (SL/VL)		2.01	
Meander Width Ratio (MWR), W_{belt}/W_{bkf}		3.24	
Stream Length Assessed for Erosion (ft)		278	
Streambank Erosion (tons/yr)		222	
Streambank Erosion (tons/ft-yr)		0.80	
Pool-to-Pool Spacing		380	
Bankfull Shear Stress, psf		0.61	
Radius of Curvature, ft (Rc)		103	
Radius of Curvature Ratio (Rc/Wbkf)		1.3	

Table 2: Stream Classification

Stream: Elkhead Creek		
Basin:	Drainage Area: acres	210 mi²
Location:		
Twp.&Rge:	Sec.&Qtr.:	
Cross-Section Monuments (Lat./Long.):	Date:	
Observers: TJ Burr	Valley Type: VIII(b)	
Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	76.7	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A_{bkf} / W_{bkf}$).	2.63	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	201.9	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	29.1	ft/ft
Maximum DEPTH (d_{max}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	4.03	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or ($2 \times d_{max}$) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	123.00	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	1.60	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the median or dominant diameter of channel materials, as sampled proportionately from the channel surface, between the bankfull stage and Thalweg elevations.	23	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20-30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	0.0017	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (S_{val} / S).	2.01	
Stream Type	**B4c**	See Classification Key (Figure 2-21)

NOTE: Cells with Text are Locked. To Unlock Cells, Unprotect Sheet under "Tools" & "Protection"

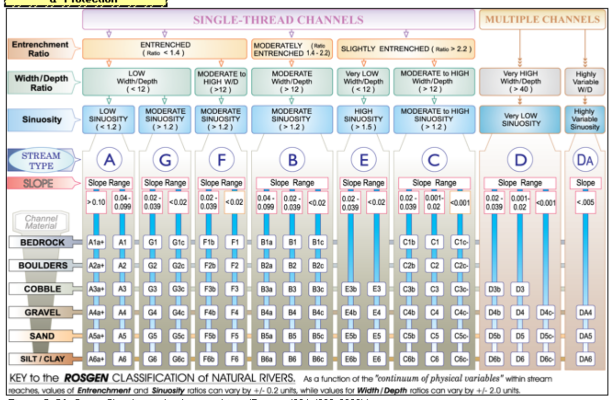


Figure 2-21. Stream Classification key for natural rivers (Rosgen, 1994, 1996, 2006b).

Characteristics from Stream Type

A B4c stream is a B stream type that is gravel dominated and has flatter slopes than typical B streams. Based on research by Luna Leopold and Dave Rosgen, the following characteristics are typical for this stream type.

- Pool-Pool spacing is generally 4-5 bankfull widths
- Have step-pool bed features
- Can be transitional stream types, such as C > B > C
- Readily transport sediment
- Excellent recovery potential

Cross Section and Discharge Analysis

We collected and analyzed survey data from 18 cross-sections within the project reaches spanning approximately 5 miles. The channel hydraulics is based on the most representative riffle cross-section. RiverMorph software was used to make calculations and identify the natural bankfull features.

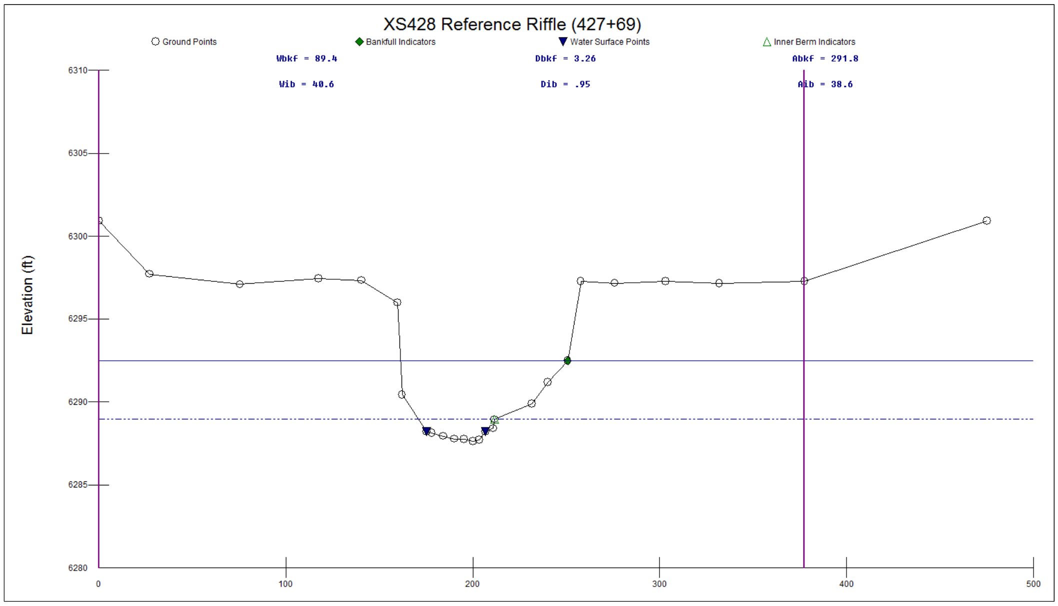


Figure 4: Riffle cross section 428, representative riffle

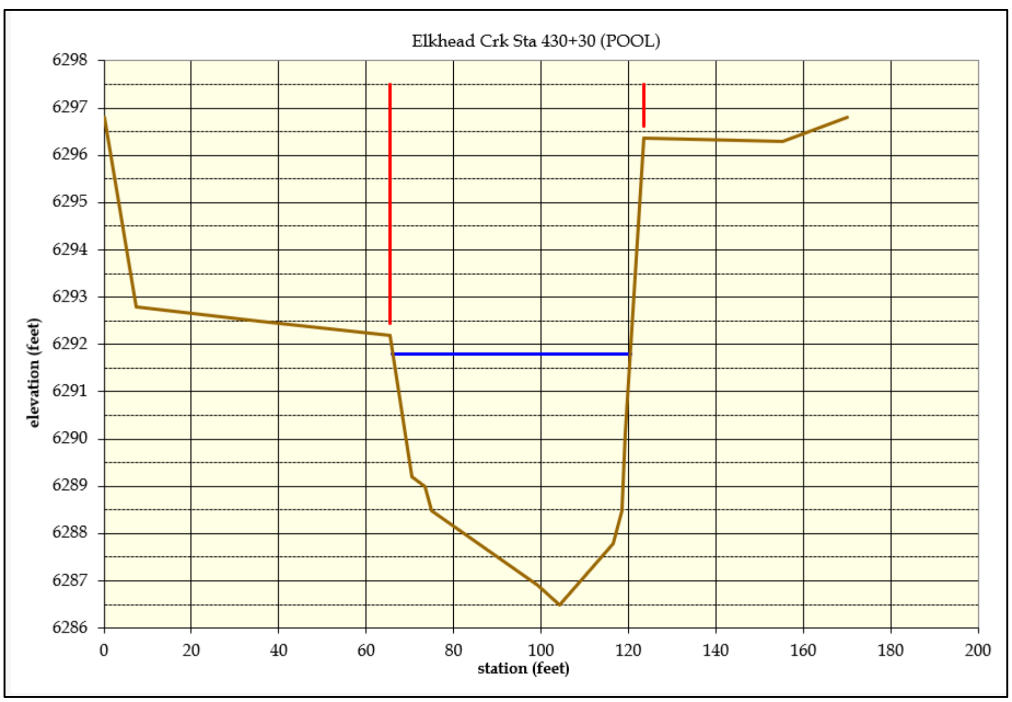


Figure 5: Pool cross section from O'Neal project site

Mannings Equation Analysis
version 15, Jan 2014
Elkhead Crk Sta 430+30 (POOL)

analyze single water surface elevation

$$V = \frac{1.486}{n} R^{2/3} S^{1/2}$$

unit system: eng
auto scale: yes

cross-section data: preview

station	elevation	n -value
0.00	6296.80	0.040
7.31	6292.80	
35.34	6292.50	
65.35	6292.20	
70.38	6289.20	
73.49	6289.00	
75.07	6288.48	
99.25	6286.90	
104.14	6286.50	
116.47	6287.80	
118.40	6288.48	
119.34	6290.10	
123.58	6296.36	0.045
155.39	6296.30	
170.00	6296.80	

hydraulic properties for given water surface elevation:

w.s. elev	flow area	wetted P	hydr. radius	top width	hydr. depth	n value	darcy-weis. f	conveyance	discharge	velocity	shear
6291.80	211.0	57.4	3.68	54.5	3.87	0.040	0.1209	18676	814.1	3.86	0.436

calculate rating table

profile slope= 0.00190

bank stations: left 65.4, right 123.6

hydraulic properties rating table:

w.s. elev	flow area	wetted P	hydr. radius	top width	hydr. depth	n value	darcy-weis. f	conveyance	discharge	velocity	shear
6296.80	778.1	176.5	4.41	170	4.58	0.041	0.0728	97206	4237	5.45	0.523
6296.50	728.5	167.1	4.36	161	4.53	0.041	0.0737	89909	3919	5.38	0.517
6296.00	661.2	127.9	5.17	122	5.43	0.040	0.0933	78982	3443	5.21	0.613
6295.50	600.6	126.3	4.76	121	4.98	0.040	0.0931	68893	3003	5.00	0.564
6295.00	540.6	124.6	4.34	119	4.53	0.040	0.0923	59485	2593	4.80	0.514
6294.50	481.2	123.0	3.91	118	4.07	0.040	0.0905	50788	2214	4.60	0.464
6294.00	422.5	121.3	3.48	117	3.62	0.040	0.0872	42840	1867	4.42	0.413
6293.50	364.4	119.7	3.04	116	3.15	0.040	0.0817	35695	1556	4.27	0.361
6293.00	306.9	118.1	2.60	114	2.68	0.040	0.0728	29437	1283	4.18	0.308
6292.50	254.1	89.0	2.86	85.6	2.97	0.040	0.0804	24307	1060	4.17	0.339
6292.00	221.9	58.0	3.83	54.9	4.04	0.040	0.1193	20170	879.2	3.96	0.454
6291.50	194.8	56.4	3.45	53.8	3.62	0.040	0.1235	16525	720.3	3.70	0.409
6291.00	168.2	54.8	3.07	52.6	3.20	0.040	0.1285	13186	574.8	3.42	0.364
6290.50	142.2	53.3	2.67	51.4	2.77	0.040	0.1346	10163	443.0	3.12	0.316
6290.00	116.8	51.7	2.26	50.2	2.32	0.040	0.1422	7468	325.5	2.79	0.268
6289.50	91.9	50.1	1.83	49.1	1.87	0.040	0.1525	5115	223.0	2.43	0.217
6289.00	67.9	45.8	1.48	45.2	1.50	0.040	0.1637	3279	142.9	2.10	0.176
6288.50	45.8	43.7	1.05	43.4	1.05	0.040	0.1838	1754	76.4	1.67	0.124
6288.00	26.2	34.8	0.75	34.6	0.76	0.040	0.2052	805.0	35.1	1.34	0.089
6287.50	11.4	23.7	0.48	23.6	0.48	0.040	0.2380	261.1	11.4	1.00	0.057
6287.00	2.73	11.2	0.24	11.2	0.24	0.040	0.2989	39.6	1.73	0.63	0.029
6286.50	0.00	0.0	0.00	0.0	0.00	0.040	0.2380	0.00	0.00	0.00	0.000

Table 3: Discharge Rating Table

Velocity and Discharge

The design velocity and discharge was derived from a variety of calculations, field indicators, and regional curve data. The flow for Lower Elkhead Creek is partially regulated. The reservoir does not have flood storage. The most reliable data is from field indicators. There are inner berm features that align with the flows released when downstream rivers need water for aquatic life.

Sediment Transport

Using sediment competence analysis, I confirmed that the bankfull discharge can transport the range of D84 particle sizes (57-93mm). The design did not warrant further sediment transport analysis because the stream is adequately transporting the sediment.

Environmental Considerations

There are no major environmental concerns regarding the proposed work. The result will be a net positive for the environment.

There are bald eagles and bald eagle nests in cottonwood trees, which will need to be considered. No trees are being removed by this project. We will take precautions to avoid disturbing the bald eagles during nesting periods.

Specifications

The specifications used for this project are standard specifications developed by Colorado NRCS for stream restoration work. The specifications parallel the numbering format and terminology used in the national NRCS specifications. The standard specifications are updated as needed to improve and incorporate lessons-learned. When necessary, the specifications are edited for specific project conditions.

Cost Estimate and Materials

The design engineer will estimate the construction cost and discuss it with respective landowners. The cost estimate is a target construction cost for the owner's information. There are numerous variables associated with construction costs, which make it difficult to accurately estimate.

Construction Review

General

This section contains a summary of items, conditions, or features encountered during construction that require a field review by the designer, geologist, soil engineer, or other specialist to ensure that conditions anticipated during design are verified and are consistent with the design assumptions.

Geologist

A geologist should be available for consultation during construction for any unexpected geology issues. However, this is not anticipated.

Design Engineer (or Stream Restoration Specialist)

The design engineer or stream restoration specialist should be available to consult with the *technical representative* as necessary to resolve any concerns that cannot be resolved in the field. The involvement of the design engineer will vary depending on the contractor's experience, complexity of design, weather, and special site conditions.

Preconstruction Meeting

A preconstruction meeting at the project site provides a time for the key participants to meet each other, and time to review the drawings and specifications before construction starts. A preconstruction meeting (meeting) is critical for a successful project.

Since the landowner is responsible for construction of the project, the landowner is responsible for arranging a preconstruction meeting with the following attendees: contractor, NRCS technical representative, NRCS district conservationist, and the design engineer or stream restoration specialist.

Quality Assurance Plan

A Quality Assurance Plan (QAP) provides guidance for the personnel, skills, resources, and expectations to help ensure the project is completed as intended. The project team will try to adhere to these guidelines, but cannot guarantee 100% compliance due to limited personnel with the necessary skills.

A project-specific QAP is part of the final design package.

Appendix

Appendix

1. SVAP2
2. Precipitation Frequency Estimates
3. Velocity Discharge Worksheet
4. Riffle Cross-Section at Pankey Site
5. Riffle Hydraulics
6. Eroding Banks at Hamilton Site
7. Longitudinal Stream Profile
8. StreamStats Report

From: Kaitlyn Vaux
To: Burr, Tee - NRCS, Denver, CO
Cc: Smith, Kendall - NRCS, Craig, CO
Subject: RE: Streambank work along Elk Head Creek
Date: Friday, June 29, 2018 10:39:15 AM
Attachments: image003.png

Morning TJ,

Here are the Elkhead Creek SVAP2 scores that Becky and I came up with.

		Benchmark Score			
Element		Keith Pankey	Tim & Laine O'Neal	Les & Bonnie Hampton	Lorraine Kawcak
1	Channel Condition	5	5	5	5
2	Hydrologic Alteration	3	3	3	3
3	Bank Condition	5	6	6	5
4	Riparian Quantity	8.5	8.5	8.5	8.5
5	Riparian Quality	9	8.5	8.5	7
6	Canopy Cover/ Stream Shading	2.5	1.5	1.5	2.5
7	Water Appearance	6	7	7	6
8	Nutrient Enrichment	6	6	6	5
9	Manure or Human Waste Present	7.5	9	7	6
10	Pools	9	9	9	9
11	Barriers to Species Movement	7	10	10	10
12	Fish Habitat Complexity	7.5	6	6	6
13	Aquatic Invertebrate Habitat	8.5	7.5	7.5	7.5
14	Aquatic Invertebrate Community	7	7.5	7.5	8
15	Riffle Embeddedness	8	9	9	8
16	Salinty	n/a	n/a	n/a	n/a
	Overall Baseline Score	6.6	6.9	6.8	6.4
		Fair	*Fair*	*Fair*	*Fair*

Please let me know if there is anything else I can provide.

Thanks,

Kaitlyn

From: Burr, Tee - NRCS, Denver, CO [mailto:Tee.Burr@co.usda.gov]
Sent: Wednesday, June 27, 2018 2:24 PM
To: Kaitlyn Vaux <Kaitlyn.Vaux@tu.org>
Subject: RE: Streambank work along Elk Head Creek

Kaitlyn,

You're welcome. I always enjoy getting out to do river work.

Please share your SVAP scores when you have them ready for prime time.

Also, could you send me Aaron's email address? I want to keep him in the loop so he can get some river engineering experience as I work on the designs.

I'm looking forward to continuing our work together on the Elkhead.

Have a good one.

Sincerely,

TJ

TJ Burr, PE
Civil Engineer | Stream Restoration Specialist
NRCS-CO | 720-544-2871 | tee.burr@co.usda.gov

Hydrology ~ Fluvial Geomorphology ~ EWP ~ Stream Restoration

From: Kaitlyn Vaux [mailto:Kaitlyn.Vaux@tu.org]
Sent: Tuesday, June 26, 2018 9:31 AM
To: Smith, Kendall - NRCS, Craig, CO <Kendall.Smith@co.usda.gov>
Cc: Burr, Tee - NRCS, Denver, CO <Tee.Burr@co.usda.gov>
Subject: Re: Streambank work along Elk Head Creek

Hi Kendall,

Thanks for letting me know - I'll plan to give Eric a call later this week. Vance said that he personally didn't survey that creek section, so I'll let TJ verify if he was able to survey the Hamilton property. If need be, hopefully Vance and/or Chayla and I can go out there in the coming weeks. The same goes for the remaining interested landowners (Pennington and Keiss).

And thank you, TJ, for all of last week's work! It is very appreciated by everyone on and involved with Elkhead Creek up here.

Cheers,

Kaitlyn

From: Smith, Kendall - NRCS, Craig, CO <Kendall.Smith@co.usda.gov>
Sent: Monday, June 25, 2018 5:16:38 PM
To: Kaitlyn Vaux
Cc: Burr, Tee - NRCS, Denver, CO
Subject: Streambank work along Elk Head Creek

Hi Kaitlyn,

I received a call from Eric Hamilton concerning the streambank work along Elk Head Creek. He is still very interested! I believe the area along his stretch was surveyed. He said the best contact phone number for him is 970-629-3627. Feel free to confirm with Vance and/or TJ.

Thanks,

Kendall A. Smith
USDA-NRCS
District Conservationist

NOAA Atlas 14, Volume 8, Version 2
Location name: Craig, Colorado, USA*
Latitude: 40.5504°, Longitude: -107.4126°
Elevation: 6433.59 ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Deborah Martin, Sandra Pavlovic, Ishani Roy, Michael St. Laurent, Carl Trypaluk, Dale Unruh, Michael Yekta, Geoffery Bonnin

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	**0.152** (0.120-0.196)	**0.184** (0.145-0.237)	**0.245** (0.193-0.317)	**0.305** (0.238-0.396)	**0.399** (0.307-0.560)	**0.482** (0.359-0.685)	**0.574** (0.411-0.841)	**0.676** (0.463-1.03)	**0.826** (0.541-1.30)	**0.949** (0.601-1.50)
10-min	**0.223** (0.176-0.286)	**0.269** (0.213-0.347)	**0.359** (0.282-0.464)	**0.446** (0.349-0.580)	**0.585** (0.449-0.820)	**0.706** (0.525-1.00)	**0.841** (0.602-1.23)	**0.990** (0.678-1.50)	**1.21** (0.793-1.90)	**1.39** (0.879-2.19)
15-min	**0.272** (0.215-0.349)	**0.329** (0.259-0.423)	**0.438** (0.344-0.565)	**0.544** (0.425-0.707)	**0.713** (0.548-1.00)	**0.861** (0.641-1.22)	**1.02** (0.734-1.50)	**1.21** (0.827-1.83)	**1.47** (0.967-2.31)	**1.69** (1.07-2.68)
30-min	**0.327** (0.259-0.421)	**0.400** (0.316-0.515)	**0.537** (0.422-0.693)	**0.667** (0.521-0.866)	**0.870** (0.667-1.22)	**1.05** (0.777-1.48)	**1.24** (0.887-1.81)	**1.45** (0.994-2.20)	**1.76** (1.16-2.76)	**2.02** (1.28-3.19)
60-min	**0.396** (0.313-0.508)	**0.480** (0.379-0.617)	**0.634** (0.499-0.819)	**0.778** (0.609-1.01)	**1.00** (0.765-1.39)	**1.19** (0.883-1.68)	**1.40** (0.998-2.04)	**1.63** (1.11-2.45)	**1.95** (1.28-3.05)	**2.22** (1.40-3.50)
2-hr	**0.464** (0.371-0.589)	**0.559** (0.447-0.711)	**0.732** (0.582-0.934)	**0.890** (0.704-1.14)	**1.13** (0.873-1.55)	**1.34** (1.00-1.86)	**1.56** (1.12-2.24)	**1.80** (1.24-2.67)	**2.14** (1.41-3.30)	**2.41** (1.54-3.77)
3-hr	**0.522** (0.420-0.659)	**0.625** (0.502-0.789)	**0.807** (0.646-1.02)	**0.971** (0.772-1.24)	**1.22** (0.940-1.64)	**1.42** (1.07-1.95)	**1.64** (1.19-2.33)	**1.87** (1.30-2.76)	**2.20** (1.46-3.36)	**2.46** (1.59-3.82)
6-hr	**0.652** (0.531-0.812)	**0.773** (0.628-0.964)	**0.981** (0.794-1.23)	**1.16** (0.937-1.47)	**1.43** (1.12-1.90)	**1.65** (1.25-2.23)	**1.88** (1.37-2.63)	**2.12** (1.48-3.08)	**2.46** (1.65-3.71)	**2.73** (1.77-4.18)
12-hr	**0.832** (0.685-1.02)	**0.971** (0.799-1.20)	**1.22** (0.995-1.50)	**1.43** (1.17-1.78)	**1.75** (1.38-2.30)	**2.01** (1.55-2.70)	**2.29** (1.70-3.17)	**2.59** (1.83-3.72)	**3.01** (2.04-4.48)	**3.34** (2.19-5.06)
24-hr	**1.05** (0.873-1.27)	**1.20** (0.999-1.46)	**1.47** (1.22-1.80)	**1.72** (1.42-2.12)	**2.09** (1.68-2.73)	**2.41** (1.88-3.19)	**2.74** (2.06-3.76)	**3.11** (2.22-4.42)	**3.62** (2.48-5.34)	**4.04** (2.68-6.04)
2-day	**1.28** (1.08-1.53)	**1.44** (1.22-1.74)	**1.74** (1.46-2.10)	**2.02** (1.68-2.45)	**2.43** (1.97-3.13)	**2.78** (2.19-3.64)	**3.16** (2.40-4.28)	**3.57** (2.58-5.01)	**4.15** (2.88-6.05)	**4.62** (3.10-6.83)
3-day	**1.41** (1.20-1.68)	**1.60** (1.36-1.91)	**1.94** (1.64-2.33)	**2.25** (1.89-2.71)	**2.71** (2.21-3.45)	**3.09** (2.45-4.01)	**3.49** (2.67-4.69)	**3.93** (2.86-5.48)	**4.55** (3.17-6.57)	**5.04** (3.41-7.40)
4-day	**1.52** (1.29-1.80)	**1.73** (1.47-2.05)	**2.10** (1.79-2.50)	**2.43** (2.05-2.91)	**2.92** (2.39-3.69)	**3.32** (2.64-4.28)	**3.75** (2.87-4.99)	**4.20** (3.07-5.82)	**4.84** (3.39-6.95)	**5.35** (3.63-7.81)
7-day	**1.79** (1.55-2.10)	**2.03** (1.75-2.38)	**2.44** (2.09-2.88)	**2.80** (2.39-3.32)	**3.33** (2.74-4.15)	**3.75** (3.01-4.77)	**4.20** (3.24-5.53)	**4.67** (3.44-6.39)	**5.33** (3.76-7.57)	**5.85** (4.00-8.46)
10-day	**2.04** (1.77-2.37)	**2.29** (1.98-2.66)	**2.71** (2.34-3.17)	**3.08** (2.64-3.63)	**3.62** (3.00-4.48)	**4.06** (3.28-5.12)	**4.52** (3.51-5.90)	**5.00** (3.71-6.79)	**5.67** (4.03-7.99)	**6.20** (4.27-8.91)
20-day	**2.72** (2.39-3.12)	**3.00** (2.63-3.45)	**3.48** (3.04-4.02)	**3.89** (3.38-4.52)	**4.49** (3.76-5.46)	**4.96** (4.06-6.17)	**5.46** (4.29-7.02)	**5.98** (4.48-8.00)	**6.69** (4.81-9.31)	**7.26** (5.05-10.3)
30-day	**3.29** (2.91-3.75)	**3.63** (3.20-4.14)	**4.18** (3.68-4.79)	**4.66** (4.07-5.37)	**5.33** (4.49-6.41)	**5.85** (4.81-7.20)	**6.39** (5.06-8.15)	**6.95** (5.25-9.21)	**7.71** (5.57-10.6)	**8.30** (5.81-11.7)
45-day	**4.03** (3.59-4.56)	**4.46** (3.97-5.05)	**5.16** (4.58-5.87)	**5.74** (5.06-6.57)	**6.54** (5.54-7.78)	**7.15** (5.91-8.70)	**7.76** (6.17-9.78)	**8.37** (6.35-11.0)	**9.19** (6.67-12.5)	**9.80** (6.91-13.7)
60-day	**4.68** (4.19-5.26)	**5.21** (4.66-5.87)	**6.06** (5.40-6.85)	**6.75** (5.98-7.68)	**7.68** (6.53-9.06)	**8.37** (6.94-10.1)	**9.05** (7.22-11.3)	**9.72** (7.39-12.6)	**10.6** (7.70-14.3)	**11.2** (7.94-15.6)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

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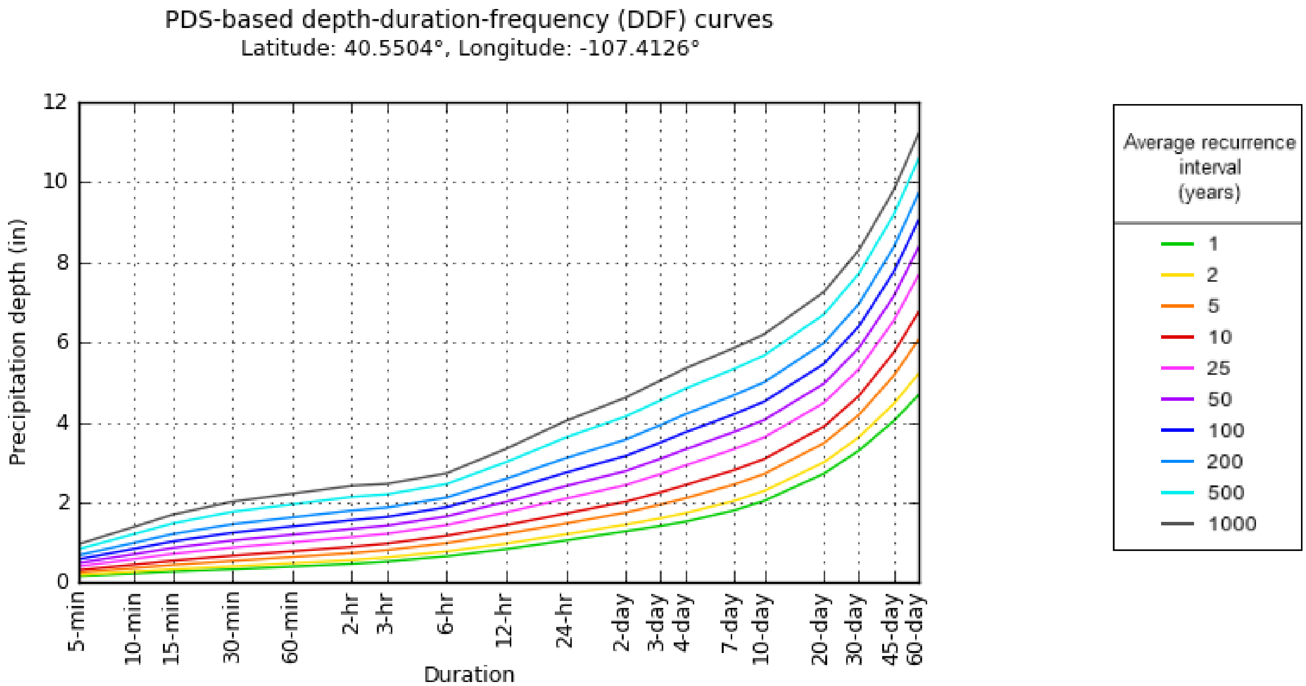
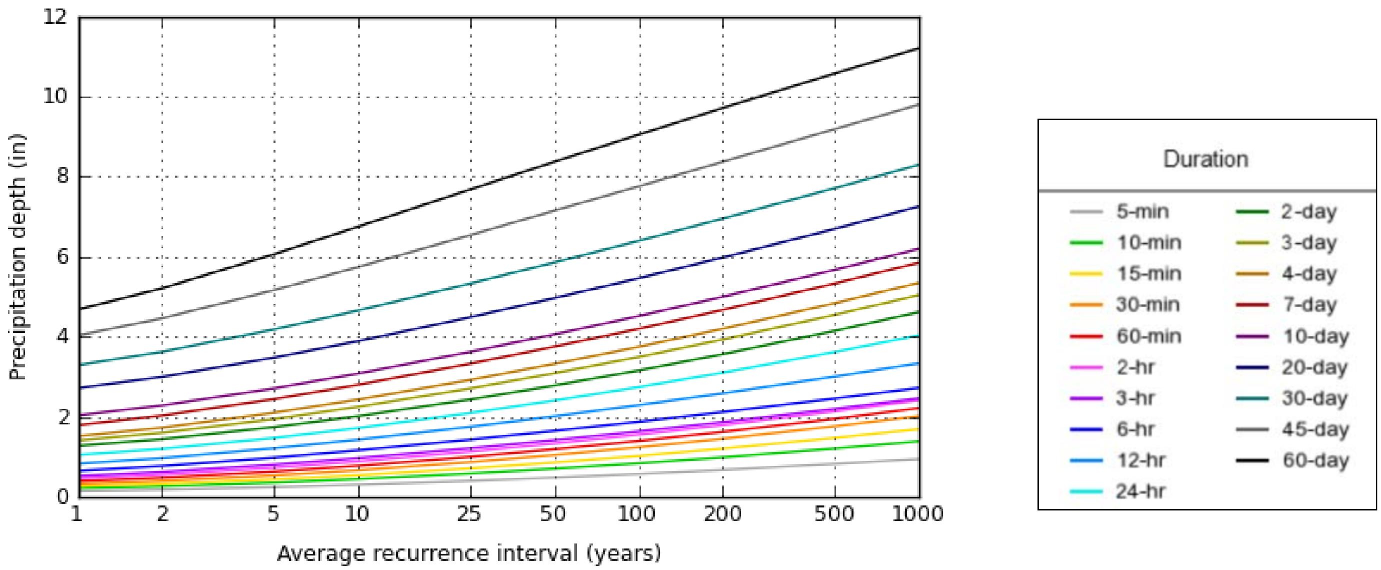
PF graphical





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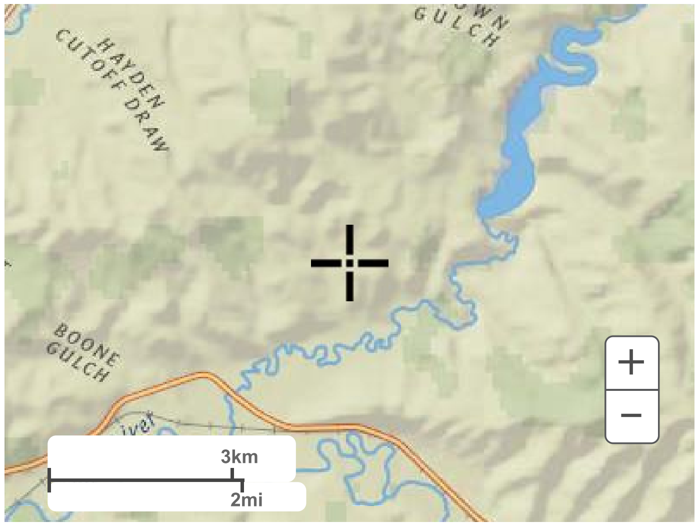
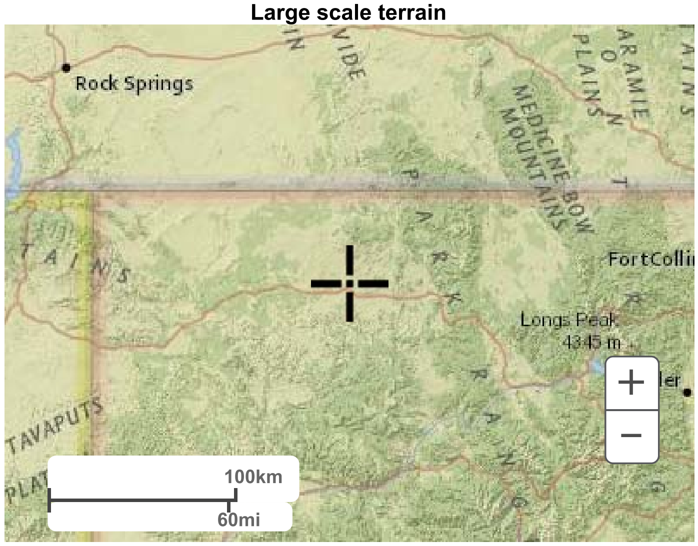
Maps & aerials

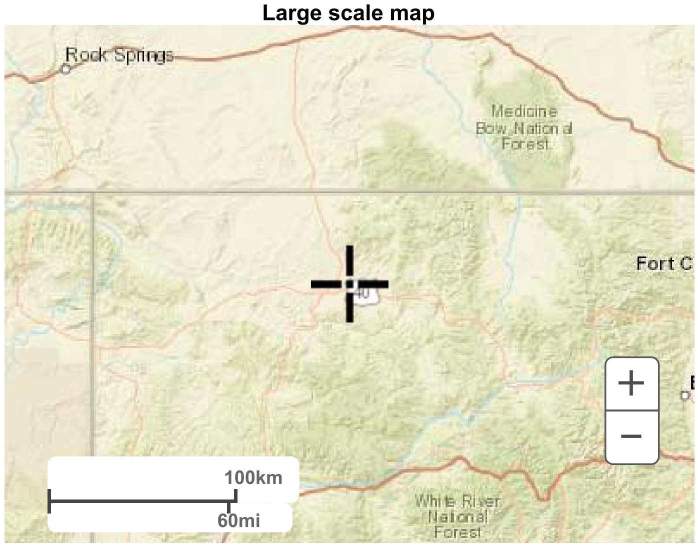
Small scale terrain



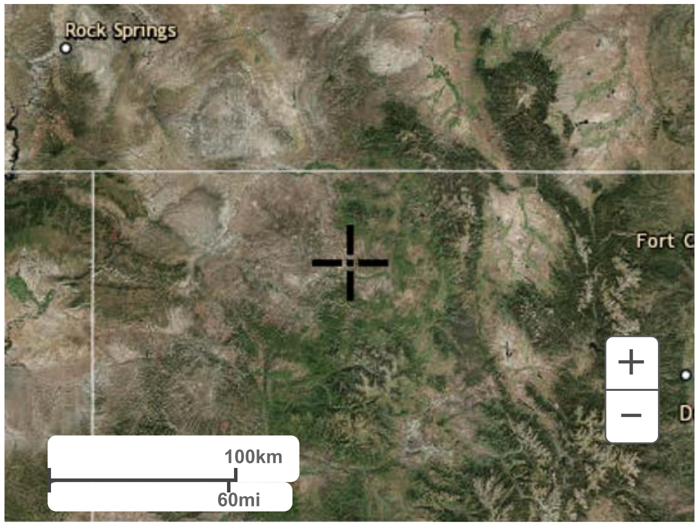
Large scale terrain



Large scale map



Large scale aerial



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US Department of Commerce
National Oceanic and Atmospheric Administration
National Weather Service
National Water Center
1325 East West Highway
Silver Spring, MD 20910
Questions?: HDSC.Questions@noaa.gov

Disclaimer

Worksheet 2-2. Computations of velocity and bankfull discharge using various methods (Rosgen, 2006b; Rosgen and Silvey, 2007).

Bankfull VELOCITY & DISCHARGE Estimates

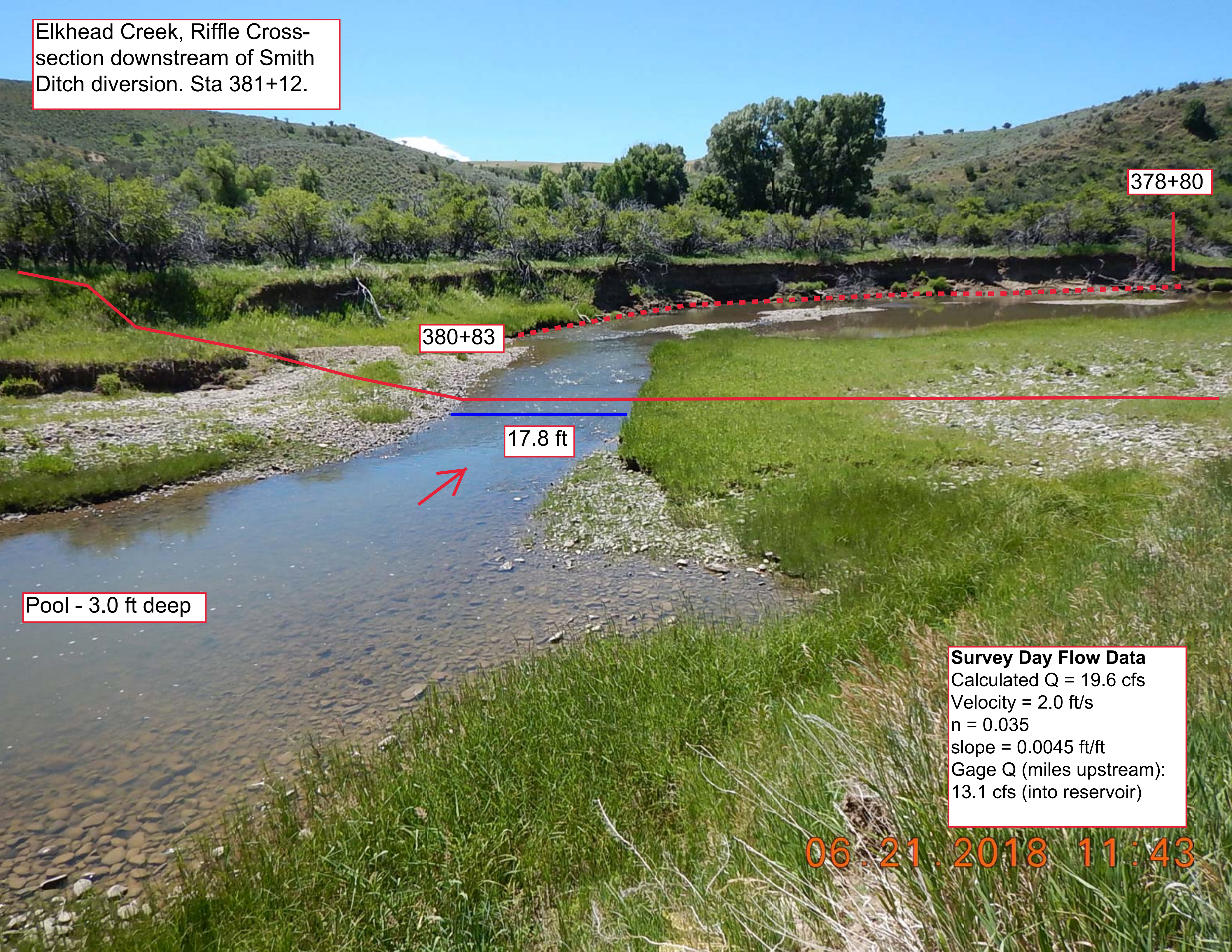
Stream:	**Elkhead Creek**	Location:	**Reach - Oneal Riffle**
Date:	**6/19/2018**	Stream Type:	**C4**
Valley Type:	**VIII**		
Observers:	**TJ Burr**	HUC:	

INPUT VARIABLES			OUTPUT VARIABLES		
Bankfull Riffle Cross-Sectional AREA	184.16	A_{bkf} (ft^2)	Bankfull Riffle Mean DEPTH	2.35	d_{bkf} (ft)
Bankfull Riffle WIDTH	78.26	W_{bkf} (ft)	Wetted PERIMETER ~ $(2 * d_{bkf}) + W_{bkf}$	79.31	W_p (ft)
D_{84} at Riffle	56.61	Dia. (mm)	D_{84} (mm) / 304.8	0.19	D_{84} (ft)
Bankfull SLOPE	0.0020	S_{bkf} (ft / ft)	Hydraulic RADIUS A_{bkf} / W_p	2.32	R (ft)
Gravitational Acceleration	32.2	g (ft / sec^2)	Relative Roughness R(ft) / D_{84} (ft)	12.47	R / D_{84}
Drainage Area	210.0	DA (mi^2)	Shear Velocity $u^* = (gRS)^{½}$	0.387	u* (ft/sec)

ESTIMATION METHODS	Bankfull VELOCITY		Bankfull DISCHARGE	
1. Friction Factor / Relative Roughness $u = [2.83 + 5.66 * Log\{R / D_{84}\}] u^*$	3.50	ft / sec	643.70	cfs
2. Roughness Coefficient: a) Manning's *n* from Friction Factor / Relative Roughness (Figs. 2-18, 2-19) $u = 1.49*R^{2/3}*S^{1/2} / n$ $n =$ 0.033	3.53	ft / sec	650.45	cfs
2. Roughness Coefficient: b) Manning's *n* from Stream Type (Fig. 2-20) $u = 1.49*R^{2/3}*S^{1/2} / n$ $n =$ 0.031	3.76	ft / sec	692.44	cfs
2. Roughness Coefficient: c) Manning's *n* from Jarrett (USGS): $u = 1.49*R^{2/3}*S^{1/2} / n$ $n = 0.39*S^{0.38}*R^{-0.16}$ $n =$ 0.032 — **Note:** This equation is applicable to **steep, step/pool, high boundary roughness, cobble- and boulder-dominated stream systems**; i.e., for Stream Types A1, A2, A3, B1, B2, B3, C2 & E3	3.63	ft / sec	668.87	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) **Darcy-Weisbach (Hey)**	3.71	ft / sec	683.06	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) **Chezy C**	0.00	ft / sec	0.00	cfs
4. Continuity Equations: a) Regional Curves **u = Q / A** **Return Period for Bankfull Discharge** **Q =** 0.0 **year**	0.00	ft / sec	0.00	cfs
4. Continuity Equations: b) USGS Gage Data **u = Q / A**	0.00	ft / sec	0.00	cfs

Protrusion Height Options for the D_{84} Term in the Relative Roughness Relation (R/D_{84}) – Estimation Method 1

Option 1.	For **sand-bed** channels: Measure 100 **"protrusion heights"** of sand dunes from the downstream side of feature to the top of feature. Substitute the D_{84} sand dune protrusion height in ft for the D_{84} term in method 1.
Option 2.	For **boulder-dominated** channels: Measure 100 **"protrusion heights"** of boulders on the sides from the bed elevation to the top of the rock on that side. Substitute the D_{84} boulder protrusion height in ft for the D_{84} term in method 1.
Option 3.	For **bedrock-dominated** channels: Measure 100 **"protrusion heights"** of rock separations, steps, joints or uplifted surfaces above channel bed elevation. Substitute the D_{84} bedrock protrusion height in ft for the D_{84} term in method 1.
Option 4.	For **log-influenced** channels: Measure "**protrusion heights**" proportionate to channel width of log diameters or the height of the log on upstream side if embedded. Substitute the D_{84} protrusion height in ft for the D_{84} term in method 1.


Elkhead Creek, Riffle Cross-section downstream of Smith Ditch diversion. Sta 381+12.
378+80
380+83
17.8 ft
Pool - 3.0 ft deep
Survey Day Flow Data
Calculated Q = 19.6 cfs
Velocity = 2.0 ft/s
n = 0.035
slope = 0.0045 ft/ft
Gage Q (miles upstream):
13.1 cfs (into reservoir)
06.21.2018 11:43

COMPUTATION SHEET | *U.S. DEPARTMENT OF AGRICULTURE*
NATURAL RESOURCES CONSERVATION SERVICE

STATE: Colorado	*COUNTY:* Moffat	*PROJECT:* Stream Stabilization			
BY: TJ Burr	*DATE:* 10/22/2018	*CHECKED BY:*	*DATE:*		
SUBJECT: **Velocity & Discharge Equations**	*STREAM:* Elkhead Creek		*SHEET:* 1	*OF* X	

Form Revised: 11/24/2015

Bankfull Hydraulic Calculations based on: **XS493 (Riffle) - Good Cross-Section**

Drainage Area (DA):	**219**	sq. mi.
Valley Type:	VIII(b)	
Calculated Discharge, Q =	754	cfs
Annual Mean Flow =	120	cfs

Information from this worksheet will be linked to and used in other worksheets in this workbook.

Entries in blue require user input; entries in dark red are calculated values.
Use this worksheet to input data from the best existing cross-section for velocity-discharge data.

Go to: Contents

STREAM CLASSIFICATION DATA

Enter bankfull Width (at riffle section):	W_{bkf} =	76.7	Ft	6299.86 Thalweg Elevation
Enter bankfull cross-sectional area (at riffle):	A_{bkf} =	201.9	SF	6307.92 Elevation at Floodprone Width (TW Elev + 2(dmax)
Mean Bankfull Depth (at riffle section), $d_{bkf} = A/W_{bkf}$:	d_{bkf} =	2.63	Ft	Small River
Width/Depth Ratio (Wbkf/dbkf):	W/D =	29.14		Very High
Enter Maximum DEPTH (dmax):	d_{max} =	4.03	Ft	Difference between bankfull elev and thalweg at riffle section
Enter Width of flood-prone Area (2 x dmax at riffle):	W_{fpa} =	123.0	Ft	The elevation is at 2x dmax, then find the width
Enter the wetted perimeter (from cross-section data or RiverMorph)	W_p =	78.00	Ft	
Entrenchment Ratio (Wfpa/Wbkf):	ER =	1.60		
Enter Particle Size Index:	D_{50} =	23	mm	Mean DIA of materials between bankfull elev and thalweg (see note 1)
Enter the D_{84} at Riffle	D_{84} =	54	mm	From riffle at surveyed cross-section (see p. 2-27, RSFG)
Enter the Bankfull Slope (riffle-riffle)(hydraulic slope): - try to get length of 20-30 x Wbkf or:	S =	0.00166	ft/ft	From RiverMorph Long Pro
Enter Stream Length:	SL =	52,900	Ft	
Enter the Valley Length (from topo or aerial map):	VL =	26,382	Ft	Straight Line from start of reach to end of reach
Channel sinuosity (SL/VL or VS/S)	k =	2.01		k<1.2 (Low), 1.2-1.5 (Moderate); k>1.5 (very high)
Valley Slope = k(S):	VS =	0.0033		

Rosgen Stream Type: **B4c**

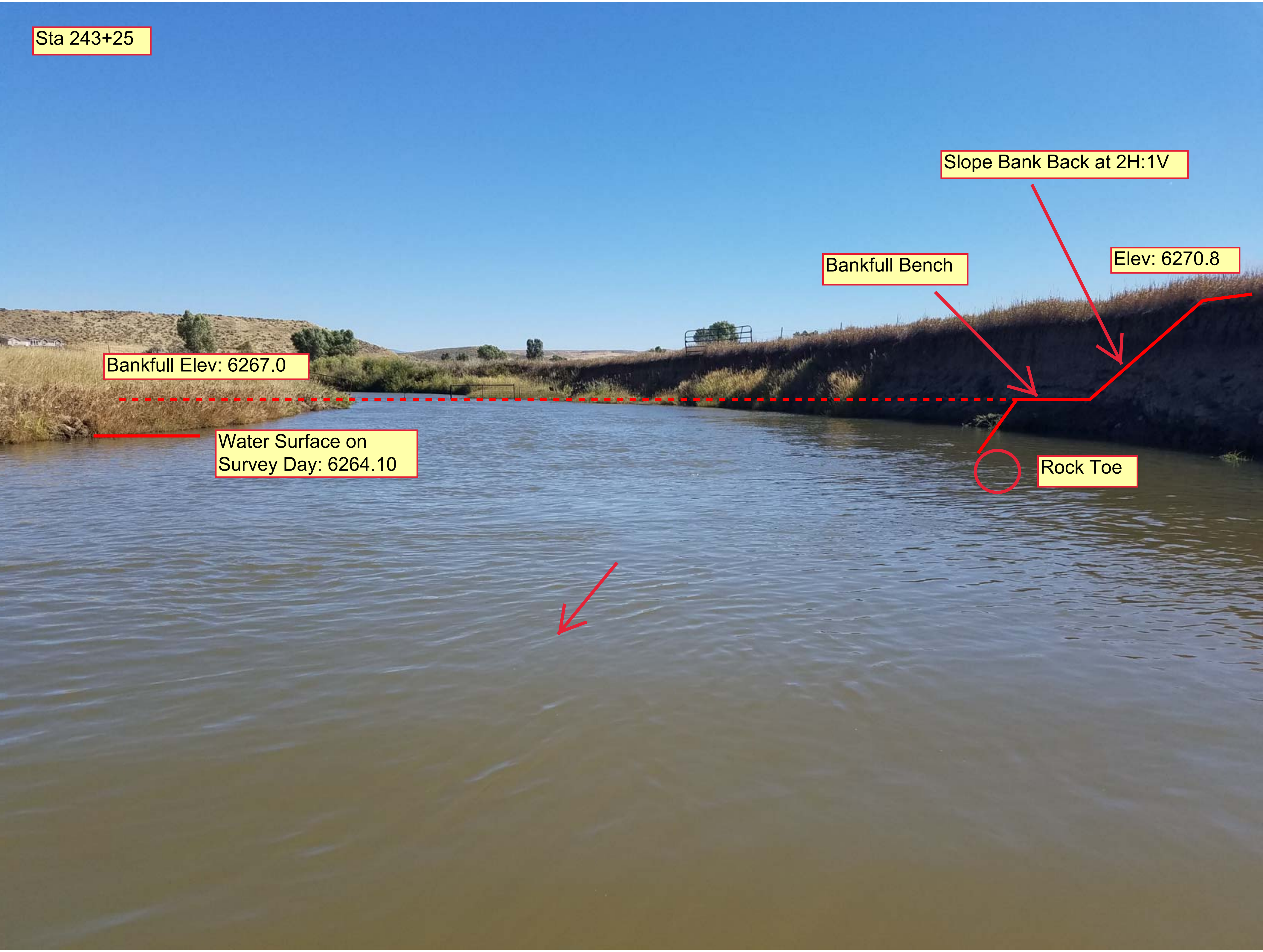
BANKFULL VELOCITY DISCHARGE ESTIMATES

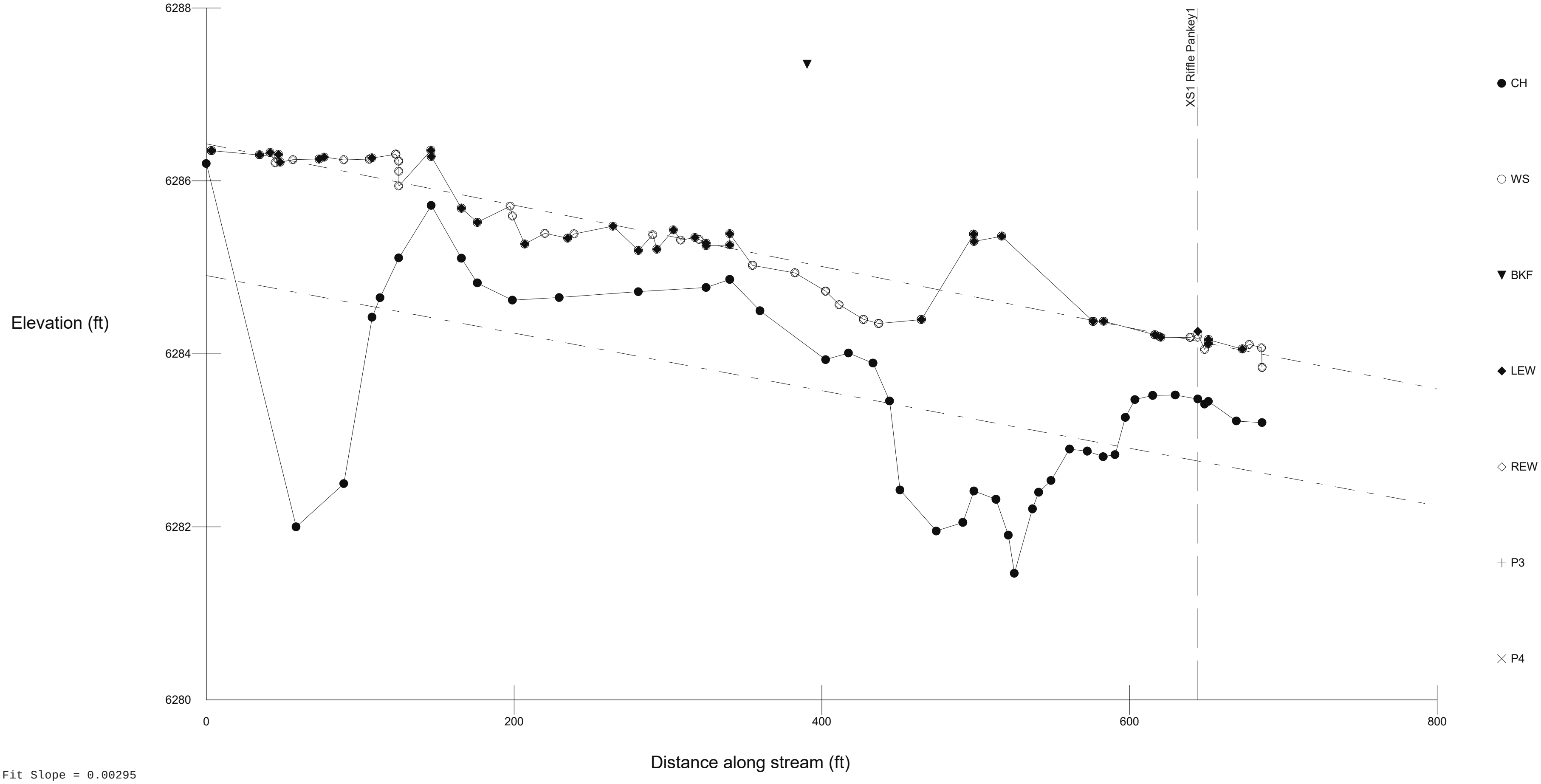
Input Variables from Above Information				**Output Variables (Calculated)**				
From above:	A_{bkf} =	201.9	SF	Bankfull mean depth:	d_{bkf} =	2.63	Ft	
From Above:	W_{bkf} =	76.7	Ft	Wetted Perimeter (Approx):	W_p =	78.00	Ft	81.9647 *Approx. 2d+W*
D_{84} at Riffle*	D_{84} =	54	mm	D84 (mm)/304.8	D_{84} =	0.177	Ft	Use protrusion ht D84 for cobble/boulder streams
Bankfull Slope:	S_{bkf} =	0.00166	ft/ft	Hydraulic Radius (Abkf/Wp):	R_h =	2.59	Ft	Also hydraulic mean depth
Gravity	g =	32.17	ft/sec2	Relative Roughness (Rh/D84):		14.61		
Drainage Area:	DA =	219.0	mi^2	Shear Velocity $(gRS)^{0.5}$	u* =	0.372	ft/sec	
Straight reach shear s	τ =	0.27	lb/ft^2		R_h/D_{84} =	14.610		
		γdS						

* From riffle at surveyed cross-section (see p. 2-27, RSFG)

Manning's "n" from Jarrett (USGS), $n = 0.39S^{0.38}R^{-0.16}$ = n = 0.02942 Jarrett's "n"
steep, step-pool, cobble-boulder, A1-3, B1-3, C2 & E3

ESTIMATION METHODS - For Range of Probable Discharges				**Roughness**	**Mean BKF Vel (fps) (Typ 3-6)**	**Bankfull Discharge (cfs)(A*u)**	**Use?** (1: Yes, 0: No)	**NOTES**
1. Friction Factor/Relative Roughness (U/u*), u = [2.83 + 5.66 Log(Rh/D84	Log (Rh/D84) = 1.1647		n =	0.0326	3.50	707	1	
Manning's Equations								
2a. Roughness Coefficient, $u = 1.4865*R^{0.667}*S^{0.5}/n$	Uses "n" from Jarrett's Eqn (steep, step-pool, cobble-boulder)		n =	0.0294	3.88	784	1	Most suitable for A1-3, B1-3, C2, E3
2b. Roughness Coefficient, $u = 1.4865*R^{0.667}*S^{0.5}/n$	Limerinos "n" from RiverMorph		n =	0.0311	3.67	741	1	Most suitable for gravel-bed streams
2c. Manning's equation using typical "n" for stream type	*Small River*		n =	0.0370	3.09	623	0	Values are built-in with RiverMorph 5.0 Software
2d. Manning's Eq. with "n" estimated from Strickler Formula	$n = 0.0474(D_{50})^{0.17}$	D_{50} in meters	n =	0.0250	4.58	924	0	For gravel bed channels
2e. Manning's Equation using "n" from engineer's judgment (compare to published information & photographs)			n =	0.0350	3.26	659	1	Visual Comparison with USGS published data
2f. Manning's Using Cowan Adjustments to "n":	(USGS Modified Channel Method)		n =	0.0400	2.86	576	0	Use worksheet in this workbook to obtain "n"
Darcy-Weisbach Friction Factor								
3a. Darcy-Weisbach, $u = [8gdS/f]^{0.5}$ OR, $u = (u/u^*)[8gRS]^{0.5}$		$f = 8gRS / V^2$	f =	0.09020	3.53	713	1	Use RiverMorph Resistance Equation to find.
3b. Darcy-Weisbach (Hey 1979), uses Dmax instead of mean depth for "d"		$f = 8gDS / V^2$	f =	0.14043	2.83	571	0	Use RiverMorph Resistance Equation to find.
Other Methods								
4a. Enter Q(bkf) estimated from USGS Stream Stats:	**708** cfs		n =	0.0326	3.51	708	1	
4b. Enter Q(bkf) estimated from Log Pearson III distribution:	**832** cfs		n =	0.0277	4.12	832	1	
4c. Estimated Q(bkf) from Exceedence analysis of gage data	**889** cfs		n =	0.0259	4.40	889	1	
AVERAGES of SELECTED RESULTS (based on groupings of Q, engineering judgment, & Velocities in Range of 3.0 - 6.0:				0.0306	**3.74**	**754**	8	

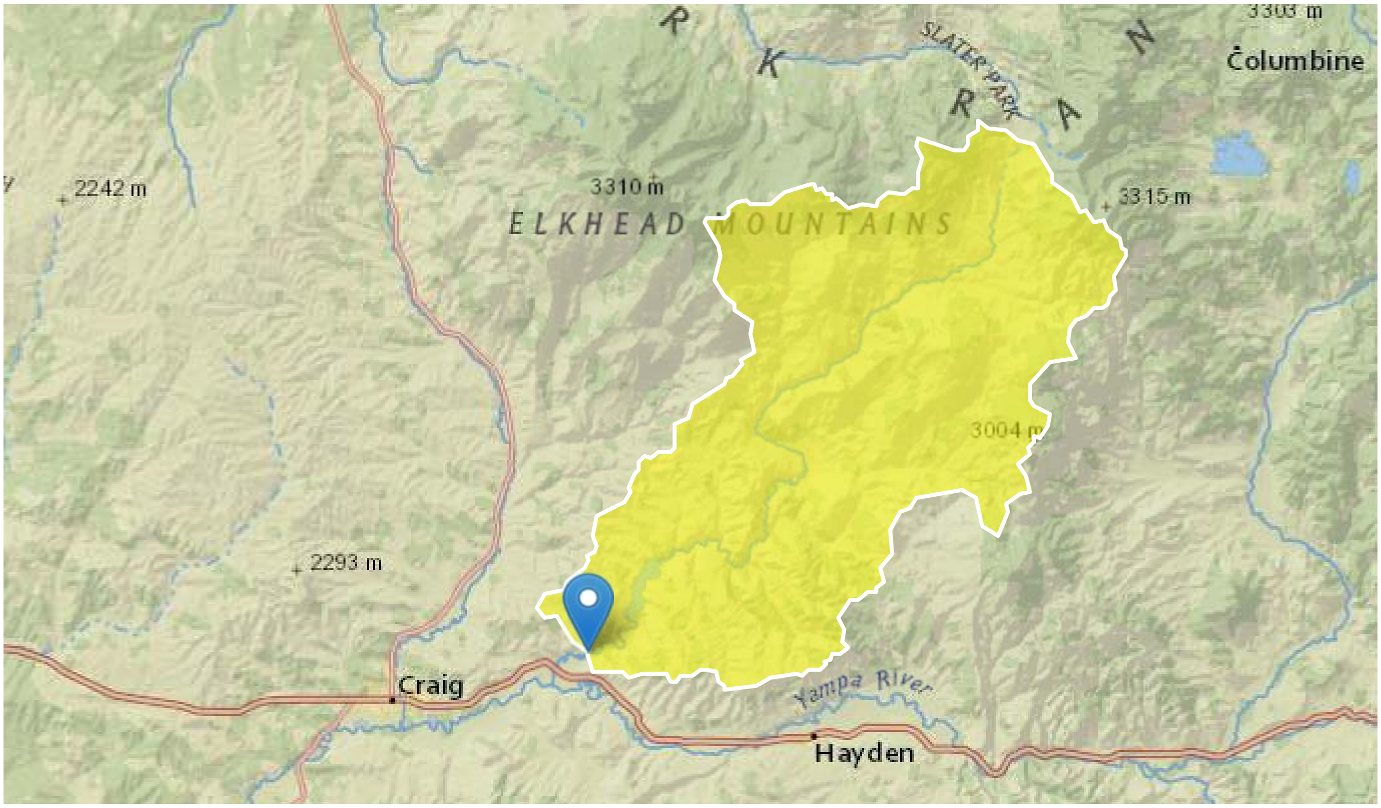

Sta 243+25
Slope Bank Back at 2H:1V
Bankfull Bench
Elev: 6270.8
Bankfull Elev: 6267.0
Water Surface on
Survey Day: 6264.10
Rock Toe



CH Best Fit Slope = 0.00295
WS Best Fit Slope = 0.00354

StreamStats Report for Lowest Point in Project Area

Region ID: CO
Workspace ID: CO20180814182753214000
Clicked Point (Latitude, Longitude): 40.53768, -107.41318
Time: 2018-08-14 12:28:09 -0600



Maximum drainage area for project. The reservoir does not contain flood storage and doesn't retain stormwater. However, it does attenuate the flow.

Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
DRNAREA	Area that drains to a point on a stream	219	square mile
PRECIP	Mean Annual Precipitation	26.27	inches
EL7500	Percent of area above 7500 ft	50	percent
ELEV	Mean Basin Elevation	7677	feet
BSLDEM10M	Mean basin slope computed from 10 m DEM	18.8	percent

Parameter Code	Parameter Description	Value	Unit
CSL1085LFP	Change in elevation divided by length between points 10 and 85 percent of distance along the longest flow path to the basin divide, LFP from 2D grid	38.7	feet per mi
ELEVMAX	Maximum basin elevation	10900	feet
I24H100Y	Maximum 24-hour precipitation that occurs on average once in 100 years	2.94	inches
I24H2Y	Maximum 24-hour precipitation that occurs on average once in 2 years - Equivalent to precitation intensity index	1.31	inches
I6H100Y	6-hour precipitation that is expected to occur on average once in 100 years	2.12	inches
I6H2Y	Maximum 6-hour precipitation that occurs on average once in 2 years	0.85	inches
LAT_OUT	Latitude of Basin Outlet	4490235	degrees
LC11BARE	Percentage of barren from NLCD 2011 class 31	0.2	percent
LC11CRPHAY	Percentage of cultivated crops and hay, classes 81 and 82, from NLCD 2011	4.5	percent
LC11DEV	Percentage of developed (urban) land from NLCD 2011 classes 21-24	0	percent
LC11FOREST	Percentage of forest from NLCD 2011 classes 41-43	43.4	percent
LC11GRASS	Percent of area covered by grassland/herbaceous using 2011 NLCD	2.9	percent
LC11IMP	Average percentage of impervious area determined from NLCD 2011 impervious dataset	1.7	percent
LC11SHRUB	Percent of area covered by shrubland using 2011 NLCD	45.7	percent
LC11SNOIC	Percent snow and ice from NLCD 2011 class 12	0	percent
LC11WATER	Percent of open water, class 11, from NLCD 2011	0.4	percent
LC11WETLND	Percentage of wetlands, classes 90 and 95, from NLCD 2011	0.6	percent
LFPLENGTH	Length of longest flow path	53.7	miles
LONG_OUT	Longitude of Basin Outlet	295625	degrees
MINBELEV	Minimum basin elevation	6260	feet
OUTLETELEV	Elevation of the stream outlet in thousands of feet above NAVD88.	6261	feet

Parameter Code	Parameter Description	Value	Unit
RCN	Runoff-curve number as defined by NRCS (http://policy.nrcs.usda.gov/OpenNonWebContent.aspx?content=17758.wba)	76.02	dimensionl
RUNCO_CO	Soil runoff coefficient as defined by Verdin and Gross (2017)	0.4	dimensionl
SSURGOA	Percentage of area of Hydrologic Soil Type A from SSURGO	8.08	percent
SSURGOB	Percentage of area of Hydrologic Soil Type B from SSURGO	44.9	percent
SSURGOC	Percentage of area of Hydrologic Soil Type C from SSURGO	19.6	percent
SSURGOD	Percentage of area of Hydrologic Soil Type D from SSURGO	21.1	percent
STATSCLAY	Percentage of clay soils from STATSGO	32.7	percent
STORNHD	Percent storage (wetlands and waterbodies) determined from 1:24K NHD	0.7	percent
TOC	Time of concentration in hours	12.64	hours

General Disclaimers

Upstream regulation was checked for this watershed.

Flow-Duration Statistics Parameters [50 Percent (110 square miles) Mountain Region Flow Duration]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	219	square miles	1	1060
PRECIP	Mean Annual Precipitation	26.27	inches	18	47

Flow-Duration Statistics Parameters [50 Percent (109 square miles) Northwest Region Flow Duration]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	219	square miles	1	5250
PRECIP	Mean Annual Precipitation	26.27	inches	8	49

Flow-Duration Statistics Flow Report [50 Percent (110 square miles) Mountain Region Flow Duration]

PII: Prediction Interval-Lower, Plu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	SEp
10 Percent Duration	393	ft^3/s	45
25 Percent Duration	129	ft^3/s	55
50 Percent Duration	52.3	ft^3/s	55
75 Percent Duration	31.7	ft^3/s	64
90 Percent Duration	23.5	ft^3/s	85

Flow-Duration Statistics Flow Report [50 Percent (109 square miles) Northwest Region Flow Duration]

PII: Prediction Interval-Lower, Plu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	SEp
10 Percent Duration	243	ft^3/s	73
25 Percent Duration	75.5	ft^3/s	77
50 Percent Duration	32.5	ft^3/s	83
75 Percent Duration	17.5	ft^3/s	NaN
90 Percent Duration	9.42	ft^3/s	154

Flow-Duration Statistics Flow Report [Area-Averaged]

Statistic	Value	Unit
10 Percent Duration	318	ft^3/s
25 Percent Duration	103	ft^3/s
50 Percent Duration	42.4	ft^3/s
75 Percent Duration	24.6	ft^3/s
90 Percent Duration	16.5	ft^3/s

Flow-Duration Statistics Citations

Capesius, J.P., and Stephens, V. C.,2009, Regional Regression Equations for Estimation of Natural Streamflow Statistics in Colorado: U. S. Geological Survey Scientific Investigations Report 2009-5136, 32 p. (http://pubs.usgs.gov/sir/2009/5136/http://pubs.usgs.gov/sir/2009/5136/)

Flood-Volume Statistics Parameters [50 Percent (110 square miles) Mountain Region Max Flow]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	219	square miles	1	1060
PRECIP	Mean Annual Precipitation	26.27	inches	18	47

Flood-Volume Statistics Parameters [50 Percent (109 square miles) Northwest Region Max Flow]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	219	square miles	5	5250
PRECIP	Mean Annual Precipitation	26.27	inches	8	49
EL7500	Percent above 7500 ft	50	percent	0	99

Flood-Volume Statistics Flow Report [50 Percent (110 square miles) Mountain Region Max Flow]

PII: Prediction Interval-Lower, Plu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	SEp
7 Day 2 Year Maximum	761	ft^3/s	46
7 Day 10 Year Maximum	1370	ft^3/s	35
7 Day 50 Year Maximum	1900	ft^3/s	31

Flood-Volume Statistics Flow Report [50 Percent (109 square miles) Northwest Region Max Flow]

PII: Prediction Interval-Lower, Plu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	SEp
7 Day 2 Year Maximum	292	ft^3/s	86
7 Day 10 Year Maximum	559	ft^3/s	59
7 Day 50 Year Maximum	902	ft^3/s	51

Flood-Volume Statistics Flow Report [Area-Averaged]

Statistic	Value	Unit
7 Day 2 Year Maximum	527	ft^3/s
7 Day 10 Year Maximum	965	ft^3/s
7 Day 50 Year Maximum	1400	ft^3/s

Flood-Volume Statistics Citations

Capesius, J.P., and Stephens, V. C.,2009, Regional Regression Equations for Estimation of Natural Streamflow Statistics in Colorado: U. S. Geological Survey Scientific Investigations Report 2009-5136, 32 p. (http://pubs.usgs.gov/sir/2009/5136/http://pubs.usgs.gov/sir/2009/5136/)

Monthly Flow Statistics Parameters [50 Percent (110 square miles) Mountain Region Mean Flow]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	219	square miles	1	1060
PRECIP	Mean Annual Precipitation	26.27	inches	18	47

Monthly Flow Statistics Parameters [50 Percent (109 square miles) Northwest Region Mean Flow]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	219	square miles	1	5250
PRECIP	Mean Annual Precipitation	26.27	inches	8	49

Monthly Flow Statistics Flow Report [50 Percent (110 square miles) Mountain Region Mean Flow]

PII: Prediction Interval-Lower, PIu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	SEp
January Mean Flow	37.1	ft^3/s	50
February Mean Flow	34.6	ft^3/s	51
March Mean Flow	42.3	ft^3/s	49
April Mean Flow	111	ft^3/s	44
May Mean Flow	441	ft^3/s	46
June Mean Flow	612	ft^3/s	46
July Mean Flow	214	ft^3/s	76
August Mean Flow	93.4	ft^3/s	80
September Mean Flow	68.4	ft^3/s	59
October Mean Flow	61.8	ft^3/s	45
November Mean Flow	47.9	ft^3/s	46
December Mean Flow	39.6	ft^3/s	47

Monthly Flow Statistics Flow Report [50 Percent (109 square miles) Northwest Region Mean Flow]

PIl: Prediction Interval-Lower, PIu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	SEp
January Mean Flow	28	ft^3/s	85
February Mean Flow	33.9	ft^3/s	77
March Mean Flow	42.5	ft^3/s	68
April Mean Flow	99.5	ft^3/s	84
May Mean Flow	341	ft^3/s	71
June Mean Flow	226	ft^3/s	80
July Mean Flow	90.9	ft^3/s	75
August Mean Flow	55.8	ft^3/s	90
September Mean Flow	54.1	ft^3/s	104
October Mean Flow	44.6	ft^3/s	94
November Mean Flow	36.9	ft^3/s	83
December Mean Flow	29.3	ft^3/s	79

Monthly Flow Statistics Flow Report [Area-Averaged]

Statistic	Value	Unit
January Mean Flow	32.5	ft^3/s
February Mean Flow	34.3	ft^3/s
March Mean Flow	42.4	ft^3/s
April Mean Flow	105	ft^3/s
May Mean Flow	391	ft^3/s
June Mean Flow	419	ft^3/s
July Mean Flow	153	ft^3/s
August Mean Flow	74.7	ft^3/s
September Mean Flow	61.3	ft^3/s
October Mean Flow	53.2	ft^3/s
November Mean Flow	42.4	ft^3/s
December Mean Flow	34.5	ft^3/s

Monthly Flow Statistics Citations

Capesius, J.P., and Stephens, V. C.,2009, Regional Regression Equations for Estimation of Natural Streamflow Statistics in Colorado: U. S. Geological Survey Scientific Investigations Report 2009-5136, 32 p. (http://pubs.usgs.gov/sir/2009/5136/http://pubs.usgs.gov/sir/2009/5136/)

Annual Flow Statistics Parameters [50 Percent (110 square miles) Mountain Region Mean Flow]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	219	square miles	1	1060
PRECIP	Mean Annual Precipitation	26.27	inches	18	47

Annual Flow Statistics Parameters [50 Percent (109 square miles) Northwest Region Mean Flow]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	219	square miles	1	5250
PRECIP	Mean Annual Precipitation	26.27	inches	8	49

Annual Flow Statistics Flow Report [50 Percent (110 square miles) Mountain Region Mean Flow]

PIl: Prediction Interval-Lower, PIu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	SEp
Mean Annual Flow	150	ft^3/s	33

Annual Flow Statistics Flow Report [50 Percent (109 square miles) Northwest Region Mean Flow]

PIl: Prediction Interval-Lower, PIu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	SEp
Mean Annual Flow	90.4	ft^3/s	55

Annual Flow Statistics Flow Report [Area-Averaged]

Statistic	Value	Unit
Mean Annual Flow	120	ft^3/s

Annual Flow Statistics Citations

Capesius, J.P., and Stephens, V. C.,2009, Regional Regression Equations for Estimation of Natural Streamflow Statistics in Colorado: U. S. Geological Survey Scientific Investigations

Report 2009-5136, 32 p. (http://pubs.usgs.gov/sir/2009/5136/http://pubs.usgs.gov/sir/2009/5136/)

Low-Flow Statistics Parameters [50 Percent (110 square miles) Mountain Region Min Flow]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	219	square miles	1	1060
PRECIP	Mean Annual Precipitation	26.27	inches	18	47
ELEV	Mean Basin Elevation	7677	feet	8600	12000

Low-Flow Statistics Parameters [50 Percent (109 square miles) Northwest Region Min Flow]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	219	square miles	5	5250
ELEV	Mean Basin Elevation	7677	feet	6880	10480

Low-Flow Statistics Disclaimers [50 Percent (110 square miles) Mountain Region Min Flow]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors

Low-Flow Statistics Flow Report [50 Percent (110 square miles) Mountain Region Min Flow]

Statistic	Value	Unit
7 Day 2 Year Low Flow	4	ft^3/s
7 Day 10 Year Low Flow	1.64	ft^3/s
7 Day 50 Year Low Flow	4.46	ft^3/s

Low-Flow Statistics Flow Report [50 Percent (109 square miles) Northwest Region Min Flow]

PIl: Prediction Interval-Lower, Plu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	SEp
7 Day 2 Year Low Flow	2.95	ft^3/s	212
7 Day 10 Year Low Flow	1.53	ft^3/s	280
7 Day 50 Year Low Flow	1.27	ft^3/s	338

Low-Flow Statistics Flow Report [Area-Averaged]

Statistic	Value	Unit
7 Day 2 Year Low Flow	3.47	ft^3/s
7 Day 10 Year Low Flow	1.59	ft^3/s
7 Day 50 Year Low Flow	2.87	ft^3/s

Low-Flow Statistics Citations

Size riffle thalweg for 2.0 cfs

Capesius, J.P., and Stephens, V. C.,2009, Regional Regression Equations for Estimation of Natural Streamflow Statistics in Colorado: U. S. Geological Survey Scientific Investigations Report 2009-5136, 32 p. (http://pubs.usgs.gov/sir/2009/5136/http://pubs.usgs.gov/sir/2009/5136/)

Peak-Flow Statistics Parameters [50 Percent (110 square miles) Mountain Region Peak Flow]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	219	square miles	1	1060
BSLDEM10M	Mean Basin Slope from 10m DEM	18.8	percent	7.6	60.2
PRECIP	Mean Annual Precipitation	26.27	inches	18	47

Peak-Flow Statistics Parameters [50 Percent (109 square miles) Northwest Region Peak Flow]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	219	square miles	1	5250
EL7500	Percent above 7500 ft	50	percent	0	99
PRECIP	Mean Annual Precipitation	26.27	inches	8	49

Peak-Flow Statistics Flow Report [50 Percent (110 square miles) Mountain Region Peak Flow]

PII: Prediction Interval-Lower, Plu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	SEp
2 Year Peak Flood	940	ft^3/s	49
5 Year Peak Flood	1320	ft^3/s	44
10 Year Peak Flood	1610	ft^3/s	41
25 Year Peak Flood	1820	ft^3/s	40

Statistic	Value	Unit	SEp
50 Year Peak Flood	2170	ft^3/s	39
100 Year Peak Flood	2450	ft^3/s	36
200 Year Peak Flood	2690	ft^3/s	36
500 Year Peak Flood	3030	ft^3/s	33

Peak-Flow Statistics Flow Report [50 Percent (109 square miles) Northwest Region Peak Flow]

PII: Prediction Interval-Lower, Plu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	SEp
2 Year Peak Flood	906	ft^3/s	113
5 Year Peak Flood	1610	ft^3/s	88
10 Year Peak Flood	2090	ft^3/s	79
25 Year Peak Flood	2880	ft^3/s	74
50 Year Peak Flood	3440	ft^3/s	74
100 Year Peak Flood	4180	ft^3/s	75
200 Year Peak Flood	4690	ft^3/s	76
500 Year Peak Flood	5710	ft^3/s	79

Peak-Flow Statistics Flow Report [Area-Averaged]

Statistic	Value	Unit
2 Year Peak Flood	923	ft^3/s
5 Year Peak Flood	1460	ft^3/s
10 Year Peak Flood	1850	ft^3/s
25 Year Peak Flood	2350	ft^3/s
50 Year Peak Flood	2810	ft^3/s
100 Year Peak Flood	3310	ft^3/s
200 Year Peak Flood	3690	ft^3/s
500 Year Peak Flood	4360	ft^3/s

Peak-Flow Statistics Citations

Capesius, J.P., and Stephens, V. C.,2009, Regional Regression Equations for Estimation of Natural Streamflow Statistics in Colorado: U. S. Geological Survey Scientific Investigations

Report 2009-5136, 32 p. (http://pubs.usgs.gov/sir/2009/5136/http://pubs.usgs.gov/sir/2009/5136/)

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