July 31, 2021

To: Ben Wade, Colorado Water Conservation Board (CWCB)

From: Left Hand Watershed Center

RE: CWCB Water Plan Grant – Stewardship through Community Science **Final Report** (POGG1,PDAA,201900000060)

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The purpose of this memo is to provide a final progress report about activities related to the Left Hand Watershed Center's (formerly Lefthand Watershed Oversight Group) Stewardship through Community Science project. The project timeline is 7/15/2018 – 7/31/2021 and CWCB project budget is $36,000 (total project budget is currently $77,500).

## 1. Project Summary and How the Project Was Completed

Over the last three years, Stewardship through Community Science was been foundational in helping the Watershed Center's build our [Community Science Program](). Through this project, the Watershed Center planned, designed, implemented, monitored, and adjusted our community science efforts into an established and successful program with a diverse audience of participants and entry points. With the goal of building community-wide stewardship ethic rooted in watershed science and place-based, participatory learning, Figure 1 below summarizes how this project was completed.


**Figure 1** shows the three key steps and associated deliverables involved in completing Stewardship through Community Science. Each of these is discussed in more detail within this report.

On the following page, Table 1 describes accomplishments, challenges, and lessons learned across the project, as well as a summary of how data collected was used to inform stewardship and effectiveness of our community science approach (based on CWCB Deliverable associated with Task 3).

**Table 1** describes accomplishments, challenges, lessons learned, and data for each deliverable.

| Deliverable | Accomplishments | Challenges | Lessons Learned (Solutions to Challenges) | How Was Data/Information Used? |
|---|---|---|---|---|
| Strategic Plan | -Interviews with more than 30 diverse community members<br>-Development of program mission, vision, goals, actions, project process, and metrics | -Engagement and research goals were often difficult to align | -To balance engagement and research goals specific goals and audiences for each project, and incorporate phased approaches (e.g. start with engagement, work towards research) | -Information from plan was used to create and assess specific projects and their effectiveness words the program mission and vision |
| **Protocols** | -Catch the Hatch and Community Monitoring protocols were developed, tested, and adjusted | -Data quality control | -Compared data collected by community scientists to data collected by researchers in similar areas at similar times | -Protocols were shared and modified for others (e.g. schools, universities, citizen science groups) |
| **Training Materials** | -Training materials and events associated with protocols were developed and provided for participants | -COVID restricted in-person and group events | -Recorded training videos helped engage additional participants who otherwise could not attend training events | -Materials were shared and modified for others (e.g. schools, universities, citizen science groups) |
| My Watershed Mobile App | -App was developed, tested, and refined with a “facelift” after one year of usage | -Unexpected bugs and COVID schedule delays | -On-going app maintenance and upkeep are required, as well as backup options for data entry | -Mobile app was used to record and share over 2,000 measurements, and help quantify engagement and data collection efforts |
| Interactive Website | -Stewardship Handbook was converted into an interactive webpage | -Consolidating PDF content into web format | -Integrating website plan earlier in the process will help improve efficiencies | -Interactive format helped increase the impact and usability of the handbook. Information was shared more directly with landowners |
| Catch the Hatch | -64 members collected data over three years | -Coverage by participants across all dates | -On-going project management helps ensure that additional outreach occurs during the project related to gaps, questions, and schedule changes | -233 observations are informing regional mayfly population health as related to stream flows and temperatures |
| Community Monitoring | -20 volunteers collected data over two years | -Data quality control | -Staff scientists are needed to oversee small groups of community scientists | -Data is informing watershed health status, weed control needs, and sediment issues |
| **Toolbox** | -Support provided for more than six external community science efforts as part of “toolbox” approach | -Prioritizing how we support external efforts | -Future iterations of the strategic plan will include additional strategies how to select and prioritize support opportunities | -Teacher lesson plans (Lyons Schools, St. Vrain Community Montessori)<br>-Independent Student Projects (Center for Sustainable Landscapes)<br>-Independent Boy Scout Vegetation Project |

## 2. Obstacles Encountered and Solutions

Through the duration of the project we experienced a number of obstacles and delays related to the development of the mobile app. Obstacles and delays were primarily related to unexpected bugs and COVID scheduling issues. To overcome these obstacles, we stored and backed up data locally to ensure that all data was maintained and compatible with app upgrades and transitions; (2) allocated additional staff time towards app upkeep and maintained; and (3) collected backup hard copy data where feasible. Overall, our community science program is benefitting from data collection and storage efficiencies provided by the app, however long-term upkeep and maintenance are necessary to ensure the app is consistent and reliable. Other obstacles are listed in Table 1, Challenges.

## 3. Confirmation of Matching Commitments

Below we provide a confirmation that all matching commitments have been fulfilled.

| Match Funding Source | Income | Expense | Status |
|---|---|---|---|
| Gates Family Foundation | $42,500.00 | $42,500.00 | Complete as of 06/2020 |
| Department of Local Affairs Community Development Block Grant – Disaster Recovery | $65,000.00 | $65,000.00 | Complete as of 06/2018 |
| **Total Match** | **107,500.00** | **108,000.00** | **Complete** |

## 4. Summary of Key Deliverables

1. Program Website: https://watershed.center/engage-community/#community-science
2. Strategic Plan: https://watershed.center/wp-content/uploads/2019/07/Community-Science-Plan.pdf
3. Catch the Hatch Project Materials: https://watershed.center/catch-the-hatch/
4. Interactive Website: https://streamhandbook.org/
5. State of the Watershed Report (integrating community monitoring): https://watershed.center/wp-content/uploads/2020/05/Watershed-Center-State-of-the-Watershed-Report-2020-Final_with-ES-v4.pdf
6. My Watershed App: https://apps.apple.com/us/app/my-watershed/id1462336274

# Strategic Plan for Community Science

Recognizing the immense values derived from engaging our community in helping advance and inform watershed science, restoration, and stewardship, Left Hand Watershed Center (the Watershed Center), in partnership with CitSci.org, developed a Strategic Plan for Community Science. This plan, detailed below, helps us to enact our vision to improve the stewardship ethic of our community for a healthy and resilient watershed.

## Mission and Vision

The Community Science Plan aims to provide high-quality community science projects that inform adaptive watershed management and engage our community in place-based learning. All projects offer value in the areas of watershed science, restoration, stewardship, and place-based education. Ultimately, we envision a community of watershed stewards with the knowledge to make science-based decisions, rooted in adaptive management, about the health and resilience of our watersheds.

## Community Science Goals

1. Fill data gaps through effective data collection
2. Inform adaptive watershed management
3. Cultivate an active community of stream stewards
4. Educate community members about adaptive management-based watershed stewardship
5. Sustain and grow successful community science projects

## Community Science Actions

1. Implement community science projects that fill data gaps
2. Implement community science projects that improve Performance Standards and Management Triggers in the Monitoring and Assessment Framework
3. Increase overall understanding of watershed health and resilience through participation in successful community science projects
4. Facilitate stakeholder collaboration and community participation by co-developing projects
5. Offer projects that engage K-12 students
6. Fully fund each community science project for the length of time needed to meet objectives and answer scientific question(s)

## Rooted in Adaptive Management

All community science projects will be rooted in the Watershed Center's Adaptive Management Plan. This plan was developed to assess the trajectory of our watersheds towards health and resilience, as illustrated by a conceptual model showing our goals. Assessing this trajectory involves iterative scientific data collection at meaningful scales over both space and time to evaluate performance standards. Community engagement in this process is necessary because people are part of our watersheds and need to be informed, engaged, and invested in adaptive management decisions that impact their lives.

## Steps to Identifying and Vetting a Community Science Project

The following steps describe our procedure for identifying and vetting community science projects. Other organizations can use and modify this process to develop new projects in other watersheds.

### Step 1 – Conduct Stakeholder Analysis

Our first step involves interviewing (listening) to stakeholders to discover their needs, motivations, desires, challenges, pain points, and potential benefits related to watershed health topics. Our goal with these interviews was to understand what motivations result in the best participation and most useful outcomes from any given project from the perspective of our community. Overall, we completed more than 15 interviews and gained useful insight that will help make our projects successful.

Although each interview was unique, we generally asked questions to help us better understand each group or individuals (1) data collection goals and needs, (2) common issues/concerns/knowledge gaps that they have identified in the community related to watershed health, and (3) interest in citizen/community science. Below is a list of sample questions:

- What kind of data do you currently collect and do you use community members to collect it?
- What goals do you have in relation to data collection and/or community participation?
- Who do you partner with regarding data collection and post processing? Do you have a plan in place for how data will be collected, analyzed, stored and made accessible to others?
- Looking back in the past year, what are common issues/questions/knowledge gaps in the community related to your work (what is something you wished they better understood)?
- Thinking back on past year, what is one thing you'd like to see improved in your watershed?

### Step 2 – Prioritize Stakeholder Needs and Potential Project Ideas

After completing interviews, we developed a stakeholder analysis matrix to track which issues were important to each stakeholder group. This matrix enabled us to quickly assess which issues were common among different stakeholder groups to help prioritize projects that would be most interesting and relevant for our community. The complete matrix is shown on the following page (Table 1).

As we collected information and developed this matrix we also learned that interviewees generally fell into two groups: (1) stakeholder groups that need data and (2) volunteer community scientists that could collect data. Realizing that meeting the needs and interests of both groups is important, we started parsing results based on these two groups.

Additionally, given the importance of adaptive management in guiding data collection, we recognized that a successful project must occur at the intersection of volunteer, stakeholder, and adaptive management interests.

**Table 1:** This matrix shows commonly important issues for each stakeholder group, as learned through interviews conducted in early 2019.

| | Stakeholder or Volunteer? | Water Quality | Flow Level | Clean Drinking Water | Flood Events/Risk | Swimmable Waters | Insect Hatch Timing | Wildlife Habitat | Restoration | Trail Conditions | Climbing Conditions | Soil Health | Climate Change Impacts | Wildfire Risk | Restoration Monitoring Data | Safety | Document Issues | Government role | How to make a difference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Stakeholder** | | **Water** | | | | | **Organisms** | | **Restoration** | | | | | | **Data** | | | **Roles** | |
| Anglers | V | x | x | | x | | x | x | x | | | | x | | x | x | x | | |
| Landowners | V | x | x | x | x | | | | x | | | | x | | | x | x | x | |
| Boulder/Longmont retired volunteers | V | x | x | x | x | | | | x | | | | x | | | | | | x |
| Recreationists (trail runners, mountain/road bikers, climbers) | V | | | | x | | | | x | x | x | | | | | x | x | | |
| High School Students | V | x | | x | | x | | | | | | | | | | x | | | x |
| Community members- Mountain Sustainability group | S/V | x | x | | x | | | x | | | | | x | x | | x | x | | x |
| Farmers/Ag Community | S/V | x | x | x | x | | | | x | | | x | x | | x | | x | x | |
| Passive Recreationists | V | x | x | | x | | | x | | x | | | | | | x | x | | |
| Families | V | x | x | x | x | x | | x | | | | | | | | x | x | | |
| City of Longmont | S | x | x | | x | | | | x | | | | | | x | | x | | |
| City of Boulder | S | x | x | | x | | | | | x | | | | | x | x | x | | |
| State Government | S | | | | | | | | | | | | | | | | | x | |
| County Government | S | | | | | | | | | | | | | | | | | x | |
| Wildland Restoration Volunteers | S | | | | x | | | | x | x | | | | | x | x | x | | |
| Other coalitions | S | x | x | x | x | | | | x | | | | x | | x | | | | |
| Keep It Clean Partnership | S | x | x | x | x | | | | x | | | | x | | x | | | | |

## Step 3 – Filter Interests to Identify Potential Projects

While the stakeholder analysis matrix (Table 1) provides a helpful snapshot of common issues, we performed further assessment to identify which issues could transfer to specific community science projects with a high likelihood of success. This required identifying potential projects associated with issues. Potential projects were identified through brainstorming and researching existing citizen science efforts. A complete list of potential projects is provided in Table 2, later in this document. To assess each potential project, we used a "SPAR" treatment, as summarized below.

- **S**ize – Size of segment of people who may be interested?
- **P**articipate – How willing might these people be to participate in a related project?
- **A**ccess – How accessible are the people who may want to participate?
- **R**isk – How risky might the related project be for our organization to implement?

We also considered the following facets for each potential project to assess costs/benefits:

- Return On Investment (ROI) – Time invested in training vs. time saved in sampling?
- Fundability – Cost to build/launch; Staff time required; Cost for Materials?
- Relevance to Adaptive Management Plan – How well does data help with known gaps?
- Relevance to Community Science Volunteers – How interested are volunteers in participating?
- Relevance to Stakeholder – How useful and trustworthy are the data for stakeholders?

## Step 4 – Develop Research Questions or Monitoring Objectives

For each priority interest considered, we devised focused research questions or monitoring objectives. Some interests had multiple singular research questions or objectives.

In cases where monitoring objectives could be modified to address research questions, we turned monitoring goals into scientific experiments. However, this was not always appropriate, and we acknowledge that some projects meet monitoring objectives rather than research goals. The example below described how a monitoring goal was reframed for research.

- **Re-Framed Research Question** – Is the ecological condition of our watershed improving, declining, or remaining the same each year?
- **Monitoring Objective** – Assess watershed health and resiliency following restoration.

**Research Question vs. Monitoring Objective**

**Research Question** – Data collection is to confirm or refute a specific inquiry.

**Monitoring Objective** – Data collection is to explore and describe a phenomenon.

## Step 5 – Are Interests a Good Fit for Community Science?

Pocock et al. (2014) developed a comprehensive decision framework to provide guidance about the suitability of a citizen science approach for any interest or potential project. We evaluated each potential project using this framework to ensure, refine, and clarify our aim. Feasibility, scalability, do-ability, and volunteer safety were key to the evaluation.

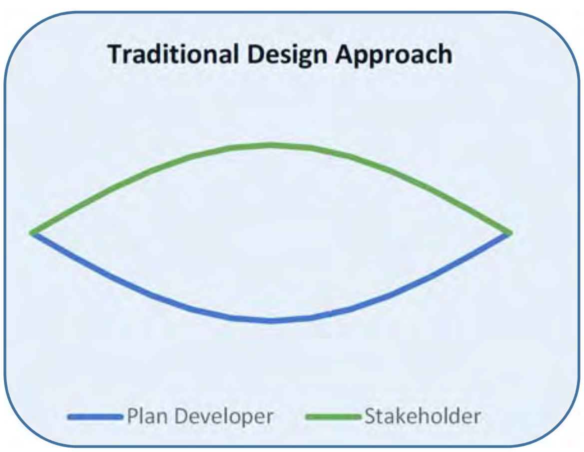
## Step 6 – Is Anyone Else Doing Similar Projects?

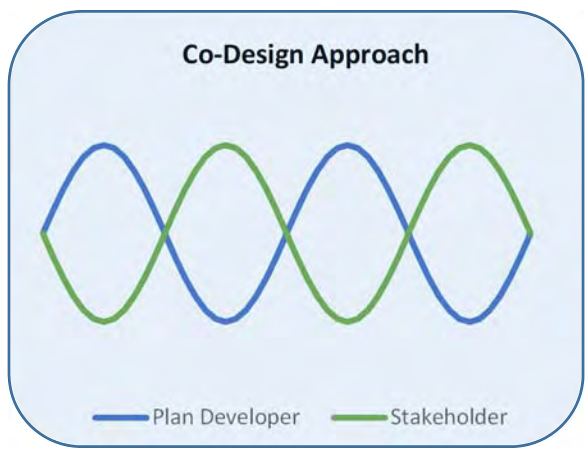
Checking for existing projects was essential to avoiding reinventing the wheel. With the growing popularity of citizen science, there are many projects that are being implemented by diverse groups. To avoid overlap, we conducted thorough research about existing projects and reached out to national organizations such as US National Phenology Network (NPN) to make sure that we were not repeating existing efforts. Reaching out to others was also critical to ensure that we could incorporate our data into other ongoing efforts where appropriate. For example, by making minor modifications to data entry methods we are ensuring that data collected as part of our "Catch the Hatch" pilot project can be incorporated into the NPN database as part of a larger, long-term effort.

## Step 7 – Re-Engage Stakeholders in Designing the Project

As we moved into project design we re-engaged with appropriate stakeholder groups on a regular basis. As illustrated below, a traditional project design approach engages stakeholders at the beginning and end of the process, while a co-design approach engages stakeholders regularly during the design process. This approach enables iterative co-design to ensure that stakeholders have an opportunity to participate in project creation and provide feedback on planning, design, protocols, recruitment strategies, retention strategies, data analyses, participant feedback loops (communication plans), and project evaluation approaches.

As illustrated below, engagement is continuous and iterative throughout the entire process so that stakeholders can have buy-in and ownership of the projects.




# Bench of Potential Projects

As mentioned in Step 3 above, we developed a comprehensive "bench" of potential projects. This bench outlines all of the potential projects that we envisioned following completion of steps one through six of the project identification and vetting process. We can move forward projects from this bench as needed, and more projects can be added to this bench as new ideas are generated.

**Table 2:** A subset of the of potential projects identified in June 2019. A complete bench is available online at https://www.dropbox.com/s/i6a6ig9316pim9y/Project%20Bench.xlsx?dl=0. This bench is a living document, with new projects added and removed as we conduct additional stakeholder analyses. The document specifies Project Name, Project Goals, Project Originator (new projects developed by Left Hand Watershed Center vs existing external projects) and Level of Effort (Green is low; Yellow is medium; Red is high). It also provides links to sample datasheets for each possible project.

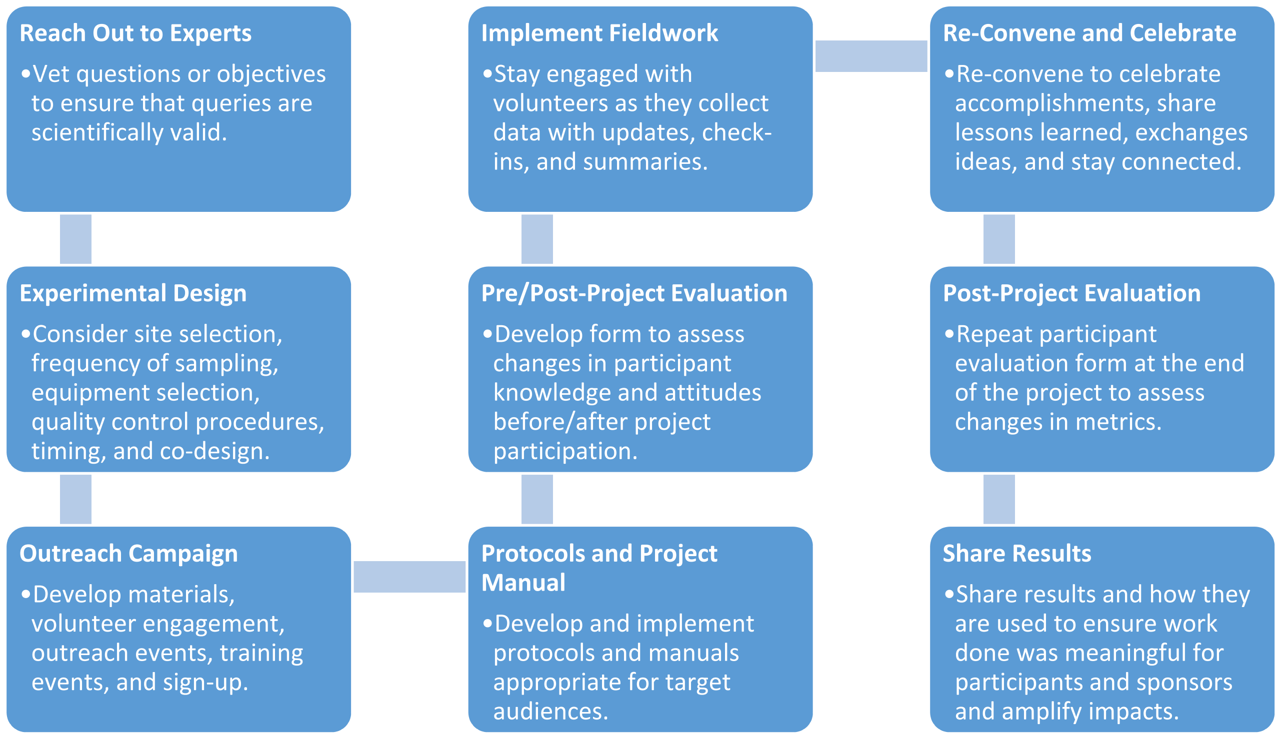
The Watershed Center or others can use this table as a starting place for potential projects. The full online version specifies Science Goals, Education Goals, Potential Target Audiences, Target Levels of Participation, and Recommended Seasonality, among many other factors to help project sponsors narrow in on an appropriate project for their specific needs and preferences.

| Project Name | Project Goal | Origin | Effort |
|---|---|---|---|
| AquaBlitz | Identify trends for comparisons upstream and downstream in biodiversity in streams and riparian zones. | | |
| BACI Stream Restoration Success Monitoring | Develop meaningful biological data for use in stream restoration monitoring. Datasheet. | | |
| Rare Bird Detectives | Monitor habitat specialists that are isolated or restricted with a focus on riparian/wetland species of concern. | | |
| HawkWatch | Monitor raptor populations. | | |
| Christmas Bird Count | Understand bird population trends. | | |
| Project FeederWatch | Track long-term trends in bird distribution and abundance. | | |
| Benthic Brigade | Monitor water quality and other indicators of watershed to educate citizens and inform decision makers about the condition of Colorado's waters. | | |
| City Nature Challenge | Make observations of nature in cities around the world. | | |
| Climbers for Bat Conservation | Understand bat ecology. | | |
| CoCoRaHS | Measure and record precipitation across the country. | | |
| CrowdWater | Collect a large amount of data to improve the forecast of hydrological events, such as droughts or floods. | | |
| EarthEcho Water Challenge | Understand the water quality of water bodies around the world (pH, temperature, dissolved oxygen, turbidity). | | |
| iNaturalist | Explore and share observations from the natural world to contribute to biodiversity science. | | |

| Project Name | Project Goal | Origin | Effort |
|---|---|---|---|
| ISeeChange | Combine anecdotal observations of change with sensor, satellite data to create a record of climate change over time. | 🌎 | ● |
| Stream Team | Identify potential flood vulnerabilities. | | ● |
| StreamTracker | Improve intermittent stream mapping and monitoring with observations of streamflow presence and absence. | 🌎 | ■ |
| Well Watchers | Monitor groundwater quality. | 🌎 | ◆ |
| The Bees Needs | More information on declining native bees. | 🌎 | ■ |
| Trail Trackers | Quantitatively assess trail conditions and potential sediment load contributions. | | ■ |
| Wildlife Watchers | Determine species presence/absence, and abundance. | | ● |
| Cat Cam Crew | Understand mountain lion and other wildlife population abundance trends. | | ■ |
| Fire Resilience Team | Assess, monitor, and reduce fuels loading in forests adjacent to streams and creeks of interest. | | ◆ |
| Crowd-out the Crowds | Assess resource conditions as they relate to recreational use. | | ■ |
| Weed Warriors | Predict current and future weed distributions; prioritize control. | | ■ |

## Steps to Designing and Implementing a Project

The following steps describe our general procedure for designing and implementing a selected project from the "bench," however steps will vary depending on the unique goals and needs of each project.




## Assessing Project Performance

The table below described how we quantitatively assess project performance relative to our overall community science goal and actions.

| Community Science Goal | Potential Success Metric |
|---|---|
| Fill data gaps through effective data collection. | Measure of data gaps filled, new data sets created, or research questions answered. |
| Inform adaptive watershed management. | Measure of parameters assessed or sites monitored. |
| Cultivate an active community of stream stewards. | Measure of number of stakeholder groups involved in co-creation or number of participants reporting changed attitude, knowledge, or behavior. |
| Educate community members about adaptive management-based watershed stewardship. | Measure of number of participants reporting changed attitude, knowledge, or behavior. Measure of number of K-8 place-based learning opportunities or workshops. Measure of number of outreach information materials (e.g. blogs, articles, or stories) shared. |
| Sustain community science efforts. | Measure of budget raised or active projects. |

## 2019 Community Science Projects List

The table below is a list of our current on-going community science projects.

| Project Name | Project Type | Project Goal | Resource Page |
|---|---|---|---|
| Catch the Hatch | Research Question | Advance understanding of mayfly emergence phenology | Project Website |
| Pebbles | Monitoring Objective | Advance understanding of riffle habitat quality | TBD, In progress anticipated Feb 2020 |
| Pools | Monitoring Objective | Advance understanding of pool habitat quality | TBD, In progress anticipated Sep 2019 |
| Run Off | Monitoring Objective | Advance understanding of high flows | TBD, In progress anticipated Feb 2020 |
| Low Flow | Monitoring Objective | Advance understanding of low flow and water needs | TBD, In progress anticipated Feb 2020 |
| Fishes | Monitoring Objective | Advance our understanding of fish populations, distributions, and conditions | TBD, In progress anticipated Feb 2020 |

In 2019 the Watershed Center we will implement monitoring projects during Front Range Watershed Days on September 28th. This event will entail a community celebration of watershed health and resilience, as well as a dedicated monitoring event using standardized protocols by community members across watersheds. By integrating celebration and monitoring we hope to raise awareness about watershed resiliency, help people connect to watershed issues, and generate region-scale scientific data about our watersheds.

## Looking to the Future

Moving forward, the Watershed Center will work to meet our community science goals by growing our existing projects and developing and implementing new projects from our bench of potential projects (Table 2). Throughout this process we will continue to adapt our efforts to the needs of our community by evaluating our projects and iterating the stakeholder engagement and interview process to update Table 1. Using project evaluations and performance metrics, we will assess the benefits of each project annually to guide decisions about which projects should be continued or how they may need to be modified. We will update this plan and our approach as new information is learned.

# Catch the Hatch

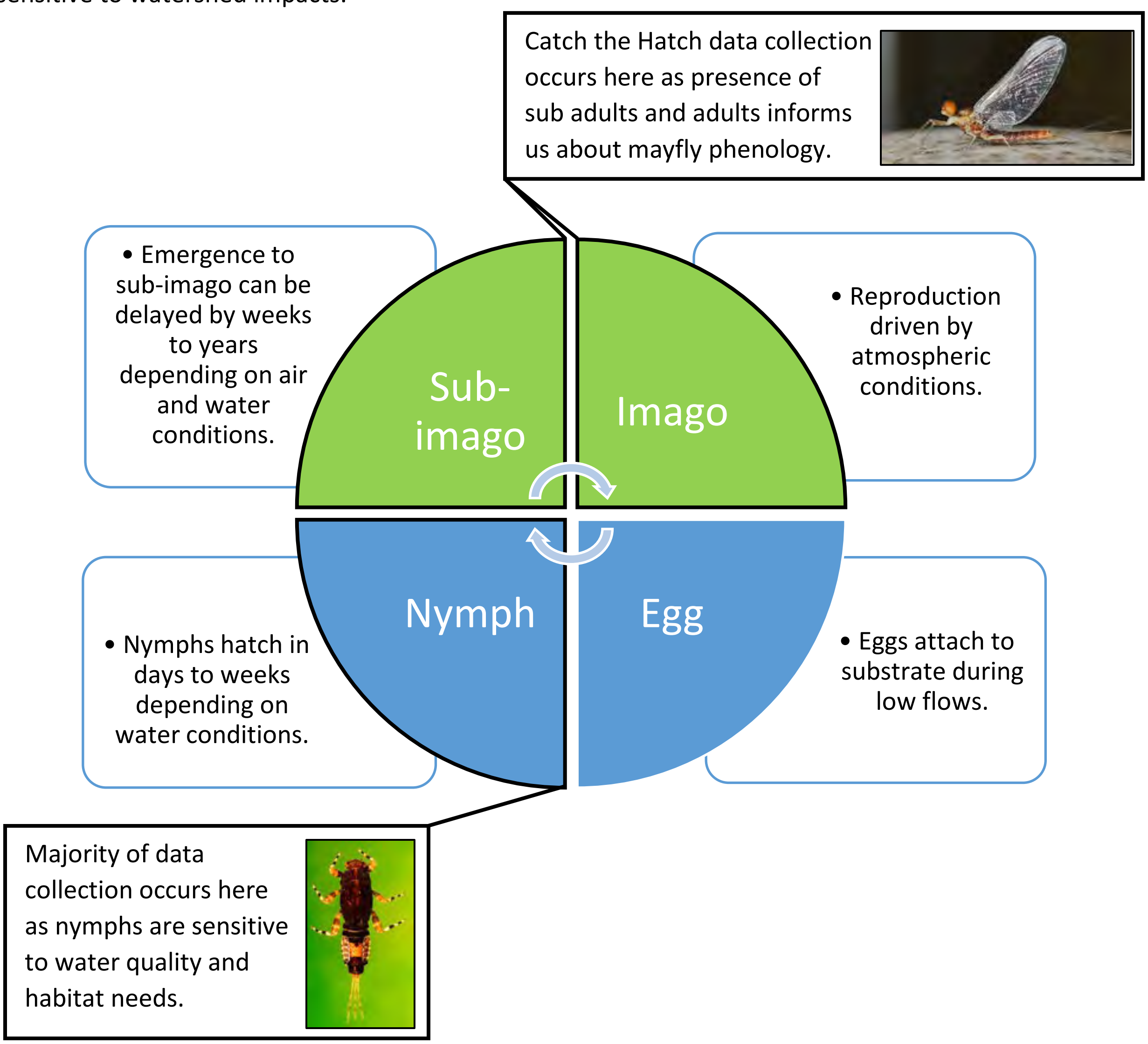
While mayflies are critical to our watersheds, science does not do a great job at measuring adult mayfly emergence. Most mayflies are measured in their larval phase because they are easier to sample and identify. Yet adult emergence is critical for reproduction and as a food source for trout. Mayfly biodiversity is also threatened by pollution and climate change. As a community that knows and loves our bugs, lets help science better understand our mayflies into the future.

Join the second year of Catch the Hatch by becoming a data catcher this June 15 through July 15!

## Why are we doing it?

Mayflies are important indicators of watershed health. Their life stages are both aquatic and terrestrial, and are driven by dynamic watershed processes such as flow and water temperature.

On the diagram below we discuss drivers behind the mayfly lifecycle and why understanding all stages of mayfly phenology is important. Science generally measures mayfly biodiversity at the aquatic nymph stage, yet terrestrial emergence is critical for successful reproduction, as prey for fish, and is highly sensitive to watershed impacts.



## Catch the Hatch Project Details

This summer we will be tracking sub adult and adult Pale Morning Duns (PMDs), a conspicuous mayfly species known and loved by anglers and fish alike.

Citizen scientists will visit three pre- selected sites from June 15 to July 15:

- **Boulder Creek** at Memorial Park
- **Left Hand Creek** at Buckingham Park
- **N. St. Vrain Creek** at Button Rock

Locations can be found online at: https://lwog.org/programs/stewardship/catch-the-hatch

*Sites are located within similar watershed locations and have public fishing access.* ***Bring your rod!***

## Volunteer Data Catcher Details

### Learn more!

- All project details are online at https://lwog.org/programs/stewardship/catch-the-hatch

### Join the effort!

- Check your availability from June 15 to July 15
- Sign up for site(s) and observation days on or website above or contact us.

### Train and get the gear!

- We'll provide you the gear and necessary training!
- Sign up for a guided or self-guided virtual training on our website above.
- Sign up for a gear pickup or delivery on our website above.

### Collect data!

- **Observe.** During your visit to the site, observe for emerging and adult PMDs.
- **Capture.** Use net & guide to ID sub adult and/or adult PMDs.
- **Record.** Presence or absence of PMDs using data sheets and online data entry via citsci.org.
- **Store.** If sub adult and/or adult PMDs are present, store one in a project vial.
- **Celebrate.** Return your data sheets and gear. Feel good that while you were enjoying your watershed you were also contributing to science!

### Looking Forward!

- Receive a project report that summarizes PMD presence related to flow and temperature at each site.
- Data will be used to help answer scientific research questions about emergence and adult phenology.
- Data will be used to validate a community approach for tracking emergence.

### Contact Us:

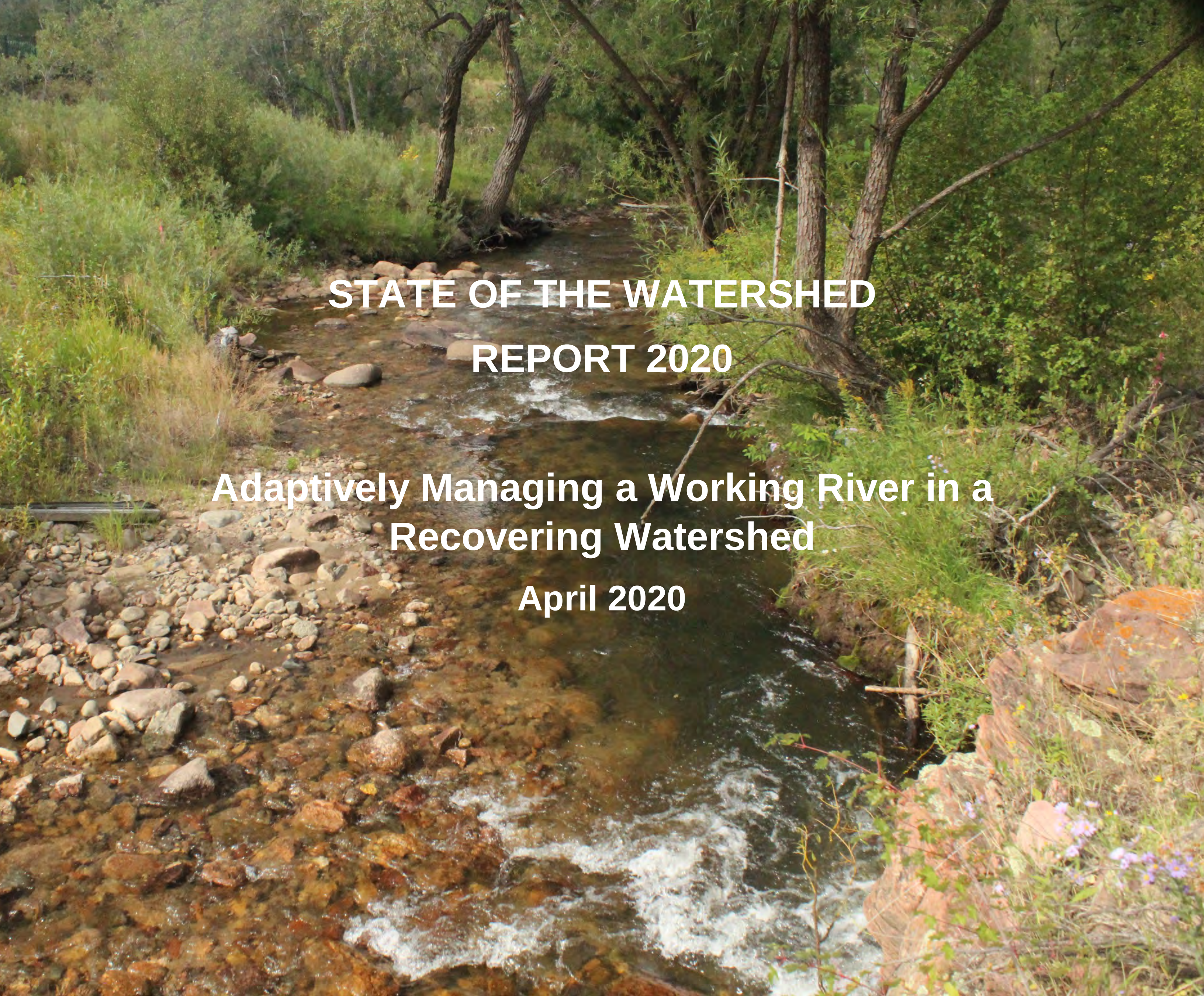
- For questions, comments, or assistance, please contact Deb Hummel at dhummel@lwog.org or 720-818-4573

**STATE OF THE WATERSHED**

**REPORT 2020**

# Adaptively Managing a Working River in a Recovering Watershed

**April 2020**



**Prepared by**


**LEFT HAND WATERSHED CENTER**
P.O. Box 1074, Niwot, CO 80544-0210
303.530.4200 | www.watershed.center

# Contents

# Executive Summary

As Left Hand Watershed recovers from the 2013 floods, Left Hand Watershed Center is monitoring and assessing the state of the watershed. We are using an adaptive management approach to answer the following question:

**Is Left Hand Creek Watershed on a trajectory towards resilience following restoration and recovery from the 2013 floods?**

## What We Learned

Watershed data collected at restored projects sites show that restoration and recovery efforts are helping our watershed maintain a trajectory towards health and resilience, but inherent watershed characteristics such as diverted flows and mine legacy impacts continue to pose challenges for ecological health and water quality.

## Key Takeaways

- 2019 monitoring shows that restored reaches are on trajectories toward increased resilience.
- Increased water quality monitoring efforts are needed to better understand watershed health.
- Monitoring and management continues to be a high priority in the Plains because these reaches showed the least improvement across all watershed health indicators.
- Lack of year-to-year water quality improvement in the upper watershed shows the continuing impact of mining activities and the importance of prioritizing monitoring and management in these reaches.
- An adaptive management approach related to forest health needs to be developed to address the growing risks to upland forests and resulting implications for aquatic health and water quality.

## Key Results

- **Floodplain connectivity** is maintaining the desired trajectory, but we need to increase our monitoring effort for a more comprehensive assessment at different flows and different locations.
- **Channel Morphology and Habitat** are maintaining the desired trajectory though locations in the Plains are likely responding less robustly due to infrastructure, including diversions.
- **Riparian Condition** is maintaining the desired trajectory with notable vegetation abundance at the creek edges; non-natives are competing with native vegetation in the plains reaches showing an increased need for ongoing adaptive management.
- **Benthic Macroinvertebrate Community** showed continued water quality impairments, unrelated to sedimentation, in the upper and lower watershed.

## Actionable Priorities

Based on the results above, Left Hand Watershed Center is prioritizing the following management and monitoring priorities to address data gaps and improve our watershed's trajectory towards resilience.

### Monitoring Priorities

- Increase water quality sampling in the Plains and pair with Benthic Macroinvertebrate Indices (BMI) to further study water quality impairments in the lower reaches of the creek.
- Assess the performance of pool-forming structures in creating self-sustaining pool habitat, specifically at 63rd Street.
- Increase fine sediment monitoring in the Plains reaches and identify potential sources.
- Quantify noxious weeds within the non-native community to better prioritize management actions.

- Increase monitoring of mine-related stressors and ecologic community responses that are continuing to impair water quality.
- Improve floodplain connectivity monitoring through increased efforts and refined hypotheses.
- Work with diverse stakeholders to develop an adaptive management plan for forests, including data consolidation to understand region-wide efforts and assessment of data gaps to identify monitoring priorities.

**Management Priorities**

- Continue weed control and re-seeding efforts to aid in native plant establishment at restored sites and increasing weed control and re-seeding in Plains sites due to greater competition.
- Address mine-related water quality impairments by working with the Environmental Protection Agency and the Colorado Department of Public Health and Environment.
- Work with water owners to assess and modify diversion structures or operations to address impairments in Plains reaches.
- Produce measurable ecological benefits by identifying opportunities to create inset floodplains or side channels in areas with disconnected floodplains

## Purpose

This State of the Watershed Report provides an annual update on monitoring results, implications, and suggested actions. The basis for this report is the Watershed Center's Adaptive Management Plan, which describes how we define and assess our watershed's trajectory toward health and resilience. This report answers the main question posed in our Adaptive Management Plan – **Is Left Hand Creek Watershed on a trajectory towards ecological resilience following restoration and recovery from the 2013 floods?** We answer this question by evaluating the performance of key ecological parameters relative to goals reflected in a conceptual model depicting desired future conditions. This report reflects data collected primarily in 2018 and 2019, following completion of eleven watershed restoration projects in 2016 and prior to completion of an additional eight restoration projects in 2020. A summary of each section is provided below.

| Section | Description |
|---|---|
| **1. What Did We Learn About Our Trajectory?** | Summarizes lessons learned, results, and actions based on monitoring and adaptive management in 2019. |
| **2. How Do We Use Adaptive Management to Assess Our Watershed?** | Describes our adaptive management approach including conceptualizing desired future conditions and the events that led to restoration and recovery. |
| **3. Monitoring and Assessment Methods** | Details our Monitoring and Assessment Framework, hypotheses, site descriptions, and data collection and analysis methods. |
| **4. Results and Discussion** | Details our results including watershed hydrologic conditions and answers to the flowing key questions:<br>• Is floodplain connectivity improved or maintained?<br>• Is channel morphology and habitat condition improved or maintained?<br>• Is native riparian condition and the native plant community improved or maintained?<br>• Is benthic macroinvertebrate (BMI) community, as an indicator of water quality and sedimentation issues, improved or maintained? |
| **5. Learning and Adjusting** | Reflects on what we learned about our adaptive management approach and how we plan to improve in the future. |

# 1. What Did We Learn About Our Trajectory?

Watershed data collected in 2018 and 2019 show that restoration and recovery efforts are helping our watershed maintain a trajectory towards health and resilience, but ongoing land and water management and use in watershed, such as diverted flows and mine legacy impacts, continue to pose challenges for ecological health and water quality. These results are most apparent in the benthic macroinvertebrate (BMI) community (as indicated by the Multimetric Index (MMI) parameter) in the Plains reaches. Also apparent is the need to address forest health in the context of watershed health and adaptive management due to increasing recognition among stakeholders about the threat of catastrophic wildfires. Given these findings, below is a summary of key conclusions in 2019.

## 1.1 Key Conclusions

- Water chemistry is fundamental to ecological resilience and efforts around water quality sampling, data sharing, and data interpretation must be increased throughout the watershed(s).
- The Plains reaches generally had the least improvement in all performance standards over time (though still no decreases) and as such, monitoring and management in these reaches should be a priority.
- Recent and historical hard rock mining activities in Left Hand Creek continue to have drastic impacts on water quality and BMI communities in the upper reaches of the watershed. Lack of year-to-year improvements indicates a need to prioritize corrective actions related to mine remediation.
- Adaptive Management should be expanded to include upland forests, which are facing risks from large wildfires that will have negative impacts on aquatic biota and water quality, and ultimately our trajectory towards watershed health and resilience.

## 1.2 Answers to Key Questions

**Is floodplain connectivity improved or maintained?**

**Metric:** Photo monitoring during high flow to observe floodplain inundation at applicable (per design specifications and annual peak flow discharges) benches and channels.

**What We Learned:** Yes, that 2019 peak seasonal flow inundated appropriate benches and side channels as expected per the design at seven monitored sites, but we need to increase our sampling effort for a more comprehensive assessment.

**Potential Actions:**

- Increase efforts to monitor more sites using similar methods.
- Refine hypotheses to evaluate depth, duration, and timing of peak seasonal flows and better understand what discharge functions as a flushing flow (promotes fine sediment transport and scour and reduces encroachment).

**Is channel morphology and habitat condition improved or maintained?**

**Metrics:** Pool habitat; Percent sands

**What We Learned:** Yes, pool habitat and percent sands met performance thresholds at most sites, but one Plains site had issues with pool habitat (63rd Street) and all Plains sites had an increase in percent sands. Lack of pool habitat may be due to inherent limitations of infrastructure-confined sites with multiple upstream diversions. We also observed shallow pools at two sites (63rd Street and Upper Left

Hand) that may be impacted by shifts in upstream structures. The increase in percent sands in the Plains site may indicate a sediment source issue but is also not surprising due to multiple diversions.

**Potential Actions:**

- Increase monitoring in the Plains sites to identify site-specific sediment issues and possible sources.
- Assess pool-forming structures at restored sites to determine if they adjusted and require improvement.

**Is native riparian condition and the native plant community improved or maintained?**

**Metrics:** Percent Native Plant Cover, Native Richness

**What We Learned:** Yes, percent native plant cover and richness (species number) increased or remained the same across all watershed zones with assistance from periodic weed control and re-seeding best management practices. Notably, the greatest increase in non-native cover occurred in the Plains, pointing to the challenge these sites face from non-native competition. Native herbaceous cover and native richness were generally greater in creek edge than upland zones, supporting the importance of maximizing restoration of lower benches and riparian edges.

**Potential Actions:**

- Continue monitoring using similar methods and similar sampling times with particular consideration of Plains sites, which face more competition from non-native plants.
- Quantify percent noxious weeds to better understand what portion of the non-native vegetation is noxious and help guide management.

**Is benthic macroinvertebrate (BMI) community, as an indicator of water quality and sedimentation issues, improved or maintained?**

**Metric:** Multimetric Index (MMI), Sediment Tolerance Indicator Value (TIV)

**What We Learned:** TIV met performance standards for sedimentation, but four out of 17 sites had water quality impairments based on MMI. Similar to 2018, impairments occurred in the upper and lower watershed, likely due to mine impacts and diversion activities. While continued impairments from mine impacts were expected at the CA Gulch site closest to the Captain Jack Mine, a new impairment was identified at Legacy 5. The cause for this impairment is unknown. Four Plains sites that were impaired in 2018 improved in 2019, but these improvements may be attributed to sampling during higher-flow (post irrigation season) conditions in 2019. Two of these Plains sites, 63rd Street and 81st Street, moved from impairment in 2018 to attainment in 2019.

**Potential Actions:**

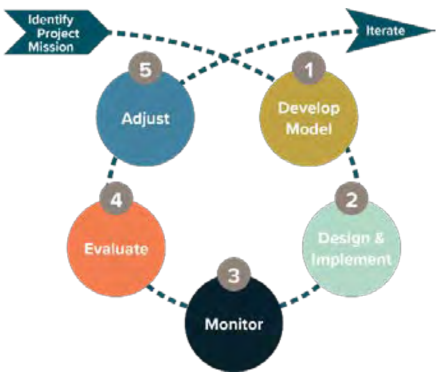
- Continue monitoring using similar sampling times and pair BMI data collection efforts with water quality samples to better understand water chemistry impacts on BMI at the time of data collection.
- Collect additional water quality samples in the Plains to track water chemistry at impaired sites.
- Assess and modify diversion structures or operations to address water quality impairments in Plains reaches.
- Increase efforts to monitor and address mine issues and impacts.

### 1.3 Considering Forest Health

Though not currently included as a key question, forest health plays a critical role maintaining our watershed's trajectory toward health and resilience. Upland forests are dense and overcrowded, increasing their vulnerability to large wildfires and other natural disturbances. Post-fire inputs from nutrients, sediments, and pollutants will have devastating consequences for aquatic health, water quality, and the overall state of our watershed. Stakeholder input in 2019 demonstrated that upland forest health is a top priority for federal, state, and local partners, and that collaboration and partnership is a necessary next step in this process. This priority is discussed in Section 5.2.

## 2. How Do We Use Adaptive Management to Assess Our Watershed?

Monitoring watershed health as a portion of our adaptive management plan enables us to actively improve our watershed's trajectory toward ecologic resilience based on the collection and synthesis of relevant scientific data. Our Adaptive Management Plan is founded on the process of iterating five key steps on an annual basis (see Figure 1 and learn more on our website). We place particular emphasis on "process" because continual iteration of the steps is necessary to assess our complex and changing watershed, and adjust annually based on what is learned. This report addresses steps four and five of our adaptive management process (Figure 1). Scientific data is essential to our process because it provides a quantitative method to assess our trajectory, communicate verifiable information to our community, and make evidence-based decisions.



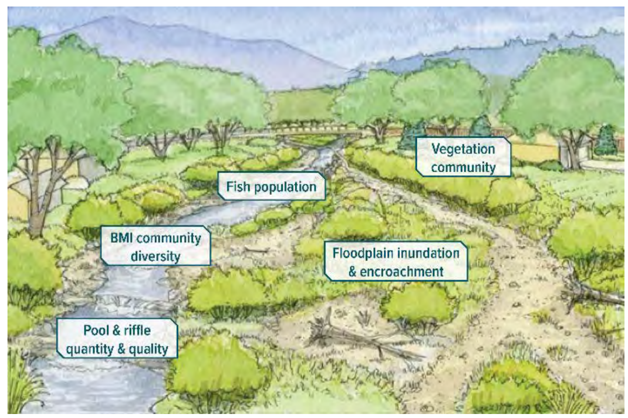




Figure 1 (Left): Figure 1: Each step of the adaptive management process. Learn more on our website.
Figure 2 (Right): Conceptual Model of future conditions in alluvial fan zone. See the complete Conceptual Model on our website.

Scientific data presented in this report are used for the basis of our assessment of our trajectory towards the desired future conditions, as illustrated in our conceptual model (see Figure 2 and learn more on our website). These desired conditions are rooted in consensus and setting realistic expectations. Diverse community members and experts came together to agree on the considerations for a healthy and resilient Left Hand Creek Watershed based on the best available science and on learning from our past. This group acknowledged that health and resilience must be set within the reality of Left Hand Creek's role as a working river, with flow modifications that date back to pre-settlement. The hydrograph below shows and explains simulated historic and present-day discharge.

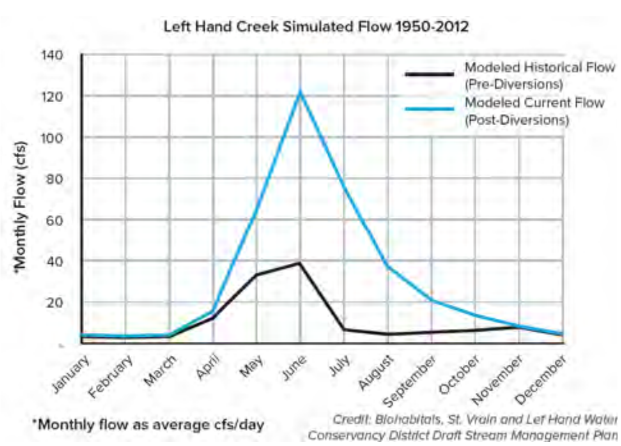



Figure 3: Left Hand Creek Simulated Flow from 1950 to 2012. Modeled Current Flow is based on simulated monthly flows including the influence of diversions. Modeled Historic Flow is based on simulated monthly flows excluding the influence of diversions, prior to Left Hand Creek's transformation to a working river.

As evidence by this hydrograph, Left Hand Creek carries more water than it would in its natural state due to an trans-basin diversion located upstream of our headwaters. However, despite this augmentation, flows are not necessarily timed with natural geomorphic and ecological processes because they are diverted to irrigation channels and reservoirs. This results in periodic creek dry-up and poses challenges for watershed health.

Though the conceptual model approach is illustrative, the goals, hypotheses, and parameters that were developed based on the model are quantitative and comprise our Monitoring and Assessment Framework (Attachment A). Our overarching goal is to maintain or improve ecological conditions and resilience following restoration and recovery from 2013 floods. To do so, our specific project goals were to:

1. Maintain or improve floodplain connectivity.
2. Maintain or improve channel morphology and habitat condition.
3. Maintain or improve native riparian condition and the native plant community.
4. Maintain or improve benthic macroinvertebrate community.

Each goal considers key components of a healthy and resilient Left Hand Creek Watershed (noted above) and is tied to specific scientific hypotheses based on ecological conditions. Hypotheses (found in Section 3 below) are assessed using ecological parameters and performance standards. Performance standards are essential to our adaptive management approach because they ensure that we remain accountable to our conceptual model. These standards are science-based metrics which represent the acceptable range for each ecological parameter that is needed to maintain our watershed's trajectory towards health and resilience. When measured performance falls outside of this range, we implement actions to help correct the trajectory. Further details about monitoring and assessment are provided in the next section.

A last important aspect of our adaptive management approach is the problem that led to our need for adaptive management – restoration and recovery following the 2013 floods. The floods were devastating to the watershed and community but also brought opportunity to rebuild and recover in a more resilient way. Starting in 2016 we designed and implemented numerous flood recovery restoration projects to jumpstart our watershed's trajectory towards the most resilient future possible. Eleven projects were complete in 2018 and eight projects were complete in 2020. All projects were designed to increase flood resilience, restore long-term stream health and stability, and improve aquatic and riparian habitat. Though our adaptive management efforts are focused on monitoring restored project sites, we also monitor unrestored sites and assess health and resilience on a watershed-scale.

# 3. Monitoring and Assessment Methods

This section describes our framework, hypotheses, sites, data collection, and data analysis methods.

## 3.1 Framework and Monitoring Hypotheses

Our Monitoring and Assessment Framework is the foundation for our methods and data provided in this report (Appendix A). The Framework is used to assess the ecological condition (physical and biological) of restored sites to determine overall watershed health. Within each ecological category included in the Framework (Floodplain Connectivity, Channel Morphology and Habitat, Riparian Condition, Benthic Macroinvertebrate Community, Fish Community), we assess key monitoring hypotheses related to our restoration goals. Each hypothesis is assessed by different methods and metrics that are tied to performance standards. Based on our results, we determine if we are meeting each performance standard or if a monitoring or management action is needed.

We update our Framework annually based on what we learn. While the Framework includes a comprehensive list of possible monitoring categories, some hypotheses are not included each year based on our priorities and capacity. Below we provide the ecological categories, questions, and hypotheses that we monitored in 2019 to assess out watershed's trajectory towards ecological resilience. Individual hypotheses often refer to the watershed zones (Canyons, Foothills, and Plains) that are described in detail in our conceptual model.

**Category: Floodplain Connectivity**

**Question:** Is floodplain connectivity improved or maintained?

- **Hypothesis:** Per the design, appropriate benches and channels are inundated during peak seasonal flows each year.

**Channel Morphology and Habitat**

**Question:** Is channel morphology and habitat condition improved or maintained?

- **Hypothesis:** Percent of habitable pool area relative to the wetted area will be greater than 20% at restored sites.
- **Hypothesis:** Average percent sands (substrate) in riffles at restored sites will remain the same or decrease from 2018 to 2019. In Canyons and Foothills sites, average percent sands in riffles at restored sites will remain less than 27.5% or 41%, respectively.

**Riparian Condition**

**Question:** Is native riparian condition and the native plant community improved or maintained?

- **Hypothesis:** Average percent of native herbaceous and woody cover types from all restored project types within each watershed zone will increase or remain the same from 2018 to 2019.
- **Hypothesis:** Average native richness (species number) from all restored project types within each watershed zone will increase or remain the same from 2018 to 2019.

**Benthic Macroinvertebrate Community**

**Question:** Is the benthic macroinvertebrate community, as an indicator of water quality and sedimentation issues, improved or maintained?

- **Hypothesis:** Multimetric Index (MMI) score per site will either attain performance thresholds based on site location (Biotype 1 or 2) or will trend towards attainment from 2016 to 2019.
- **Hypothesis:** Sediment Tolerance Indicator Value (TIV) score per site will either attain performance thresholds based on site location (Sediment Regions 1 through 3) or trend towards attainment from 2016 to 2019.

In addition to these monitoring activities, we visually assess channel morphology and riparian conditions at each site by photo monitoring during low flow. Sample photos for sites can be found in Appendix B.

### 3.2 Site Descriptions

Left Hand Creek Watershed covers 132 square miles in the St. Vrain Basin and extends from headwaters just east of the continental divide at Lake Isabelle through the high plains and City of Longmont, where it meets the confluence with the St. Vrain River. Within the watershed, James Creek is a major tributary that also transports trans-basin water from the South St. Vrain to Left Hand Creek. The watershed has three distinct zones (Canyons, Foothills, and Plains) that are defined by different geomorphic characteristics. For the purpose of this report, all sites are grouped and assessed by the three watershed zones, however, we acknowledge that tributaries within each zone may impact site specific results.

In 2019, we implemented our Monitoring and Assessment Framework at 25 sites in Left Hand Creek Watershed: 24 sites on Left Hand Creek and one site on James Creek used for reference (Figure 4.). Sites are classified by watershed zone and site type (restored, unrestored, and pre-project; see below for descriptions). Site and monitoring details are provided in Table 1.

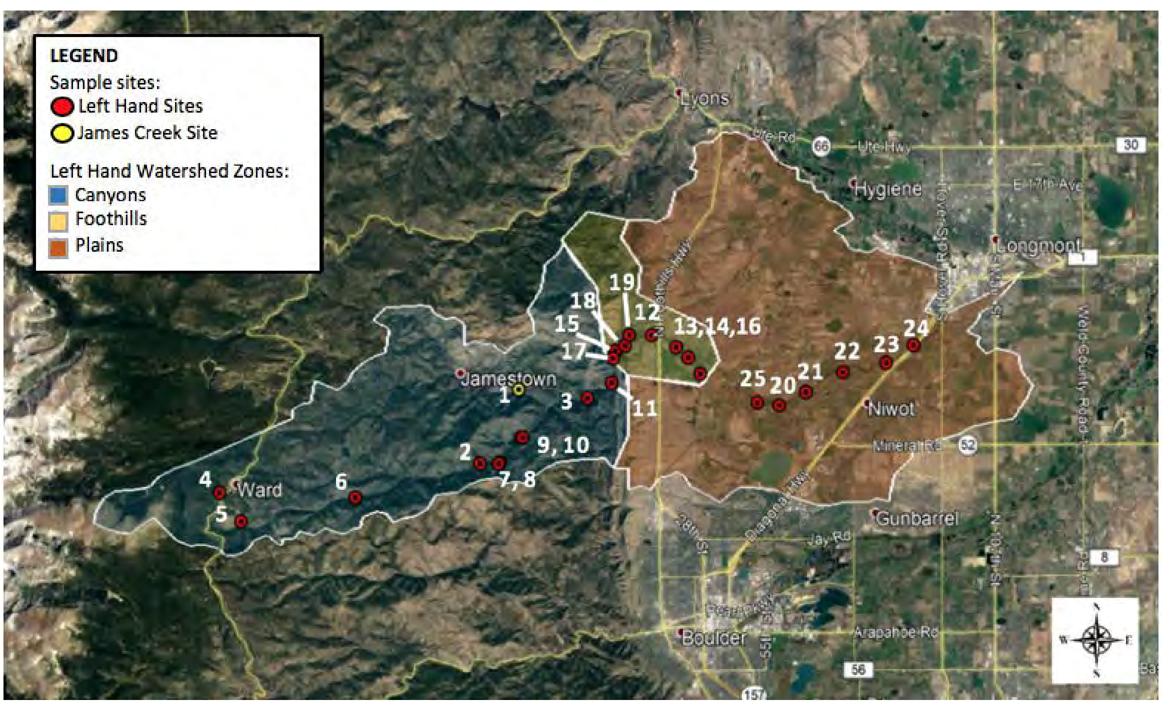



Figure 4. A map of all sites in Left Hand Watershed. Watershed zones and sample sites on Left Hand Creek and James Creek are indicated by color. Site numbers are linked to site names listed in Table 1.

Table 1. A list of all sites in Left Hand Watershed that were monitored in 2019. Sites are ordered and described by Number, Watershed Zone, Site Type, Name and applicable monitoring activities. Monitoring activities by ecological category assessed at each site are marked with an "X." All sites are located on Left Hand Creek with the exception of one site on James Creek, indicated by an asterisk (*). Site Numbers are linked to Figure 4.

| No. | Watershed Zone | Site Type | Site Name | Floodplain Connectivity | Channel Morph. & Habitat | Riparian Condition | BMI Community |
|---|---|---|---|---|---|---|---|
| 1* | Canyons* | Project* | Harms* | | | | X* |
| 2 | Canyons | Project | Upper Left Hand | | X | X | X |
| 3 | Canyons | Project | US Buckingham | | X | X | X |
| 4 | Canyons | Unrestored | Peak to Peak | | | | X |
| 5 | Canyons | Unrestored | California Gulch | | | | X |
| 6 | Canyons | Unrestored | FS Meadow | | X | X | X |
| 7 | Canyons | Unrestored | Legacy 7 US | | | X | |
| 8 | Canyons | Pre-project | Legacy 7 DS | | X | | X |
| 9 | Canyons | Pre-project | Legacy 5 US | | X | | X |
| 10 | Canyons | Unrestored | Legacy 5 DS | | | X | |
| 11 | Canyons | Unrestored | Buckingham | | X | X | X |
| 12 | Foothills | Project | Streamcrest | X | X | X | |
| 13 | Foothills | Project | Ranch | X | X | X | X |
| 14 | Foothills | Project | 41st Street | X | | | |
| 15 | Foothills | Unrestored | Legacy 2 DS | | X | X | |
| 16 | Foothills | Unrestored | Kauvar | | X | X | X |
| 17 | Foothills | Pre-project | Legacy 2 US | | X | | X |
| 18 | Foothills | Pre-project | Legacy 1 US | | X | | X |
| 19 | Foothills | Pre-project | Legacy 1 DS | | X | | X |
| 20 | Plains | Project | 63rd Extension | X | | | |
| 21 | Plains | Project | 63rd Street | X | X | X | X |
| 22 | Plains | Project | 73rd Street | X | | | |
| 23 | Plains | Project | 81st Street | X | X | X | X |
| 24 | Plains | Project | Reach 3B | | X | X | |
| 25 | Plains | Unrestored | Haystack | | X | X | X |

Our adaptive management plan focuses on monitoring and assessing restored project sites. In 2019, restored sites include projects that were implemented in 2017. At these sites, projects aimed to increase floodplain capacity by broadening and lowering benches, improve instream habitat by creating pools and base flow sediment transport channels, and increase floodplain habitat and resilience by increasing native riparian plant diversity and stabilizing banks with bio-stabilization techniques.

Though our primary focus is on the trajectory of restored projects, we also monitor and assess unrestored and pre-project sites using the same methods. Unrestored sites are reaches that were less impacted by the 2013 floods and not designated as priority restoration sites. Monitoring these sites helps us understand our data in the context of the entire watershed. We include notable results about comparisons between restored and unrestored sites in this report and additional data by ecological category can be found in Appendices C and D. Our pre-project sites were monitored in 2018 before construction in 2019. These sites will be included in future reports to make pre- and post-restoration comparisons and to improve our understanding of trends at restored sites. Notably, almost all of the pre-project sites are located in the Canyon zone and future monitoring will improve our understanding of this zone due to greater site representation.

To provide basin-scale context we compare our results to a similar watershed. In 2019 we implemented our Monitoring and Assessment Framework at six restored sites in the St. Vrain Watershed. We include notable results and comparisons in Appendix C based on one year of limited monitoring at six sites (all in the Foothills). In the future, we plan to expand these efforts to improve comprehensive data collection across watershed zones, better understand watershed health in the St. Vrain, and enable cross-watershed comparisons.

## 3.3 Data Collection and Analysis Methods

**Floodplain Connectivity**

In 2019, we monitored seven Foothills and Plains restored sites downstream of the LEFCRECO stream gage on 6/26/2019 and 6/27/2019 when reported flows at the stream gage were between 150 cfs and 200 cfs. Floodplain connectivity was assessed based on visual (photo monitor) observations of floodplain inundation at applicable benches and channels based on peak seasonal flows (Table 2), which vary year to year. Applicable benches and channels are defined by our project designs, which use flow regime to determine appropriate floodplain elevations for inundation to occur at specific locations. Our restored sites are designed to accommodate a range of seasonal peak flows including bankfull, bench, and high flows, as described in Table 2. However, the variable and sometimes erratic flow regime of Left Hand Creek poses challenges for selecting appropriate elevations, reiterating the need for monitoring floodplain connectivity per designs.

Table 2. List of floodplain locations where inundation is expected at various seasonal peak flow discharges. Approximate cfs describes estimate discharge range associated with the potential seasonal peak flow, though actual discharge associated with specific floodplain locations varies by design and watershed zone.

| Peak Seasonal Flow Description | Approximate cfs | Expected Floodplain Inundation Location |
|---|---|---|
| Bankfull Flow | 15-290 cfs | Bankfull Bench |
| Bankfull Flow | 15-290 cfs | Side-Channel |
| Bench Flow | 200-500 cfs | Bench |
| High Flow | >2,000 cfs | Overflow-Channel |

**Channel Morphology and Habitat**

*Habitable Pools*

In 2019, we initiated new physical habitat surveys of sample reaches in an effort to quantitatively assess pool habitat at each site. In August 2019, we completed habitat surveys on seven restored and 10 unrestored or pre-project representative reaches that were generally 1,000 feet in length. The surveyed metrics were representative of each sample reach and included: total wetted area, percent pool area relative to wetted area, average residual pool depth, and pool count. Percent pool area was standardized by total surveyed wetted area to compare between sites. We analyzed percent pool area relative to wetted area and average residual depth for each site and between zones.

*Substrate*

We have conducted Wolman Pebble Counts during low flow since 2017 and each year we have increased our sampling effort to increase sample size (Wolman 1954). In August 2019, we completed counts at one to three representative riffles in each habitat survey reach. From each pebble count, we recorded frequency of particles in each size class: sands, gravels, cobbles, boulders, and bedrock. Percent sands were calculated by dividing the frequency of sands by the total sample count per pebble count. We analyzed average percent sands for each watershed zone by comparing over time and to percent sand thresholds for Colorado Sediment Regions 1 and 2 (CDPHE WQCD 2014).

**Riparian Condition**

We have conducted vegetation surveys since 2018. In 2019, we sampled seven restored sites and seven unrestored or pre-project sites in August. This sampling timeframe was modified from 2018 methods, when we sampled later in the growing season (September 2018). At a minimum, we sampled four vegetation zones along one or two cross sections per site. These zones included creek edge and upland vegetation plots on each bank. Additional floodplain and upper riparian zones were identified and sampled at the discretion of the surveyors. We analyzed average percent native herbaceous, woody, and non-native cover and native richness for each watershed zone.

**Benthic Macroinvertebrate Community**

We have conducted benthic macroinvertebrate (BMI) surveys in 2016, 2018, and 2019. In 2019, we surveyed 17 sites from September through early November. Importantly, all Plains sites were sampled after October 31, which is the conclusion of the irrigation season. This sampling timeframe was modified from 2018 methods, when we sampled during the irrigation season. We used Colorado Department of Public Health and Environment Water Quality Control Division (CDPHE WQCD) kick sample methods in representative riffles and collected one sample from each site. Samples were sorted and identified to genus or species level. For analysis, Multimetric Index (MMI), Hilsenhoff Biotic Index (HBI), and diversity scores were calculated based on sample composition and site location (Biotype 1 or 2). Between 2016 and 2018 sampling, the MMI method was updated from version three to four. While our 2016 scores were determined using the previous MMI version three method, all biotype and attainment thresholds have remained the same. Therefore, we are able to compare 2016 versus 2018 and 2019 scores against these thresholds and generally between years.

### 3.4 Data Sharing

All data presented in this report is publically available. Please submit a request to dhummel@lwog.org for more information.

# 4. Results and Discussion

## 4.1 Hydrology and Precipitation

Hydrology and precipitation are underlying drivers to all watershed processes and are key to understanding changes in ecological parameters. The hydrograph of Left Hand Creek is characterized by a peak seasonal flow from May through July (driven by snowmelt) and low flows through the remainder of the year (driven by groundwater recharge and intermittent rainstorms). Flows in Left Hand Creek are also impacted artificially by ditches and diversions, as they provide water for farmers and ranchers throughout the watershed. Typically, seasonal flows peak and are sustained from late May to early July. Average peak discharge is typically between 125 cfs and 175 cfs (Figure 5). The timing, magnitude, and duration of these flows also impacts the geomorphological and ecological condition of the creek. Since the completion of the restoration projects in 2017, peak seasonal flows in Left Hand Creek have varied (Figure 5). In 2017, peak flows had typical timing but exceeded typical magnitude for the expected duration. In 2018, timing and magnitude of peak flows were average, but only lasted for a week due to drought conditions. In 2019, peak flows were delayed by a few weeks and slightly greater than typical magnitude due to colder spring temperatures that delayed snow melt.

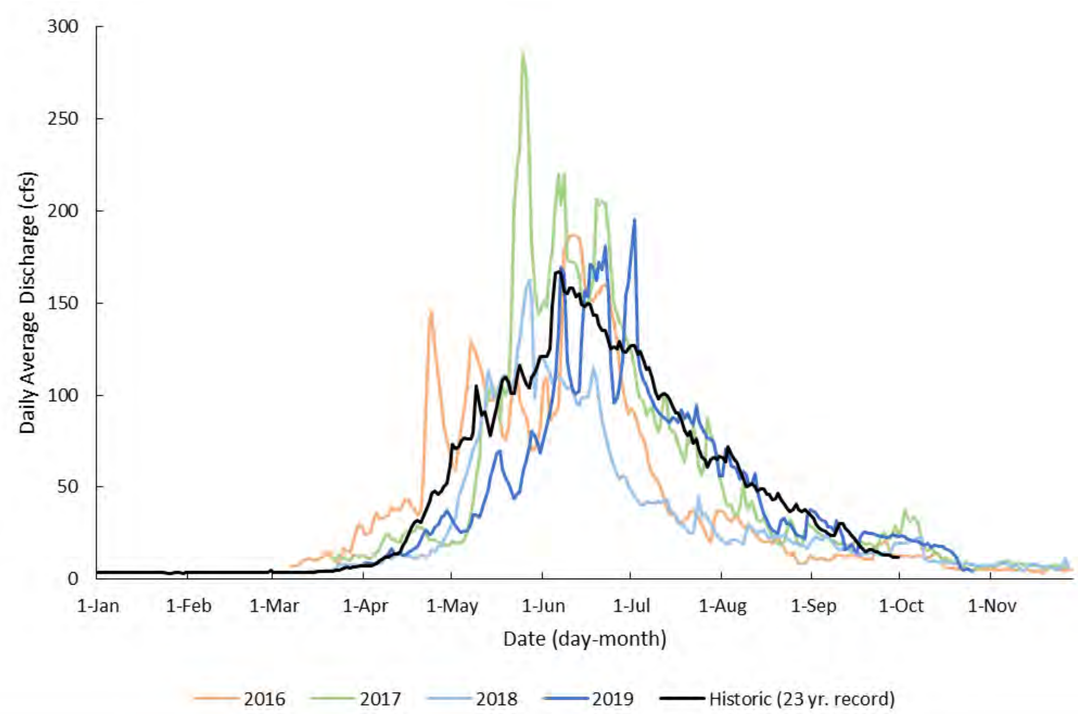



Figure 5. Historic (based on 23 years) and 2016- 2019 annual average daily discharge (cfs) in Left Hand Creek canyon at the LEFCRECO gage. Data record provided by the Colorado Division of Water Resources.

Precipitation also impacts watershed processes and ecological condition. Peak seasonal flows are driven by winter and early spring precipitation, especially snow accumulation in the mountainous region of the watershed. From spring through fall, precipitation (including ice, snowfall, and rainfall) also impacts instream flows and riparian condition. Precipitation during low flow provides critical water depths for the survival of aquatic organisms and water for the surrounding plant community during growing season. In Left Hand Creek, water diversion in the summer and fall exacerbate the effects of low precipitation by reducing instream flow, potentially resulting in dry up periods.

Since flood recovery restoration was implemented in 2016, total monthly precipitation values in Left Hand Watershed and the surrounding region (Boulder County) have been within or just outside (less than 0.5 inches) the recent climatic range (period of record: 1971 to 2000), with the exception of heavier precipitation in April 2016 and May 2017 (Figure 6). Total monthly precipitation values in 2018 and 2019 were relatively similar to each other compared to previous years and both years had relatively low precipitation in August. While we can say there have not been any outstanding precipitation events since restoration, we also recognize that variability (within the climatic range) in monthly precipitation from year to year may impact ecological condition at restored sites on a local, site-specific scale. Therefore it is important to consider precipitation over space and time, especially at reaches with upstream diversions.

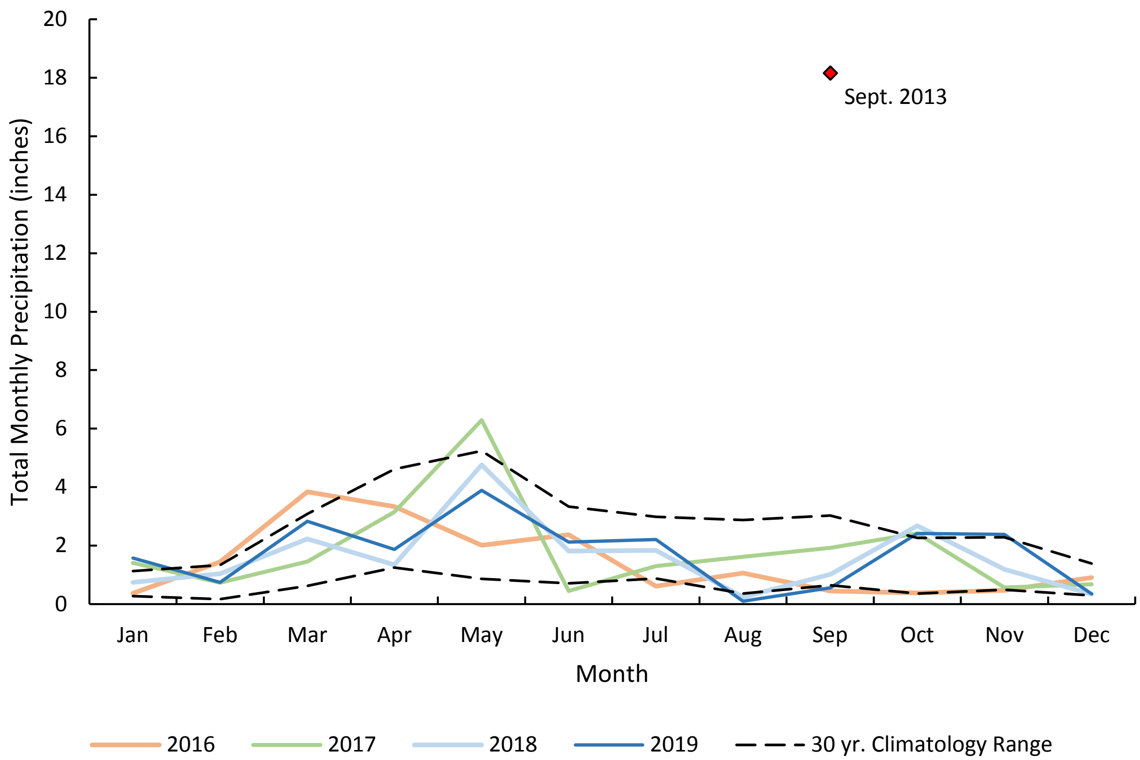



Figure 6. The 2016 through 2019 total monthly precipitation (inches) and the most recent 30 year precipitation climatology range (upper and lower limits shown on graph) for Boulder County (range is based on average total monthly precipitation +/- standard error from 1971 through 2000). Total monthly precipitation in September 2013 (resulting in historic floods) indicated in red. Precipitation includes all rain, snow, and hail. Snow/ice amounts are either directly measured or snow water equivalent of 1:10 is applied to measurements (1 inch precipitation to every 10 inches of snow/ice fall). Data provided by the National Oceanic and Atmospheric Administration's Physical Science Laboratory.

### 4.2 Floodplain Connectivity

Floodplain connectivity is the accessibility of the floodplain to instream flows. Accessible floodplains offer room for rivers to move and accommodate high flow events. During high flow events, inundated floodplains are essential habitat for fish and wildlife because they provide protected and slow moving aquatic habitat. Floodplains also promote deposition of fine sediment and resilient plant communities. Connected floodplains reduce flood risk for properties downstream by attenuating (spreading out and slowing down) high flows and sediment. We evaluate floodplain connectivity using this approach based on the following hypothesis:

1. Per the design, appropriate benches and channels are inundated during peak seasonal flows each year.

In 2019, we monitored bankfull benches and side channels because our peak seasonal flow did not exceed bankfull (200 cfs) flow (Figure 6). We found bankfull bench activation at all seven sites and side channel activation at all three of the applicable sites (Ranch, 73rd Street, and 63rd Street) (Figure 7). A key assumption associated with these observations is that high flow (150 cfs and 200 cfs) at the LEFCRECO stream gage translates to flow at the monitoring sites, despite the occurrence of multiple diversion between the gage and the sites. The gage is located at the mouth of Left Hand Canyon, which is upstream of the monitoring sites between Legacy 1 US and Legacy 2 DS. Our assumption is supported by long-term observations by the Left Hand Ditch Company and others that diversions have minimal impact on instream flows during peak seasonal flows due to the overall magnitude of flows during this period.

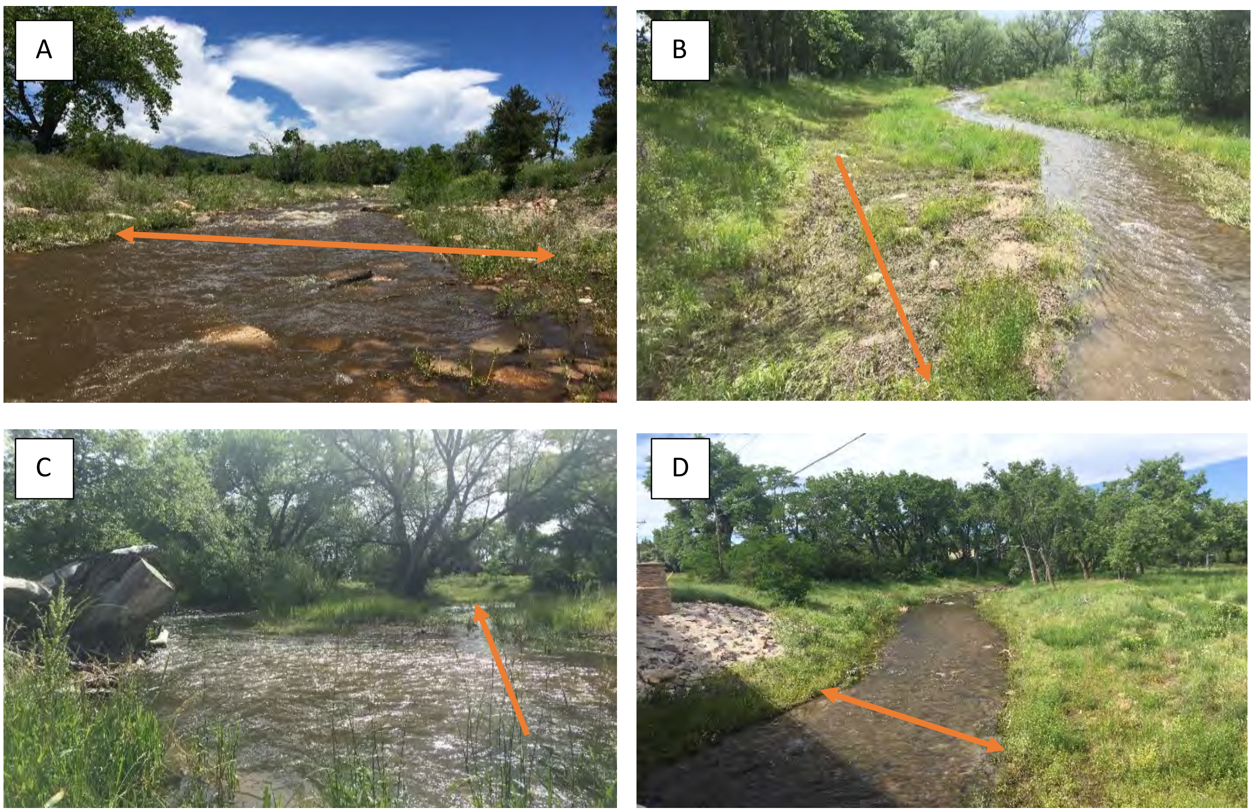



Figure 7. Peak seasonal flow observations from 6/26 and 6/27/2019 at restored sites on Left Hand Creek. Photo description match letter and arrow: A. activated bankfull channel at Ranch; B. activated side channel at 73rd Street; C. activated side channel at 81st Street; D. activated bankfull channel at 63rd Street.

Floodplain connectivity depends on river form and flow regime, so restored floodplains must be designed to meet both form and flow requirements for inundation. Our 2018 monitoring results show that restored floodplains are lower and wider, indicating that river form was improved to reconnect the floodplain to its channel. However, a variable and sometimes erratic flow regime confounds our ability to determine appropriate floodplain elevations for restoration design. While we observed appropriate inundation at the seven sample sites in 2019, multiple years of observations are needed to capture the annual variability of the flow regime and determine whether designs are appropriate for the flow regime. Additionally, peak seasonal flows were reported at 200 cfs or greater during just four confined windows lasting one to three days each, resulting in a flashy and challenging timeframe for monitoring. In the future, we will continue to monitor at flows greater than 150 cfs to allow for pre- or post-peak seasonal flow observations and increase our sampling capacity at all sites.

In summary, we found that 2019 peak seasonal flows inundated all of the constructed bankfull benches and activated side channels. However, we were unable to visit all of our restored sites during the peak seasonal flow period, especially during the short period of time when flows exceeded 150 cfs. In the future, we will increase our effort to visit all restored sites when flows are reported greater than 150 cfs. By increasing our effort, we hope to identify areas with floodplains benches that are not inundated and that may require management action such as lowering benches or side channels. We also plan to quantitatively assess peak seasonal flows by evaluating depth, duration, and timing of peak flows and determine what flow is considered a functional flushing flow (transports sediment, promotes scour, reduces encroachment). Lastly, we will continue to consider how floodplain connectivity relates to other ecological indicators throughout the watershed. For example, we hypothesize that floodplain connectivity influences riparian vegetation and encroachment while flow regime drives channel morphology.

## 4.3 Channel Morphology and Habitat

Channel morphology and habitat features are essential for supporting aquatic life and are indicators of watershed processes including flow and sediment regime. We assessed channel morphology and habitat by testing the following sub-hypotheses.

1. Percent of habitable pool area relative to the wetted area will be greater than 20% at restored sites.
2. Average percent sands (substrate) in riffles at restored sites will remain the same or decrease from 2018 to 2019. In Canyons and Foothills sites, average percent sands in riffles at restored sites will remain less than 27.5% or 41%, respectively.

*Pool Habitat*

In 2019, we found that the average percentage habitable pool areas relative to wetted areas exceeded 20% at all sites except the 63rd Street project in the Plains (Table 3). Habitable pools are defined as pools that can support fish and have residual depths greater than or equal to 0.8 feet in the Canyons or 1.0 foot in the Foothills and Plains. Throughout the watershed, restored sites vary in habitat and pool frequency. Generally, sites are classified as step-pool (small but frequent pools) in the Canyons, pool-riffle (larger and less frequent) in the Foothills, and pool-riffle or plane-bed (largest and least frequent) in the Plains reaches. While we assume that pool area will fluctuate in a given reach from year to year, we expect that the proportion of pool area relative to wetted area to be greater than 20% based on recommended pool-to-pool spacing averages for natural step-pool, pool-riffle, or plane-bed reaches (Leopold and Wolman 1957, Montgomery et al. 1995). In comparison, unrestored sites in other parts of the watershed also met the 20% threshold, with an average of 32% habitable pool area (Appendix D). Year-to-year comparisons of pool data were not possible because 2019 was the first year we collected pool data. Channel morphology efforts in 2018 focused on longitudinal profiles which showed more improved pool habitat in restored compared to un-restored reaches.

One possible explanation for low pool area at 63rd Street (14.3%) may be related the restoration design of the site. Generally, many of our sites were designed to be transport reaches because they are surrounded by homes and infrastructure that lack space for natural deposition. Therefore, inherent design elements may prohibit these sites from achieving the expected habitable depth found in other natural or depositional reaches. While percent pool area at 63rd Street does not reach our performance threshold of 20%, we will continue monitoring to determine appropriate action given inherent limitations at this location. Future management actions may include improving any adjusted pool-forming structures.

Table 3. The 2019 habitat survey summary or all restored sites grouped by watershed zone. Metrics for each site include percent pool area relative to wetted area, average residual pool depth and pool count. Watershed zone averages and sample size (n) listed in bold.

| | Site | % Pool Area: Wetted Area | Avg. Residual Pool Depth (ft) | Pool Count |
|---|---|---|---|---|
| Canyons | **Upper Left Hand** | 45.5% | 1.0 | 9 |
| | **US Buckingham** | 33.7% | 1.9 | 3 |
| | **Canyons Avg. (n)** | **39.6% (2)** | **1.45 (2)** | **6 (2)** |
| Foothills | **Streamcrest** | 34.5% | 1.4 | 8 |
| | **Ranch** | 42.5% | 1.4 | 8 |
| | **Foothills Avg. (n)** | **38.5% (2)** | **1.4 (2)** | **8 (2)** |
| Plains | **63rd Street** | 14.3% | 1.1 | 3 |
| | **81st Street** | 53.5% | 1.6 | 11 |
| | **Reach 3B** | 50.0% | 1.7 | 5 |
| | **Plains Avg. (n)** | **39.3 (3)** | **1.4 (3)** | **6.3 (3)** |

In addition to design characteristics, our results for habitable percent pool area may reflect unanticipated adjustments to the original design intent. While we expect restored pools and pool-forming processes to fluctuate naturally, constructed pools were designed to maintain depth and area by promoting scouring during seasonal flushing flows (peak seasonal flows that transport sediment) (Figure 8). In 2019, we found that both 63rd Street and Upper Left Hand sites had shallow pools relative to habitable pool classification thresholds (1.0 foot in the Plains and 0.8 foot in the Canyons; Table 3). One possible explanation is that constructed riffles or boulder cross vanes, designed to promote scour and pools downstream, have adjusted or settled We will start photo monitoring these specific locations to identify any visual adjustments that may be inhibiting pool-forming processes and require management action.



Figure 8. Pool forming cross sections at restored sites on Left Hand Creek. Photo description matches letter. A. boulder cross vane with immediate downstream pool at Upper Left Hand site in Left Hand Creek Watershed. Photo courtesy of OTAK, September 2019. B. constructed riffle at 63rd Street site in Left Hand Creek Watershed. Fine sedimentation visible immediately downstream of structure. Photo taken 8-28-2019.

Other drivers that influence habitable pool area are flow and sediment regime. As described above, flushing flows maintain pools by scouring sediment. However, ditches and diversions throughout the watershed regulate the magnitude of flushing flows. Without adequate flushing flows, coarse and fine substrate may fill in restored pools, reducing the percent area and average residual depth of habitable pools. Multiple diversions upstream of 63rd Street that may be reducing flushing flows, resulting in increased deposition (Figure 8). We also found, as described in the following section, an increase in percent sands in riffles at restored Plains sites that may indicate a sedimentation issue (Figure 9). Since we have limited pool and riffle data, we will continue habitat surveys to assess these trends over the next few years.

In summary, we found that habitable pool condition at all sites, except 63rd Street, attained our 2019 performance threshold. While there may be a potential management action needed at 63rd Street, we need to further investigate potential drivers. We will continue monitoring pool performance at this location to determine how conditions trend in additional years and how they relate to average pool areas at other Plains sites. Lastly, we will continue to consider how percent pool area relates to other ecological indicators throughout the watershed. Pool formation depends on properly functioning flow and sediment regimes. If we continue to find reductions in percent habitable pool area and average residual depth, we may also find increased deposition in riffles. These combined metrics may indicate an issue with sediment and flow regime in the watershed.

*Substrate*

Over time, percent sands (all particles 0 to 2 mm diameter) met performance standards at Canyons and Foothills restored sites. Year-to-year comparisons show that percent sands remained the same in restored Canyons sites (2018 to 2019), remained the same or decreased in restored Foothills sites (2017 vs. 2019), but increased in restored Plains sites (2018 vs. 2019) (Figure 9). We expected to see no change or decreasing percent sands over time because, as discussed above, many restored sites were designed as transport reaches that flush sediment downstream. In comparison, we found that percent sands at unrestored sites across all zones showed no difference from 2018 to 2019 (Appendix D). This suggests that not all creek locations in the Plains have increased percent sands. The average increase in percent sands at restored Plains sites may be indicative of a site-specific sedimentation issue. In the future, we plan to look for possible sediment sources (e.g. bank erosion from bank slumping and lateral migration) throughout the Plains zone. From there, we can focus our instream sampling efforts at specific locations and look for fine sedimentation issues.

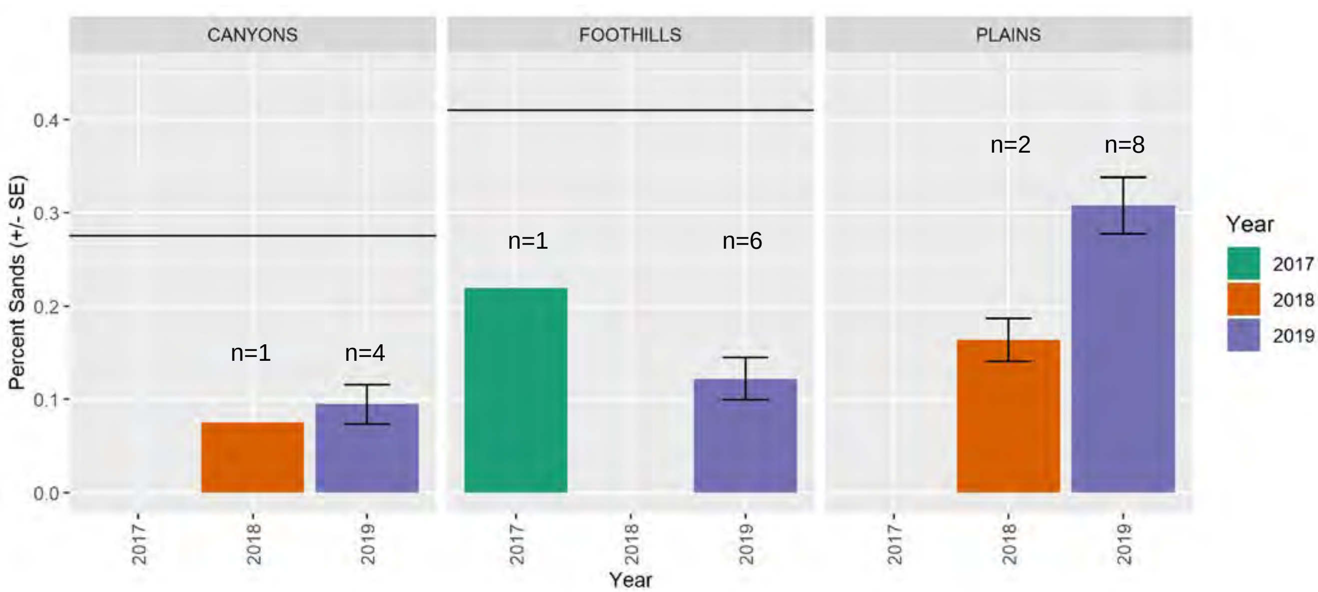



Figure 9. The 2017 through 2019 percent sand and average percent sand (+/- standard error) for all restored sites within each watershed zone of Left Hand Creek Watershed. Thresholds for Canyons (0.275) and Foothills (0.41) indicated by black lines. Sample size indicated by 'n' value.

Additionally, while we know that percent sands will fluctuate from year to year, we expect the proportion to be less than 27.5% in the Canyons and 41% in the Foothills based on suggested thresholds for Colorado streams in Sediment Regions 1 through 3 (CDPHE WQCD 2014). We found that in 2019 average percent sands at restored Canyons (11%) and Foothills (13%) sites attained relevant thresholds. Currently, CDPHE does not provide a percent sand threshold for Plains reaches because these sediment regions are not yet established, likely due to geology (many Plains streams flow through sandy terraces and deposits and are naturally sand-bedded). Due to the lack of existing threshold and the observed increase in percent sands from 2018 to 2019, we plan to increase efforts in the Plains to determine if certain sites have outstanding sediment issues compared to other restored and unrestored locations.

Percent sands are influenced by watershed location, flow regime, and sediment regime. Despite the lack of existing percent sands threshold for the Plains, we expect to see higher deposition rates and greater percent sands in these reaches due to upstream erosion and sediment mobilization. Notably, new river restoration projects were being implemented in the Canyons and Foothills reaches prior to the 2019 surveys and this work likely increased the supply of fine sediment into downstream reaches during the survey period. Active construction occurred September through November 2019, after seasonal peak flow. Future monitoring is needed to assess the possible impact of upstream activities.

The flow and sediment regimes throughout the watershed are influenced by the operation of ditches and diversions. Without adequate flows, fine sediment is not transported across riffles, increasing the percent sand. Multiple diversions upstream of the Plains sites reduce flows during irrigation season, likely resulting in deposition of fine sediment. If we continue to see increases in percent sands in the Plains, we also expect to see decreases in percent habitable pool area and average residual depth due to deposition. Since we have limited pool and riffle data, we will continue habitat surveys to assess trends in pool area, pool depth, and percent sands over time.

In summary, from 2018 to 2019, we found that percent sand for restored Canyons and Foothills sites remained the same or decreased, while the Plains sites increased. Additionally, percent sands for restored Canyons and Foothills sites attained performance thresholds. While there may be potential deposition issues in the Plains, we are unsure if this increase is a site-specific issue, related to upstream restoration activity, or related to issues with flow and sediment regime. We will investigate if there are reach specific fine sedimentation issues in the Plains by increasing our monitoring to make site-by-site comparisons and monitor year-to-year trends. Lastly, we continue to consider how percent sands relates to other ecological indicators throughout the watershed. Riffles are maintained by properly functioning flow and sediment regimes. If we continue to find increases in percent sand, we may also find decreases in percent pool area and residual depth or impaired benthic macroinvertebrate communities (see Benthic Macroinvertebrate Community section). These combined metrics would indicate sediment issues in the watershed.

### 4.4 Riparian Condition

Riparian condition provides critical physical habitat for aquatic and terrestrial organisms, as well as bank stability. It also benefits overall ecological function by serving as a buffer for nutrient and mineral cycling. Riparian condition is an important indicator of watershed health because it depends on the interaction of flow regime and geomorphology, including floodplain connectivity. We assessed restored riparian condition by testing the following sub-hypotheses:

1. Average percent of native herbaceous and woody cover types from all restored project types within each watershed zone will increase or remain the same from 2018 to 2019.
2. Average native richness (species number) from all restored project types within each watershed zone will increase or remain the same from 2018 to 2019.

Overall, we found that percent cover and native richness increased or showed no difference for woody and native herbaceous cover types across all watershed zones (Figure 10; Figure 11), though these results may also be reflective of sampling time. We expected overall cover and total richness (including all native and non-native species) to increase from 2018 to 2019 because these years were the first two growing seasons after revegetation in fall 2017. During this time, we also changed our sampling time from September to August. While this change improved our ability to identify plants during peak growing season, it may have also biased our results (e.g. identifying more native plants, observing a higher percent cover earlier in the growing season).

Additionally, we implemented weed control and re-seeding best management practices during each growing season to aid native establishment (Figure 12). Though these activities are necessary to support revegetation efforts by ensuring that newly planted vegetation is not outcompeted by weeds, these activities also confound our annual monitoring results because different treatments are applied based on site-specific circumstances. For example, 73rd Street in the Plains had dense sweet clover patches in summer 2018. We mowed some of the denser areas and found that sweet clover was replaced by wetland and riparian vegetation in 2019 (Figure 12). If these activities were included in a sample plot, then our cover and richness data would reflect the weed control results in 2019.

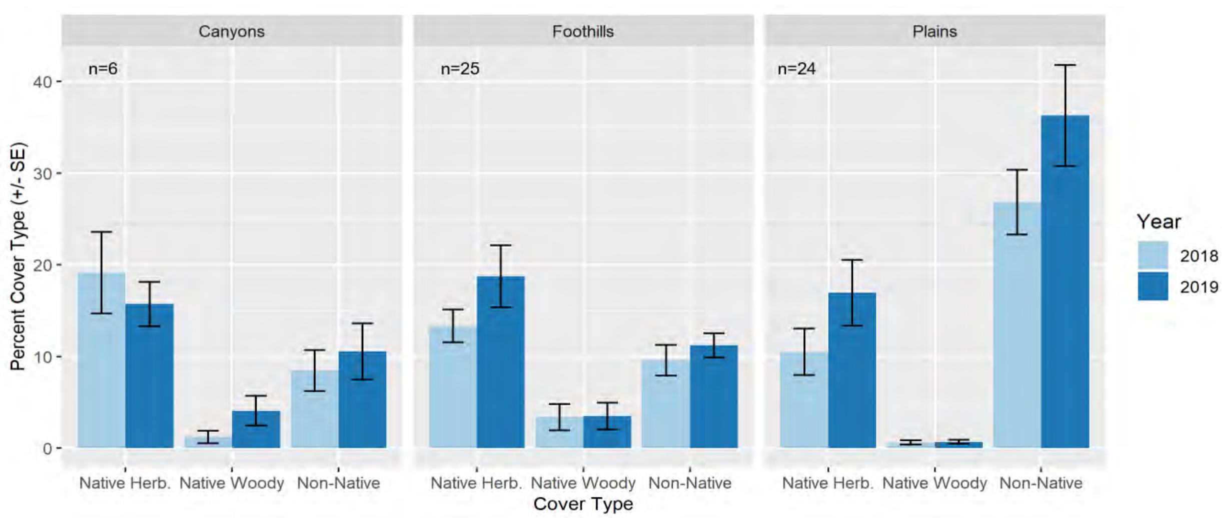



Figure 10. The 2018 and 2019 average percent of cover types (+/- standard error) for all restored sites within each watershed zone of Left Hand Creek Watershed. Cover types are classified as Native Herbaceous, Native Woody, and Non-Native. Sample size indicated by 'n' value.

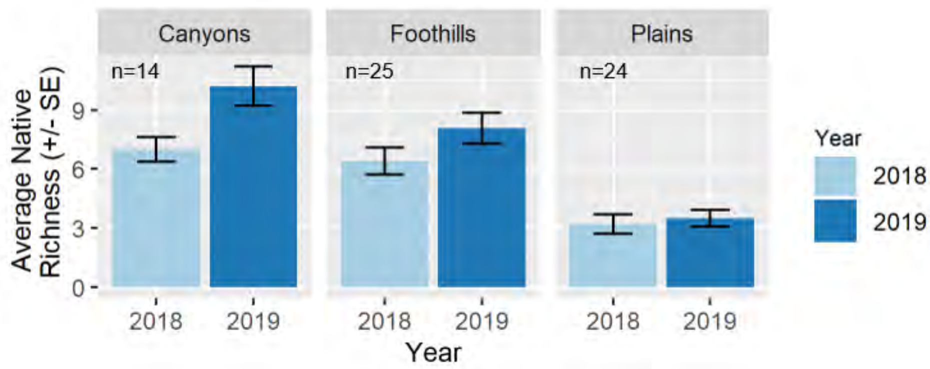



Figure 11. The 2018 and 2019 average native richness (+/- standard error) for all restored sites within each watershed zone of Left Hand Creek Watershed. Sample size indicated by 'n' value.

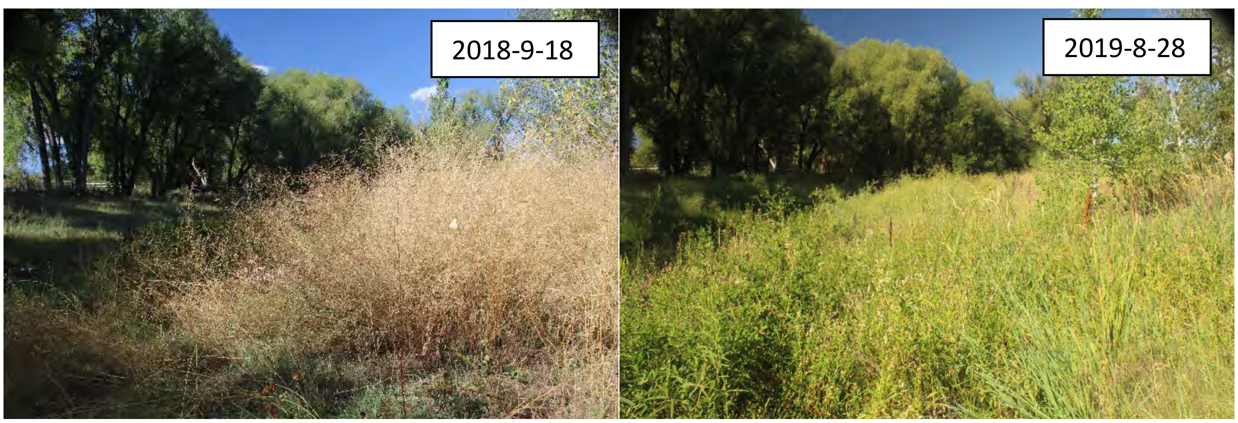



Figure 12. In 2019, wetland and riparian vegetation replaced dense sweet clover patches near the creek edge of 73rd Street restoration project in the Plains of Left Hand Creek Watershed. Sweet clover was mowed between photo dates in fall 2018.

Additional drivers that influence native establishment include site location in the watershed and floodplain inundation. Vegetated composition changes from the Canyons to the Plains, as watershed area increases. Canyons plant richness and non-native competition is limited by a smaller watershed area and shorter growing season. We found that Canyons sites had higher native richness and less non-native cover compared to the Plains. These results suggest that Canyons sites have less non-native competition, which allows for more native establishment. In the Plains, plant richness and potential for non-native competition is greater because of the larger watershed area (larger seed source), longer growing season, and higher diversity of land use (e.g. agricultural areas with existing invasive species). As expected, we found that Plains sites had the lowest native richness in both years, and average percent non-native cover was greatest and increasing from 2018 to 2019 (Figure 10; Figure 11). These results show that Plains reaches appear to have greater non-native competition and therefore less native richness during post-restoration establishment.

Riparian condition is also dependent on the magnitude and duration of floodplain inundation by high flows and precipitation because water availability aids vegetated establishment. Generally, creek edge riparian zones experience longer inundation periods than upland zones simply based on proximity to the creek. As expected, we found that both native herbaceous cover and native richness were greater in creek edge zones than upland zones during both years (Figure 13, Figure 14). The creek edge also experiences fluctuation of fine sediment deposition as flushing flows recede. In 2019, we observed an increase in naturally recruited wetland vegetation at depositional areas along the creek edge (Figure 15). Monthly precipitation may also impact overall survival and growth of riparian plants, especially throughout the summer and fall. While our restoration projects included drought tolerant grasses and forbs, in 2018 and 2019, total August precipitation was less than 0.25 inches (Figure 6). Low precipitation during the growing season, especially in the upland riparian zone, may increase mortality of establishing plants. Based on these results and observations, it is important to consider the vegetation characteristics along the creek edge and upland riparian zones separately.

Lastly, we compared our data in the context of the watershed by comparing restored sites to unrestored sites. Though the focus of our current adaptive management efforts are on year-to-year trends at restored sites, we also collect data at unrestored sites to track watershed-wide changes. In future years, we plan to use this data to account for watershed-wide variability in native composition and assess how native communities at restored sites compare to unrestored sites. Though two years of data allows limited assessment of these relationships, we found that native richness in 2019 was greater at restored Canyons and Foothills sites than unrestored sites (Appendix E).

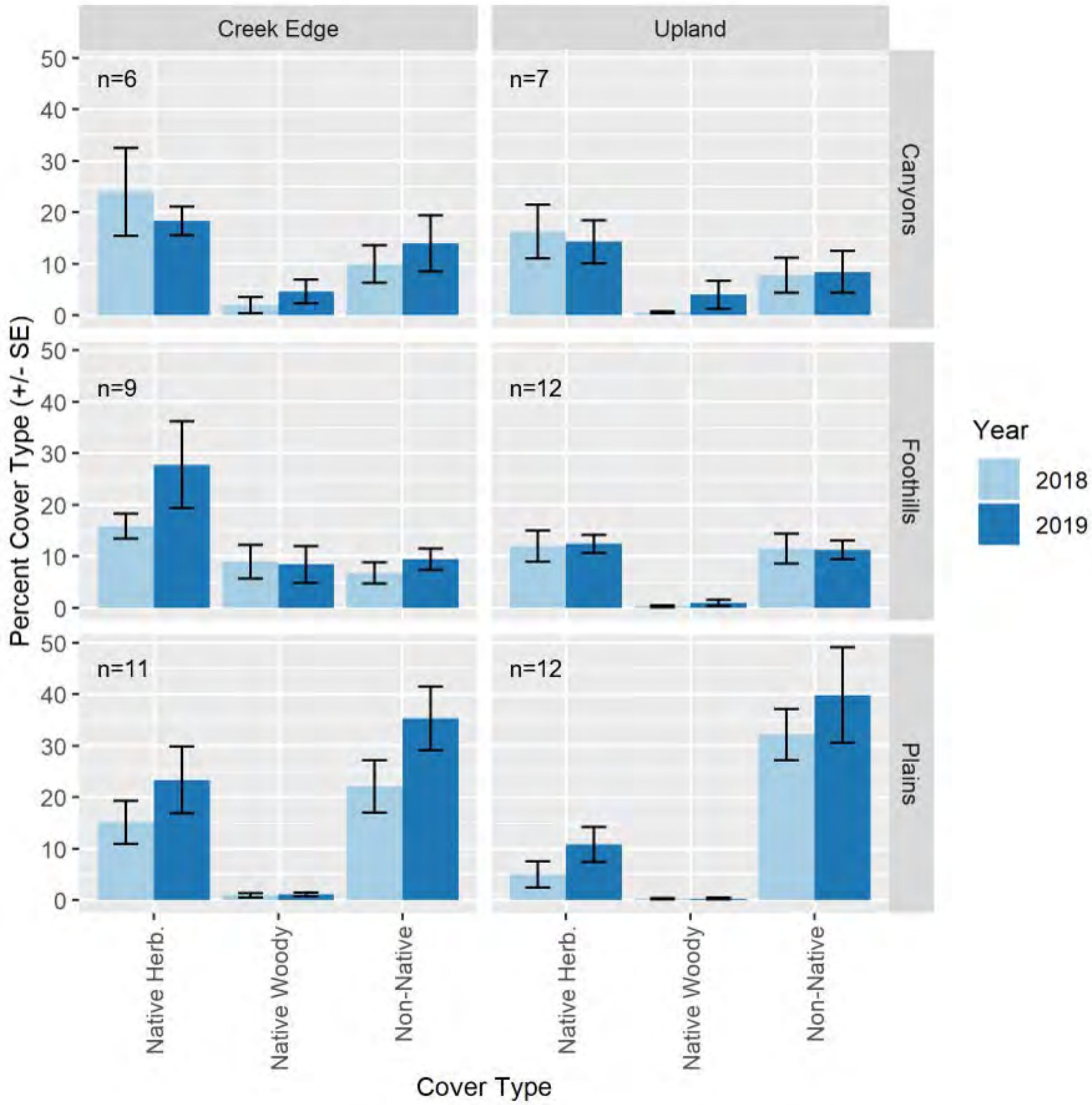



Figure 13. The 2018 and 2019 average percent of cover types (+/- standard error) for Creek Edge and Upland riparian zones in all restored sites within each watershed zone of Left Hand Creek Watershed. Cover types are classified as Native Herbaceous, Native Woody, and Non-Native. Sample size indicated by 'n' value.

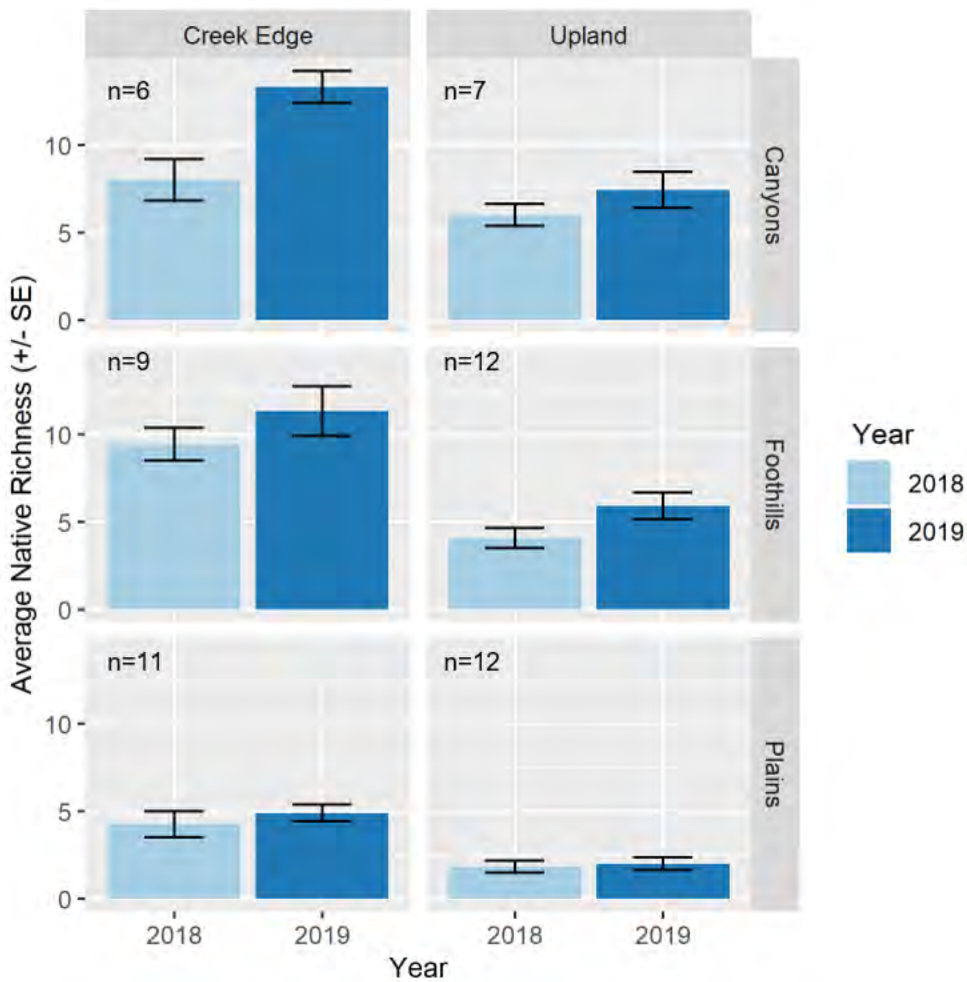



Figure 14. The 2018 and 2019 average native richness (+/- standard error) for Creek Edge and Upland riparian zones in all restores sites within each watershed zone of Left Hand Creek Watershed. Sample size indicated by 'n' value.


Figure 15. In 2019, wetland vegetation establishes in fine depositional area near the creek edge of Upstream Buckingham restoration project in the Canyons of Left Hand Creek Watershed.

In summary, we found that restored riparian condition (native cover and richness) improved or maintained from 2018 to 2019. Notably, restored sites in the Canyons and Foothills also had greater native richness than unrestored sites. In the future, will pay close attention to restored sites in the Plains, as these sites are challenged by more non-native competition than Foothills and Canyons sites. We will also continue to evaluate the creek edge and upland riparian zones separately throughout the watershed, as revegetation in these zones is different and varies based on deposition and water availability. Lastly, we continue to consider how riparian condition relates to other ecological indicators throughout the watershed. Vegetated vigor (high percent cover and native richness) is one critical component of overall flood attenuation capacity. If restored riparian native cover and richness do not continue to increase or remain the same over time, we expect to see issues with fine instream sedimentation after high flow or runoff events.

### 4.5 Benthic Macroinvertebrate Community

The benthic macroinvertebrate (BMI) community is an important indicator of water quality and can give indications of impairments in water chemistry and sedimentation. We assessed BMI throughout Left Hand Creek Watershed in 2016, 2018, and 2019 by testing the following sub-hypotheses:

1. Multimetric Index (MMI) score per site will either attain performance thresholds based on site location (Biotype 1 or 2) or will trend towards attainment from 2016 to 2019.
2. Sediment Tolerance Indicator Value (TIV) score per site will either attain performance thresholds based on site location (Sediment Regions 1 through 3) or trend towards attainment from 2016 to 2019.

MMI and TIV scores were evaluated in relation to applicable performance thresholds and trends over time. While we expect annual variability in our results due to low sample size and fluctuating conditions, MMI results suggested water quality impairments in the upper and lower watershed are ongoing. TIV results did not suggest the creek is experiencing sediment-related impairments.

In 2019, we found that most sites attained the MMI performance threshold for Biotype 2 (score= 50) or Biotype 1 (score= 52). Two Canyons sites (California (CA) Gulch and Legacy 5) and two Plains sites (Kauvar and Haystack) did not attain performance thresholds in 2019. (Figure 16). Most sites also increased to attainment over time. CA Gulch scores decreased and never attained standards from 2018 to 2019, and Legacy 5 scores decreased from attainment in 2018 to below attainment in 2019. Kauvar and Haystack attained MMI in 2016, decreased below attainment in 2018, then increased in 2019.

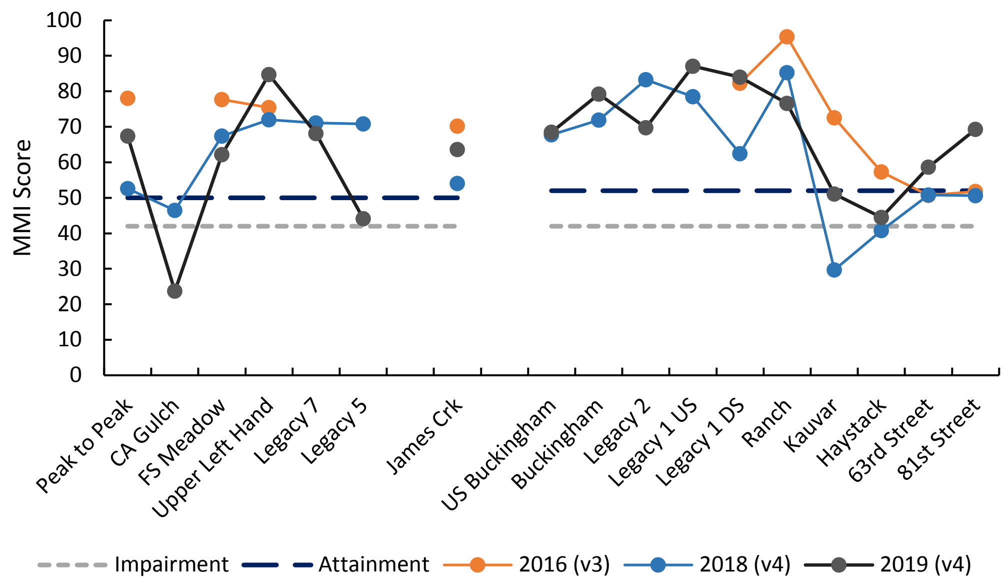



Figure 16. MMI scores from 2016, 2018, and 2019 at sites on Left Hand Creek and James Creek. Short dotted line indicates Impairment threshold and long dotted line indicates attainment threshold for Biotypes 1 and 2. Impairment indicated by MMI scores below Attainment Threshold. MMI versions (3 or 4) used to calculate HBI scores are noted next to each sampling year.

In the upper watershed, impaired MMI scores at CA Gulch and Legacy 5 indicate conditions are worse than they were in 2018. Similar to 2018, we expect water quality impairments at CA Gulch are related to the Captain Jack Mine. In fall 2018, an emergency release occurred at the Mine, less than a mile upstream of CA Gulch. Highly acidic and metals laden water resulted in a fish kill in reaches greater than five miles downstream of the Mine. In addition to the impaired MMI score at CA Gulch, we also found that diversity was impaired at CA Gulch and Forest FS Meadow (Appendix F). This means that the current BMI community at CA Gulch and FS Meadow has lost desired sensitive species. These results are also reflected in our water chemistry data at CA Gulch. At this location we continue to see impairment caused by elevated metals concentrations (Zinc and Copper) that are acutely toxic to aquatic life (Appendix G). We also found an unexpected impairment at Legacy 5 and we plan to test water chemistry at this site for potential water quality issues. Future monitoring and management activities may include collecting water quality data at all BMI sampling locations and increasing monitoring and assessment activities related to mine issues that may be impairing other ecological indicators.

In the lower watershed, impaired MMI scores indicate conditions improved from 2018 to 2019, though we expect impairments are related to diversion activities and our scores are impacted by sampling time. While four sites (Kauvar, Haystack, 63$^{rd}$ Street, and 81$^{st}$ Street) were impaired in 2018, 63$^{rd}$ Street and 81$^{st}$ Street reached attainment in 2019. Despite impairments at Kauvar and Haystack in 2019, both sites improved diversity and Hilsenhoff Biotic Index (HBI) scores compared to 2018. These scores indicate the presence of more desired sensitive species at Kauvar and Haystack in 2019 (Appendix F). As noted, sample timing may be a primary reason for the 2019 improvements. In 2018, we sampled during the irrigation season and attributed impairments to low flow conditions. In 2019, we sampled after the irrigation season when flows are higher, resulting in more dilution of water quality impairments. Overall, differences point to some improvement in water quality in the lower watershed over time, but sampling time may be amplifying results. We plan to address this sampling time issue by maintaining post-irrigation season sampling in future years. Future management actions may include working with water owners to assess and modify diversions structures or operations to allow for base flow during peak irrigation season.

In 2019 and over time, all sites attained TIV performance thresholds for Sediment Region 1 (score= 6.1), Sediment Region 2 (score= 7.0), or Sediment Region 3 (score= 6.3) (Table 4). Currently, there are no standards for sediment regions in the Plains. This score is determined by BMI community metrics that consider the proportion of species in a sample that are inhibited by or favor fine sedimentation. Since all applicable sites attained TIV standards, we conclude that sedimentation issues do not impair BMI communities in the Canyons and Foothills.

Table 4. Tolerance Index Value (TIV) scores from 2018 and 2019 at sites on Left Hand Creek and James Creek in Sediment Regions 1 through 3. No impairment indicated.

| | | 2018 | 2019 |
|---|---|---|---|
| Site | Sediment Region | TIV Score | TIV Score |
| **Peak to Peak** | R1 | 4.66 | 5.22 |
| **CA Gulch** | R1 | 3.87 | 4.29 |
| **FS Meadow** | R2 | 3.78 | 4.35 |
| **Upper Left Hand** | R2 | 4.88 | 4.87 |
| **Legacy 7** | R2 | 4.95 | 4.42 |
| **Legacy 5** | R2 | 4.91 | 5.32 |
| **US Buckingham** | R2 | 4.51 | 4.92 |
| **Buckingham** | R2 | 3.09 | 4.54 |
| **Legacy 2 US** | R2 | Not reported | 4.97 |
| **Legacy 1 US** | R3 | Not reported | 5.19 |
| **Legacy 1 DS** | R3 | Not reported | 5.05 |
| **Ranch** | NA | | |
| **Kauvar** | NA | | |
| **Haystack** | NA | | |
| **63rd Street** | NA | | |
| **81st Street** | NA | | |

In summary, we found water quality impairments in the upper and lower watershed based on MMI scores but not sedimentation-related TIV scores. Abandoned mine drainage in the upper watershed continues to impair water quality downstream since fall 2018. In the lower watershed, we attribute impairments related to diversion activities. In 2019, we found that MMI scores improved between 2018 and 2019, a likely cause may be sampling time. In 2019, we adjusted sampling time from during irrigation season (when flows were low to intermittently dry) to after (when flows were higher). In the future, we will maintain similar sampling time and collect water chemistry data at all BMI locations to help determine other causes of impairment. Lastly, we continue to consider how BMI scores relate to other ecological indicators throughout the watershed. If we continue to find impaired MMI, Diversity, or HBI scores, we expect to also find impaired fish populations, as we did in fall 2018. If we find impaired TIV scores, we expect to also find increased percent sands or reduced habitable pool area caused by a sedimentation issue in the watershed.

# 5. Learning and Adjusting

Two years of post-restoration monitoring provided valuable insight about the strengths and weaknesses of our adaptive management process. This section reflects on lessons learned and how we plan to improve our process to help address key restoration questions and evaluate our trajectory toward resilience.

## 5.1 Refining Monitoring and Assessment

Two years of monitoring and assessment reiterate the importance of continued monitoring in future years. Though some issue areas are obvious (e.g. water quality at mine sites), other observed trends are often nuanced. For example, sampling time issues complicate year-to-year comparisons of riparian community data and water quality data in the Plains. Meanwhile, limited available quantitative data restrict our interpretations about floodplain connectivity and percent sands. Lastly, natural variability in drivers such as flow regime affect year-to-year comparisons. Given these caveats, a key takeaway is that natural and dynamic systems such as watersheds require many years of monitoring to understand trends and select appropriate actions. While improvements in our approach from 2018 to 2019 helped us hone in on measurable hypotheses and appropriate data collection methods, improvements from 2019 to 2020 will help fill data gaps that limit year-to-year interpretation. Improving the reliability of year-to-year observations will help provide strong justification for decisions about future management and monitoring actions. Based on results in 2019, we plan to improve our monitoring and assessment methods in the following areas:

- **Water Chemistry:** While our adaptive management approach is centered on ecological conditions, monitoring in 2019 revealed the importance of water chemistry in supporting potential conclusions. This was particularly evident in our BMI sampling at Legacy Site 5, where we unexpectedly found an impaired MMI score. Increasing our efforts around water quality monitoring water chemistry will be an important adjustment in future years.
- **Plains Reaches:** Most issues noted occurred in the Plains reaches of the watershed where infrastructure, multiple diversions, and mixed land use pose challenges for restoration projects. Notable issues include reduced pool habitat, greater non-native vegetation, potential sedimentation issues, and BMI impairments. The frequency of these issues point to the importance of continuing and increasing monitoring in the Plains. These issues also point to the importance of assessing and implementing modifications to diversion structures and/or operations to improve instream conditions.
- **Ongoing Mining Impacts**: Recent and historical mining activities continue to have drastic impacts on water quality and BMI communities in the upper reaches of the watershed. In contrast to other noted issues that require future monitoring, this issue is persistent over time and requires increased efforts. Collaborating with the Environmental Protection Agency and Colorado Department of Public Health and Environment to address these issues is an important adjustment in 2020.
- **Floodplain Connectivity**: Our assessments of floodplain connectivity are limited to qualitative observations. In the future, we plan to develop quantitative metrics that build our understanding of depth, duration, and timing of floodplain inundation and what peak discharge functions as a flushing flow (promotes fine sediment transport and scour and reduces encroachment)

## 5.2 Expanding Adaptive Management to Forests

Incorporating upland forests health into our Adaptive Management Plan is an important next step for our organization. Forest health is a critical issue for the region as forests throughout the St. Vrain Basin have become dense and crowded, increasing their vulnerability to large wildfires and other natural disturbances, particularly in the face of climate change (Addington, et. al. 2018). Action is required to address forest health and avoid potentially devastating impacts on our watersheds and communities, including loss of critical habitat and reductions in water quality, caused by wildfires. However, this action must be rooted in smart adaptive management to ensure consensus about desired future conditions and data-driven monitoring and assessment.

To start this process, the Watershed Center is currently leading a partnership of stakeholders and community members to plan and implement forest health projects. We are leveraging our existing adaptive management approach and modifying based on the forest-specific adaptive management approaches that have been well researched by others (e.g. US Forest Service, Colorado Forest Restoration Institute). Understanding existing forest health data is key to this effort. Forest health data collection efforts in the St. Vrain Basin are currently led by Boulder County and City of Longmont on their respective properties. As we work collaboratively to address forest health, data consolidation and assessment of data gaps are necessary next steps. We plan to address this need in future iterations of our Adaptive Management Plan.

### 5.3 Expanding Adaptive Management to Include Other Efforts

Incorporating information from existing data collection efforts, management plans, and monitoring tools related to watershed health is an important future step for our Adaptive Management Plan. In 2019, we began working with partners to improve our shared understanding about the types of watershed health data collected throughout the St. Vrain Basin through initiation of a new “Adaptive Management at Scale” project. This project enables us to work with partners throughout the basin to incorporate data, plans, and tools into a shared adaptive management framework. A preliminary list of relevant on-going efforts includes St. Vrain and Left Hand Stream Management Plan, Keep It Clean Partnership 319 Basin Plan, City of Boulder Grasslands Plan, Boulder Creek Master Plan, Mile High Flood District adaptive management planning efforts, City of Longmont Channel Maintenance Plan, Stream Quantification Tool, Stream Health Index, and Ecological Integrity Assessment and Floristic Quality Assessment tool. We plan to expand and refine this list during the project.

## References

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## Appendix

A. Monitoring and Assessment Framework
B. Sample Photo Monitoring Locations
C. 2020 St. Vrain Watershed Monitoring Report
D. Channel Morphology and Habitat Additional Data
E. Riparian Condition Additional Data
F. Benthic Macroinvertebrate Additional Data
G. 2020 Left Hand Watershed Water Quality Report

All appendices are saved on the following Dropbox folder: 2020 State of the Watershed Appendix