ESTES VALLEY WATERSHED COALITION

WPG ENVIRO & REC- FISH CREEK AT CHELEY CAMP RESTORATION

FINAL REPORT

PREPARED FOR: COLORADO WATER CONSERVATION BOARD, WPG PROGRAM
ATTN: ANDREA HARBIN-MONAHAN

APRIL 5, 2024
GRANT AMOUNT: $30,000

PREPARED BY

ESTES VALLEY WATERSHED COALITION
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PROJECT DESCRIPTION

During the flood of 2013, Fish Creek was flooded out and eventually had to be channelized by the county to protect the nearby road. Both the flood and channelization had negative impacts on the existing beaver meadows that were commonplace along Fish Creek in Estes Park. Some restoration, completed in 2018, helped restore a portion of the beaver meadow on Cheley Camp, but annual observations and new approaches to restoration indicated that the meadow would benefit from additional work. In 2021, EVWC partnered with Cheley Camp and the Stillwater Sciences Team to design additional restoration actions to support the beaver meadow. In addition, using an adaptive management approach has allowed us to make adjustments to the project as indicated by the natural environment. The project was initially designed to be in stream work, but updated floodplain regulations and funding restrictions moved Phase I restoration into the adjacent meadow to the channelized creek.

PROJECT GOALS & OBJECTIVES

- Monitor existing beaver and wildlife populations
- Use hand dug channels and low tech processed based structures (LTPBS) to re-wet the beaver meadow to provide more habitat and food sources
- Plant additional native vegetation
- Fence project area to reduce browsing pressure
- Continue to strengthen EVWC community and agency partnerships
- Engage with volunteer groups to provide materials and labor to support the project
- Develop monitoring plan to inform and support Phase II

METHODS

Following annual site visits with EVWC and Stillwater Sciences (in 2019 and 2020), the EVWC board and contractors reached out to Cheley Camp about continuing the beaver meadow restoration along Fish Creek on the camp property. All parties agreed that the continued restoration would provide many benefits to the property and downstream neighbors.

EVWC worked with Stillwater Sciences to update a design plan and source grants to fund the project. The group visited the project site, took reference photos, and updated the recommendations. EVWC reached out to the Cheley Camp for approval of the project design and grant submissions.

EVWC and the Stillwater Sciences team were able to use a combination of handwork and equipment to install a total of eight simulated beaver structures and two earthen dams. We also dug channels and repaired part of an existing beaver dam to help redirect water flow back into the beaver meadow. Using an adaptive management approach allowed us to make changes to the project design as needed.

Site visits and work were completed over the course of two years and designs were adjusted as the environment dictated. Volunteers also helped harvest willow stakes, helped build beaver structures, and replant native plants. The Cheley Camp also provided fill material, heavy equipment use, and volunteer time. This project ended up being supported by many different groups and had a great outreach component..

PROJECT TIMELINE

DECEMBER 2021 - MAY 2022

Update and finalize existing design build plans to reflect current conditions and apply for permits

JUNE-AUGUST 2022

First round of visits to restore the beaver meadow complex using additional SBS, digging channels, and building earthen dams.

SEPTEMBER 2022 - APRIL 2023

Formalize a monitoring and adaptive management protocol. Site visit to make modifications.

MAY - JUNE 2023

Site visits to assess work and modifications done in 2022. Plans for additional adaptive management work.

JULY 2023

Year 2 SBS modifications and revegetation to address additional erosion issues.

AUGUST - SEPTEMBER 2023

Implement monitoring plan and coordinate with Dr. Sholtes for additional site monitoring.

OCTOBER 2023 - APRIL 2024

Reporting and project follow up.

CONCLUSIONS

This project ended up being a great opportunity for local and visitor outreach efforts. EVWC partnered with local volunteers, Cheley Camp, the Estes Park Middle School Resiliency Team, and visitor volunteers to install and adaptively manage the project over 2 years. The EPMS Resiliency Team will also be working on signage to educate people who travel along the property boundary about beaver meadows and the importance of these systems in the environment.

EVWC, Dr. Joel Sholtes, and the Stillwater Sciences Team will continue to monitor the site post project to track successes and any adjustments that may be needed.

753 WILLOW STAKES
(HARVESTED & PLANTED)

30 - 5 GALLON NATIVE CONTAINER PLANTS INSTALLED

71 VOLUNTEERS
322 HOURS DONATED

7 SBS AND 2 EARTHEN DAMS INSTALLED

LESSONS LEARNED & PROJECT ADDITIONS

Lessons Learned

Overall the project ended up being a great opportunity for trying new processes and for outreach, but we will consider the following on future projects:

- Ensure that we continually follow any floodplain restriction updates
- Reach out to partners early about any parallel project opportunities
- Include at least 2 years of weed control measures and work with property owners to ensure these are planned effectively

Project Adjustments

With approval, we reallocated funds to:

- shift the project scope of work from the channel to just outside the designated 100 year floodplain
- provide additional funds to cover fencing material cost increases
- provide snacks and drinks for volunteers on the project site

BUDGET

Project Name: Fish Creek at Cheley Camp Restoration

Billing/Timeline: April 2021-April 2024

TASK	TOTAL BUDGET	CWCB BILLED	EVWC MATCH FUNDS	IN KIND*	DESCRIPTION
1	$24,295.00	$8,672.00	$15,623.00		Update and finalize existing design build plans to reflect current conditions and apply for permits
2	$78,585.80	$1,800.00	$56,543.46	$6,021.80	Restore the beaver meadow complex using additional SBS. Due to county floodplain regulations changing before project implementation, in channel work was suspended. *In kind rate=$28.54
3	$26,709.30	$4,560.00	$22,149.30	$4,138.30	Revegetation to address additional erosion issues
4	$15,718.00	$14,968.00	$750.00		Formalize a monitoring and adaptive management protocol
5	$2,761.20	$0.00	$2,761.20	$856.20	Planting/SBS modifications/Weed Control Year 2 - Stillwater Team
6	$2,500.00	$0.00	$2,500.00		Project Management/Reports
7	$488.00	$0.00	$488.00		Mileage for Stillwater Team (10 trips from Ft. Collins to Estes at 80 miles per trip)
TOTALS	$151,057.30	$30,000.00	$100,814.96	$9,400.00	Due to changes in county floodplain regulations, EVWC and the Stillwater Sciences Team had to adjust the SOW to move work outside of the channel. Funds remaining: CWCB $1,468.47, BOR: $19,329.44 EVWC $912.90

Budget Narrative

The original grant budget included funding to support in channel work along Fish Creek like moving sediment and using material for bank stabilization. Due to county floodplain regulation updates, the project scope was adjusted to provide work outside the designated 100 yr floodplain.

EVWC and the Stillwater Sciences Team was able to get permitting for the new scope of work. We were also able to use funds to purchase extra native plants and provide extra funding to account for increases in fencing materials for the elk exclusion fence around the project.

Funding reallocation mean that EVWC did not need to use $1,468.47 of the CWCB funds, $19,329.44 of the BOR funds, or $912.90 of the EVWC match funds.

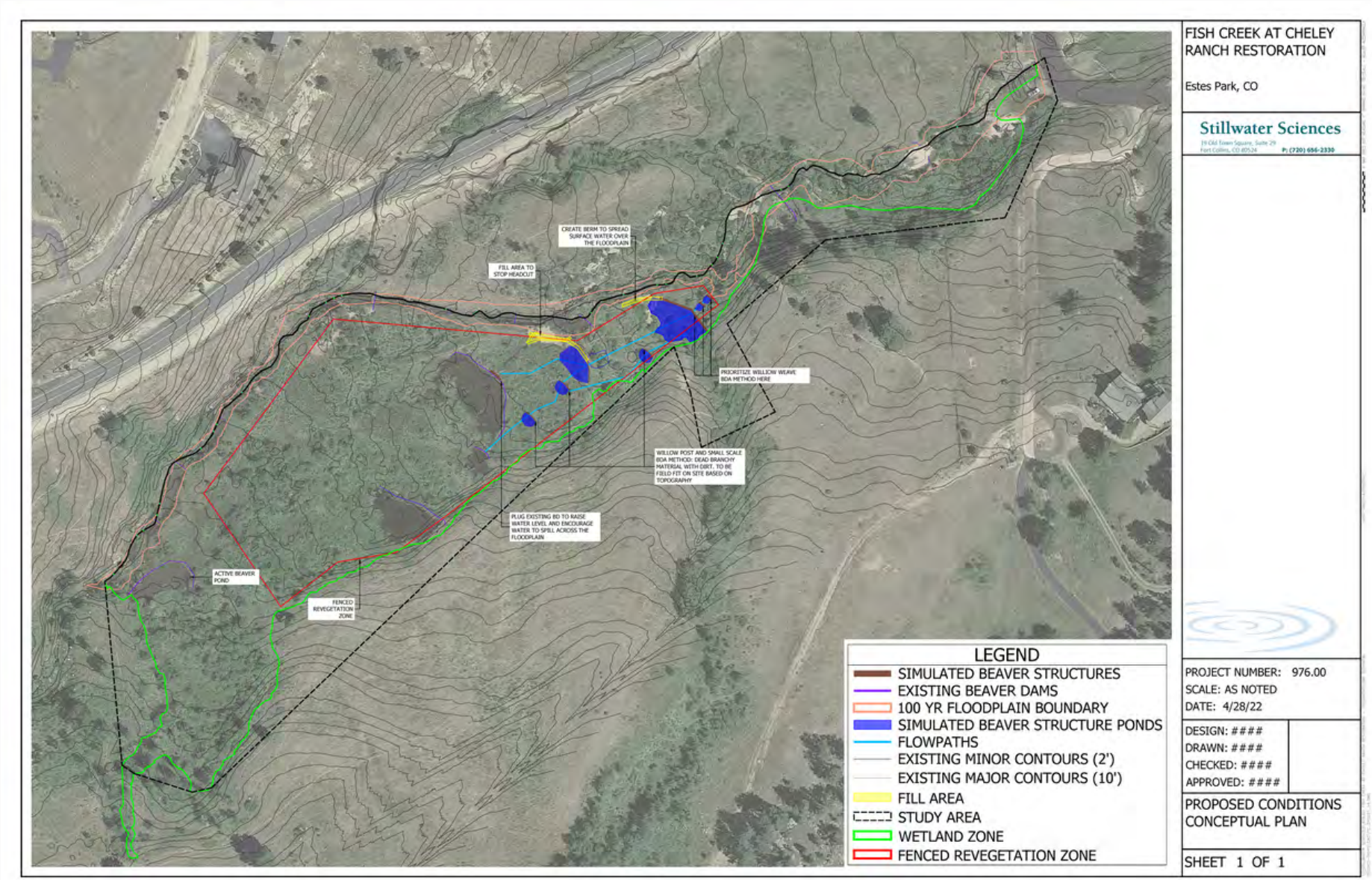
THANK YOU

WE WANT TO THANK THE CWCB, THE BUREAU OF RECLAMATION, THE FLY FISHERS INTERNATIONAL, CEMEX AND NORTHERN COLORADO WATER CONSERVANCY DISTRICT FOR THE FUNDING SUPPORT!

THANKS ALSO TO OUR MANY VOLUNTEERS AND THE PROPERTY OWNERS FOR HELPING US GET THE PROJECT FINISHED!

APPENDIX

A. UPDATED DESIGN BUILD PLAN




CWMPII-017
FISH CREEK AT
CHELEY CAMP
RESTORATION
PROJECT
ESTES VALLEY WATERSHED
COALITION
GRANT REPORT
OCTOBER 2022

CWMP II-017 FISH CREEK AT CHELEY CAMP RESTORATION

Fish Creek at Cheley Camp Restoration Background

The 2013 flood washed out Fish Creek and the creek was eventually channelized by the county to protect the nearby road. Both the flood and channelization wiped-out the existing beaver meadows that were commonplace along Fish Creek in Estes Park. Some restoration was completed in 2018 to help restore the beaver meadow on Cheley Camp, but annual observations have indicated that the meadow and earlier restoration would benefit from additional work. As a result, EVWC partnered with the Stillwater Sciences Team to continue the restoration of the beaver meadow along the upper reach of Fish Creek at Cheley Camp. Using an adaptive management approach has allowed us to make adjustments to the project as indicated by the natural environment.

WATERSHED GRANT FISH CREEK AT CHELEY CAMP RESTORATION - PHASE I

EVWC and the Stillwater Sciences team focused on five main areas for the first phase of the project:

1. **Area 1** - repaired a lower beaver dam to prevent overflow and added pilot channels to redirect water flow into the beaver meadow.
2. **Area 2** – built an earthen berm to help fix a headcut and redirect water east towards the beaver meadow. We also dug some pilot channels to help redirect water.
3. **Area 3** – built a second earthen berm and dug pilot channels to continue to redirect water towards the beaver meadow.
4. **Area 4** - built three simulated beaver structures using the willow-weave technique and coarse-and-fine fill.
5. **Area 5** – planted locally harvested willow stakes in April 2022 to support streambank stabilization and habitat.

PROJECT SUMMARY

EVWC and the Stillwater Sciences team were able to use a combination of handwork and equipment to install three simulated beaver structures and two earthen dams. We also dug channels and repaired part of an existing beaver dam to help redirect water flow back into the beaver meadow. Using an adaptive management approach allowed us to make changes to the project design as needed. We will go back out to review and adjust the project site in the Spring/Summer of 2023. Volunteers also helped harvest **453 willow stakes** and donated **53.25 hours** towards the beaver structure construction. The Cheley Camp also provided **50 cubic yards** of fill material along with **$2,720 for equipment use and volunteer time**.

CWMP II-017 FISH CREEK AT CHELEY CAMP RESTORATION

Area 1: Repair existing lower beaver pond - In August, EVWC, Stillwater, and volunteers moved fill and sod mats to this area to repair the area on the west side of an existing beaver dam. This has helped to stop some of the water overtopping the dam and has also allowed water flow back to the east side of the meadow and floodplain. During the September visit, we added more fill and sod mats to build up the dam on the west side.

Water overtopping the existing lower beaver pond after August work (September 2022).

Existing pond repair after more sod mats and fill added in September 2022 (view is facing opposite direction).

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Area 1 continued: Dug pilot channels to redirect water from lower pond
- We also dug channels in and near the east side of the dam in August. This helped to re-direct water flow back into the beaver meadow and also supports existing and new vegetation growth for both habitat and food sources. In September, we made some adjustments on the channels and added one more channel to the beaver pond.

Pilot channel with water and good vegetation establishment (September 2022).

Pilot channels are narrow (less than 6" wide) channels that help distribute runoff the beaver meadow.

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Area 2: Upper Earthen Berm - In August, EVWC, the Stillwater team, and volunteers were able to use a combination of equipment and handwork to build an earthen berm, fill a headcut, and add pilot channels to continue to re-direct water towards the beaver meadow. This area is just below the lower pond in Area 1. In September, EVWC and Stillwater determined that the berm needed more fill and we were able to add this using handwork.

Excavator helping to build berm (August 2022).

Same location facing the other direction showing berm and headcut filled in (August 2022).

Area 2 continued: Headcut repair near upper earthen berm - Due to some heavy rains between the August and September visits, the previously filled headcut needed repairs. We also adjusted the pilot channels to help direct water flow back into the beaver meadow and away from the headcut repairs.

Back side of the headcut that needed repairs (September 2022).

Repaired headcut using fill and handwork (September 2022).

Area 3: Lower earthen berm - In August, EVWC, the Stillwater team, and volunteers built a second earthen berm and dug pilot channels to continue re-directing the water. During the September 2022 visit, we used more fill in this area to reinforce the berm.

Second earthen berm (August 2022).

Backside of second earthen berm after fill was added (September 2022).

Area 4: Priority beaver structures - In August, EVWC, the Stillwater team, and volunteers also built three simulated beaver structures outside of the 100-year floodplain. This was done in a steep area to help slow the velocity and keep water in the meadow. We used the willow-weave technique along with coarse and fine fill to complete the structures. The upper two structures needed to be reinforced with more fill during the September site visit.

Beaver structures before fill (September 2022).

Beaver structures after more fill was added (September 2022).

Beaver structures from below (October 2022).

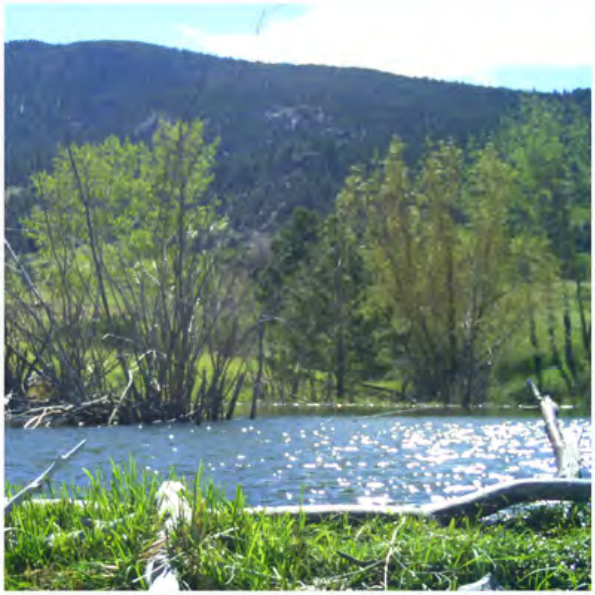
Area 5: Willow stake replanting - In April, EVWC, the Stillwater team, and volunteers planted 175 willow stakes along the banks of Fish Creek in an area downstream from where the priority beaver structures (Area 1) were installed. The willows are thriving and will provide habitat and a food source that had been previously removed by the 2013 flood and subsequent redirection of Fish Creek following the flood of September 2013.

Some of the willow stakes planted along the banks (photo in May 2022).

Good willow establishment along the banks (photo in October 2022).

CWMP II-017 FISH CREEK AT CHELEY CAMP RESTORATION

Wildlife and beaver colony on Fish Creek at Cheley Camp - using game camera footage we have been able to monitor the wildlife in the project site. There is an active beaver pond and at least one beaver in that pond. Game camera monitoring also helps us with the adaptive management of the project and knowing where we need to use exclosure fencing to protect vegetation and habitat for the beaver colony.



Active beaver pond (June 2022).

Elk along beaver pond (May 2022)

We regularly see coyotes around the active pond (July 2022).

Beaver in the active pond (August 2022).

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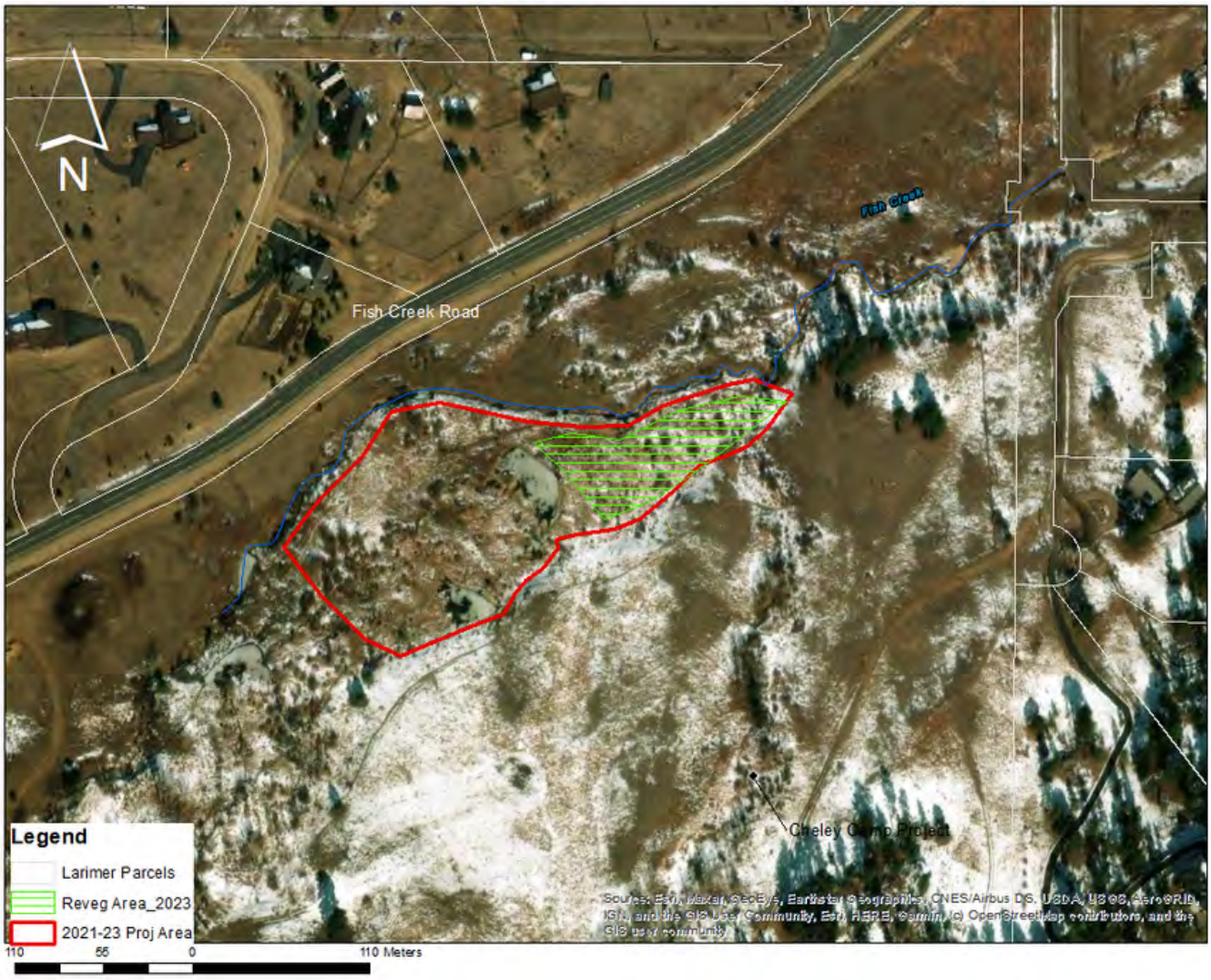
C. SPECIES LIST AND PLANTING LOCATION

Plant Species	Number Planted	Size
Alnus incana tenuifolia Alder, Thin Leaf	5	5 gallon
Populus tremuloides Aspen	10	5 gallon
Salix exigua Willow, Coyote	15	5 gallon
Narrowleaf and Bebb's willow	305	stakes

Fish Creek Restoration at Cheley Camp



D. YEAR 2 PHOTO POINTS OF STRUCTURES & STABILIZATION REPORT

Fish Creek at Cheley Camp Restoration Background

The 2013 flood in Estes washed out Fish Creek resulting in the creek being channelized by the county to protect the nearby road. Both the flood and channelization wiped-out the existing beaver meadows that were commonplace along Fish Creek in Estes Park. Some restoration was completed in 2018 to help restore the beaver meadow on Cheley Camp, but annual observations have indicated that the meadow and earlier restoration would benefit from additional work. As a result, EVWC partnered with the Stillwater Sciences Team to continue the restoration of the beaver meadow along the upper reach of Fish Creek at Cheley Camp. Using an adaptive management approach has allowed us to make adjustments to the project as indicated by the natural environment.

WATERSHED GRANT FISH CREEK AT CHELEY CAMP RESTORATION - PHASE I

EVWC and the Stillwater Sciences team focused on five main areas for the first phase of the project:

1. **Area 1** - repaired a lower beaver dam to prevent overflow and added pilot channels to redirect water flow into the beaver meadow.
2. **Area 2** – built an earthen berm to help fix a large headcut and redirect water east towards the beaver meadow. Pilot channels were dug by hand to help redirect water. FIVE simulated beaver structures were added after the earthen berm failed during high water in Spring of 2023. Planted native willow stakes and plants in areas 2 and 3 in the Spring of 2023.
3. **Area 3** – built a second earthen berm and dug pilot channels to continue to redirect water towards the beaver meadow.
4. **Area 4** - built three simulated beaver structures using the willow-weave technique and coarse-and-fine fill.
5. **Area 5** – planted locally harvested willow stakes in April 2022 to support streambank stabilization and habitat.

PROJECT SUMMARY

EVWC and the Stillwater Sciences team were able to use a combination of handwork and equipment to install a total of eight simulated beaver structures and two earthen dams. We also dug channels and repaired part of an existing beaver dam to help redirect water flow back into the beaver meadow. Using an adaptive management approach allowed us to make changes to the project design as needed. Site visits and work were completed over the course of two years and designs were adjusted as the environment dictated. Volunteers also helped harvest a total of **753 willow stakes** and donated **321.25 hours**. The Cheley Camp also provided **50 cubic yards** of fill material along with **$3,720 for equipment use and volunteer time**. This project ended up being supported by many different groups and had a great outreach opportunity.

D. YEAR 2 PHOTO POINTS OF STRUCTURES & STABILIZATION REPORT

Area 1: Repair existing lower beaver pond - EVWC, Stillwater, and volunteers moved fill and sod mats to this area during both site visits (2022 & 2023) to repair the west side of an existing beaver dam. This has helped to stop some of the water overtopping the dam and has also allowed water flow back to the east side of the meadow and floodplain. This pond is filled by the main tributary of Fish Creek and is a main source of water.

Water overtopping the existing lower beaver pond after August work (September 2022).

Volunteers in July 2023 adding more sod mats and native plants to the beaver pond (view is facing opposite direction).

Area 1 continued: Dug pilot channels to redirect water from lower pond - Channels were dug near the east side of the dam at the start of the project (2022) to help re-direct water flow back into the beaver meadow. Adaptive management techniques supported adding additional channels to promote existing and new vegetation growth for both habitat and food sources.

Pilot channels are narrow (less than 6" wide) channels that help distribute runoff the beaver meadow (September 2023).

Ponded water from the hand dug channels has increased vegetation in the meadow restoration site (September 2023).

D. YEAR 2 PHOTO POINTS OF STRUCTURES & STABILIZATION REPORT

Area 2: Upper Earthen Berm - Initially, EVWC, the Stillwater team, and volunteers were able to use a combination of equipment and handwork to build an earthen berm, fill a headcut, and add pilot channels to continue to re-direct water towards the beaver meadow. High water movement in Spring 2023 washed out the headcut filled area. We were able to add in a series of 5 willow weave simulated beaver structures secured with sod mats and native vegetation in July 2023 that appears to be holding.

Excavator helping to build berm (August 2022).

Same location facing the other direction showing berm and headcut filled in with 5 simulated beaver structures (Sept 2023).

Area 2 continued: Headcut repair near upper earthen berm - Due to some heavy rains in 2022 and 2023, the previously filled headcut needed repairs. The team and volunteers added in a series of simulated beaver structures secured using a willow weave technique, sod mats, and native vegetation. We also adjusted the pilot channels to continue to help direct water flow back into the beaver meadow and away from the headcut repairs.

Back side of the headcut that needed repairs, second wash out of the earthen berm (September 2022).

Repaired headcut using willow weave simulated beaver structures, sod mats and native vegetation (Sept 2023).

Area 3: Lower earthen berm - In August, EVWC, the Stillwater team, and volunteers built a second earthen berm and dug pilot channels to continue re-directing the water. These were reinforced by hand during work days in 2022 and 2023. Native vegetation and native willow stakes were added to provide additional stability to the berms in 2023.

Second earthen berm (May 2023).

Second earthen berm after fill and native vegetation were added (September 2023).

D. YEAR 2 PHOTO POINTS OF STRUCTURES & STABILIZATION REPORT

Area 4: Priority beaver structures - In August, EVWC, the Stillwater team, and volunteers also built three simulated beaver structures outside of the 100-year floodplain. This was done in a steep area to help slow the velocity and keep water in the meadow. We used the willow-weave technique along with coarse and fine fill to complete the structures. The upper two structures needed to be reinforced with more fill and willow stakes during the various site visits.

Beaver structures before fill (September 2022).

Beaver structures after more fill and willow stakes were added (Sept 2023).

Beaver structures from below (September 2023).

Area 5: Willow stake replanting - In April 2022, EVWC, the Stillwater team, and volunteers planted 175 willow stakes along the banks of Fish Creek in an area downstream from where the priority beaver structures (Area 1) were installed. The willows are thriving and will provide habitat and a food source that had been previously removed by the 2013 flood and subsequent redirection of Fish Creek following the flood of September 2013. During the last site visit we noticed an additional beaver structure downstream of this location as well.

Some of the willow stakes planted along the banks (photo in May 2022).

Good willow establishment along the banks (photo in Sept 2023).

New beaver dam downstream of project site (photo in Sept 2023).

D. YEAR 2 PHOTO POINTS OF STRUCTURES & STABILIZATION REPORT

WATERSHED GRANT FISH CREEK AT CHELEY CAMP RESTORATION

Wildlife and beaver colony on Fish Creek at Cheley Camp - using game camera footage we have been able to monitor the wildlife in the project site. There is an active beaver pond and at least one beaver in that pond. Game camera monitoring also helps us with the adaptive management of the project and knowing where we need to use exclosure fencing to protect vegetation and habitat for the beaver colony.

Beaver activity in restoration area (Sept 2023).

Beaver working in the pond (June 2023)

Elk around the active pond (April 2023).

Great blue heron fishing in the active pond (June 2023).

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D. YEAR 2 PHOTO POINTS OF STRUCTURES & STABILIZATION REPORT

Wildlife and beaver colony on Fish Creek at Cheley Camp - using game camera footage we have been able to monitor the wildlife in the project site. There is an active beaver pond and at least one beaver in that pond. Game camera monitoring also helps us with the adaptive management of the project and knowing where we need to use exclosure fencing to protect vegetation and habitat for the beaver colony.

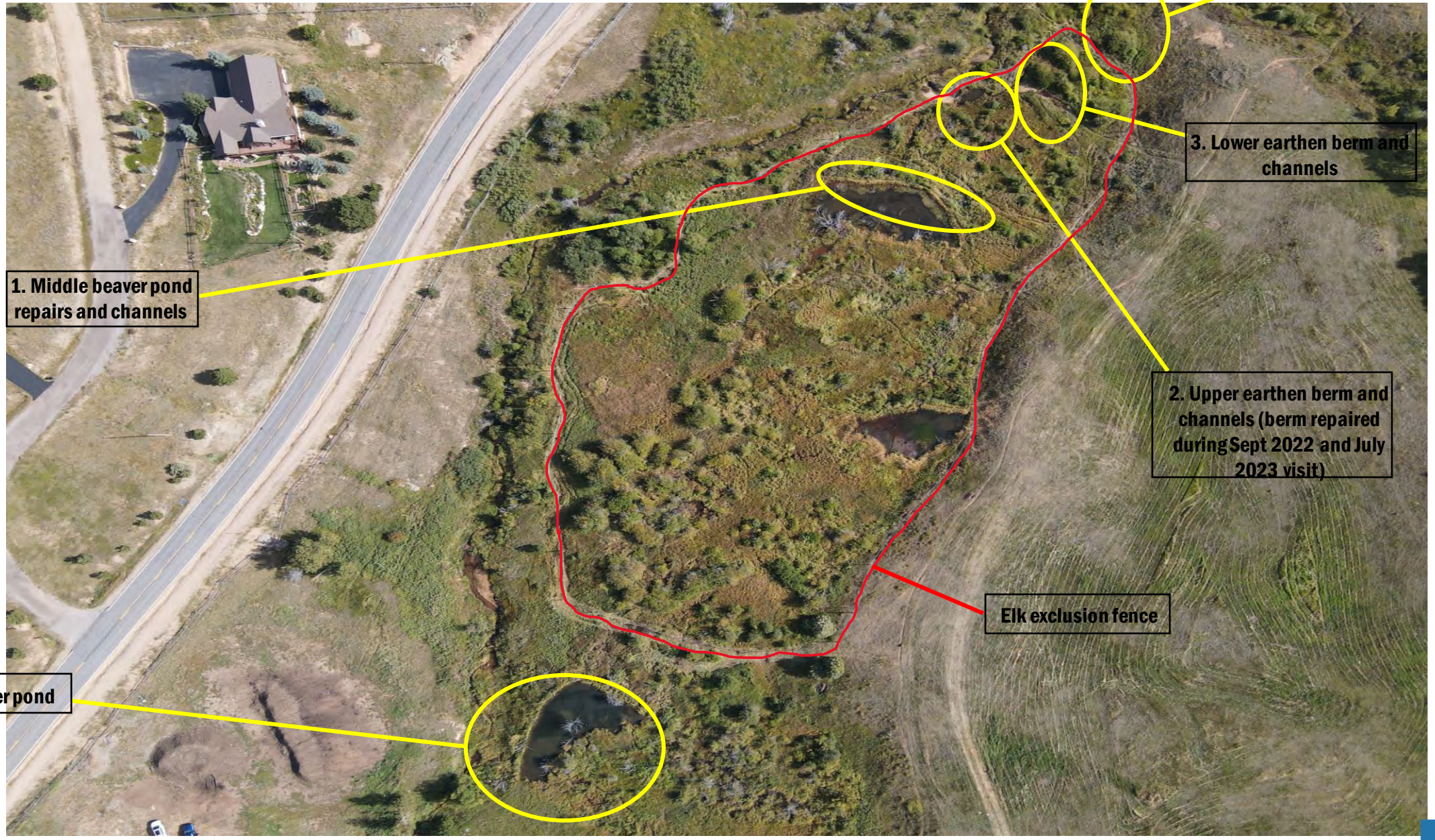
Volunteers helping to build SBS (July 2023).

Volunteers planting native vegetation and willow stakes (July 2023)

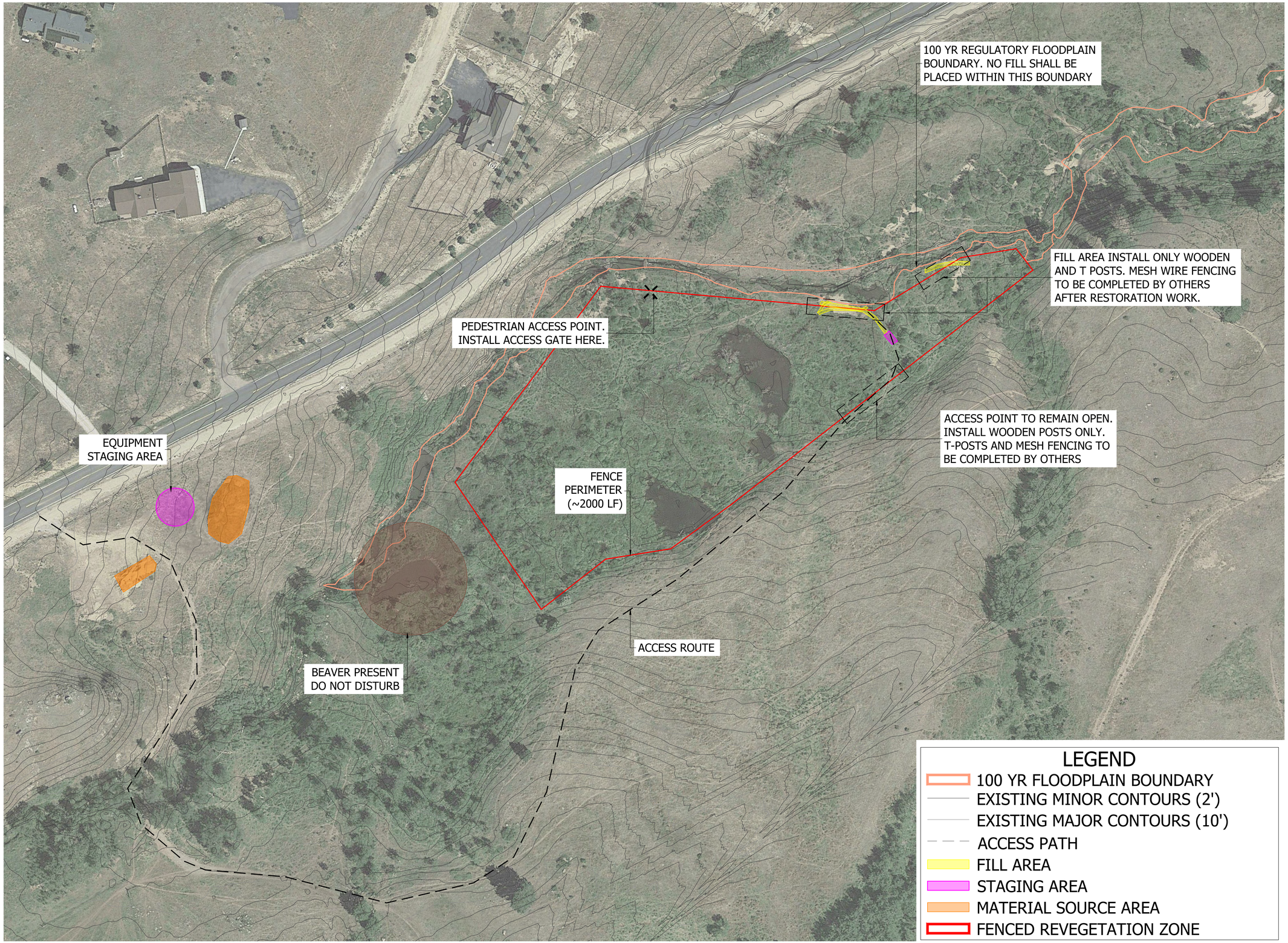
Beaver in the active pond (June 2023).

Native vegetation and willow stakes in project area (Sept 2023).

SITE OVERVIEW



Appendix E. Elk exclusion fencing plan



FISH CREEK AT CHELEY RANCH RESTORATION

Estes Park, CO

Stillwater Sciences

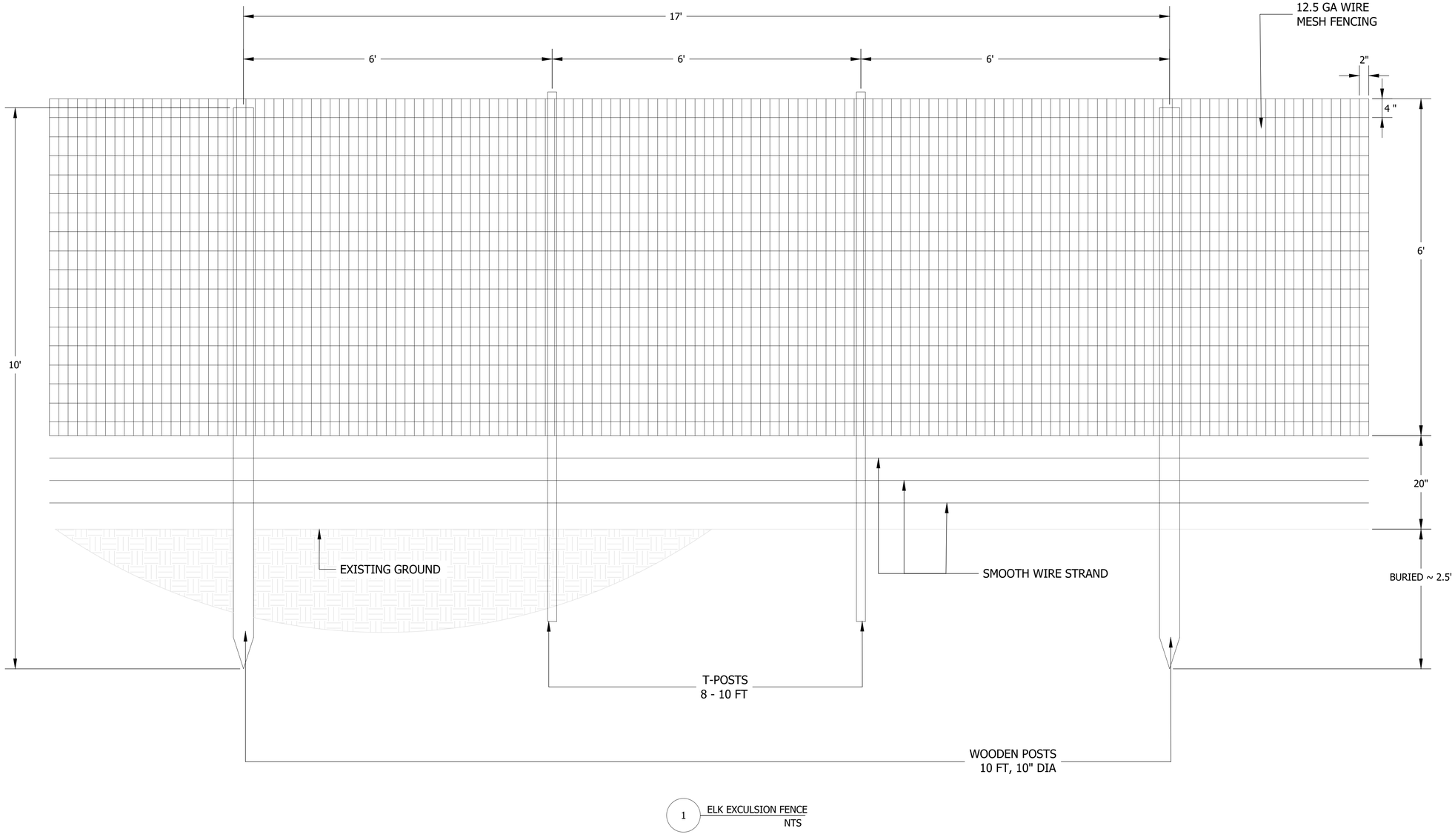
19 Old Town Square, Suite 29
Fort Collins, CO 80524 **P: (720) 656-2330**

PROJECT NUMBER: 976.00
SCALE: AS NOTED
DATE: 5/9/22

DESIGN: ####
DRAWN: ####
CHECKED: ####
APPROVED: ####

STAGING AND ACCESS PLAN

SHEET 1 OF 2



1 ELK EXCULSION FENCE
NTS

FISH CREEK AT CHELEY RANCH RESTORATION

Estes Park, CO

Stillwater Sciences
19 Old Town Square, Suite 29
Fort Collins, CO 80524 **P: (720) 656-2330**

PROJECT NUMBER: 976.00
SCALE: AS NOTED
DATE: 5/26/22

DESIGN: ####
DRAWN: ####
CHECKED: ####
APPROVED: ####

ELK EXCULSION FENCE DETAIL

SHEET 2 OF 2

Appendix F. Fish Creek at Cheley Camp Monitoring Plan & Overview

TECHNICAL REPORT ◦ SEPTEMBER 2023

Fish Creek at Cheley Camp Restoration: Adaptive Management and Monitoring Plan

PREPARED FOR

Estes Valley Watershed Coalition
1191 Woodstock Dr
Estes Park, CO 80517

PREPARED BY

Stillwater Sciences
19 Old Town Square, Suite 238
Fort Collins, CO 80524

Stillwater Sciences

Suggested citation:
See "Citation Guide" or contact Kelli Wheat Dawson for correct format.

Cover photos: Fish Creek at Cheley Camp property.

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Appendices:

1 INTRODUCTION

1.1 Background

During the 2013 Flood, Fish Creek jumped out of its channel and ran down Fish Creek Road. As an emergency repair, a new straight channel was excavated down the middle of an existing beaver meadow within the Cheley Camp property to move it away from Fish Creek Road (Figure 1). As a result of the shortened channel length, Fish Creek incised, and most of the surrounding beaver meadow became disconnected and dried out. Recent observations (refer to Section 3.1.1) suggest that only one beaver remains on the property today, which is unsurprising given the reductions of habitat and food source associated with the emergency channel.

Figure 1: Aerial imagery (a.) pre-2013 flood with the channel in its historic alignment and (b.) post-2013 flood with the new straighten emergency repair channel alignment.

1.2 Project Purpose

The Fish Creek at Cheley Camp Restoration Project (Fish Creek Project or project) employs the adaptive management approach to restoration. Adaptive management is "an iterative process of decision making in the face of uncertainty, with the intent of reducing uncertainty through system monitoring, and continually moving toward a stated goal through ongoing actions

informed by monitoring" (Skidmore et al., 2011). The goal of the Fish Creek Project is to restore the beaver meadow complex on Fish Creek at Cheley Camp by reconnecting the floodplain via beaver mimicry treatments, specifically using Simulated Beaver Structures (SBS). The Estes Valley Watershed Coalition (EVWC) is working with Stillwater Sciences, Johnson Environmental Consulting (JEC), and Dr. Ellen Wohl with Colorado State University (CSU) (Stillwater Team or Team) on the planning, analysis, permitting, design, and construction implementation of the Fish Creek Project.

At the onset of the project, the design intent was to move Fish Creek back to its pre-disturbance channel and fill-in the existing emergency channel to reconnect the entire beaver meadow. However, it was discovered that Larimer County has pre-emptively adopted RiskMap Modeling for their Floodplain Development Permitting process which, due to the costs associated with the CLOMR/LOMR process, did not allow for work in the main channel. Therefore, this project shifted focus to a phased implementation approach where restoration focused on the portion of beaver meadow supported by a tributary that enters Fish Creek on the property (Figure 2, Restoration Area 1 & 2). Additional funding is being pursued to complete restoration in on the main channel of Fish Creek (Figure 2, Restoration Area 3), including funding for the full CLOMR/LOMR process.

For this phase of the project, the intent of the new SBSs in Restoration Area 1 and 2, on the tributary, is to improve beaver habitat through restoring riparian and woody vegetation by spreading water across the floodplain and locally raising shallow groundwater levels.

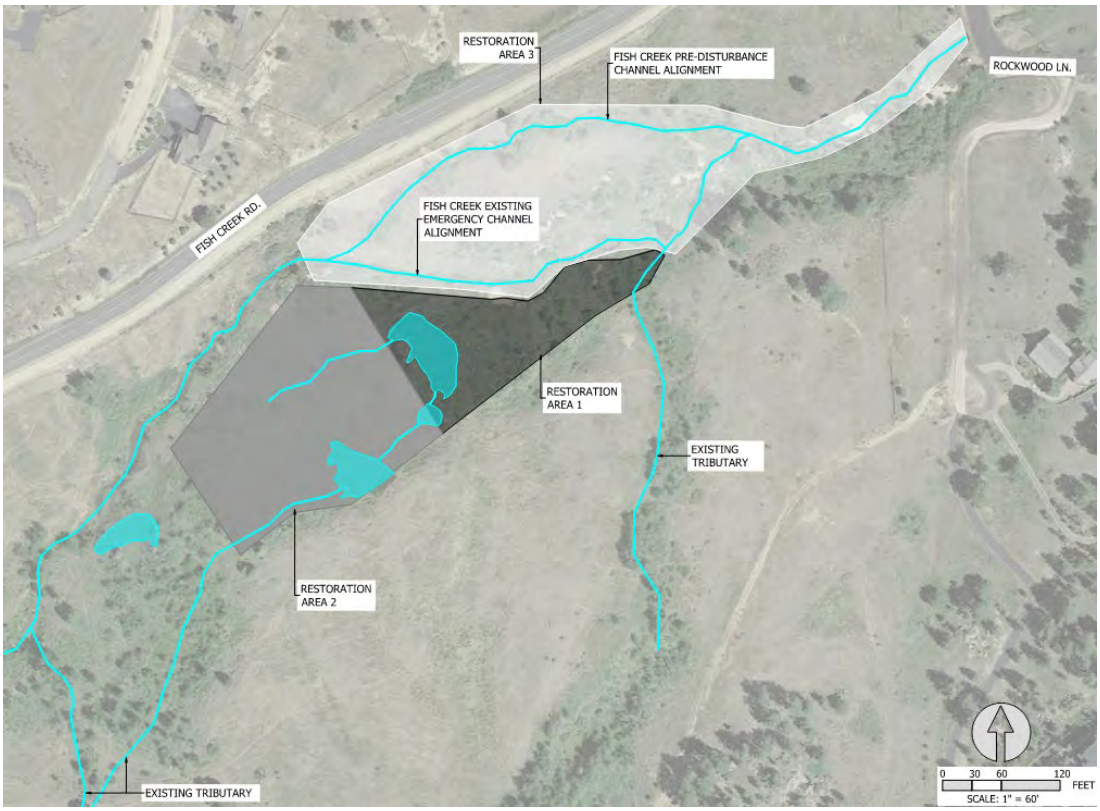

Figure 2: Overview of Restoration Areas for the Fish Creek at Cheley Camp Restoration Project.

2 ADAPTIVE MANAGEMENT PLAN

The adaptive management plan for the project is structured as follows:

- Years 0-2: Initial assessment, design/permitting, and phases 1 and 2 of construction.
- Years 3-5: Performance monitoring, SBS refinements based on monitoring results, and grant funding procurement to start design work to realign the main channel of Fish Creek realignment and continue beaver meadow restoration for the Cheley property.

The adaptive management approach is well suited to beaver mimicry restoration, enabling the monitoring of natural system response to treatments with application of monitoring results to inform future construction phases. This process leads to maximum on-the-ground results and offers rich opportunity to improve understanding of the benefits, including for wildfire resilience, of beaver modified systems.

Adaptive management will be implemented in phases as defined below:

2.1 PHASE 1

- **Year 0 (2021):**
  1. Conduct initial site assessment.
  2. Develop design of Restoration Area 1 (Figure 2).
  3. Acquire necessary project permits.
- **Year 1 (2022):**
  1. Fill headcut channels outside of 100 yr. floodplain.
  2. Plug existing beaver dams within Restoration Area 1.
  3. Install SBS within Restoration Area 1.
  4. Handwork to cut new flowpaths through the floodplain.
  5. Install willow slips along Fish Creek.
- **Year 2 (2023):**
  1. Fence off Restoration Areas 1 and 2.
  2. Evaluate success of revegetation and SBSs within Restoration Area 1. Modify as needed:
     a. willow slips in channel, install additional willow slips as needed.
     b. regrowth within Restoration Area 1.
     c. beaver dam sod mat plugs.
     d. SBS installation.
  3. Begin monitoring restoration performance according to Monitoring Plan (Section 3).
  4. Install SBS and plug existing beaver dams within Restoration Area 2 (Figure 2).

2.2 PHASE 2 (Year 3-5):

1. Continue monitoring restoration performance according to Monitoring Plan (Section 3).
2. Evaluate success of revegetation and modify as needed:
   a. willow slips in channel, install additional willow slips as needed
   b. regrowth within exclusion fencing.
   c. exclusion fence condition
3. Evaluate success of beaver dam plugs and modify as needed.

4. Evaluate success of SBS installation and modify as needed.
5. Secure funding and begin designs for Restoration Area 3 (Figure 2)

3 MONITORING PLAN

Monitoring of the project will focus on evaluating the success of the project goals and informing adaptive management actions as defined by the monitoring categories with successful outcomes presented in Table 1. More detail on protocols for monitoring outcomes for each category are provided in Table 2.

Table 1. Monitoring categories with successful outcomes

Monitoring Category		**Successful Outcomes**
Biology		increase in beaver activity in channel and on tributary
		increase in beaver population
Vegetation		increase in woody vegetation (abundance and height)
		increase in wetland vegetation
Hydrology		increase in surface water area
		increase in hydrologic connection
Effectiveness of Restoration Treatment	Elk Exculsion Fencing	increase in woody vegetation (abundance and height)
		no elk/moose within enclosure
	SBS treatments	structures leaky but spreading water
		improved water quality (nutrient, water temperature, and sediment retention)

The Stillwater Team investigated potential monitoring methods at a range of financial, time, and labor investments. The Team identified many low-cost monitoring methods that provide coarse, yet generally quite robust, evidence of successful outcomes as suitable and feasible for this meadow restoration project. The low-cost, coarse methods are less sensitive, and may not be able to distinguish smaller year-to-year changes or support more detailed conclusions on the effectiveness of given treatment approach(es).

This project offers an opportunity to collect additional data that provides a more robust picture of the effectiveness of beaver mimicry restoration treatments on water quality and quantity. The restoration community has not yet come to a consensus on the effects of beaver mimicry treatments. This project affords a powerful opportunity to expand monitoring beyond the successful outcomes defined for biology, ecology, and hydrology because it a supportive landowner and the involvement of Dr. Ellen Wohl, a local CSU research professor, as part of the Stillwater Team. Expanding monitoring to a broader scope will help inform not only this project, but also future beaver mimicry restoration projects.

The intent for this project is to identify a suite of monitoring options that will provide meaningful results in a defensive, dependable, and repeatable manner, with documentation of associated level of uncertainty, and developed a range of low-, medium-, and high-cost options. Methods known to be simple, quick, and easy, while still remaining defensible, dependable, and repeatable, constitute the options in the low-cost category. Methods that require more robust sampling and equipment as well as need support of trained experts constitute the options in the high-cost category.

Table 2 summarizes potential methods and provides information on pros and cons, as well as relative costs.

Table 2. Potential beaver meadow restoration monitoring methods. "Low" relative cost assumes minimal equipment and little expert guidance, or training needed.

Monitoring Method	Monitoring Category	Purpose	Pros/cons	Frequency	Relative Cost
Trail Cameras	biology	gather information about beaver activity and monitor changes	easy data collection, trail cameras are already purchased by EVWC pre-restoration baseline data from upstream active beaver pond	Biweekly download from SD cards and change batteries	Low
Aerial Photos *Description:* Imagery collected via drone flight	ecology	gather imagery of meadow to track vegetation and hydrology changes after construction and changes in the following years	efficient for a large area, need drone pilot, strong long-term line of evidence for tracking meadow changes through time	Biannually: Pre and post growing season	Mid
Repeated Photo Points *Description:* Photo documentation repeated at strategic photo points	ecology	track the recovery of the vegetation. use this information to inform future adaptive management activities	easy data collection, identifies areas that need adaptive management	Annually: during growing season.	Low
Vegetation Transects	ecology	track the recovery of the vegetation. use this information to inform future adaptive management activities	well-established methodologies can detect relatively rapid change. requires training and expertise, is time-consuming	Annually: during growing season.	High
Fence inspection	effectiveness of restoration treatments	inspect fencing to ensure no holes, damage, or animal intrusions. use this information to inform future adaptive management activities.	easy inspection to complete, necessary for fence to function	Biannually/ Opportunistically through landowner observations	Low

SBS inspection	effectiveness of restoration treatments	inspect SBS to ensure structure is functioning appropriately. use this information to inform future adaptive management activities.	easy inspection to complete, necessary for restoration to function	Biannually: After runoff, before snowfall	Low
Weather Station	effectiveness of restoration treatments hydrology ecology	Quantify air temperature, evapotranspiration, precipitation	well-established methodologies, Expensive materials and equipment set up.	Telemetry sends	Mid
Water Quality/ Water Temperature	effectiveness of restoration treatments	quantify SBS/floodplain connection effect on moderating water temperature	use sensors for monitoring, sensors relatively low cost, easy data collection data processing needed	Biannual – data download Hourly – automated sensor	Mid
Water Quality/ Nutrients	effectiveness of SBS treatments hydrology	measure improvements to water quality through nutrient retention through the meadow	easy data collection, expensive data analysis, expensive sensors unlikely to detect changes based on project scale	Monthly Hourly – automated conductivity sensor Biannual – data download	High
Streamflow	effectiveness of SBS treatments hydrology	quantify changes in water quantity throughout the restoration site	well-established methodologies, Expensive materials and equipment set up, No baseline data available, Need to create stage discharge relationship with dilution gaging (technical and expensive) site has many inlets and outlets which makes this type of monitoring difficult	Hourly – automated sensor Monthly – manual measurements for stage discharge relationship Biannual – data download	High

Groundwater Level	hydrology	quantify SBS/floodplain connection effect on shallow groundwater recharge	well-established methodologies, easy data collection, expensive materials and equipment set up, no baseline data available	Hourly – automated sensor Biweekly – manual measurements	High

3.1 Monitoring Locations

Monitoring locations are dependent on which monitoring methods are selected. Figure 3 shows an overview of the site, work completed in Restoration Area 1, and monitoring locations recommended for the entire Fish Creek Project site for each monitoring method. A rationale for the placement of the monitoring sites for each method is described in the following sections. Recommended monitoring sites within Restoration Area 1 are included to assess work completed and inform adaptive management decisions. Monitoring sites within Restoration Areas 2 and 3 are included to collect control data to inform future restoration work and compare areas with restoration treatments to those without.

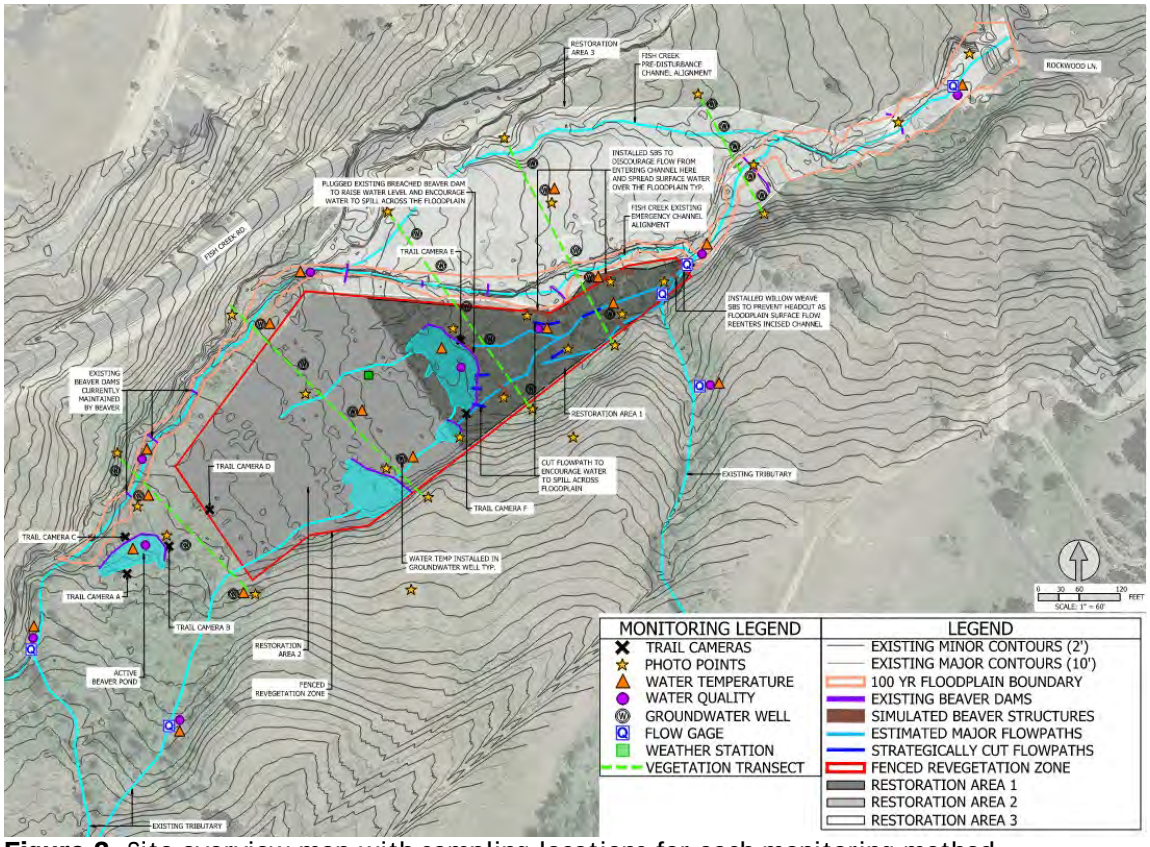

Figure 3: Site overview map with sampling locations for each monitoring method.

3.1.1 Trail Cameras

In 2022, the EVWC partnered with Worcester Polytechnic Institute (WPI) to conduct pre-restoration trail camera monitoring of the beaver population on Fish Creek at the project restoration site. The camera monitoring confirmed the presence of one beaver living in a lodge on the active beaver pond located about 550 feet southwest of our restoration site (Figure 3). Results from this monitoring study are documented in the *Trail Camera Monitoring of the Fish Creek Beaver Population* report provided in Appendix A. Recommended trail Camera placement for monitoring this project is informed by the 2022 camera monitoring results.

Six trail cameras are recommended for this project to gather information on and changes in beaver activity (Figure 3). Cameras A through C are located on the active beaver pond on confirmed routes where the beaver has previously been spotted (Appendix A). Camera D is located inside of the elk exclusion fence in Restoration Area 2. This camera is placed near where beaver activity has previously been noted, such that it may provide information on whether the beaver is travelling farther from its known routes. Additionally, as the willows inside of the fence mature to taller heights without elk grazing, this camera will monitor if the beaver capitalizes on the taller more mature willows for building materials and food.

Camera E and F are located in Restoration Area 1 near the historic beaver pond where improvements and repairs were made during phase 1. This location was chosen for closest proximity to the active beaver pond, which makes it a likely location for the beaver to utilize due to the deep water depth and abandoned beaver lodge.

3.1.2 Photo Points

The adaptive management and monitoring plan specifies 28 photo point locations for monitoring. Points are strategically placed throughout the Fish Creek project site. Locations were selected to capture key areas within the following zones:

- the active beaver area outside of the fenced revegetation zone,
- within the fenced revegetation zone where restoration work was completed in Restoration Area 1,
- within the fenced revegetation zone in Restoration Area 2,
- within the Phase 1 restoration work area (points have been adjusted in this area to capture the work completed),
- at the start and end of each vegetation transect, and
- within Restoration Area 3.

Photo points within these identified zones will provide information on the following:

- Is fencing keeping elk out of the restoration site? Is vegetation inside fence growing taller without grazing pressure?
- Is control data adequate for the future Restoration Area 3?
- Comparison of areas where work was completed to the areas where no restoration work was completed (both fenced and unfenced)?
- Which treatments work best?

3.1.3 Vegetation Transects

Five vegetation transects will be collocated with groundwater well transects. These are recommended in the following locations: one transect outside of the fenced revegetation area near the active beaver pond, once transect within Restoration Area 2, two transects that intersect both the Restoration Area 1, where work was completed in phase one and Restoration Area 3, where future restoration work is planned, and one transect in Restoration Area 3 downstream of Restoration Area 1.

These locations help answer the following research questions:

1. Is woody vegetation re-establishing as a result of the restoration work?
2. Are wetland species regrowing in newly wetted areas?
3. Does vegetation not grazed by elk (fenced off) have more success in re-establishment? How long does regrowth/re-establishment take?
4. Is vegetation in Restoration Areas 1 and 2 transitioning from drying meadow upland dominated species to wetland and woody riparian species?

Vegetation monitoring will be completed using a line intercept method. In this method, a tape is strung between two benchmarked points on either end of the monitoring transect. Each time a shrub intersects the tape, shrub size will be documented in three categories (small defined as less than 1 meter, medium as less than or equal to 2 meters and tall as greater than 2 meters). An estimate of the percent areal coverage of shrubs will be determined through the average percent of the transect length intercepted by shrubs. Additionally, a wetland boundary will be delineated each year. Delineations will be compared year to year to determine the change in wetland area.

3.1.4 Weather Station

One weather station is recommended for placement in a centrally located position on the restoration site to cover both project phases and all three Restoration Areas. The weather station will monitor environmental variables, including air temperature, wind speed, solar radiation, precipitation, and relative humidity. These environmental variables can be used to calculate evapotranspiration for the site and monitor changes to evapotranspiration as vegetation develops.

Additionally, these variables work in concert with other monitoring methods to add to the system understanding. For example:

- How does stream water temperature change with air temperature?
- Are changes in stream temperature due to precipitation, cool weather or increase groundwater connection?
- How does evapotranspiration vary over the years as vegetation within the fenced areas begins to grow and then stabilizes?
- Do beaver mimicry treatments within the restoration site attenuate peak stream flow from storms?

3.1.5 Water Temperature

Water temperature sensors are recommended for installation throughout the mainstem of Fish Creek, tributaries to the meadow, concentrated flowpaths in Restoration Area 1, within the active and abandoned beaver ponds, and in select groundwater wells. Monitoring water temperature in the surface water and groundwater within the site will characterize the water temperature within these water storage compartments and provide information on what is causing cooling or warming of water as it moves through the site.

Collecting this data at the locations described in Figure 3 aims to collect data on the following questions:

- What is the stream temperature as it enters the restoration site?
- How does stream temperature change as it moves downstream through the restoration site?
- How does stream temperature change due to existing beaver dams on the upper reach of Fish Creek through the restoration site?
- How does stream temperature vary seasonally?
- How is stream temperature characterized before any work is conducted in Restoration Area 3?
- Do beaver ponds provide thermal refuge at the deepest depths?

For the Fish Creek Project, twelve surface water and eight groundwater water temperature sensors are recommended. The surface water monitoring locations include five sensors on the mainstem of Fish Creek, one on a concentrated flowpath within Restoration Area 1, four sensors on beaver ponds (two sensors at different depths on each the active and abandoned beaver ponds), and one sensor on each tributary (two in total). Surface water sensor installation in the beaver ponds is recommended to vary in water depth, with one sensor placed just below the water surface and another placed near the bottom of the pond to gather information on temperature throughout the water column.

The eight groundwater temperature sensors are recommended for strategic placement to capture groundwater wells in upland areas, within Restoration Area 1, and near the stream channel. These locations are best identified in the field.

3.1.6 Flow Gage

Fish Creek through the restoration site has multiple water inputs from the surrounding hillslopes. In order to quantify streamflow throughout this site and understand the effect beaver mimicry restoration has on the movement and storage of water through the site, stream discharge will need to be monitored at each input and output of the floodplain as well as throughout the mainstem of Fish Creek.

The two main inputs to the floodplain are streams entering from the southwest of the site. Measurement of flow is recommended at each of these streams before the water enters the meadow. Additionally, water seeps from the hillslope running along the southeast edge of the meadow are expected. These seeps provide additional surface water inputs as water moves downstream through the meadow. Measurement of flow is additionally recommended at the

main outlet of the meadow and at the main area of concentrated flow above where the second tributary enters the meadow to help quantify the flux of water through the floodplain.

Within the mainstem of Fish Creek, flow monitoring locations include the most upstream and downstream ends of the site. Additionally, measurement of flow is recommended on the mainstem of Fish Creek just above Restoration Area 3 to begin collecting control data for the future restoration site. The flow measurements on the mainstem will gather information on the hydrologic connection of the stream and the meadow and will quantify if the stream is gaining or losing water to the meadow and surrounding area.

Stream flow will be measured by creating a rating curve between stage and discharge at each monitoring site. Discharge or streamflow will be measured monthly at each site to create the rating curve. At each flow gage a stage sensor will be installed to collect data on an hourly basis resulting in an hourly streamflow record.

3.1.7 Water Quality

Recommended water quality monitoring locations are concurrent with surface water, water temperature sensors and flow gages located throughout the mainstem of Fish Creek, tributaries to the meadow, concentrated flowpaths in Restoration Area 1, and within the active and abandoned beaver ponds. Each water quality monitoring location will include a continuous (1-hr interval) conductivity sensor. Measuring conductivity has multiple benefits, including use of conductivity to measure streamflow discharge with dilution gaging and characterization of groundwater and surface water mixing (generally groundwater has higher conductivity than surface water). Nitrate and Phosphate (nutrient) concentrations will be monitored through grab samples collected monthly.

Conductivity and nutrient concentration data will help and the questions:

1. How do nutrient levels change as vegetation and wetlands increase?
2. How does beaver mimicry restoration affect surface water and groundwater interactions?

These water quality monitoring locations will provide data on:

- stream nutrient concentration and conductivity as it enters the restoration site.
- changes in stream nutrient concentration and conductivity as it moves downstream through the restoration site.
- changes in stream nutrient concentration and conductivity due to existing beaver dams on the upper reach of Fish Creek through the restoration site.
- changes in nutrient concentration and conductivity in areas with connected floodplain in the restoration site.
- seasonal variations in nutrient (NO_3 and PO_4) concentrations throughout the restoration site.
- control data for the Restoration Area 3.

3.1.8 Groundwater Level

Five transects of groundwater wells (23 wells in total) are recommended for monitoring: one transect outside of the fenced revegetation area near the active beaver pond, once transect within Restoration Area 2, two transects that intersect both the Restoration Area 1, where work was completed in phase one and Restoration Area 3, where future restoration work is planned, and one transect in Restoration Area 3 downstream of Restoration Area 1.

These locations help answer the following research questions:

5. How do groundwater levels vary throughout the site (near beaver pond vs. Restoration Area 1 & 2 vs disconnected floodplain, Restoration Area 3)?
6. Is Fish Creek a gaining or losing stream? Does restoration work change this dynamic?
7. How does vegetation not grazed by elk (fenced off) affect the groundwater levels? How does this change over time?

3.2 Monitoring Recommendations

The following monitoring recommendations are offered to help evaluate project outcomes, inform adaptive management actions, and answer meaningful research questions that investigate the effectiveness of the restoration treatments.

The minimum monitoring recommendations were selected to have a "low" relative cost (assumes minimal equipment and little expert guidance, or training needed) and high probability of capturing meaningful data that will directly inform project success and adaptive management actions.

Higher cost monitoring methods are included in the minimum monitoring recommendations only when a lower cost method could not meet the minimum requirements of evaluating the success of the project goals and informing adaptive management actions.

The maximum monitoring recommendations include alternatives that expand monitoring beyond the successful outcomes defined for biology, ecology, and hydrology to a broader scope that will help inform future restoration projects of this kind.

3.2.1 Minimum Monitoring Recommendations

The following minimum monitoring recommendations are offered to measure project success and inform adaptive management actions:

- Restoration treatments including elk exclusion fencing and SBS should be inspected by a restoration professional biannually pre and post growing season. Observations should inform annual adaptive management activities.
- Aerial photos should be collected via drone flight annually during growing season.
- Trail cameras should be deployed at consistent locations to track changes in beaver activity throughout the project site. Citizen scientists should be engaged to download, review, and sort data.

- Photo points should be collected annually at the end of each growing season to track changes in vegetation through time and monitor the condition of restoration treatments through time. Citizen scientists should be engaged to collect, review, and sort data.
- Vegetation transects should be conducted annually during growing season by a trained/experienced expert. Timing of vegetation transects, and aerial photo data collection should coincide.
- Water temperature sensors should be deployed to collect temperature data at hourly intervals in surface water locations as defined in Figure 3. Data should be downloaded biannually and analyzed annually by a trained/experienced expert.
- One weather station should be deployed in a centrally located position on the restoration site. The weather station should be equipped with telemetry and data should be transmitted to a trained professional and analyzed annually.
- A report summarizing the monitoring data should be completed annually. Report should be prepared by a trained professional but may rely on citizen scientists to help gather and organize data at their direction.

3.2.2 Maximum Monitoring Recommendations

The maximum monitoring recommendations include all the minimum monitoring recommendations outlined in the minimum monitoring recommendations and additionally recommends the following actions.

The maximum monitoring recommendations not only measure project success and inform adaptive management actions but also provide a more robust picture of the effectiveness of beaver mimicry restoration treatments on water quality and quantity.

- Water temperature sensors should additionally be deployed in groundwater wells, as defined in Figure 3, to collect temperature data at hourly intervals. Data should be downloaded biannually and analyzed annually by a trained/experienced expert.
- Pressure transducers should be deployed in flow measurement locations defined in Figure 3 to collect stage data at hourly intervals. Data should be downloaded biannually and analyzed annually by a trained/experienced expert.
- Discharge or streamflow should be measured monthly at each site through dilution gaging by a trained/experienced expert.
- Conductivity sensors should be deployed at water quality sites defined in Figure 3. Data should be collected at hourly intervals, downloaded biannually, and analyzed annually by a trained/experienced expert.
- A water grab sample should be collected monthly by a trained/experienced expert and sent to a laboratory for nitrate and phosphate analysis.
- Groundwater wells should be established throughout the site as defined in Figure 3.
- Pressure transducers should be deployed in groundwater wells to collect groundwater level data at hourly intervals. Data should be downloaded biannually and analyzed annually by a trained/experienced expert.

- A report summarizing the monitoring data should be completed annually. Report should be prepared by a trained professional but may rely on citizen scientists to help gather and organize data at their direction.

4 REFERENCES

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APPENDIX A

Trail Camera Monitoring of the Fish Creek Beaver Population

Trail Camera Monitoring of the Fish Creek Beaver Population

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WPI

ESTES VALLEY WATERSHED COALITION

Trail Camera Monitoring of the Fish Creek Beaver Population

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Abstract

Beavers play a critical role in preserving riparian environments and mitigating the effects of climate change in the western United States. The Estes Valley Watershed Coalition is working to repair the Fish Creek beaver meadow in Estes Park, CO following severe flooding in 2013. Our team assisted the EVWC by performing site observations and installing trail cameras to monitor the beaver habitat, producing an initial assessment to inform the direction of restoration efforts. We determined that there is likely only one beaver inhabiting the site, identified foraging locations and resource preferences, and assessed the impact of other species. Our team recommends continued monitoring, revegetation, and fencing to support the beaver population and promote the long-term health of the ecosystem.

Acknowledgements

OUR TEAM WOULD LIKE TO EXTEND THE GREATEST OF THANKS TO THE FOLLOWING PEOPLE AND ORGANIZATIONS FOR WELCOMING US TO COLORADO AND HELPING OUR PROJECT BECOME A REALITY:

- Professor Robert Hersh, our IQP advisor and co-director of our IQP site
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- David Neils
- Jenifer Waters
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Executive Summary	Fernandez	Beskid, McMahon, Pan
Introduction	Beskid, McMahon	Beskid, McMahon, Pan, Manger
Background	Fernandez, Manger, McMahon, Pan	Beskid, McMahon, Pan
Methods	Beskid, Fernandez, McMahon, Pan	Beskid, McMahon, Pan, Manger
Findings	Beskid, Manger, Pan	Beskid, McMahon, Pan
Conclusion	Fernandez, McMahon	Beskid, McMahon, Pan, Manger

Team members pictured from left to right: Charles Manger, Michelle Pan, Michael Beskid, Joshua Fernandez, Sean McMahon

Meet the Team

Michael Beskid

Hi, my name is Michael Beskid. I am a WPI student from Averill Park, NY double majoring in aerospace engineering and robotics engineering. As an Eagle Scout and avid outdoor enthusiast, I was thrilled to have the opportunity to work on this project in the Colorado Rockies. I've learned so much about the local environment and wildlife in my time here and feel incredibly fortunate to have contributed to preserving this beautiful landscape through our work with beaver habitats.

Joshua Fernandez

Hi! My name is Joshua Fernandez and I'm a robotics engineering student at WPI. I'm originally from Amesbury, Massachusetts. I feel incredibly satisfied and lucky to have had done this project in the town of Estes Park, Colorado. Everyone here has been welcoming and helpful to the completion of our project work. Through our work, I have been able to grow personally and build up many writing and communication skills. I'm thankful for the IQP opportunity I was given and will remember and cherish the experience for the rest of my life.

Charles Manger

Hi! My name is Charles Manger. I'm a student at WPI studying mechanical engineering. My career interests include either working in manufacturing or in construction. However, during the project, I enjoyed reviewing the camera trap footage and splicing the footage into a final video. I was excited to see all of the progress we made in the last seven weeks and believe our work will have a lasting impact. Working with my teammates, members of the EVWC, David Neils, Dr. Ellen Wohl, and others were truly a privilege; it was awesome to meet so many kind, genuine people who were so passionate about their careers.

Michelle Pan

Hi! My name is Michelle Pan and I am a biology & biotechnology student at WPI originally from Andover, MA. I have always loved exploring the outdoors and been fascinated by wildlife so working on a beaver project in Estes Park has been a super exciting opportunity for me. I am very thankful for the whole IQP experience being able to explore a new area while learning valuable skills and working on a meaningful wildlife conservation project.

Sean McMahon

Hello! My name is Sean McMahon and I am an aerospace engineering student at WPI who is originally from Natick, Massachusetts. Throughout my life I have always had a passion for nature and stargazing so I was very excited to hear I would be conducting a project around beavers in Estes Park, Colorado. The last seven weeks working on this project was an overall incredible experience from hiking around the Rocky Mountain area, going to shops in the center of town and talking to locals, and monitoring the beaver lodge in the Fish Creek riparian corridor. I am proud to say I am a member of this team that is assisting the Estes Valley Watershed Coalition start this long-term project that will make a real difference for the local ecosystem, and I am excited to follow where the project goes from here!

Executive Summary

Background

Climate change has had a drastic effect on the hydrology of the Front Range of the Colorado Rockies. The rise in temperatures causes the vegetation in the Front Range to dry out and for there to be an increased amount of moisture in the air. These atmospheric changes lead to both drought and flooding. Riparian corridors are areas with rich vegetation by a body of water and are critical to mitigating the effects of natural disasters like drought and wildfire. The bodies of water transport sediment, nutrients, and carbon, allowing for the preservation of biodiversity (Nilsson & Svedmark, 2002). Preservation of riparian corridors is vitally important because they provide many benefits to the environment. Due to the importance of riparian corridors and the damage done to them by climate change, it is essential to try to restore these ecosystems.

One option that has proved successful is using beaver populations to restore riparian corridors. Many species depend on beavers, making them a keystone species for the environments they inhabit. They are considered eco-engineers due to their ability to modify the areas around them and to the impact their activities have on wildlife and human-made structures (Brazier et al., 2021). Beavers play a crucial role in the formation and evolution of rivers, streams, and creeks through the dams and lodges they build. These dams create ponds, slow down the movement of water, and help to create side channels that spread water over the landscape (Brazier et al., 2021). These dams also store water during dry periods, helping to protect riparian areas against droughts and contributing to groundwater recharge, denser vegetation growth, and carbon sequestration.

Our study site, Fish Creek, is located in the southwestern section of Estes Park, Colorado, and is owned by Jeff Cheley as a part of Cheley Ranch. The upstream area of the ranch is primarily used as a camp for children, but the remainder is mostly used as grazing range for horses. The site has historically been rich in wildlife and popular for tourists who would go to see the animals that passed through. However, Fish Creek was impacted by the flood of 2013 which was considered a “1000-year flood” (Ferner, 2017). Prior to 2013, the Fish Creek site boasted vibrant, diverse animal and plant life, and provided a home to a colony of between four and twelve beavers (Fish Creek Coalition, 2015). The beaver population maintained several lodges and dams along the creek, distributing the flow of water over the meadow through many interconnected channels.

Figure I: Maps of Fish Creek showing its transformation through the years with the 2013 flood included.

However, the beavers disappeared after the flood and most of the water was diverted into a single incised stream after emergency action was taken by the county.

To mitigate the effects of the incised stream, artificial beaver dam analogs (BDAs) were installed throughout Fish Creek. However, further efforts were needed to restore the site. The Estes Valley Watershed Coalition proposed a 5-year plan to restore the beaver habitat at Fish Creek in order to revitalize the wetlands, restore biodiversity, and build resistance against wildfires, flooding, and drought. A comprehensive assessment of current beaver activity and conditions at Fish Creek is an essential first step to inform the direction of this restoration project.

Approach

The goal of our project was to document beaver behavior and activity along the Fish Creek riparian corridor. Our team placed five trail cameras at the beaver meadow site. The cameras were strategically placed to maximize footage of the beaver population in the habitat. We placed one camera near the lodge to estimate the number of beavers living within it. We also placed three cameras along slides headed to areas with willows that are suitable for building and maintaining dams. We placed the last camera along the perimeter of the pond to capture beaver activity there.

Our team conducted site visits twice each week to retrieve data from the cameras. We uploaded the data to a shared folder hosted by the Estes Valley Watershed Coalition and reassessed our camera placements as determined by capture rates and data quality. The cameras were checked to ensure they were operating properly, cleared of stored videos, and armed once again after being serviced. The trail camera data was used to estimate the population of beavers in the lodge, to make observations about their behavior patterns, and to identify their preferred food and building material choices and frequented locations. We also conducted in-person observations to gain a better understanding of the beaver population's behavior. This included examining the dams and lodges on the site to see how fresh the building materials were, scanning for holes in the ice covering the pond, scouting for scat, beaver slides, and other evidence both of beavers and of other animal species passing through the Fish Creek site.

Our team also helped the EVWC and its consultant firm, Stillwater Sciences , stake willows at the site to slow the water flow from the main tributary and influence the beaver population to move downstream. Live staking willows at the site consisted of taking sections of willows and replanting them along the creek in areas where the beavers were building dams. The first step in live staking involved harvesting willow cuttings from an area north of Brook Lane off of Fish Creek, an area rich in willows shown in Figure II . The area we chose for revegetation was a short distance downstream from the active beaver lodge. We chose a spot where the stream was shallower and flowed more slowly than in other areas, marking a suitable location for the beavers to dam. The location was also far enough away from the pond to reduce the likelihood that the beavers would forage them before the transplanted willows had a chance to root. This new vegetation ideally will spread through the area providing resources to encourage the beaver population to seek new sites for lodges and dams downstream. The willows were staked into the banks downstream and next to a BDA nearby. Figure III shows the locations of the stakes. They were staked on the banks so the root systems would be close to the water and would hold sediment. This would hopefully slow the stream to allow more time for the groundwater to recharge.

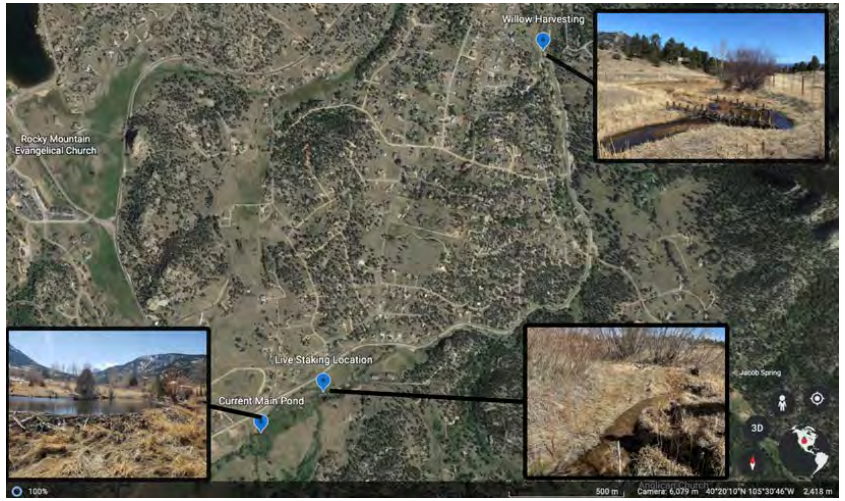

Figure II: Map of where the willow was harvested and staked.

Figure III: Map of where the willows were staked at Fish Creek.

Results and Conclusions

Over the span of four weeks, the cameras recorded considerable beaver activity. Our team was able to determine the location of the active lodge on the site, but we were unable to confirm if there was more than one beaver residing within it. This is important to the EVWC because another beaver may need to be relocated to the site to form a mating pair with the residing beaver. We also determined the locations of four different foraging sources where the beaver most likely obtained most of its food and building materials and predicted the routes it took to get to each of these sites based on the footage we captured. The creation of these routes was based off the camera footage we captured and the directions the beaver moved in each video as it went into and out of frame.

The routes we predicted the beaver was most likely to take to get resources are shown in Figure IV. We found evidence of elk and mule deer on the site in the form of scat, marks on aspen trees, and through some of our camera footage. This indicates a potential need to fence off some of the beaver's foraging sites to ensure that the beaver will have adequate resources. We also assessed the effectiveness of the BDAs located on the downstream portion of the site. Most of the BDAs are placed in incised channel locations. There was scant evidence of recent beaver activity on these BDAs, implying that the beaver population is not interested in moving further downstream even with the food and material caches that the EVWC had previously placed there.

Based on the information we have gathered from our fieldwork and research, continued monitoring of the beaver population is important to the Fish Creek ecosystem in order to gain a better understanding of the population. To achieve this, we recommend the EVWC add five more cameras, for a total of ten, along the routes outlined by the route maps in Figure IV. This consistent monitoring will provide updated information regarding how the Fish Creek landscape changes over time. This information could also show how many more resources, like willows or aspen trees, may need to be added to the environment to ensure there are adequate supplies for the beaver population.

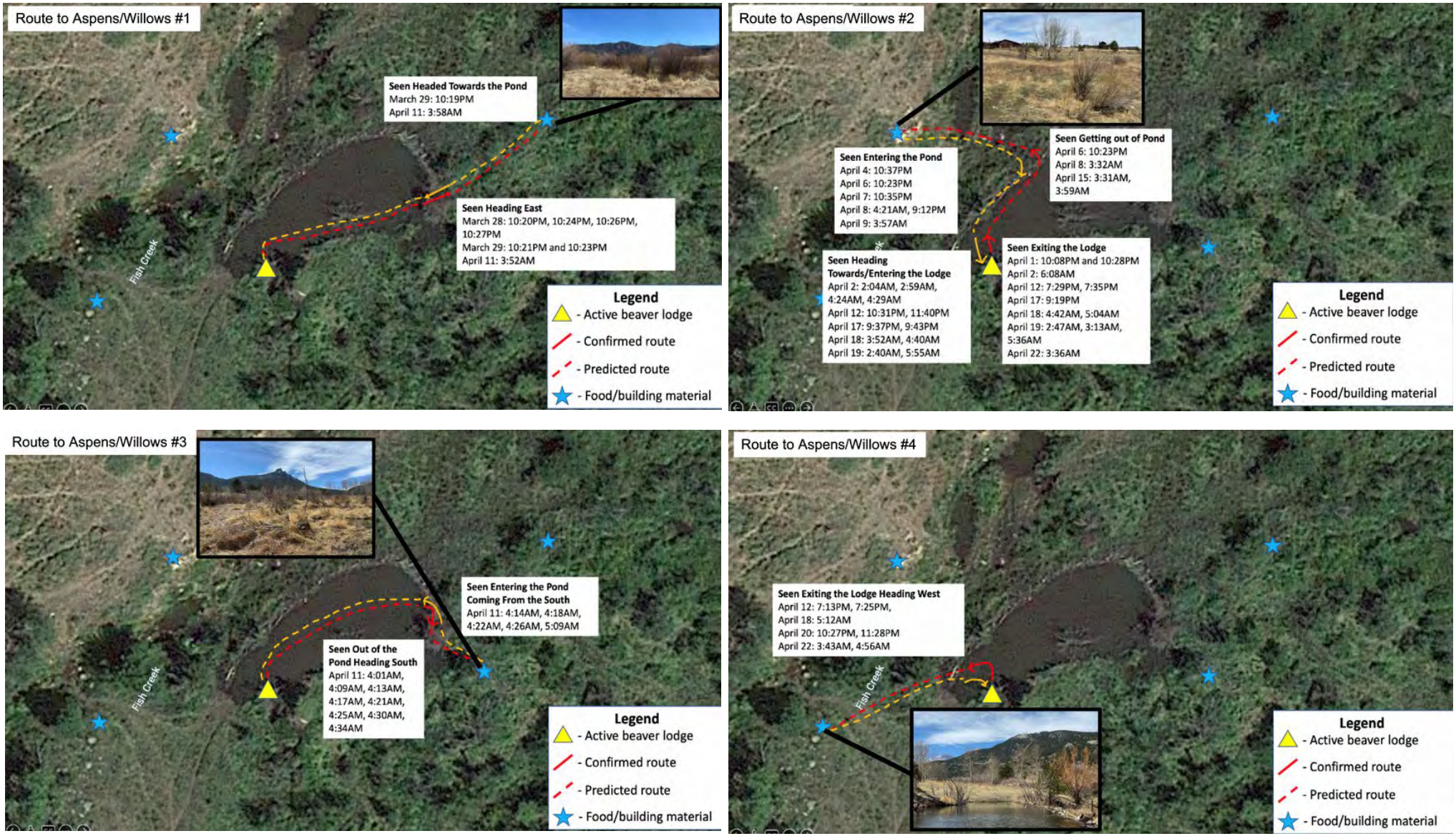

Figure IV: Routes the beaver is likely to have traveled to get to resources. Maps made by Michelle Pan.

Beavers are very social animals, so we acknowledge in typical situations there is generally more than one living in an active lodge. However, based on our trail cameras and field observations, we have only been able to detect one beaver. A crucial next step would be to try to confirm if there is only one or if there are multiple beavers living in the Fish Creek site. The best way to confirm the presence of more than one beaver would be by having both in one camera frame or by having two separate cameras capture different beavers at the same time stamp. Another way to determine the number of beavers in an area is to continue in-person stakeouts during the times when the beavers are most active. The hope would be to see at least two outside of the lodge. If this does not happen, beaver calls or beaver tail slaps in the water could indicate that there are multiple beavers residing in the area since beavers primarily make noises to communicate with other beavers.

If it is determined there is only one beaver in Fish Creek, the beaver should be captured temporarily, its gender should be determined, and a beaver of opposite gender should be introduced to the site. The beaver could also be tagged while in captivity to make monitoring of its movements much easier. There are many people and organizations dedicated to safe beaver relocations. We recommend contacting the Beaver Believers and specifically Sherri Tippie, a professional beaver trapper and relocator. Ms. Tippie aided in the Scotts Pond beaver relocation back in 2015.

If multiple beavers are confirmed to be living at the Fish Creek site, they are most likely a mating pair (Crawford, 2008). Assuming this is true, there is a high probability that beaver kits are living in the lodge with their parents. Once the kits become adults, they move out of the lodge and establish their own territory. The offspring would most likely move downstream to create more lodges and dams where there are larger willow populations and more resources.

Willow staking is an important part of ensuring the health of the riparian corridor. The camera data and field observations show that beavers use the local willow as a resource, so we recommend staking willows on a regular basis. The willow roots will slow the water flow of the main channel and throughout the area. Slowing the water flow will restore the level of the local groundwater to a higher resting point and rejuvenate the ecosystem. The increased amounts of willow in the area from the live willow staking also give the beaver more resources to work with, which may encourage more beavers to return to this area and create more lodges. Fish Creek will reap the benefits of this action for many years following.

We also created a five-minute video that covers how beavers are beneficial to their local environment by creating fire breaks, mitigating the effects of drought, and sequestering carbon in the soil. The video also addresses common concerns about beavers' negative impacts on environments such as flooding culverts and roads, cutting down local trees, and blocking pipelines. We then explain afterwards how these issues can be mitigated or prevented. The video will be released to the public through the Estes Valley Watershed Coalition mailing list and directly to interested parties to build enthusiasm for beaver reintroduction.

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Chapter 1: Overview of Fish Creek and Project Goal

Overview of Fish Creek and Project Goal

Climate change is one of the greatest problems facing our generation. Temperatures are rising across the United States and the American West is facing the most severe drought in 1,200 years according to the National Drought Mitigation Center (2022). More than 98% of the land in the West is experiencing some level of drought and nearly 60% falls under the "extreme drought" classification or worse (U.S. Drought Monitor, 2022). Additionally, wildfires are ravaging the landscape with just under 60,000 fires burning 7.1 million acres in 2021 (Wildfires and Acres, 2022). The harsh reality of climate change is only getting worse, as the average temperature in Colorado has risen approximately two degrees Celsius since 1970.

Understanding the gravity of this situation, finding solutions to mitigate these dangers is of the utmost importance. Despite making up less than 2% of land in the West, wetlands and riparian ecosystems play a critical role in protecting against the threat of climate change. These environments help to add moisture to the atmosphere, recharge groundwater, sequester carbon in the soil, and support vital aquatic and riparian vegetation. It is important to take action to expand and preserve these valuable ecosystems to combat the effects of climate change.

A key species in maintaining the health of river and stream ecosystems is the beaver. Beaver meadows mitigate the effects of drought and act as firebreaks to reduce the spread of wildfires (King County, 2022). Furthermore, beavers help encourage ecosystem biodiversity by building dams and forming side channels. These structures redistribute the water in an area, resulting in richer vegetation and drawing more diverse wildlife to the riparian corridor. Without beavers to maintain dams, the risk of wildfires, drought, and extreme flooding in the region will increase. This will also result in the disappearance of valuable wetlands and in turn the loss of critical vegetation, creating a less ideal environment for other species that previously relied on the vegetation there.

Our study site, the Fish Creek riparian corridor in Estes Park, Colorado was ravaged by a large flood in 2013. The flooding destroyed the beaver dams in the corridor, uprooted vegetation, and pushed the beavers downstream. The main channel of water flowed into the adjacent Fish Creek Road where it undermined the street causing it to collapse. The town's emergency response involved digging a narrow channel to direct the stream away from the road and to prevent further infrastructure damage, which unfortunately exacerbated the environmental

damage to the ecosystem. The new channel is less suitable for a beaver habitat as the high banks make it extremely challenging to create a new beaver dam and the fast stream fails to support the wetlands with fertile soil that the region was previously known for. Considerable work is needed to restore the biodiversity and health of the wetlands at the site.

The beaver population was critical to preserving the hydrology and biodiversity of the landscape at the Fish Creek site prior to the flooding. This project's sponsoring organization, the Estes Valley Watershed Coalition, has been working in conjunction with the Fish Creek Coalition on a five-year plan to restore the beaver meadow and revitalize the beaver population. This plan involves creating a better habitat for beavers by planting more vegetation and by providing food and building resources for the beavers to construct lodges and dams. To inform the direction of this project, the EVWC wanted to better understand beaver activity on the site.

Our project was undertaken with the goal of analyzing beaver activity on the Fish Creek site by performing in-person field observations and conducting trail camera monitoring. We utilized the camera footage to study the beaver population on the site, looking into factors such as its size, its behavior, and where its primary resources are located. This analysis was completed with the end goal of assisting in the completion of the Fish Creek Corridor Plan for Resiliency to revitalize the riparian ecosystem and restore the beaver meadow on the site.

Chapter 2: Beaver Habitat Restoration as a Method of Preserving Riparian Ecosystems

Impacts of Climate Change on Riparian Environments

Climate change has had a drastic effect on the hydrology of the Front Range of the Colorado Rockies. During the last ten years, the amount of rainfall in the state of Colorado has decreased by an average of half an inch across the state each year (Stein, 2021). This is around a 2.3 percent decrease in rainfall from the ten-year average of around 22 inches (National Oceanic and Atmospheric Administration, 2022). Bradley Udall and Jonathan Overpeck, scientists from the Colorado River Research group, have shown that since the year 2000, the rivers in the Front Range have flowed at a rate that is on average 19 percent lower than the prior 95 years. Each of the large reservoirs in the Colorado River Basin recorded an average volume that was 40 percent less than average during the 20th century (Overpeck and Udall, 2017).

Climate change has caused several natural disasters in the Front Range of the Colorado Rockies. Specifically, drought and flooding have had the greatest impact on the Front Range of the Colorado Rockies. The National Climate Assessment states that the rise in temperature causes an increased amount of evaporation. Evaporation leads to increased water loss from leaves and the soil. The increased water loss leads to drier soil and dead, dried out plants. The dry landscape makes the Front Range of the Colorado Rockies more susceptible to wildfires.

Conversely, the increase in temperature allows for the atmosphere to hold more moisture. With this, heavier rainfalls can occur leading to flooding (U.S. Global Change Research Program, 2014).

Riparian corridors are critical to mitigating the effects of natural disasters like drought and wildfire. These unique ecosystems consist of elements of land, groundwater, and aquatic ecosystems. According to Christer Nilsson and Magnus Svedmark of the Umeå University, riparian ecosystems often reside between the high and low-water marks on stream banks. Near these stream banks, there is often land above the high-water mark that contains vegetation that has an inch or two of water at its base. This vegetation, often consisting of grasses and willows, is easily influenced by flooding of the nearby river or stream (Nilsson & Svedmark, 2002).

Riparian corridors provide two major benefits: transportation of beneficial materials within streams and preservation of biodiversity in the stream. Rivers transport sediment, nutrients, and carbon and this movement of materials can either be upstream or downstream. The transportation ensures there are enough food sources for all species in the riparian corridor. or instance, some birds remove fish carcasses from lower sections of the riparian corridor and move them upstream.

This allows for elk and other omnivores to eat the fish carcasses (Nilsson & Svedmark, 2002).

Preserving riparian corridors is significant, but climate change has had a tremendous impact on these ecosystems. According to Kathleen Dwire and her colleagues at the United States Forest Service, climate change causes drastic changes in both stream runoff patterns and the frequency, severity, and duration of wildfires. Climate change has diminished snowpack in the West and decreased precipitation have extreme low stream flow rates, reduction in groundwater recharge, and a decrease in the available nutrients in the riparian corridor (Dwire et al., 2017).

The change in flow, water level, and nutrient availability has had dire effects on the function of riparian corridors across the Front Range. Climate change has also reduced the size of riparian corridors and caused there to be less moisture within the ecosystem, two factors that fabricate the negative feedback loop of a worsening environment. The size and resource availability of riparian corridors is shrinking due to climate change (Dwire et al., 2017).

Given the importance of riparian corridors and the damage done to them by extreme events, namely drought and floods, it is important to try to restore these ecosystems.

Influence of Beavers in Riparian Areas

Ponds that collect water retain water in the floodplain through groundwater recharge, a process that is crucial for the surrounding ecosystem, especially the vegetation of the riparian corridor. Dams store water that is accessible during dry periods which helps in protecting riparian areas against drought. Additionally, the effects of higher ground water level and improved soil nutrients promote denser vegetation growth, which is important in slowing down the movement of floodwaters thereby preventing serious flooding (Brazier et al., 2021). Beavers also play a critical role in carbon sequestration. Dr. Ellen Wohl, a fluvial geomorphologist from Colorado State University, found that cumulative carbon storage in beaver meadows with active beaver populations was more than three times higher than in areas with loss of beaver populations (Wohl, 2013). The carbon is sequestered primarily in sediments which are trapped by beaver structures, storing it in the soil rather than in the atmosphere.

An example of how important beavers are to ecosystems can be seen in a wildfire study that looked at five different wildfires in five Western U.S. states both with and without beaver-dammed riparian corridors. Using a Normalized Difference Vegetation Index (NVDI) estimated through remotely sensed data based on wildfire burn severity and landcover, environmental scientist Dr. Emily Fairfax (2020) found that in riparian corridors with beaver dams, the NDVI was three times higher than in areas without beaver dams. A higher NVDI value indicates lusher, greener vegetation while a lower NVDI value indicates unhealthy, dying vegetation. The results of this study indicated that the riparian corridors with beaver-built dams were protected due to groundwater storage which kept the surrounding plants hydrated enough to make them energetically unfavorable to burn. Therefore, the beaver-dammed riparian corridors were measurably less affected by the fires when compared to riparian corridors without beaver damming (Fairfax, 2020).

Beavers influence not only the water flow but also the surrounding geomorphological banks. In addition to dams, beavers excavate bank burrows where they reside and dig shallow channels, or canals, which extend from beaver ponds and are used for access to food and building resources. These burrows and canals contribute greatly to the hydrogeomorphology of floodplains. Hydrogeomorphology is defined as the “interdisciplinary science that includes the linkage among various hydrologic and geomorphic processes” (Sidle and Onda, 2004, p. 597). Bank excavation also acts as a large source of erosional

fine sediment as well as depositional sediment, shaping the floodplain's connectivity and surface vegetation (Brazier, 2021). These hydrological and geomorphological changes all aid in plant and subsequently animal recruitment, abundance, and diversity. These benefits showcase the direct role beavers have in creating more hospitable and healthier ecosystems.

Figure 2.1: Bank burrow that leads to a canal. (Life Beaver).

Beaver Relocation Programs

Beaver relocation programs exist in certain states where beavers are moved from an area where they are causing damage or threatening infrastructure to an area that would benefit from the creation of a rich wetland ecosystem (Davis, 2018). While beaver relocation programs can be very beneficial to the riverine restoration process, challenges arise when beavers are introduced to a new location. Beavers will often make desperate attempts to return to their mate or previous lodge, sometimes dying in the process due to predators, human interactions, or change of environment. However, even if the beaver is willing to adapt to its new environment, other challenges like fast flow rates, incised streams, resource constraints or competition may arise. Beaver dam analogs, as seen in Figure 2.2, help to alleviate some of these challenges to an extent. BDAs are man-made structures that mimic the function of a natural beaver dam. BDAs create favorable conditions for beavers and also act as a natural dam slowing the flow rate of water and creating a deep-water habitat which can also reduce the risk of predation (Pollock et al., 20. BDAs are also found to be able to restore incised streams. Pollock et al. (2014) found that the BDAs help slow down the water flow and widen the trench it was

Figure 2.2: Beaver Dam Analog on Fish Creek. Image taken by Michael Beskid.

built in. Once the trench is wide enough, it can sustain dams and the incised stream will rise above the dam and reconnect with the flood plains and aggradation can occur.

Figure 2.3: Bank burrow that leads to a canal. (Life Beaver).

An example of a successful beaver relocation program for riparian restoration was on the Zuni Indian Reservation in New Mexico. In the 18 th century, early explorers described the area as a lush riparian system with abundant water in the stream and rich in beavers (Albert & Trimble, 2000). However, the late 18 th century to the early 20 th century saw a severe decline in beaver populations in the Zuni Indian Reservation as well as throughout the rest of North America. The riparian ecosystem was lost, and small ponds no longer filtered out sediment causing water quality to decline. To restore the area, a beaver reintroduction program was started (Albert & Trimble, 2000). Nuisance beavers from farm areas were introduced to the Zuni Reservation and within 1-2 weeks, the flow of water was slowed allowing sediment to drop and raising the stream bed allowing for larger pools of water to form. After about a year, there was more abundant riparian vegetation and wildlife came back. Some nearby farmers complained that the dams kept water from entering their fields, but in the drought of 1996, some farmers were able to irrigate their fields using beaver ponds. This program also had a persistent issue with transplanting beavers into areas with insufficient vegetation to sustain the population. To resolve this issue, they planted willows prior to reintroduction, and this proved to be successful (Albert & Trimble, 2000). This program as well as numerous others all prove how useful beaver relocations can be for restoring riparian corridors.

Effects of the 2013 Flood in Estes Park, CO

A defining moment in the recent history of Estes Park was the substantial flooding on September 11 th , 2013. The town received over half of its average yearly rainfall, over 9 inches of rain, in the span of only a few days. The flooding damaged bridges, buildings, and nearly every main road into or out of the town (Clemons, 2018). Some homes suffered thousands of dollars in property damage; sinkholes swallowed up roads and multiple power lines were knocked down (Clemons, 2018). Beyond the damage to town infrastructure and personal property, the local ecosystem was also hurt by the flood, especially the beaver meadow located in the Fish Creek riparian corridor.

Figure 2.5: View of the town center from Little Prospect Mountain during the flood (Grigsby).

Figure 2.4: Building that collapsed into the stream following the flood in 2013 (Kwak-Hefferan).

Figure 2.6: East Elkhorn Avenue flooded from 2013 (Messal).

Effects on Fish Creek

The flood of 2013 was considered a "1000-year flood," meaning that a flood of this severity is expected to occur once every thousand years (Ferner, 2017). Prior to 2013, Fish Creek was rich in wildlife as well as in native plants along the riparian corridor. The ecological diversity of the corridor was due in large part to a beaver colony of about 4-12 beavers (Fish Creek Coalition, 2015) that had constructed dams and lodges along the lower reaches of the riparian corridor. The locations of these dams can be seen in the years 2005 and 2011 in Figure 2.7. The flooding destroyed many of the structures built by the beavers and swept the beaver population from the area. Furthermore, the emergency response action taken to alleviate flooding diverted most of the water into a single powerful stream. The fast-moving water in this narrow, incised channel flows straight out of the ecosystem, and the high banks of the channel prevents water from spilling over onto the surrounding meadow.

The Hydrological Evolution of Fish Creek from 2005 to the Present

As seen in Figure 2.7, the riparian corridor in 2005 and 2011 had rich vegetation and three active beaver lodges as evident by the beaver ponds formed by the dams surrounding the lodge. These satellite images also show that there is a small stream that flows through the northern end of the riparian corridor which interconnects these ponds. This is supported by Dr. Ellen Wohl who was at this location before the flood and assessed the population of the corridor. She recalled that when she visited the site there were at least two active lodges. According to her field work on the site, it was likely that each of these lodges had a mating pair and potential beaver kits.

The results of the 2013 flood are seen in the third photo within Figure 2.7. The flood ripped out much of the corridor's vegetation, including many aspen trees and willow bushes. This left the ground without a strong root system to contain the steady flow of the floodwater. The course of Fish Creek was altered considerably when the town dug the emergency channel to direct the stream away from the road. Despite the immediate success that the channel had in mitigating flood damage, the long-term consequences of this action have had a negative effect on the landscape. The channel funneled water out of the environment incredibly quickly, not allowing adequate time for the groundwater to recharge. This lower groundwater

Figure 2.7: Maps of the Fish Creek riparian corridor over the last 20 years highlighting stream direction and beaver activity.

level is a crisis as it makes the ecosystem more prone to the effects of drought and wildfires. Satellite imagery from 2019 shows at least one beaver dam in the upstream section of the corridor. In addition, the Estes Valley Watershed Coalition also constructed multiple BDAs along the incised stream. This beaver presence has led to increased vegetation in the region along with the return of a thin water table around the beaver lodge area.

Figure 2.8: The Big Thompson River flooding and breaking nearby U.S. 34 (Lafley).

Figure 2.9: Collapsed road after the 2013 flood exposing unearthed pipelines (Town of Estes Park).

Fish Creek Restoration Project

Following the flood and the digging of the emergency drainage channel, the county installed multiple BDAs to the Fish Creek area with hopes of drawing in beavers to continue damming the creek. From discussing with hydrologist Johannes Beeby, we learned that the major effort behind installing these BDAs in the main channel was to slow down the flow of water so a beaver could return to the area. This was critical as the state of the environment after the incised stream was dug would most likely deter any beaver that may have wanted to inhabit the area. This also prevented the beaver population from travelling further upstream towards Cheley Ranch, where the owners would prefer not to have a beaver that close to their property.

The Fish Creek Corridor Plan for Resiliency is a plan drawn up by the EVWC and other organizations like Stillwater Life with the main goal of the project being to find solutions for a few key issues which are currently limiting the area from becoming a thriving habitat for beavers. One challenge relates to floodplain regulations developed by Larimer County. Any land within the 100-year floodplain cannot be improved or worked on without a Floodplain Development Permit (FDP) and approval by the County Engineer (Larimer, 2021).

The 100-year floodplain for Fish Creek extends a few feet from the banks on either side of the main channel, preventing any work in this area without a permit. The process for obtaining one is long, arduous, and expensive, and an FDP can still be denied at the end of the process. The EVWC and other groups involved in this project are not seeking a permit to work within the floodplain and will comply with the county regulations. The project will study how beaver activity along the main channel and its tributaries can in time reshape the hydrology of the site.

Looking at the Fish Creek Corridor Plan for Resiliency, one piece of the project intended to influence the beavers that has already been implemented to a degree is the construction and placement of BDAs. The shallower streams generated that regrow vegetation would further contribute to stream restoration and healing of the riparian corridor by attracting other species, such as beaver, as the habitat is improved (Bouwes, 2018). Several BDAs have been placed in the area already to help raise the water level of the main channel and its tributaries, with many of them being maintained and improved upon by the beaver inhabiting the ecosystem (Fish Creek Coalition, 2015). Placing BDAs in areas of Fish Creek where beavers are known to be active, assumes that beavers will

maintain the BDAs without any human involvement, and therefore not violate the 100-year floodplain regulations which applies to the main channel (Larimer, 2021).

More work must be done to ensure that beavers can continue to live in the area and have the food and materials necessary to thrive there. While the project is in the preliminary stages of development, the project stakeholders seek to gather information about the current beaver population numbers, to monitor their behavior, and to identify areas of current activity and lodging (Fish Creek Coalition, 2015). The reason why it is important to know the number of beavers is because discovering whether there is a breeding pair or just one lone beaver at the site will affect the action taken to restore the habitat. This assessment will serve as an important baseline in determining the best course of action for continuing restoration work and supporting the beaver population.

Along with monitoring beaver behavior, the organizations involved in the project also wish to identify and monitor the sources used by the beavers for food and building materials. This will be done to determine how to best protect the aspens and willows on the site from being overgrazed by other wildlife, particularly elk. To prevent this, the monitored area will be fenced so the elk will be unable to enter the ecosystem, but the beavers will be able to freely come and go as they please (Fish Creek Coalition, 2015). The EVWC has also proposed staking willows near the borders of the main channel and tributaries that flow through Fish Creek to revegetate the area and provide more food and materials for the beavers, and as natural fencing against the elk (Fish Creek Coalition, 2015).

Figure 2.10: Beaver footage captured on our trail camera.

Since beavers primarily forage for aspen trees and willow brush, a good supply of these resources is vital to a healthy beaver population. Denser vegetation in a beaver meadow provides the added benefit of an interconnected root network which gives rigidity to the soil and lessens the effects of erosion. Plant growth also aids in flood mitigation as the floodwaters are slowed and spread out upon reaching thicker vegetation. With these benefits in mind, introducing new willow plants along the banks of Fish Creek would improve the ecosystem and support the beaver population.

Chapter 3: Developing a Strategy to Monitor and Assess the Beaver Population

Goal & Objectives

The goal of our project was to document and analyze beaver activity on the site through field observations and camera captures. We placed and monitored five trail cameras around the active beaver lodge to study the size and behavior of the beaver population, to identify the areas along the riparian corridor where the beavers were active, and to assess their competition for food and building materials. Through site visits, we also surveyed the surrounding vegetation for evidence of feeding and identified areas for willow replanting. Our team also produced an educational video outlining the project goals and the important role of beavers in the ecosystem to assist the Estes Valley Watershed Coalition with outreach efforts. The objectives for our project were as follows:

- Conduct interviews with hydrologists, fluvial geomorphologists, and beaver ecologists in Estes Park and the wider Front Range region to identify the potential benefits and challenges associated with restoring the beaver habitat at Fish Creek.
- Place and monitor five trail cameras around the active beaver lodge on Fish Creek to collect data about the population, behavior, and food and building material preferences of the beaver population.
- Perform observations in the field to assess the behavior and preferences of the beaver population and monitor its activity as a supplement to trail camera data.
- Determine the ideal area to stake willows along the riverbed to provide additional food and resources for the beavers while also revegetating the area.
- Design an appropriate deliverable highlighting the effect that beavers have on the environment regarding issues like drought mitigation, wildfire prevention, biodiversity and groundwater recharge.

Interviews to Learn About the Fish Creek Site

To begin our field work in the project, we met with a team of hydrologists and ecologists from Stillwater Sciences working on the Fish Creek Corridor Plan for Resiliency in order to gain an in-depth view of the study site. This team included senior river scientist/designer Johannes Beeby and river scientist/restoration engineer Karin Emanuelson. The interview we conducted with them involved discussions about the site's hydrology, the beaver dams' pivotal role in spreading water over the site and locations for the cameras.

We later conducted key informant interviews with Dr. Ellen Wohl, the fluvial geomorphologist at CSU, and Jessica Doran, an individual who has a master's degree in wildlife and conservation biology. From these interviews, we learned about why riparian environments are necessary for areas such as Estes Park, garnered how beavers interact with these environments, and gained insight into the benefits and perceived drawbacks of beavers being present in an area.

We eventually toured the Fish Creek site with Wilynn Formeller, our sponsor and Development and Program Coordinator for the EVWC, and some of her colleagues working on the greater Fish Creek restoration project. This included Rachel and Andy Ames, members of the board of directors of the Estes Valley Watershed Coalition. Rachel and Andy particularly helped us identify evidence of beaver activity and assisted us in determining which of the three lodges on the site was the active one.

A local trail camera expert, David Neils, showed us effective ways to set up our cameras to capture beaver activity. He advised us to place them low to the ground, within ten feet of where the beaver would be, and away from most grasses in order to prevent false captures.

Figure 3.1: Photos of the Fish Creek Riparian corridor when assessing the hydrology of the area.

Figure 3.2: Map of the Fish Creek riparian corridor on Google Earth Pro from 2019.

Trail Camera Monitoring

A major objective of the project was to learn more about the beaver population currently inhabiting the lodge on Fish Creek. Our team sought to use the video data collected from our trail camera installations to determine the number of beavers living in the lodge, their behavior, and their food and building material preferences. Trail cameras are an excellent method for performing remote observations to collect this data because they operate at all hours of the day and provide a minimally invasive view into wildlife behavior.

Our team placed a total of five trail cameras at the beaver meadow site along Fish Creek as seen in Figure 3.3. Our cameras sense motion and can capture footage during both day and night, utilizing infrared flashes to prevent startling animals at night. The cameras also have a microphone, a PIR sensor and a small screen to preview the captures before removing the SD card to upload the footage to a computer. We used these onboard SD cards to collect data from all five of the cameras on each site visit.

The cameras were placed strategically to maximize captures of the beaver in the Fish Creek habitat and to observe its different behaviors. We placed one camera near the lodge to estimate the number of beavers living within it. We also placed three cameras along slides headed to areas with willows that are suitable for building and maintaining dams. We placed the last camera along the perimeter of the pond to capture beaver activity there. A map of the team's initial camera placements is shown in the first picture as a part of Figure 3.3.

Our team conducted site visits twice each week to retrieve data from the cameras. We uploaded the data to a shared folder hosted by the Estes Valley Watershed Coalition and reassessed our camera placements as determined by capture rates and data quality. The new camera locations can also be seen in Figure 3.3. The cameras were checked to ensure they were operating properly, cleared of stored videos, and armed once again after being serviced. The trail camera data was used to estimate the population of beavers in the lodge, to make observations about their behavior patterns, and to identify their preferred food and building material choices and frequented locations. The results of these observations are displayed in the following chapter.

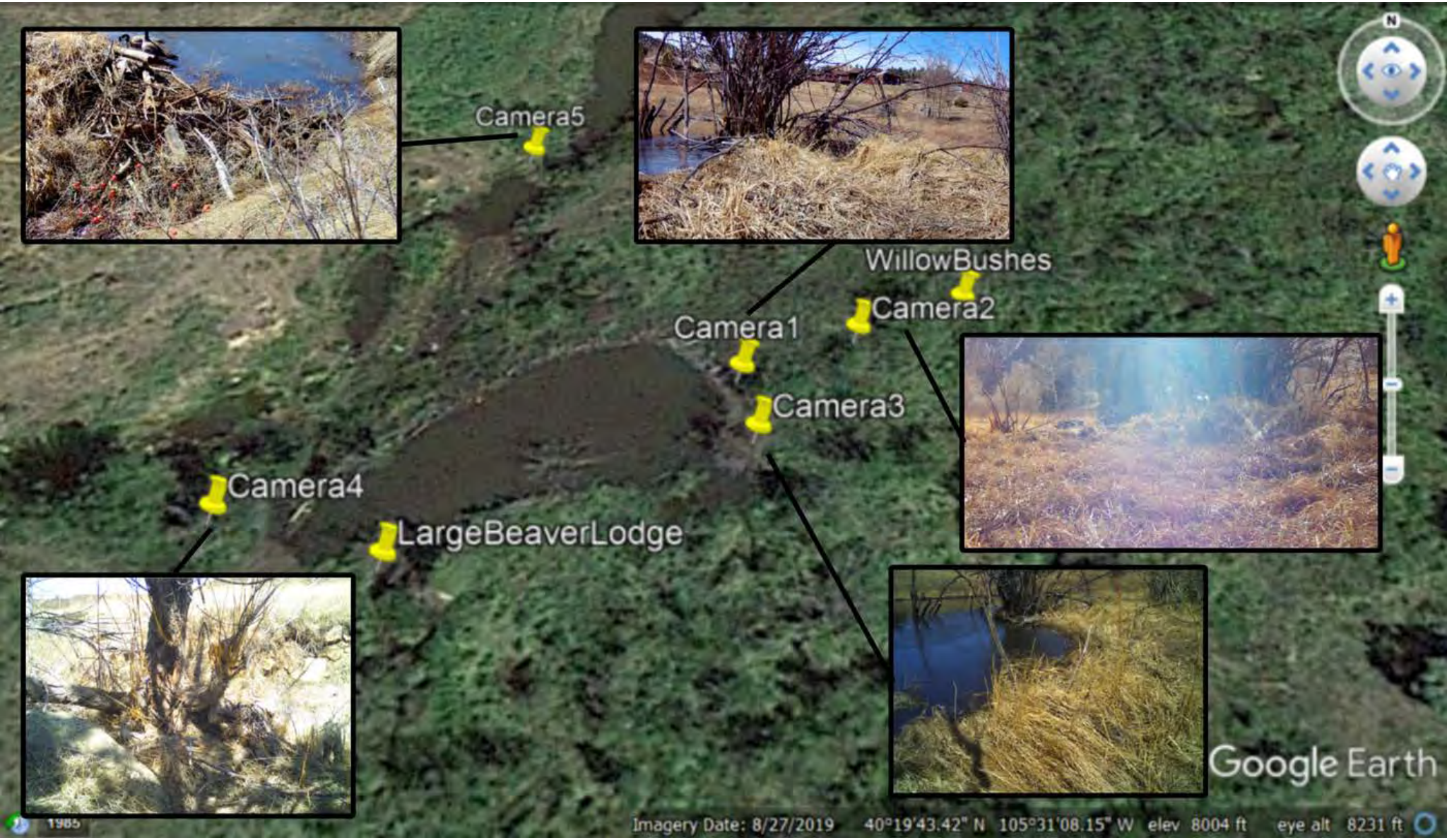


Figure 3.3: Map of Trail Camera Placement Around Beaver Pond in Week 1.

Figure 3.3: Map of Trail Camera Placement Around Beaver Pond in Week 2.

Figure 3.3: Map of Trail Camera Placement Around Beaver Pond in Week 3.

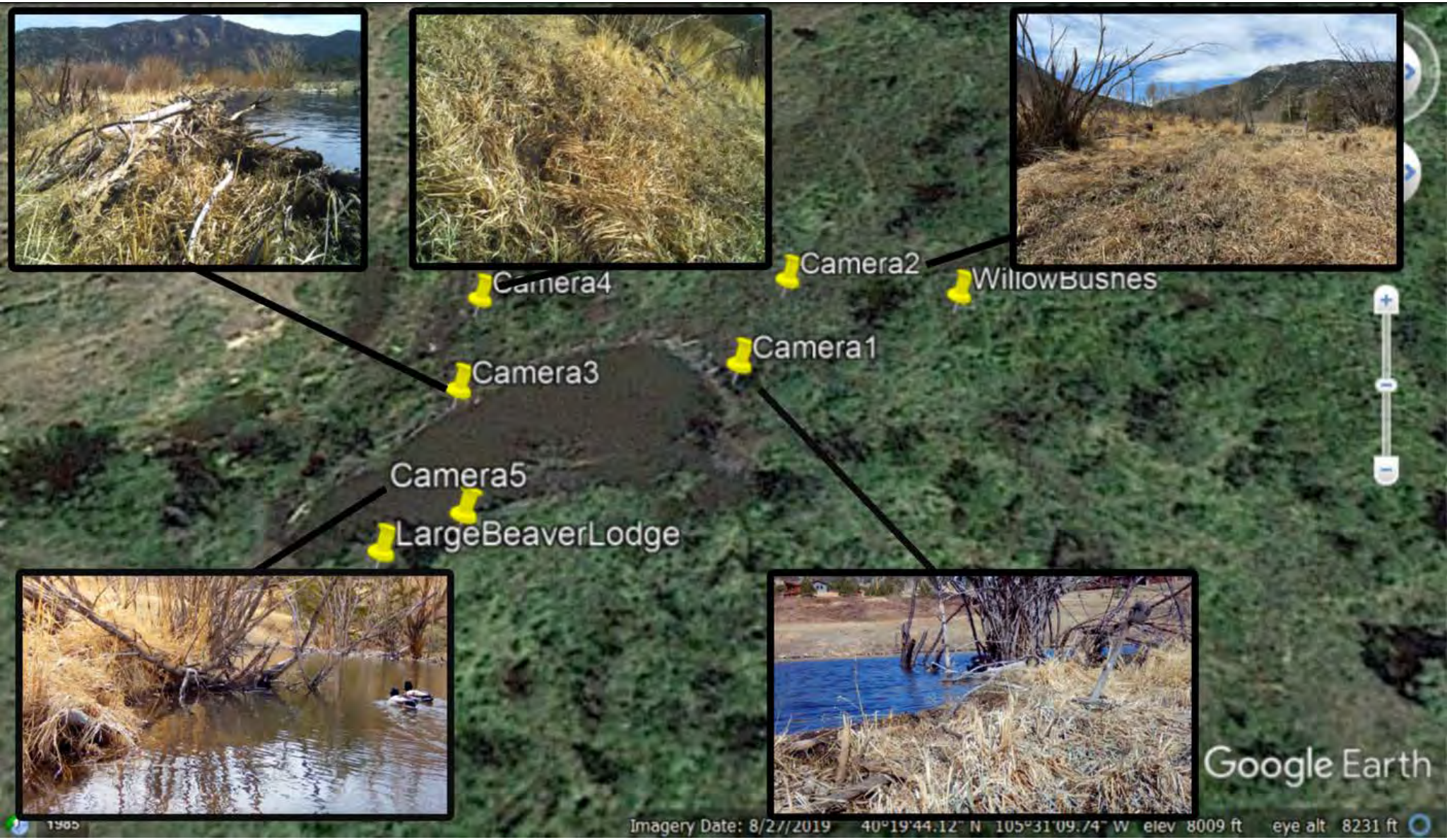


Figure 3.3: Map of Trail Camera Placement Around Beaver Pond in Week 4.

Beaver Colony Behavior Observations

In order to gather additional information about the beaver colony aside from the trail camera data, we monitored the area for signs of beaver activity. Beavers are known to be very active, constantly gathering materials by cutting down trees and collecting branches, mud, and sticks to build their dams. Since they are mostly nocturnal and are often only seen between dusk and dawn, we observed the area around the pond during the day for traces of beaver activity.

Figure 3.4: The active beaver lodge. Photo taken by Michelle Pan.

We looked for evidence of floating debarked willow sticks along with plant leaves and feces in the pond as an indication that a beaver was present. Based on the freshness of the sticks, plants, and feces, we could estimate whether the remnants were recent. Along with our interviews, our team also physically observed the three beaver lodges that we found in the Fish Creek area to try to identify which was possibly the active lodge. We compared the freshness of mud and sticks supporting each lodge to try to predict which was the active beaver lodge.

In addition, our team had a stakeout by the beaver pond to try to see beaver activity for ourselves. We met at 7:30pm around dusk in order to try to observe beavers in person. Through the stakeout, we wished to observe what the beaver ate and where the beaver gathered its food from. An image of us on our stakeout is shown in Figure 3.5. Additionally, Janene and Dan Centurione, who assisted in building the BDAs located on the site, conducted their own night stakeouts to spot beaver activity in person in an effort to find multiple beavers at the site.

Figure 3.5: An image of the team observing the beaver habitat. Photo taken by Michelle Pan.

We also examined the vegetation around Fish Creek. The physical structures like the sticks and leaves within the stream and surrounding it provided information on the food and building resources the beaver population used. Along with this, we were able to identify the species of animals that passed through the area by observing the graze marks on the aspen and willow shrubs and by identifying track marks and feces to determine the other animals living or passing through.

Live Staking of Willow at Fish Creek

Figure 3.6: The area north of Brook Lane off Fish Creek where we harvested willow. Image taken by Michelle Pan.

Live staking willows at the site consisted of taking sections of willows and replanting them along the creek in areas where the beavers were building dams. The first step in live staking involved harvesting willow cuttings from an area north of Brook Lane off of Fish Creek, an area rich in willows shown in Figure 3.6.

Working with the EVWC and its consultant firm, Stillwater Science , we selected a bout 170 healthy willow stems of ½ to 1 ¼ inches in diameter . Our team focused on finding long, straight, stakes from the plants at least as wide as a pinky finger. Care was also taken to remove only a few stakes from each individual plant and to take clippings from a wide area in order to minimize the impact on the vegetation at the harvesting site.

Figure 3.7: Harvesting willow bushes upstream of the Fish Creek riparian corridor near Brook Lane. Photo taken by Michael Beskid.

Each stake was cut at a clean diagonal angle to allow for easier replanting later. The willow stakes were tied into two bundles of 100 stakes each and then taken to the active beaver pond at the Fish Creek site where they were submerged in the water for four days to increase the rate of root formation. The willow bundles can be seen soaking in Fish Creek in Figure 3.9.

Figure 3.8 Harvesting willow bushes upstream of the Fish Creek riparian corridor near Brook Lane. Photo taken by Michelle Pan.

Figure 3.9: The bundles of harvested willow soaking in Fish Creek. Image taken by Michelle Pan.

The area we chose for revegetation was a short distance downstream from the active beaver lodge. We chose a spot where the stream was shallower and flowed slower than in other areas, a suitable location for the beavers to dam. The location was also far enough away from the pond to reduce the likelihood that the beavers would forage at it before the transplanted willows had a chance to root. This new vegetation ideally will spread through the area providing resources to encourage the beaver population to seek new sites for lodges and dams downstream.

Figure 3.10: Map of where the willow was harvested and staked. Map made by Michelle Pan.

Figure 3.11: Where the willows were staked along the stream and BDA (blue box). Map made by Michelle Pan.

After soaking, the stakes were further trimmed to be about 18 inches in length. Substantially long branches on the main stakes were trimmed, many of which were placed as their own stakes into the ground. The willows were trimmed in this way so that energy would be focused on root formation instead of stem growth. After trimming, about 200 stems were inserted carefully into the ground along the stream banks about one foot away from the stream.

The willows were staked into the banks of the creek a distance downstream from the lodge and next to a BDA, as this is where Stillwater Sciences believed to be the best staking location. Figure 3.11 illustrates the locations of the stakes on a map of the site. The willows were staked on the banks close to the creek so the root systems would be close to the water and to reinforce the soil against erosion. This action will provide a future foraging source for the beaver population and will help to slow the stream and allow more time for the groundwater to recharge.

Figure 3.12: The area the willows were staked before staking. Image taken by Michelle Pan.

Figure 3.13: Staked willows on the bank of the Fish Creek site. Photo taken by Michael Beskid.

Figure 3.14: Team members staking rebar into the stream banks to prepare for willow planting. Photo taken by Michael Beskid.

Figure 3.15: Team members planting willow stakes along the banks of the creek. Photo taken by Michael Beskid.

Producing an Informational Video

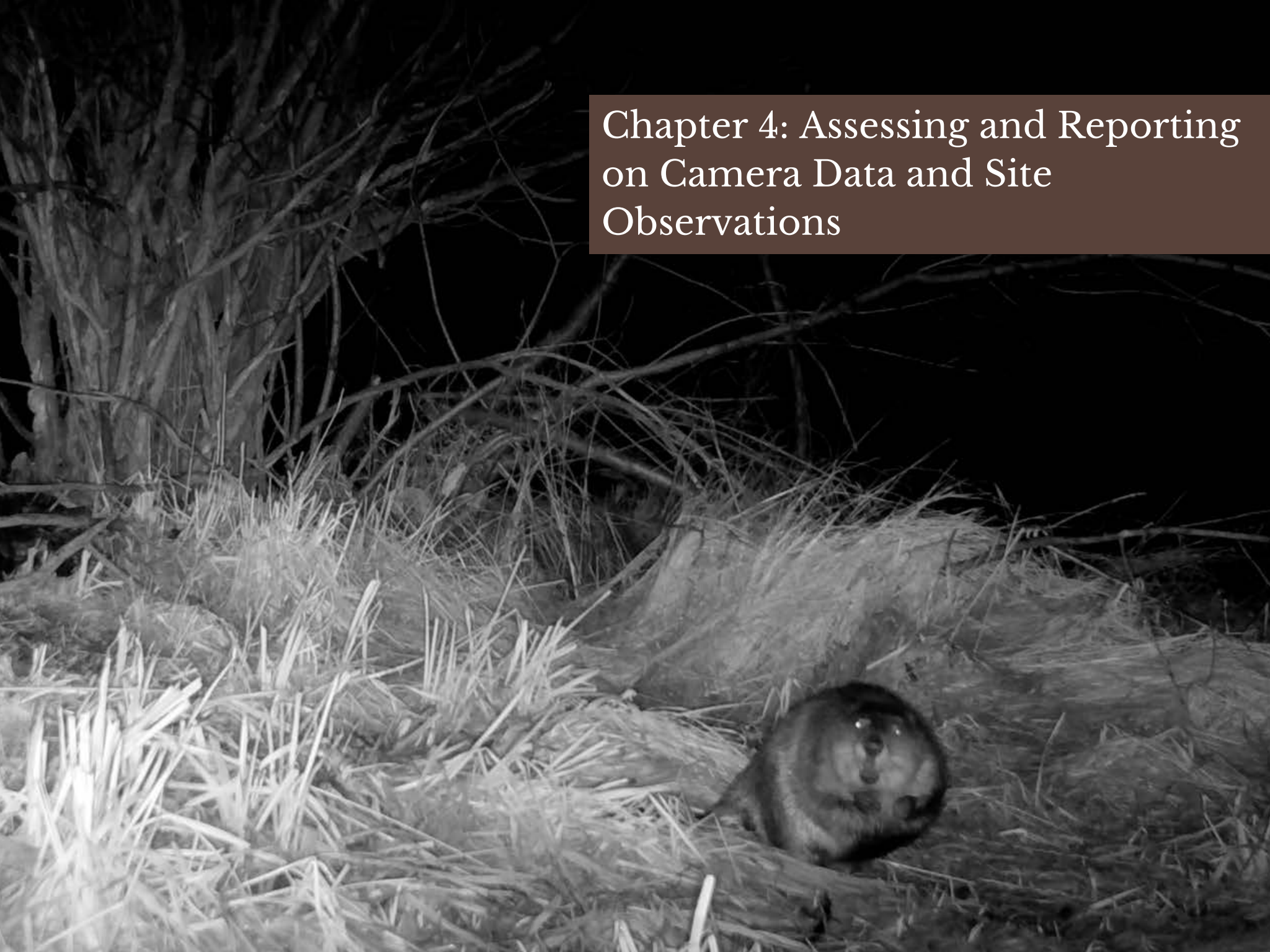
Figure 3.16: Title card from the informational video produced by the team. Taken from YouTube.com

Our final major project objective was to determine a suitable deliverable to describe the riparian restoration efforts and the role beaver's play. Over the course of the project, our team talked with Wilynn Formeller and other key informants that we interviewed like Dr. Ellen Wohl to get recommendations on the best medium to create our beaver outreach deliverable. Through these conversations and due to the high volume of videos we captured of beaver activity through our trail cameras, we decided that the most engaging way to explain the benefits of beavers was through a video format.

We created a five-minute video using the iMovie software. It consists of the footage we collected at the Fish Creek site to show beaver activity at the main pond. Accompanying this footage is background music to hopefully make the video more engaging to viewers along with commentary from Dr. Ellen Wohl and Charles Manger, one of our team members. We distributed the video to Wilynn Formeller, who then shared it with the Estes Valley Watershed Coalition's mailing list along with posting it on the Estes Valley Watershed Coalition's YouTube channel, website, and social media account.

Figure 3.17: Screenshot from the informational video about beaver ecoogy produced by the team. Taken from YouTube.com

Chapter 4: Assessing and Reporting on Camera Data and Site Observations



Central Questions

Our trail cameras helped us to illuminate critical questions about the beaver population at the Fish Creek site, such as:

- Where is the location of the active lodge?
- How many beavers are present in Fish Creek?
- What are the locations of the primary resources for the beaver population?
- How does the beaver population behave given the resource locations?
- What can we learn about the beaver's behavior from the trail cameras?
- What evidence of beaver activity can be seen on the site in person?
- What other animals are passing through Fish Creek? Are they competing with the beaver population for resources?
- How does the beaver population interact with the beaver dam analogs on the site?

Identifying the Large Lodge as the Active Beaver Lodge

Figure 4.1: Two beaver lodges surrounding the main pond. Abandoned lodge (left) seen by dry mud and old sticks. Active lodge (right) seen by wetter mud and fresher sticks. Image taken by Michelle Pan.

Through our examinations of the three lodges located at the Fish Creek site and our talks with informants like hydrologist Johannes Beeby, we were able to determine which of the three observed lodges on the site was the active one. We figured that the lodge shown in Figure 4.1 was the active lodge due to the fresher branches and wetter mud located on and within it. With evidence from the trail cameras that we set up next to this lodge, we were able to confirm that a beaver was present and inhabiting it as we caught footage of it entering and exiting this suspected lodge on multiple occasions.

We Were Unable to Determine the Size of the Beaver Colony

Determining the size of the beaver colony at the Fish Creek site was an important question as mentioned earlier in the section Fish Creek Restoration Project, however, our results were inconclusive. Members of the Estes Valley Watershed Coalition and hydrologists from Stillwater Science believe that the active lodge is large enough to support more than one beaver, so it is possible that multiple beavers are using the active lodge on the main pond. However, our team has only been able to produce definitive evidence of one beaver inhabiting the site based upon our observations and trail camera data. We believe there is most likely a single beaver living at the site but must acknowledge the possibility of a second beaver and cannot provide a conclusive answer.

From our trail camera monitoring, one beaver was observed entering and exiting the lodge and is foraging for resources in the surrounding area. While our team has captured multiple sightings across several different locations near the main pond, it is difficult to discern the actual number of beavers from this data because it is difficult to differentiate between individual animals. Our team has never captured more than one beaver in the same frame and notes similarities in the appearance of the beaver in each video, leading us to believe that there is most likely one beaver at the site.

Additionally, we were not able to identify the gender of the beaver since it is impossible to determine the sex of a beaver from trail camera data. The only way to determine the gender of a beaver is by trapping it and analyzing its glandular discharges since the excretions look and smell different depending on the gender (Goldfarb, 2015). Beavers are known to be social animals and most often live together in breeding pairs, which suggests that it is generally more common to find two beavers together in a lodge (Crawford, 2008). Also, through our talks with key informants and our on-site observations, the number of dams present on the site suggests the presence of more than one beaver, further supporting this hypothesis. This can however be attributed to the historically larger beaver population at the site. Considering these factors, our team cannot offer a conclusive answer to the number of beavers at the Fish Creek site.

We Identified Four Primary Locations Where the Beaver Foraged for Food and Materials to Maintain the Pond

Resource Locations and Routes to Them

Through our visits to Fish Creek, we have determined four locations around the active pond shown in Figure 4.2 that were rich in aspen and willow; these areas are denoted by blue stars in Figure 4.3. These four locations were used in developing maps of the potential routes the beaver was taking to get resources.

Since our trail cameras were only able to capture the beaver moving a relatively small distance in frame, we were not able to precisely determine where the beaver was headed. However, we could predict its routes based on the directions the beaver moved in and out of frame using the timestamps of the different captures to organize the timeline. The four predicted routes along with the times that they were captured on camera are seen in Figures 4.4-4.7. Figure 4.4 shows the first predicted route to the area rich in willows northeast of the pond. This was captured by the camera pointing at a slide coming out of the pond on that side along with another camera focused along the path towards this willow source.

Figure 4.2: The Main Beaver Pond at the Fish Site Creek Facing the Active Lodge. Image taken by Michelle Pan.

Figure 4.3: Annotated Map of Beaver Foraging Locations. Lodge Identified by Yellow Star. Foraging Locations Indicated by Blue Stars. Map made by Joshua Fernandez.

In the footage we used to make this map from those cameras, we saw the beaver heading north, so we predicted it was going to that area. Figure 4.5 shows the predicted route the beaver took to the northwestern area rich in aspen and willow. This map was made based off two cameras: one facing the entrance of the lodge, and one facing a slide on the north side of the pond. Figure 4.6 was made using the same camera as in Figure 4.4.

However, we saw the beaver heading in a southern direction which is why we predicted it was heading towards the southeastern area of willow. Figure 4.7 was made using the camera facing the entrance of the lodge where the beaver was seen heading west out of the lodge.

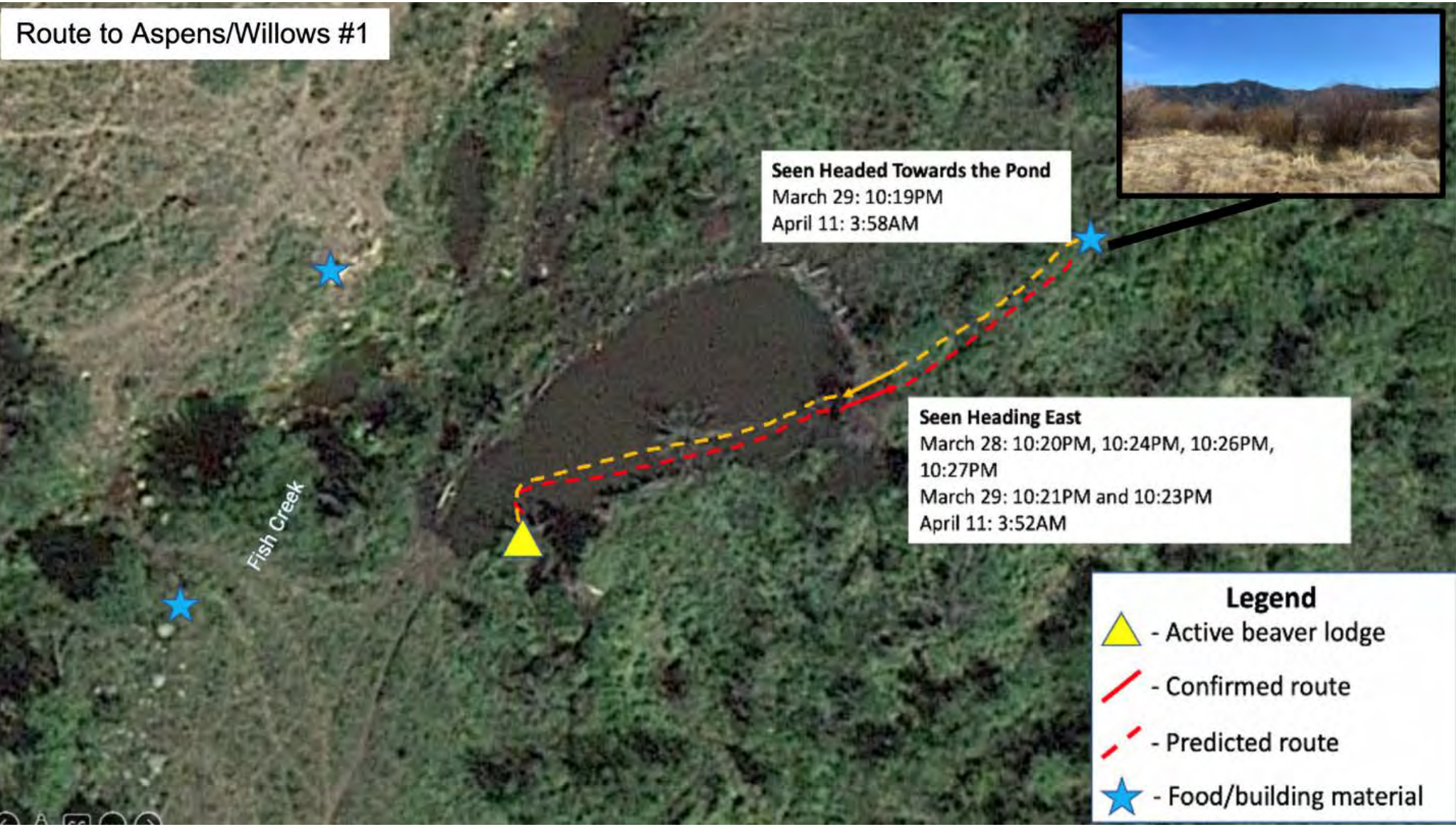


Figure 4.4: One route the beaver is likely to have traveled to get to the large willow bushes. Map made by Michelle Pan.

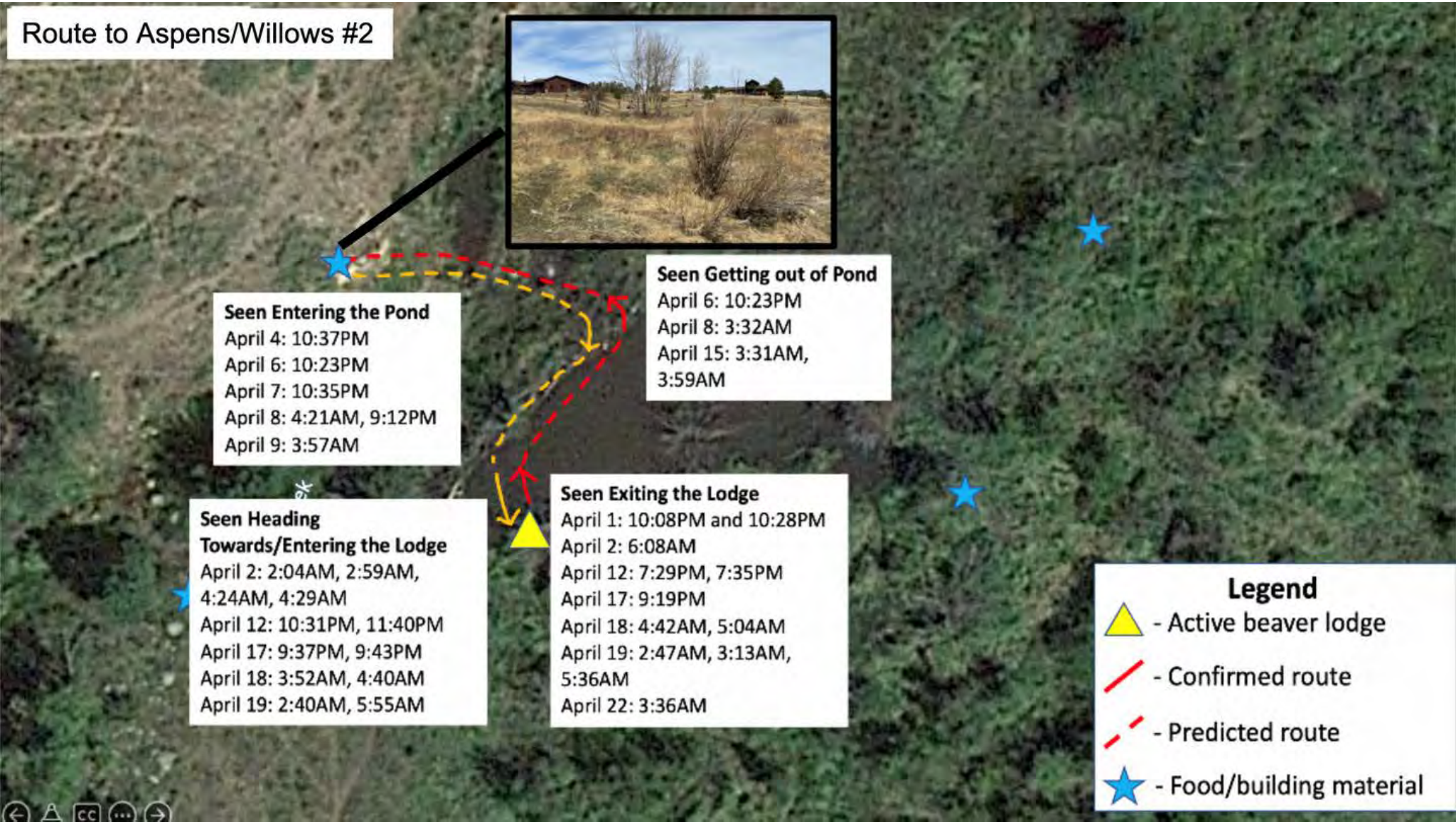


Figure 4.5: One route the beaver is likely to have traveled to get to the shorter willow bushes or BDAs. Map made by Michelle Pan.

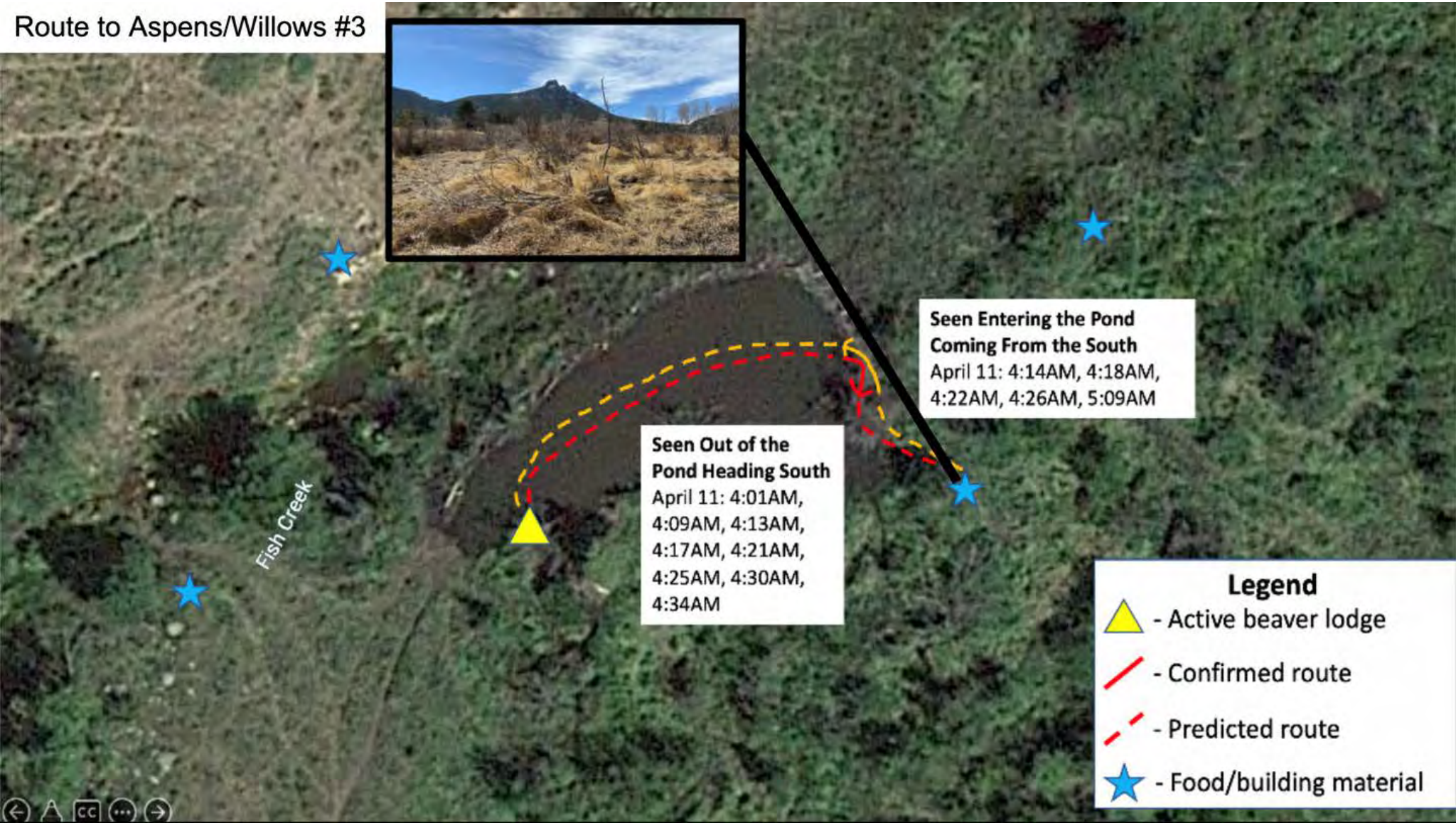


Figure 4.6: One route the beaver is likely to have traveled to get to the large willow bushes. Map made by Michelle Pan.

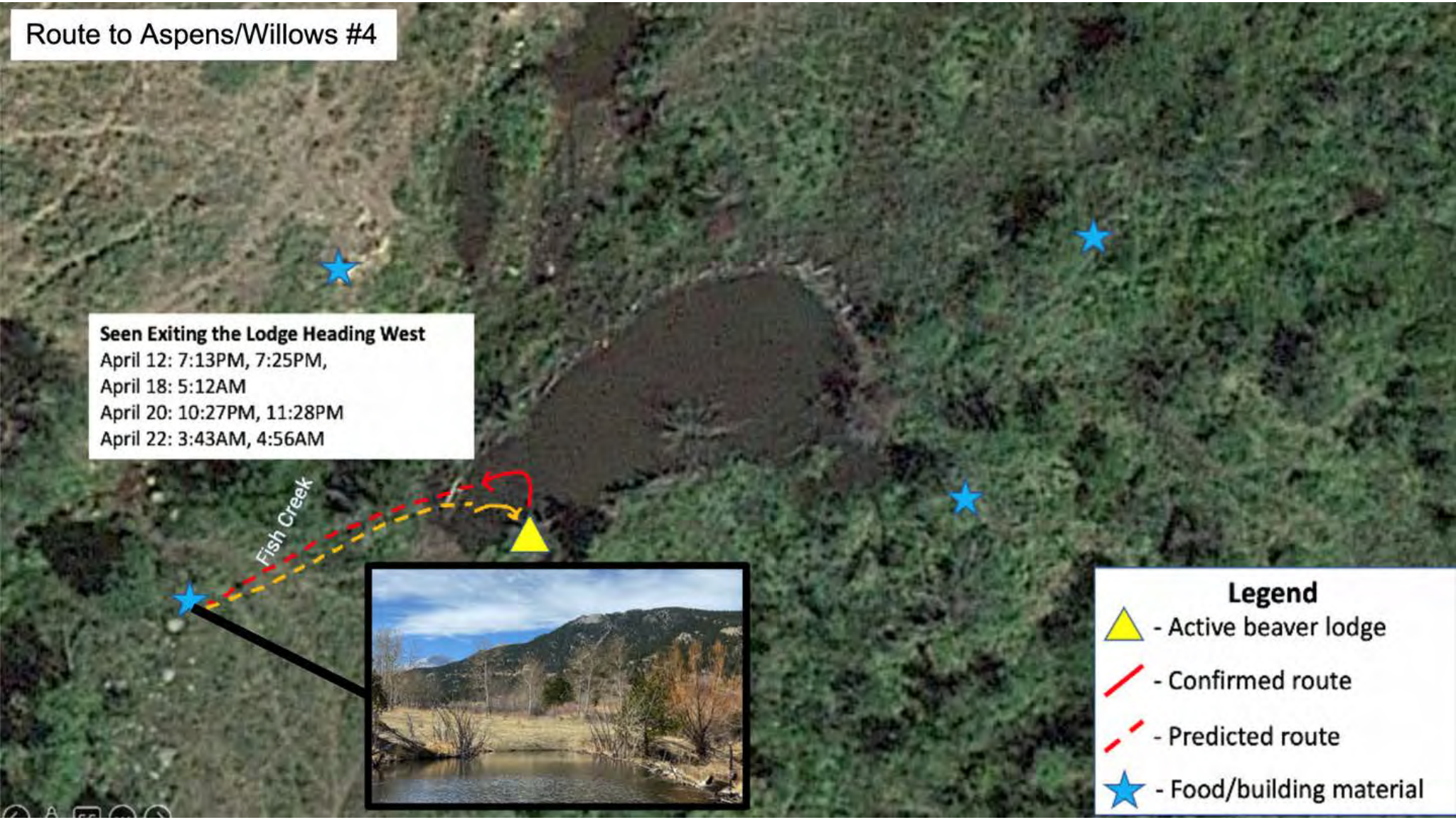


Figure 4.7: One route the beaver is likely to have traveled to get to the aspen trees. Map made by Michelle Pan.

Beaver Found to be Most Active at Night

The videos captured from our trail camera installations helped us gain more insight into the beaver's preferences for food and building materials as well as the locations from which it frequently collects these materials. Due to the time stamps on each camera capture, we know that the beaver was found to be most active at night, particularly a few hours before sunrise and a few hours after sunset. The times of day the beaver was found to be most active are 4:00am and 10:00pm, evident from the histogram in Figure 4.8.

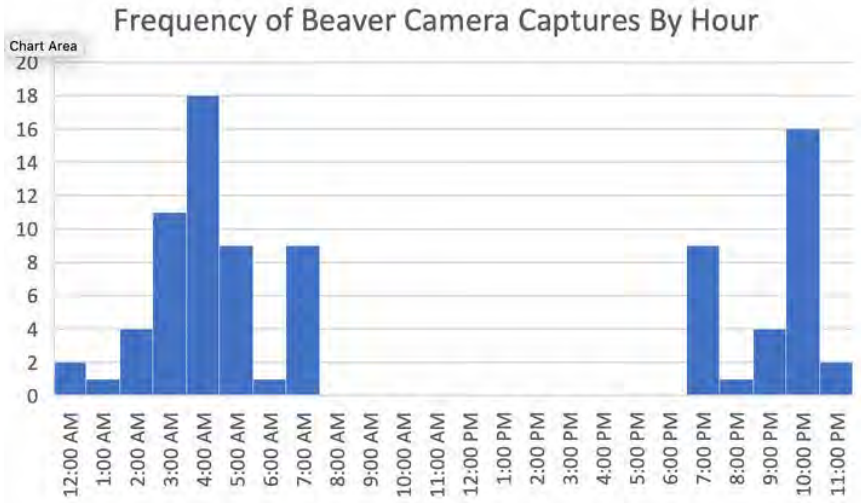


Figure 4.8: A histogram showing the times of day where the beaver was found to be most active through camera footage analysis.

The beaver primarily used aspen trees and willows for feeding and maintaining its lodge and the dams at the site. Some of the footage we collected shows the beaver swimming into the lodge carrying willow branches, an example of which is shown in Figure 4.9, confirming this behavior.

Figure 4.9: An image of a beaver swimming with a willow branch near the active beaver lodge. Image captured through one of our cameras on site.

The beaver on the site was captured most frequently in the immediate vicinity of the active pond. It was seen entering and exiting the lodge, roaming the perimeter of the pond, or traversing the slides and paths to resources. While our camera

placement varied throughout the course of the study, we found it much more difficult to capture footage of the beaver farther away from the lodge, closer to the foraging sources we identified. We suspect this is due to having inadequate camera coverage to monitor the larger area surrounding the lodge, as there were only five cameras available for us to use. For this reason, it was difficult to obtain footage of the beaver taking willow branches from the nearby vegetation, but we were successful in capturing the beaver taking branches back to the lodge and swimming across the pond carrying sticks. We also observed that the beaver often made several trips back and forth along the same route within a short time span in the same night, then appeared to be less active for a couple of nights. This suggests that the beaver's behavior is characterized by periodic foraging trips to gather materials, followed by periods of building, feeding, and resting in the lodge.

Through our findings, we found that the beaver preferred to forage on the eastern and northern sides of the site, with the other sides of the pond being traveled too less frequently. These sides of the pond had the highest density of willows, which is most likely where the beaver obtained most of its food and building materials. Some of our camera

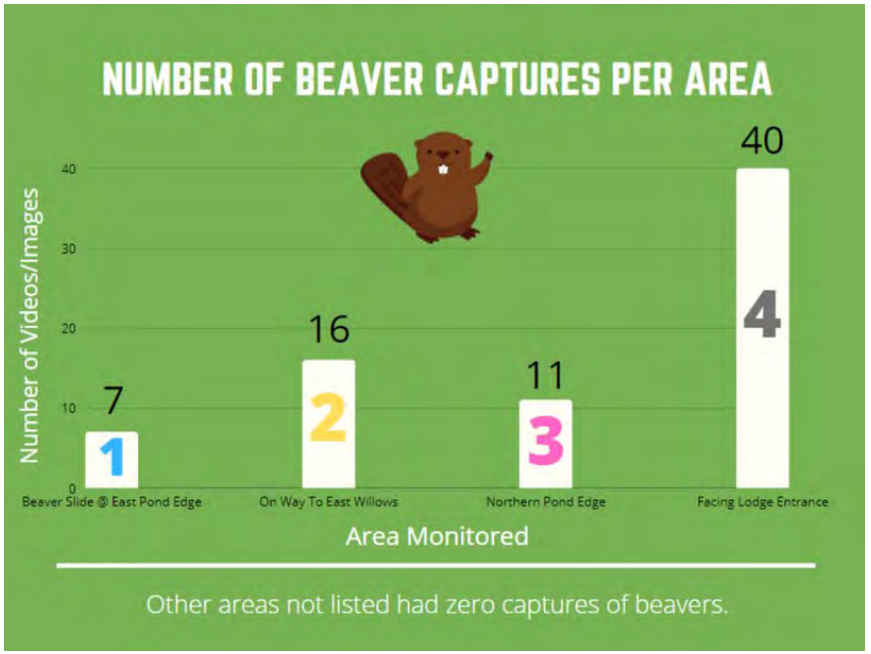


Figure 4.10: A graph showing the number of pictures/videos we captured on our cameras at the Fish Creek site, sorted by areas around the pond. Locations on a map are seen in Figure 4.11 and correspond by number. Graph made by Joshua Fernandez.

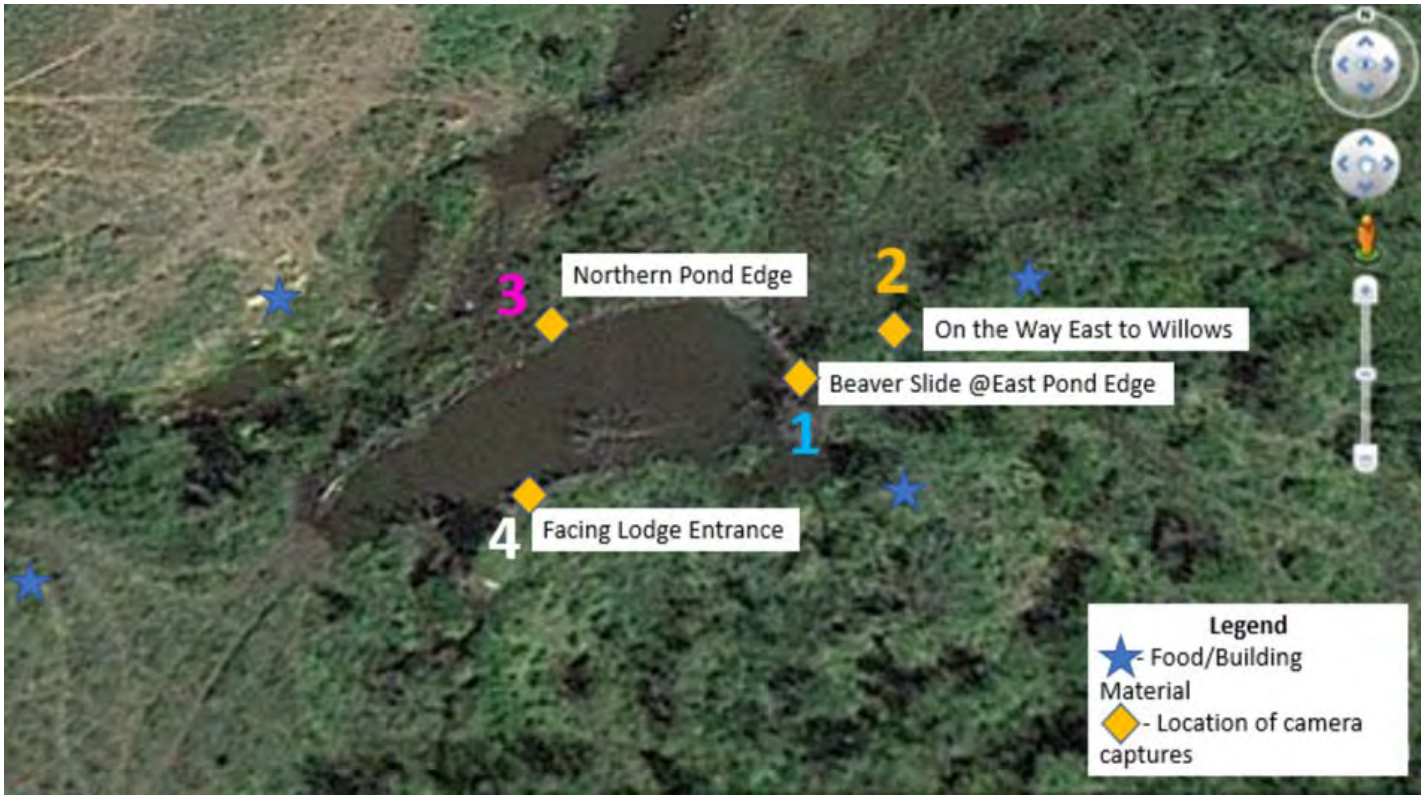


Figure 4.11: Locations described in figure 4.10. Map made by Michelle Pan and Joshua Fernandez.

footage facing the eastern side of the pond showed the beaver dragging willow branches along the pond and into its lodge. We have also recorded the beaver on multiple occasions on the pond's edge holding willow limbs, confirming that it is gathering resources at nearby locations. Aspen branches were also found lying next to the lodge at a considerable distance away from the western source of aspens, indicating that the beaver was also using the aspen trees on that side of the pond. However, we did not capture the beaver on the western side of the pond, suggesting that the beaver prefers foraging on the east side. A graph showing the frequency of beaver captures that we obtained per area is shown in Figure 4.10 and a map of these four locations in relation to the foraging sources is shown in Figure 4.11.

Physical Evidence of Beaver Activity Through In-Person Field Observations

Figure 4.12: Debarked aspen and willow floating in the main pond. Image taken by Michelle Pan.

Figure 4.13: Slide coming out of the main pond. Image taken by Michelle Pan.

We visited the Fish Creek site two times a week for four weeks and surveyed the site for beaver activity as well as for signs of other plant and animal species. We identified signs of the beaver's feeding preferences through various bite marks on trees and twigs surrounding the main lodge as seen in Figure 4.12. By the pond where the beaver lodge is located, we saw many floating aspen sticks that had been debarked, a telltale sign of a beaver's presence as beavers typically eat the bark and leave willow branches stripped. We also found green plant leaves from this year's growth floating in the water, showing that the beaver's activity in the area is recent. Additionally, we saw slides out of the pond as seen in Figure 4.13 and evidence of beaver feces, indicating its movement around the site. The slides can help identify which ponds the beaver is actively visiting or what paths it is taking to get resources. The feces in the active pond are also another sign of a beaver's presence since they typically defecate close to the lodge.

Evidence of Horses, Mule Deer, Elk and Bobcats in Fish Creek

Our team was able to identify signs of other animals passing through the area from the droppings present in the vicinity of the beaver pond. Evidence of horses was found most often at the site as we found dried horse scat as seen in Figure 4.14, since the owners of Cheley Ranch use the area as a grazing zone for up to 150 horses. Evidence of elk was also found through elk scat scattered around the site, pictured in Figure 4.15.

Additionally, we captured footage of several different species on our cameras, supplementing the physical evidence. On camera we captured species like mule deer, geese, and bobcats and mapped their predicted routes as shown by the map in Figure 4.16. Knowing what species pass throughthe area helps us gain a grasp of the competition for resources between the beaver population and these other animals. We found that

Figure 4.14: Dried horse scat. Image taken by Michelle Pan.

Figure 4.15: Older elk scat seen, indicating the presence of elk roaming through Fish Creek. Image taken by Josh Fernandez.

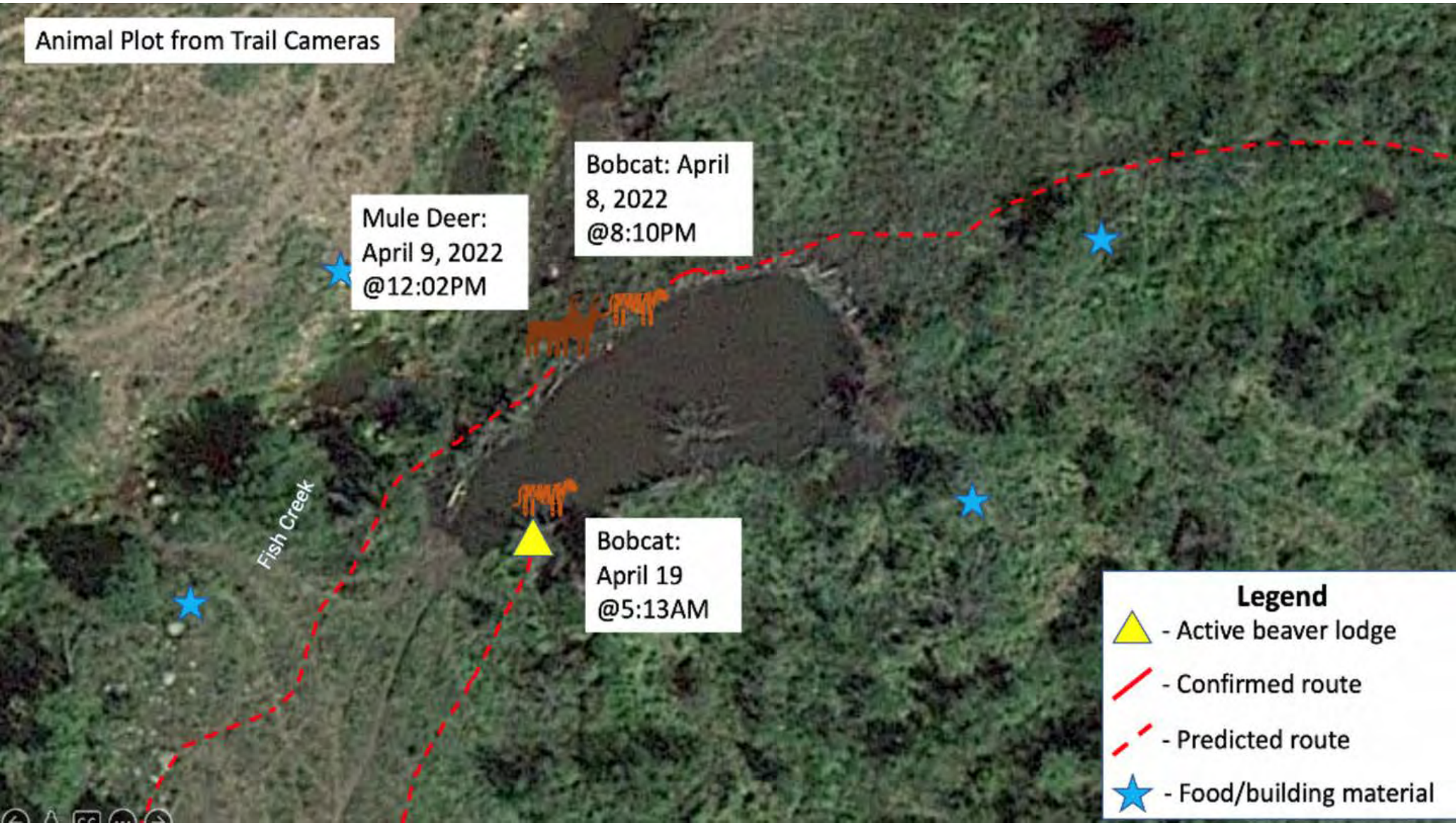


Figure 4.16: Where other animals traveled over the course of the four-week monitoring period. Map made by Michelle Pan.

most of the aspen trees had bark eaten off as seen in Figure 4.17. This was most likely grazed by elk and mule deer since the debarked parts of the aspens were above the reach of beavers. Additionally, as Andy Ames, a member of the Estes Valley Watershed Coalition Board of Directors pointed out, we saw many willows whose branches appeared to be nibbled on by elk and/or mule deer. This led us to believe that the beaver's main competition for aspen and willow is mainly with elk and mule deer. Knowing this information also informs us as to where the best locations to stake willow for the beaver along the main creek and its tributaries are.

Figure 4.17: Aspen tree with elk and mule deer grazing marks. Image taken by Michelle Pan.

Beaver Dam Analogs Elevate Water Level but Fail to Attract Much Attention from Beavers

Figure 4.18: A BDA on the Fish Creek site that is being maintained by the beaver. Photo taken by Michael Beskid.

The beaver dam analogs installed primarily at the downstream portion of the Fish Creek site during the earlier restoration effort have succeeded in raising the water level of the channel slightly but not in drawing the beaver downstream. These simulated structures were well-constructed and have been successful in slowing the flow of the creek and have helped mitigate the risk of heavy erosion from fast-flowing waters. The BDAs have also aided in the creation of small ponds, contributing to increased groundwater storage and surface flooding. Additionally, the BDAs have trapped sediment from flowing farther downstream, helping to prevent erosion and fostering aquatic life within these streams. An example of a BDA at the Fish Creek site is shown in Figure 4.18.

Looking at the BDAs, the man-made parts of the structures remain the most dominant, and we are unsure of how recently beavers last contributed to the dams. The structures may be difficult for beavers to maintain due to the fast, high-volume flow through the dammed sections of the creek. Our team was unable to capture any footage of beavers working on the BDAs during the period of our trail camera observations and site visits, suggesting that the beavers are not particularly interested in moving downstream to improve these BDAs.

While the introduction of the beaver dam analogs has been a positive development for the health of the ecosystem, their placement has left more to be desired. BDAs are most effective when they divert water to spill over the banks of a stream, creating a thin and evenly distributed volume of

water to saturate the landscape. This helps to recharge the groundwater, aids in the formation of ponds, and improves the quality of the soil by moistening the ground and increasing nutrient storage (Munir & Westbrook, 2020).

The BDAs at the site were installed primarily in the main channel of Fish Creek, which is deeply incised. The effectiveness of the BDAs is diminished by the height of the banks on either side of the stream which channels the water and prevents spillover onto the surrounding meadow. These structures have been successful in slowing down the water flow rate and creating small ponds but would have been much more effective if placed slightly downstream where the channel becomes wider and less incised. We also noticed while on the site, with confirmation from hydrologist Johannes Beeby, that there were numerous food and material caches placed around the beaver dam analogs. These caches were primarily composed of loose branches from aspen trees and willow bushes and were placed strategically with the end goal of influencing the beaver population to move downstream towards the BDAs.

Initial Feedback on the Informative Video

Once the informative video about the benefits of beavers was completed, we sent it out to anyone who was in the video or worked closely with us in order to get initial reactions and feedback. The video was well-received by the people who responded with their feedback. The people who replied included Wilynn Formeller, Dr. Ellen Wohl, and members of the EVWC's board of directors, Rachel and Andy Ames. They told us that they enjoyed the video and were excited to see it shared among more of the community.

Chapter 5: Recommendations and Conclusion

Expanding Trail Camera Monitoring at Fish Creek

Moving forward at the Fish Creek riparian corridor, our team recommends expanding efforts to monitor the beaver population using trail cameras. Based on the information we have gathered from our research and fieldwork, continued monitoring of the beaver population is important to assess how many beavers are present, to learn more about their behaviors, and to find out what they are using for resources over an extended period. We recommend keeping the trail cameras in place and continuing to monitor them regularly to obtain information about the movement of beavers and the resources they use to find out how to best support the population's growth. It would also be useful to install more cameras around the edge of the pond in order to capture the beaver in additional locations, limiting uncertainty on where it travels and attaining more solid behavioral evidence. To achieve this, we recommend the EVWC add five more cameras in addition to the five present along the routes outlined by the maps in Figures 4.4-4.7 of the previous section.

Overall, to capture beaver activity on camera, we believe the most effective way would be to place multiple cameras pointed at the main lodge in the water to determine the direction the beaver is most likely to travel. With this information, cameras should be placed on the banks of the pond where there are potential beaver slides.

When the most likely direction of travel is confirmed, cameras should be placed near the resources on that side of the pond in hopes of seeing the entire beaver's journey from the lodge to the resource and back. Checking the cameras every three or four days is also highly recommended throughout the project as it gives immediate feedback on if beavers are being captured or if a camera should be moved to a better location.

Continuing In-Person Stakeouts

Besides cameras, another way to potentially determine the number of beavers in an area and view their behavior is to continue in-person stakeouts during the times where the beavers are most active. Beavers are nocturnal so these times are typically a few hours after sunset and an hour before sunrise. The goal would be to see at least two beavers outside of the lodge at once. If this does not happen, beaver calls or beaver tail slaps in the water could indicate that there are multiple beavers residing in the area since beavers primarily make noises to communicate with each other, so any noises should be closely monitored while on a stakeout.

Using Bait

A recommendation that could increase the chances of seeing beaver activity and hopefully capture multiple beavers on camera is to bait the trail cameras. Using bait may be important if there are no distinct features found on the beavers captured on camera that can be used to identify individuals or if the footage collected is not enough to confirm the presence of multiple beavers in the area as was the case with our project. Baiting the cameras could also help encourage the beavers at the Fish Creek site to focus on using certain sources of material by strategically placing the bait by specific foraging areas. Baiting could also make the beaver behavior more predictable and easier for the owners of Cheley Ranch to adapt to, especially in the chance that the beaver population unfavorably moves upstream in the future.

As of now, we only have data of the beaver using willow as building material, but there is evidence of aspens being used in the past as there are chewed tree stumps located near the main pond. It is preferable that the beaver use the willow sources since willows are already very prevalent in the Fish Creek area and it is easier to stake in more willow plants in comparison to planting more aspen trees. The bait could be made from local willow branches found in the area, which may encourage the beavers to continue using this resource as opposed to the nearby aspen trees. If this is not an option, castor lure can be easily bought from stores for around ten dollars a jar as an alternative. The main issue with this is the fact that many people believe that using bait takes away the natural feeling of capturing an animal, as using bait introduces human influence and somewhat interrupts an animal's natural behavior. However, as the main goal of our project was to gain information on the beaver population residing in the Fish Creek site as quickly as possible for restoration purposes, it may be worthwhile to use bait.

Introducing a Second Beaver

This recommendation depends on how many beavers are found at the Fish Creek site and would probably be started after around another few months of continued monitoring. If it is determined there is only one beaver in Fish Creek, the beaver should be captured temporarily, its gender should be determined, and a beaver of opposite gender should be introduced into the ecosystem. The beaver could also be tagged while in captivity to make monitoring of its movements much easier. For more information on beaver trapping see the section titled Beaver Relocation Programs from Chapter 2. There are many people and organizations dedicated to safe beaver relocations. We would recommend contacting the Beaver Believers and specifically Sherri Tippie, a professional beaver trapper and relocator. Ms. Tippie aided in the Estes Park Scotts Pond beaver relocation back in 2015.

If multiple beavers are confirmed to be living at the Fish Creek site, they are most likely a couple as beavers traditionally live in mated pairs (Crawford, 2008). Assuming that there is a mating pair, there is a high probability that there are or will be beaver kits living in the lodge with the parents. Once the kits become adults, they move out of the lodge and establish their own territory. The offspring would most likely move downstream to create more lodges and dams where there are larger willow populations and more resources overall. However, there is a chance that the beaver population could move upstream closer to Cheley Camp, but this seems unlikely as resources for feeding and building are more plentiful downstream with the addition of newly staked willows.

Willow Staking

Our team highly recommends the continuation of the willow staking process in order to expand the resources for the beavers and help morph the local hydrology of the area. Willow staking is a relatively simple process and has a great impact on the local environment by slowing water flow and enlivening the soil. Our team believes that new willow plants should be planted every few months so the impact of the revegetation will be evident. We recommend expanding downstream to fully revegetate the entire area and draw the beaver downstream, seen in Figure 5.1. Continued monitoring of the beaver population through trail cameras, as suggested previously, could also give a good indication of where to stake willows based on the foraging habits of the beaver. It may also be important to reintroduce more aspen trees into the area to allow for the beaver population to have more resources and to create a more biodiverse region for the vegetation and animals residing there.

Fencing Implementation

Based off the evidence of other animals roaming through the Fish Creek site that we collected, we believe it is likely that there is competition with the beaver population for resources. To make sure the willow plants are given time to grow, we recommend that the area surrounding the site should be fenced to prevent the local deer and elk from grazing the willow and aspen plants. Recommended fencing locations can also be seen in Figure 5.1. This fence should have enough space to allow the beavers to enter and exit the site freely so that they can continue their work to heal the landscape. This fencing will be useful when mule deer and elk eventually migrate through the area preventing them from interfering with the willows that were previously staked. We recommend limiting the total amount of fencing to mainly focus on the areas around newly staked willow and along the dense willow area directly east of the beaver pond.

Figure 5.1: (Orange Circle) Where we recommend planting new willows to revegetate the area. (Red Boxes) Areas where we recommend fencing in Fish Creek to prevent overgrazing by mule deer and elk based on current willow populations.

Conclusion

Our team's work in performing site observations and monitoring the beaver population at Fish Creek will provide a useful foundation for the restoration efforts at the site. The Estes Valley Watershed Coalition is doing amazing work in preserving this important ecosystem, and it has been our honor and pleasure to work alongside them in tackling this issue. We believe that the current and future work at Fish Creek will be very beneficial in revitalizing the ecosystem to support the beaver colony and promote increased vegetation and biodiversity. It is our sincere hope that the information we were able to collect and analyze will prove helpful to their going efforts to restore the valuable wetlands at Fish Creek.

Over the course of our work on this project, we learned a great deal about how beavers act and how they influence riparian ecosystems. Through our research and field visits, it was enlightening to gain an understanding of trail camera monitoring as a minimally invasive method of performing wildlife research in natural environments. It was incredibly exciting to deepen our connection and appreciation for nature through studying this unique environment and discovering the nuances of beaver behavior. Having the opportunity to travel to Colorado and work with an interdisciplinary team to take on this fascinating project has been an amazing experience. We all learned so much from this project and feel incredibly fortunate and thankful to have been a part of a riparian restoration effort like the one taking place at the Fish Creek site.

Figure 5.2: A picture of the team with our sponsor Wilynn Formeller, our advisors Robert Hersh and Despoina Giapoudzi, and trail camera expert David Neils

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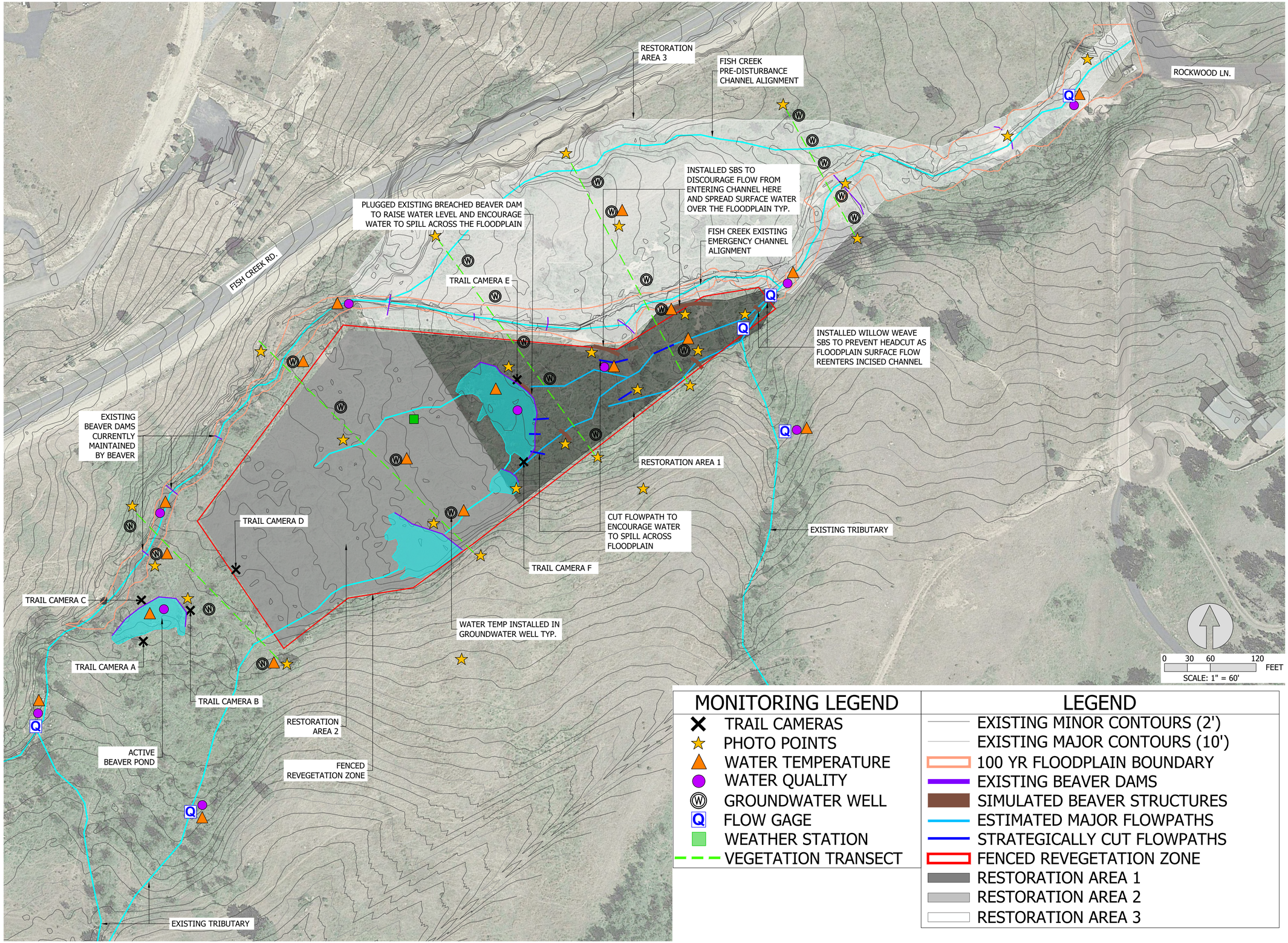

MONITORING LEGEND

- TRAIL CAMERAS
- PHOTO POINTS
- WATER TEMPERATURE
- WATER QUALITY
- GROUNDWATER WELL
- FLOW GAGE
- WEATHER STATION
- VEGETATION TRANSECT

LEGEND

- EXISTING MINOR CONTOURS (2')
- EXISTING MAJOR CONTOURS (10')
- 100 YR FLOODPLAIN BOUNDARY
- EXISTING BEAVER DAMS
- SIMULATED BEAVER STRUCTURES
- ESTIMATED MAJOR FLOWPATHS
- STRATEGICALLY CUT FLOWPATHS
- FENCED REVEGETATION ZONE
- RESTORATION AREA 1
- RESTORATION AREA 2
- RESTORATION AREA 3

FISH CREEK AT CHELEY RANCH RESTORATION

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PROJECT NUMBER: 976.00
SCALE: AS NOTED
DATE: 5/17/23

DESIGN: ####
DRAWN: ####
CHECKED: ####
APPROVED: ####

MONITORING

SHEET 1 OF 1