# Lower Henry's Fork Hydrology and Habitat Assessment

Progress report submitted to meet conditions of Ora Bridge mitigation agreement

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Fremont County, Idaho
Local Highway Technical Assistance Council

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# Executive Summary

The Henry's Fork Snake River supports world-renowned and economically important wild-trout fisheries. From the 1880s through the 1990s, the most popular fisheries were located in Island Park, in the upper portion of the watershed. However, over the past 20 years, the popularity and economic importance of fisheries on the lower Henry's Fork have greatly increased. In addition, the lower Henry's Fork and its tributaries support ecologically important riparian forests and wetland habitats, irrigated agriculture, and delivery of water to the Egin Lakes managed aquifer recharge site, which plays an important role in restoring the Eastern Snake Plain Aquifer. Despite the high economic and ecological importance of the lower Henry's Fork, scientific understanding of hydrology and of relationships among streamflow, groundwater returns, and habitat in the lower Henry's Fork greatly lags that of the upper Henry's Fork and is insufficient for informing management decisions that balance the needs of irrigation, aquifer recharge, recreational angling, and aquatic, riparian, and wetland habitat throughout the whole watershed. For the purposes of this study, we define the lower Henry's Fork as the river and immediately adjacent reaches of its tributaries downstream of Ashton Dam.

Fisheries and transportation are linked by use of roads and bridges. During busy times of the angling season, as many as 100 boats per day float sections of the lower Henry's Fork. Given the need to run shuttles for these trips, the effect of 100 float trips is 200-300 vehicle trips between launch points and takeout points, in addition to traffic from wade-fishing anglers. This is a substantial amount of vehicle traffic on what are almost exclusively narrow county roads originally built to accommodate local farm traffic. Fishing and shuttle traffic contributes a large fraction of the total use of Del Rio Bridge, Ora Bridge, and Fun Farm bridge, all of which have been recently replaced or are scheduled for replacement soon. Construction associated with transportation infrastructure upgrades often requires mitigation for wetland disturbance. Because of the need to mitigate wetland disturbance associated with replacement of Ora Bridge, Fremont County invited the Henry's Fork Foundation (HFF) to submit a proposal to the Local Highway Technical Assistance Council (LHTAC) for a project that could satisfy this mitigation. After revision based on input from LHTAC, HFF's proposal was approved and funded by the Federal Highway Administration and Fremont County Idaho. The Memorandum of Agreement that formalized the funding required submission of the following deliverables:

1. Map identifying points of diversion and canals, the Egin Lakes managed recharge site, gaining and losing river reaches, and major transportation infrastructure.
2. Report including literature review, field work accomplished to date, photos documenting groundwater return flows and associated habitat, discussion of how aquifer recharge benefits wetland habitat and water quality, and estimates of angler use and economic value of fishing on the lower Henry's Fork.
3. Wetland assessment including prioritized potential wetland improvement and/or mitigation projects and sites and discussion on how these potential wetland improvement and/or mitigation projects could be used as wetland impact mitigation for upcoming and future transportation projects.

The map listed as item 1 above is included as Appendix A to this document. The wetland memo listed as item 3 will be submitted as a separate, stand-alone report. The remainder of this document contains the report and its content as specified in item 2.

## Field work accomplished to date

From June 28 to October 27, 2019, we used an Acoustic Doppler Current Profiler to conduct streamflow measurements to 1) quantify and monitor reach gains and 2) measure stream habitat at different flows. For the first objective, we measured full-channel streamflow at four mainstem cross-sections between the USGS St. Anthony streamflow gage (#13050500) and Red Road Bridge. Half of the river reaches gained flow, one lost flow, and the other remained constant.

Within the larger St. Anthony to Red Road reach, we measured wetted habitat area, depth, velocity, and temperature at cross-sections within two braided sections of the larger study reach. In the upstream braided section, we identified two habitat types—riffles and cut banks—and sampled two sites of each type. In the downstream section, we identified one habitat type not sampled at the upstream site—pools—and sampled three sites for this habitat type.

We also specifically investigated the groundwater return flows visually identifiable within a 0.6-mi subreach below the Railroad Trestle. Within this subreach, we documented locations of groundwater springs along the right bank on July 17 and July 22. At each site, we captured a thermal infrared image to depict differences in the temperature of incoming groundwater return flow and that of the river. We also took instantaneous temperature measurements with a handheld thermometer at three locations along a lateral transect: the spring and 2 ft and 20 ft from where the spring entered the river. We found that temperature at the springs and in the river 2 ft from the spring inflow point were 7°F and 4°F cooler, respectively, than in the river 20 ft from the inflow point.

## Benefits of managed aquifer recharge to habitat and water quality

Managed aquifer recharge (MAR) is the intentional addition of surface water to groundwater for storage and recovery. By elevating the water table and increasing spring discharge to surface water, MAR can capture and redistribute high surface water flows temporally to provide water to wetland and stream ecosystems year-round and particularly during low-flow periods due to high irrigation diversion. Such groundwater flow maintenance sustains the wetness of wetland habitats and its vegetation. This, in turn, improves the quality of surface water runoff to streams as wetland plants mitigate pollution via sediment trapping and nutrient removal. Groundwater discharge also benefits stream habitat quality for aquatic organisms. Trout have been observed using habitat proximal to groundwater seeps, where local water temperature is warmer in the winter and cooler in the summer. Lastly, aquifer recharge that is managed, rather than incidental, restricts recharge to canal seepage and infiltration at a designated recharge site, preventing groundwater contamination associated with recharge on working agricultural lands.

## Angler use and economic value

Angler use on the lower Henry's Fork in 2017 was 36,318 trips, 29% of the total effort observed in 2017 on the Henry's Fork, its tributaries, and Ashton Reservoir. Anglers spent an average of $231.14 per trip in the upper Snake River region and $52.47 per trip outside of the region for a total of $283.60 per trip. Thus, angling use on the lower Henry's Fork generated $8.4 million in expenditures in the upper Snake River region and $1.9 million outside of the region, for a total expenditure of $10.3 million. For the Henry's Fork as a whole, angler use and spending in 2017 was similar to that observed by IDFG in 2003, but our data indicate that the lower Henry's Fork accounts for a larger fraction of angler use and spending than in previous years.

# Introduction

The Henry's Fork Snake River supports world-renowned and economically important wild-trout fisheries. From the 1880s through the 1990s, the most popular fisheries were located in the upper portion of the watershed, in the vicinity of Island Park Reservoir (Figure 1). However, the popularity and economic importance of fisheries in the lower watershed have greatly increased over the past 20 years. This is attributed to 1) changes in fishing regulations that have increased size and number of wild trout and to 2) substantial population growth in Teton Valley, Idaho Falls-Rexburg areas, and Jackson, Wyoming—population centers that are closer to the lower Henry's Fork than to Island Park.

In addition, the lower watershed supports ecologically important riparian forests and wetland habitats, which are contiguous with those of the South Fork Snake River. These riparian forests provide critical habitat for the yellow-billed cuckoo, which was listed as Threatened under the federal Endangered Species Act in 2014. At the same time, the vast majority of surface water withdrawn for irrigation in the watershed is diverted in the lower watershed—from the mainstem Henry's Fork between Ashton Reservoir and the North Fork Teton River confluence and from the lower reaches of Fall River and Teton River. Water is also diverted from the lower Henry's Fork for managed aquifer recharge at Egin Lakes (Figure 1), which is the most hydrogeologically important of all managed-recharge sites upstream of American Falls Reservoir. The Idaho Water Resource Board has invested over $1.5 million to expand the capacity of the Egin Lakes site because of its importance to meeting State objectives for managing the Eastern Snake Plain Aquifer.

Despite the high economic and ecological importance of the lower Henry's Fork, scientific understanding of hydrology and streamflow-habitat relationships in the lower Henry's Fork greatly lags that of the upper Henry's Fork and is insufficient for informing management decisions that balance the needs of irrigation, managed recharge, recreational fishing, and wildlife habitat. It should also be noted that water use and management in the lower Henry's Fork has a direct effect on the most popular fishery in Island Park. Delivery of irrigation water from and subsequent need to fill Island Park Reservoir are the two most important factors that determine angling conditions and the fish population immediately downstream of the reservoir (Van Kirk et al. 2019). Hence, improved water management in the lower watershed benefits the entire river.

The immediate link between the proposed study and transportation is current and projected use of roads and bridges in the study area by vehicle traffic associated with recreational fishing. During busy times of the season, as many as 100 boats per day float sections of the river in the study area. Given the need to run shuttles for these trips, the effect of 100 float trips is 200-300 vehicle trips between launch points and takeout points, in addition to traffic from wade-fishing anglers. This is a substantial amount of vehicle traffic on what are almost exclusively narrow county roads originally built to accommodate local farm traffic. Fishing and shuttle traffic contributes a large fraction of the total use of Del Rio Bridge, Ora Bridge, and Fun Farm bridge, all of which have been recently replaced or are scheduled for replacement soon.

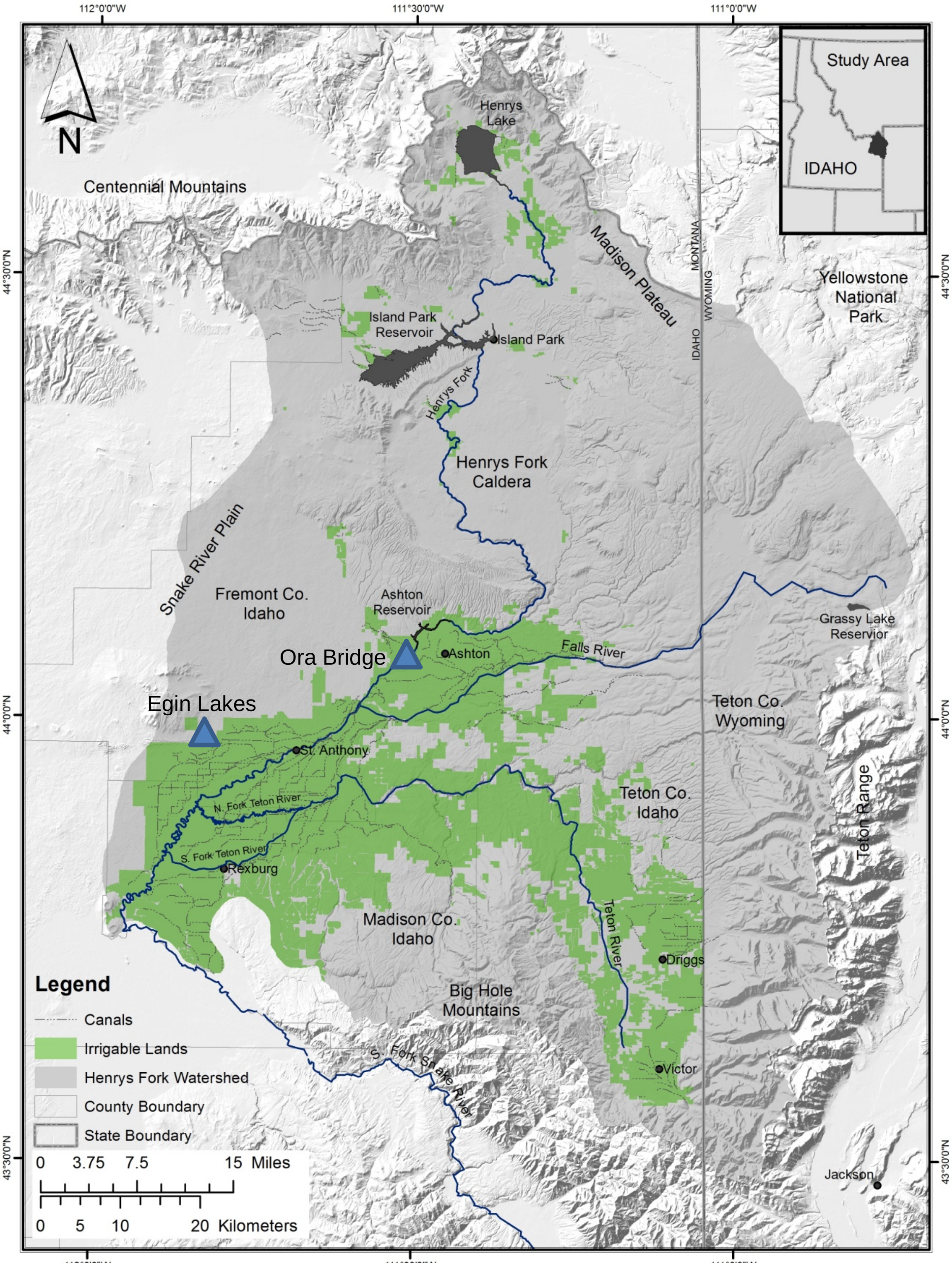


**Figure 1.** Map of Henry's Fork watershed. Ora Bridge and Egin Lakes recharge site are included for reference.

Construction associated with transportation infrastructure upgrades often requires mitigation for wetland disturbance. With no wetland bank in place in the Henry's Fork watershed, mitigation for any given project must be determined on a case-by-case basis. Because of the need to mitigate wetland disturbance at Ora Bridge, Fremont County invited the Henry's Fork Foundation (HFF) to submit a proposal to the Local Highway Technical Assistance Council (LHTAC) for a project that could satisfy this mitigation. The proposal included partial funding for a larger project HFF developed to investigate groundwater-surface water interactions on the lower Henry's Fork. That project will integrate field measurements, statistical analysis, and hydrologic modeling to quantify the dependence of stream, riparian, and wetland habitat conditions in the lower Henry's Fork watershed on hydrologic regimes (groundwater and surface water) and water management strategies. This basic scientific information will then be combined with stakeholder input to inform development of system-management models and strategies that will be used to improve water management across the whole watershed to meet current and future needs of multiple stakeholders. The proposal also included funding for an inventory of wetland areas on the lower Henry's Fork and assessment of restoration potential.

After revision based on input from LHTAC, HFF's proposal was approved and funded by the Federal Highway Administration and Fremont County Idaho. The Memorandum of Agreement that formalized the funding required submission of the following deliverables.

1. Map identifying:
    a. the relevant points of diversion and canals,
    b. the primary managed recharge site in the study area,
    c. gaining and losing reaches of the river, and
    d. major transportation infrastructure.
2. Report including:
    a. literature review,
    b. field work accomplished to date,
    c. photos documenting groundwater return flows and associated habitat,
    d. general discussion of how managed aquifer recharge (MAR) and incidental recharge benefit wetland habitat and water quality, and
    e. initial estimates of angler use and economic value of fishing on river reaches in the study area from a study currently being conducted by the Henry's Fork Foundation and its partners,
3. Wetland identification memo including:
    a. prioritized potential wetland improvement and/or mitigation projects and sites (prioritization based on benefit to the watershed/groundwater, clean/filter sediment and pollutants, and other criteria)
        i. map identifying wetlands and potential project locations
        ii. list of general parameters for potential wetland mitigation projects (improvements or functional uplifts, vegetation, hydrology, access, etc.)
    b. discussion on how these potential wetland improvement and/or mitigation projects could be used as wetland impact mitigation for upcoming and future transportation projects.

The map listed as item 1 above is included as Appendix A to this document. The wetland memo listed as item 3 will be submitted as a separate, stand-alone report. The remainder of this document contains the report and its content as specified in item 2.

# Hydrology and habitat assessment

## *Literature review*

In spring-fed streams, groundwater return flows are important for maintaining baseflows that buffer periods of low streamflow (Brunke and Gonser 1997; Bertrand et al. 2012) and moderate extreme stream temperatures (Caissie 2006; Webb et al. 2008). Thus, groundwater return flow is important for maintaining stable environments and suitable aquatic habitat (Ward and Tockner 2001; Barquín and Death 2006). However, systems with shallow, unconfined aquifers are less tolerant to variable climate (Winter 1999; Healy and Cook 2002; Sophocleous 2002; Lee et al. 2006). As a result, aquifer volume and stream seepage may diminish (Dams et al. 2012; Taylor et al. 2013; Kløve et al. 2014) as the timing and magnitude of natural recharge change (Döll 2009; Green et al. 2011; Taylor et al. 2013). Summer irrigation diversions and warming temperatures may compound return flow reductions, exacerbating low summer streamflows and further stressing aquatic ecosystems (Poole and Berman 2001).

In regions with shallow aquifers, winter recharge enhances groundwater storage important for streamflow in subsequent months (Kløve et al. 2014). In snow-driven hydrologic systems, studies predict precipitation regime shifts from snowfall to rainfall, earlier snowmelt, and reduced summer streamflow (Dai 2013; Ficklin et al. 2018). Rather than lose this snowmelt downstream, managed aquifer recharge (MAR) can redirect it into the aquifer to augment both storage and late-summer return flows (Kendy and Bredehoeft 2006; Fernald et al. 2015; Niswonger et al. 2017). Recharge can also lag peak runoff timing (Tague et al. 2008; Barber et al. 2009; Ronayne et al. 2017), safeguarding systems from runoff variability (Brunke and Gonser 1997) and relieving critical low-flow periods (Barber et al. 2009; Palmer et al. 2009; Fernald et al. 2010). Although studies suggest that MAR may benefit aquatic ecosystems (Kendy and Bredehoeft 2006) by augmenting low baseflows (Scherberg et al. 2018) and providing cool-water refugia during low-flow, high-temperature periods (Fernald et al. 2010), these hypotheses have yet to be field-tested. Furthermore, the quality of MAR return flows are uncertain—and may also be system-dependent. Some studies have identified groundwater return flow as a mediator for riverine temperatures given climate change (Snyder et al. 2015), but others have demonstrated that warming air temperatures will also warm shallow groundwater (Taylor and Stefan 2009; Kurylyk et al. 2014, 2015; Menberg et al. 2014). Beyond thermal uncertainty, MAR also risks nutrient mobilization and pollutant loading to streams and riparian soils (Scanlon et al. 2005; Dillon et al. 2009a; Morway et al. 2013; Niswonger et al. 2017). Thus, using MAR to mitigate the effects of climate change on aquatic ecosystems must be further studied to understand the quantity and quality of MAR return flow.

In southeastern Idaho, the Eastern Snake Plain Aquifer is an unconfined aquifer that underlies the region where the majority of the state's agricultural commodities are grown (Ryu et al. 2012). Under natural conditions, the aquifer was recharged by tributary underflow, channel seepage from the Snake River, and direct precipitation on the Plain—the first two of these sources ultimately being fed by snowmelt (Ryu et al. 2012). Recharge is facilitated by highly permeable basalt with sedimentary interbeds (Cosgrove and Johnson 2005). However, incidental recharge from flood irrigation practices from 1915-1955 enhanced recharge beyond natural conditions (Ryu et al. 2012). The transition away from flood irrigation to sprinkler irrigation and groundwater pumping diminished this incidental recharge of the Eastern Snake Plain Aquifer (Johnson et al. 1999). As a result, aquifer levels and spring discharge have been in decline for 60 years—leading to increased groundwater pumping costs, reduced stream gains from aquifer discharge, increased reliance on reservoir storage, and costly legal conflicts among water users (Johnson et al. 1999; Idaho Water Resource Board 2009; Boggs et al. 2010).

The Eastern Snake Plain Aquifer underlies the mainstem of the Henry's Fork, downstream of the Henry's Fork Caldera and provides baseflow to the system (Figure 2). In an effort to increase aquifer levels and spring discharge, the Idaho Water Resources Board has invested over $1 million USD to expand MAR infrastructure in the lower Henry's Fork since 2015 (Patton 2018). MAR occurs from November to March and uses existing irrigation infrastructure to route excess streamflow to the Egin Lakes recharge site, 8 km from the river, for aquifer infiltration and percolation (Idaho Department of Water Resources 1999). Excess streamflow is defined as that which exceeds reservoir storage capacity, irrigation demand, hydropower rights, and existing minimum stream flow rights (Idaho Department of Water Resources 1999). Groundwater models have shown that water recharged at Egin Lakes returns as base flow to the lower Henry's Fork in three months (Contor et al. 2009), and if effectively timed, recharge can supplement summer low-flow periods when irrigation diversions peak (Idaho Department of Water Resources 1999; Van Kirk et al. 2019).

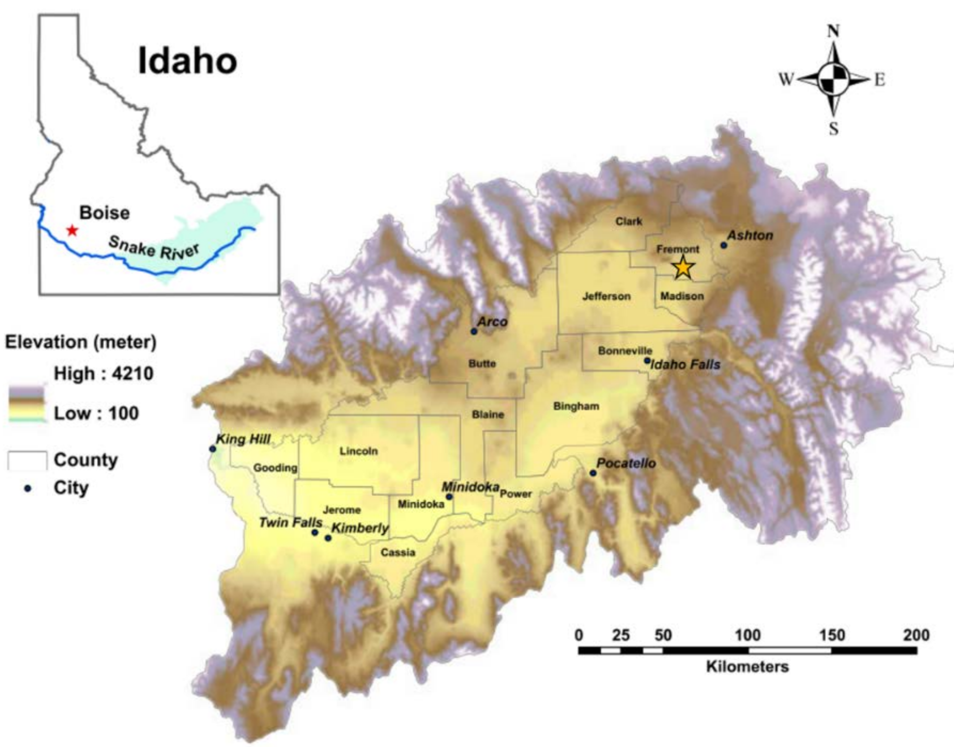


**Figure 2.** Schematic of the Eastern Snake Plain and its tributaries, adapted from Ryu et al. 2012. The star notes the location of the lower Henry's Fork, near St. Anthony, Idaho.

Under natural conditions in the lower Henry's Fork, 80,000 acre-feet of groundwater is discharged per year to the Henry's Fork below St. Anthony (Spinazola 1994). However, the extent to which MAR supplements the quantity of summer base flows may be quite small (<0.5% of recharge volume; Van Kirk et al. 2019). Whereas aquifer recharge may introduce water quality concerns in other regions, return flow from the Eastern Snake Plain Aquifer is of high quality that is suitable for instream habitat uses (Low 1987). Furthermore, stream temperatures in the lower Henry's Fork are significantly cooler (1.1ºF) where they are influenced by shallow groundwater (Van Kirk et al. 2019).

## *Fieldwork accomplished to date*

### Streamflow measurements

From June 28 to October 7, 2019, we measured streamflow with an Acoustic Doppler Current Profiler (ADCP; Figure 3) at four mainstem cross-sections between the USGS St. Anthony streamflow gage and Red Road (see maps in Appendix A). We conducted measurements 3-4 times per week from June 28 to July 18 to capture quickly changing flows as irrigation demand increased and natural flow decreased and weekly from August 7 to October 7 given more gradual flow changes during this period (Figure 4). We aimed to sample each site on the same day and were largely successful. Rare discrepancies in sample frequency occurred due to battery failure and low flows preventing access to interior sites Mile 1 and Mile 2 that lacked immediate boat ramp access. In the early season, measurements at Trestle were the densest in comparison to any other site, given overlapping fieldwork opportunities above and below the site that allowed flow measurements to be done more frequently. Analysis of flow measurement at each of the four locations indicated both gaining and losing reaches of the river within the study area (Table 1; Appendix A).

**Figure 3.** Using the ADCP to conduct a streamflow measurement at the Railroad Trestle site.

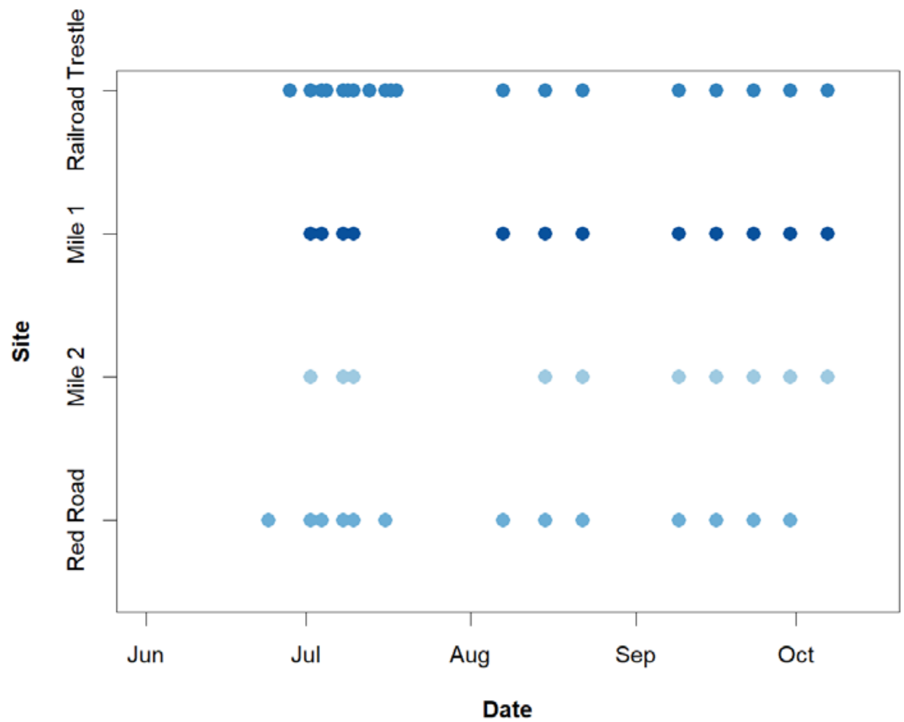


**Figure 4.** Streamflow sampling dates, by location.

**Table 1.** Summary of reach gains and losses in the Henry's Fork between St. Anthony and Red Road Bridge. The reaches are shown visually on the map in Appendix A.

| Reach | Classification |
|---|---|
| St. Anthony to Railroad Trestle | Gaining |
| Railroad Trestle to Mile 1 | Losing |
| Mile 1 to Mile 2 | Gaining |
| Mile 2 to Red Road | Neutral |

## Stream habitat measurements

Within the reach from St. Anthony to Red Road, we used the ADCP to measure wetted habitat area, depth, velocity, and temperature at cross-sections within two braided sections of the larger study reach (Figure 5). These braided sections are located 1) between Independent Canal and the Railroad Trestle, referred to as the "Top Braids," and 2) below the Railroad Trestle, referred to as the "Bottom Braids" (Figure 6). Within the Top Braids, we identified two habitat types—riffles and cut banks (Figure 7). We sampled two sites of each type, each site of a different channel width (0-50 ft and >50 ft). We sampled sites in the Top Braids from June 26 to July 17, 2019. We aimed to sample each site on the same day and were largely successful. Discrepancies in sample frequency were rare. The sample window was short because the Top Braids experienced a large flow range (1600 cfs to 400 cfs) over a short period of time (Figure 8).

**Figure 5**. Using the ADCP to conduct habitat measurements.

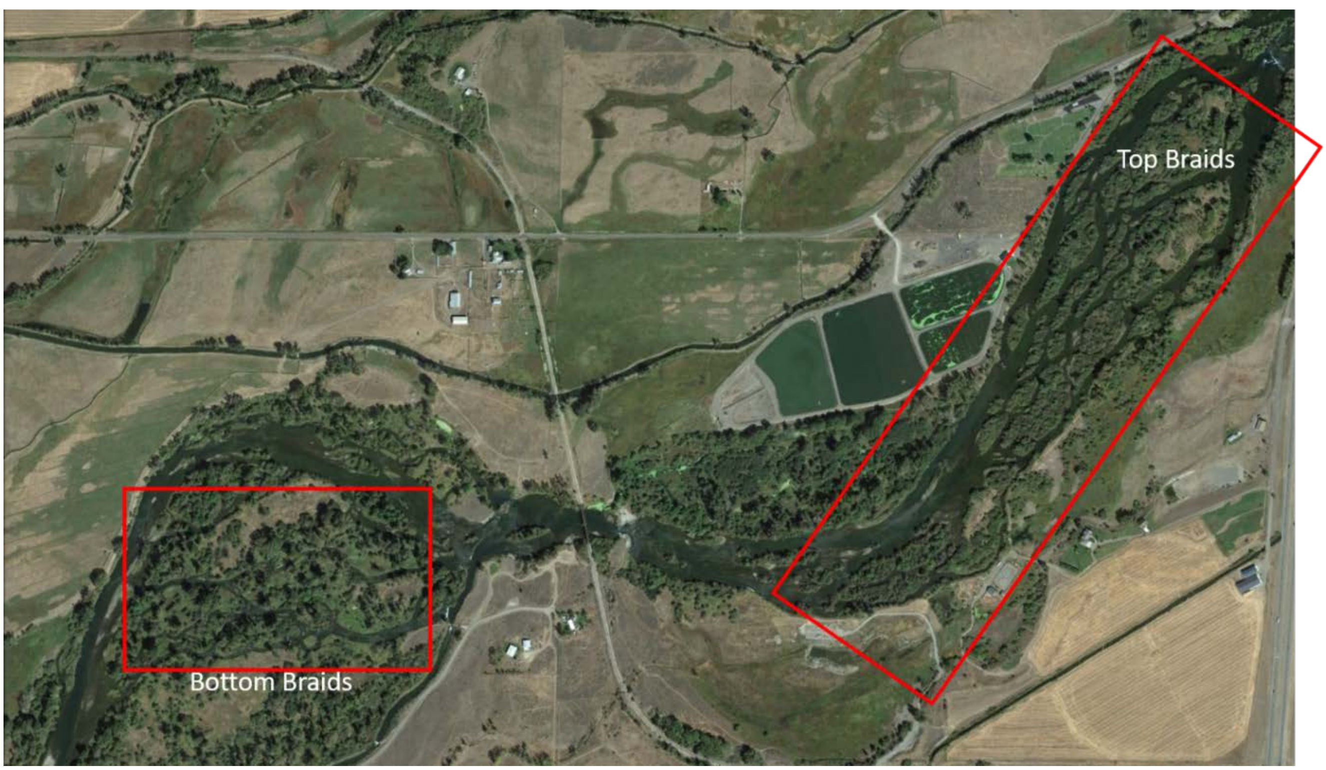


**Figure 6.** Braided reaches of the lower Henry's Fork in which habitat measurements were conducted.


**Figure 7.** Habitat sampling locations in the Top Braid reach.

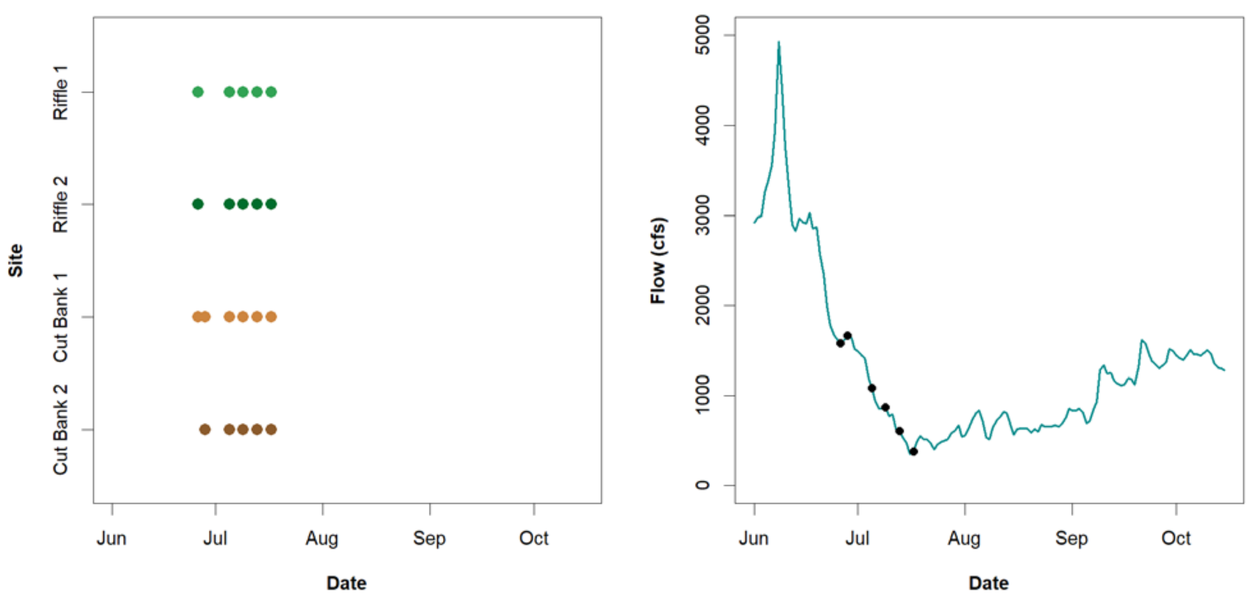


**Figure 8.** Top Braid habitat sampling dates, by location (left) and by streamflow (right).

Within the Bottom Braids, we identified one habitat type not sampled at the upstream site: pools (Figure 9). We sampled three sites for this habitat type, each site with a different channel width (20 ft, 45 ft, and 60 ft). We sampled sites in the Bottom Braids from July 4 to September 30 (Figure 10). We aimed to sample each site on the same day and were largely successful. Discrepancies in sample frequency were rare. A delayed start in sampling the Bottom Braids missed the high flow period of late June. Thus, an extended sampling window was required to capture a larger flow range.


**Figure 9.** Habitat sampling locations in the Bottom Braid reach.

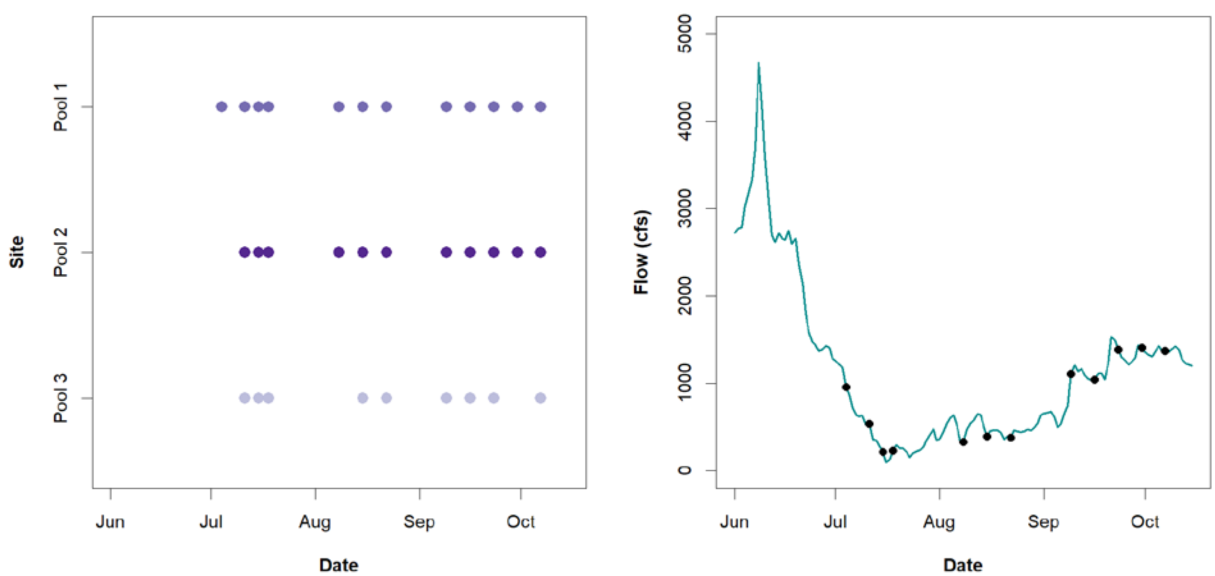


**Figure 10**. Bottom Braid habitat sampling dates, by location (left) and by streamflow (right).

## Groundwater return flow investigation

In addition to using flow measurements to identify and characterize gaining and losing reaches between St. Anthony and Red Road, we also specifically investigated the groundwater return flows visually identifiable within a 0.6-mi subreach below the Railroad Trestle (Figure 11). Within this subreach, we conducted a walking survey of the right bank and documented locations of groundwater springs on July 17 and July 22.

Sites were classified as either 1) a single discharge point, where water originating from the bluff face created an actively flowing channel to the river, or 2) a “wall seep,” where water emerged from continuously saturated soil and contributed water to the river via unchannelized flow. We collected a GPS point at each site; wall seeps had two points to document upstream and downstream extent. Most sites flowed into a channel secondary to the mainstem. At each site, we also captured a thermal infrared image using a FLIR T450sc to depict differences in the temperature of incoming groundwater return flow and that of the river (Appendix B). Additionally, we took instantaneous temperature measurements with a handheld thermometer at three locations along a lateral transect: the spring and 2 ft and 20 ft from where the spring entered the river. We found that temperature at the springs and in the river 2 feet from the spring inflow point were 7°F and 4°F cooler, respectively, than in the river 20 feet from the inflow point (Figure 12). Lastly, we took photos of plants at each site to document habitat associated with groundwater return flows (Figures 13 and 14).


**Figure 11.** River reach in which groundwater springs were investigated.

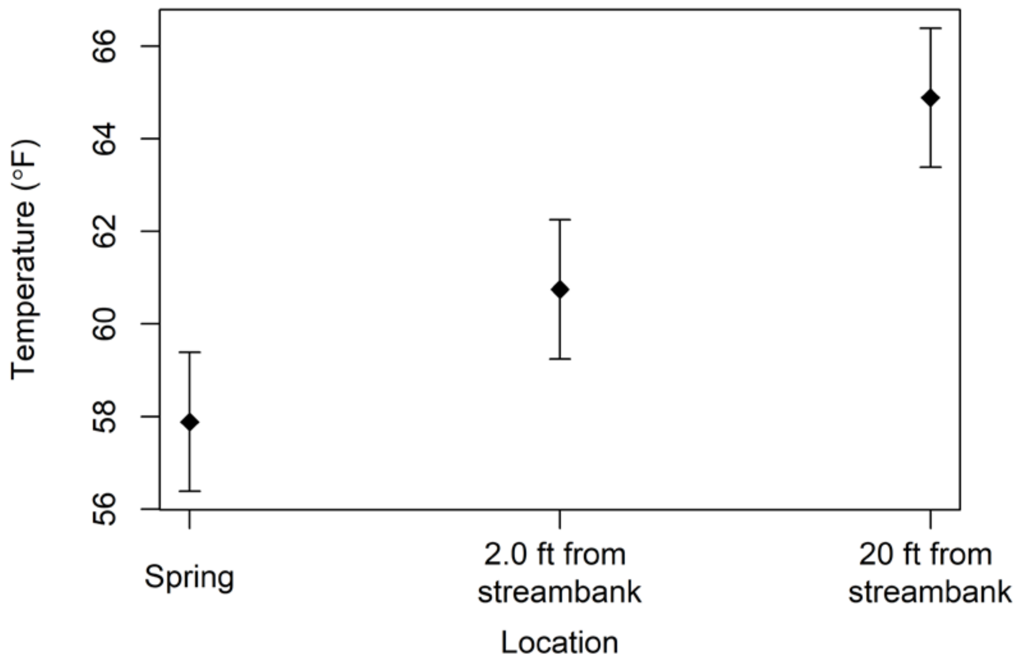

**Figure 12.** Mean water temperature, with 95% confidence intervals, at three locations measured at each of 20 distinct spring inflow points.

**Figure 13.** Photos of groundwater springs. Most of the groundwater return flows we observed emerged from the bottom of a 10 ft bluff, with agricultural land and an unlined irrigation canal on the upland face, and flowed through riparian cottonwood forest.

**Figure 14.** Plants observed in areas of groundwater springs. In addition to a native riparian cottonwood forest, we found Watercress (*Nasturtium officinale*), Field Mustard (*Brassica rapa*), an unidentified grass, and true forget-me-not (*Myosotis scorpioides*). Watercress and field mustard are nonnative; true forget-me-not is introduced. Of those observed and identified, watercress and true forget-me-not are wetland obligates as defined by the U.S. Army Corps of Engineers.

## *Aquifer recharge benefits to wetland habitat and water quality*

Managed aquifer recharge (MAR) is the intentional recharge of water to aquifers for storage and recovery (Dillon et al. 2009a). Aquifers are permeable basin-like formations that hold water and are replenished naturally through either water soaking through to the aquifer below or by infiltration from streams (Dillon et al. 2009a). Globally, managed aquifer recharge is conducted through two main mechanisms—injection and infiltration. On the Eastern Snake Plain Aquifer, managers conduct recharge via infiltration. This uses the existing and expanded canal infrastructure to deliver recharge water to designated aquifer recharge sites (Patton 2018). These sites allow water to naturally percolate through the ground and into the aquifer. However, a significant contribution to the aquifer occurs incidentally via canal seepage (Patton 2018). Incidental recharge occurs when water escapes into an aquifer from water deliveries for irrigation or other uses (Patton 2011). In addition to managed recharge efforts, canal seepage elevates the water table and increases spring discharge to surface water (Ryu et al. 2012). On the Eastern Snake Plain, incidental recharge typically occurs during the irrigation season and MAR usually happens outside of the irrigation season. This continuous recharge is important for replenishing the aquifer because, among other ecological benefits, it contributes to wetland habitat and is favorable for water quality.

Groundwater is needed for certain ecological services such as groundwater-dependent ecosystems (GDEs). GDEs have three classifications: those within groundwater, those that require surface expression of groundwater, and those that need sub-surface groundwater within rooting depth (Eamus et al. 2016). Both the second and third classification are present in the lower Henry’s Fork, as wetland habitat and riparian forests, respectively. Depth-to-groundwater and groundwater pressure, flows, and quality are important attributes for both of these GDEs (Eamus et al 2016). Groundwater pressure sustains groundwater discharge to springs, providing water to the ecosystem both seasonally and, in some systems, year-round. Groundwater flow sustains wetness of wetland habitats and base flow, which maintains the vegetation and in turn improves the groundwater quality of water exiting into the stream. The groundwater quality that discharges into GDEs is important for sustaining the chemical composition of the system, making it habitable for the living environment (Kløve et al. 2011). In unconfined aquifers, like the Eastern Snake Plain Aquifer, depth-to-groundwater is one of the most significant factors for sustaining GDEs because it determines the amount of groundwater that is available to vegetation (Eamus et al. 2016). This factor also provides a water-logged environment, prevents activation of acid sulphate soil, and maintains the hydraulic gradient for groundwater discharge (Eamus et al. 2016). Therefore, disrupting or significantly decreasing the groundwater flows can significantly inhibit the presence of GDEs.

GDEs like wetlands are important because they have a direct impact on the quality of water that enters the river. Wetlands improve water quality by removing pollutants from surface waters via sediment trapping and nutrient removal (Johnston 1991; Zedler 2003; Verhoeven et al. 2006). The value of wetlands further increases as anthropogenic activities such as agriculture further degrade the quality of water entering the aquifer. Although initial assessments did not identify groundwater discharge as low quality (Low 1987), recent reports have identified nitrogen and phosphorus amounts as increasing in the southern region of the Eastern Snake Plain Aquifer (Cohen 2019)—200 miles downstream of the lower Henry’s Fork. Nitrate levels are high because of agricultural crops like potatoes and sugar beets that are on top of the shallower basin in this region (Rupert et al. 2014). There are some cases where the nutrient amounts exceed state and federal water-quality standards, as was observed in wells sampled in Magic Valley (Cohen 2019).

The quality of water entering the aquifer is important, especially where groundwater and surface water are highly interconnected (Dillon et al. 2009a). Fluvial hydrosystems—such as streams, riparian areas, floodplains, alluvial aquifers, and downstream waters—are physically and chemically connected (Fritz et al. 2018). The quality of groundwater is important to riparian wetlands and large surface waters given the physical connectivity between surface and subsurface flows. This interconnectedness allows for the transfer of contaminants between streams and riparian wetlands, and downstream waters (Fritz et al. 2018). Water quality is vital for maintaining the chemical composition of an ecosystem, but is threatened by groundwater contamination from chemical applications to agricultural land as well as soil and water salinization due to vegetation clearing and excessive irrigation (Eamus et al. 2016). Increased nutrient-rich water entering the aquifer is a water quality hazard (Dillon et al. 2009b).

The water quality in the southwestern part of the Eastern Snake Plain Aquifer (ESPA) is particularly susceptible to contamination due to its geologic structure and local human activities. The basalt aquifer has well-drained soils and permeable rocks increasing susceptibility to pollutants (Rupert et al. 2014). Therefore, the thin layer of sediments on the upper surface of the aquifer does little to filter out irrigation water carrying nitrates and pesticides that enter groundwater (Rupert et al. 2014). Nitrate persists in the groundwater because of the oxygen-rich conditions, which prevent nitrate from transitioning to nitrogen gas (Rupert et al. 2014). Conducting managed aquifer recharge via canal seepage and infiltration at Egin Lakes, as is done in the lower Henry's Fork region of the ESPA, is a way to recharge outside of working agricultural land and prevent such groundwater contamination. However, should contamination occur via incidental recharge, maintaining wetlands to naturally filter out these pollutants is a feasible way to address this concern.

The temperature of groundwater is also significant to this discussion as the temperature of the river greatly impacts the quality of trout habitat. Trout have been observed utilizing habitat proximal to groundwater discharge, where local water temperature is warmer in the winter and cooler in the summer (Gibson 1966; Hynes 1983; Cunjak and Power 1986). Therefore, MAR and incidental recharge can be useful for sustaining trout habitat. In the lower Henry's Fork, water temperatures rise during summer low-flow periods. Groundwater return flows provide cooler habitat and may serve as refuge for trout during these periods (Van Kirk et al. 2011). Groundwater can also provide more temperate temperatures for trout habitat throughout the year and be a significant contributor to baseflow when there are low flows in the lower Henry's Fork.

Climate change, water consumption, and irrigation needs present a large threat to the maintenance of aquifers and its resulting groundwater discharge (Kløve et al. 2014). Natural recharge becomes less dependable as precipitation becomes more variable. Thus, aquifer recharge is becoming increasingly important. MAR and incidental recharge moderate the impact of these threats and consequently improves the health of the river, the aquifer, and the recreational benefit that it brings the eastern Idaho region.

## Angler use and economic value of fishing

Between 2016 and 2018, HFF, Friends of the Teton River, Weber State University, and Idaho Department of Fish and Game (IDFG) studied angler use and fishing-related expenditure on Henry's Lake, the Henry's Fork and tributaries, and Teton River. The lower Henry's Fork was surveyed in 2017, along with the rest of the Henry's Fork and its tributaries. Angler use was quantified using access-point counts during late fall and winter and by aerial counts during spring, summer and early autumn. Counts were conducted according to a standard stratified random sampling design. Economic value was assessed with a survey instrument distributed to anglers at access points on randomly selected days. The key information requested from survey respondents included annual number of trips, travel time and distance, primary purpose of trips, fish species caught, total expenditures in and out of the upper Snake River region, contingent valuation questions, and demographics. We defined the Upper Snake River region as Bonneville, Clark, Fremont, Madison, Jefferson, Teton counties in Idaho, and Teton County, Wyoming. Total value of angler spending was estimated by multiplying the number of angler trips by the expenditure per angler trip.

Angler use on the lower Henry's Fork was 36,318 trips, 29% of the total effort observed in 2017 on the Henry's Fork, its tributaries, and Ashton Reservoir (Figure 15). This was over four times the number of trips observed by IDFG in 2008, the last time it conducted a survey of angler use on the lower Henry's Fork (IDFG, unpublished data), although differences in methodology account for some of the difference. Anglers spent an average of $231.14 per trip in the upper Snake River region and $52.47 per trip outside of the region for a total of $283.60 per trip. Thus, angling use on the lower Henry's Fork generated $8.4 million in expenditures in the upper Snake River region and $1.9 million outside of the region, for a total expenditure of $10.3 million. A previous expenditure study conducted by IDFG in 2003 (Grunder et al. 2008) did not subdivide expenditure and use estimates into different reaches of the river, but for the Henry's Fork and its tributaries as a whole, angler use and expenditure were similar in 2017 to those in 2003 (Table 2). This is contrast to use and spending on Henry's Lake, which was much lower in our 2016 survey than in 2003, and use and spending on Teton River, which was much higher in our 2018 survey than in 2003. Our observations indicate that angler use has increased on the lower Henry's Fork and Teton River over the past 15 years while it has decreased on the upper Henry's Fork and Henry's Lake.

**Table 2**. Comparison of angler use and total spending between this study (surveys conducted in 2016, 2017, and 2018) and that of Grunder et al. (2008) in 2003.

| Location | Year Surveyed | Annual use (trips) 2003 | Annual use (trips) This study | Total annual spending 2003 inflation-adjusted | Total annual spending This study |
|---|---|---|---|---|---|
| Henry's Lake | 2016 | 56,829 | 12,366 | $16.47 million | $1.97 million |
| Henry's Fork & tribs | 2017 | 118,330 | 124,492 | $41.69 million | $37.28 million |
| Teton River | 2018 | 9,144 | 33,492 | $0.92 million | $4.21 million |
| TOTALS | | 184,303 | 170,350 | $59.08 million | $43.46 million |

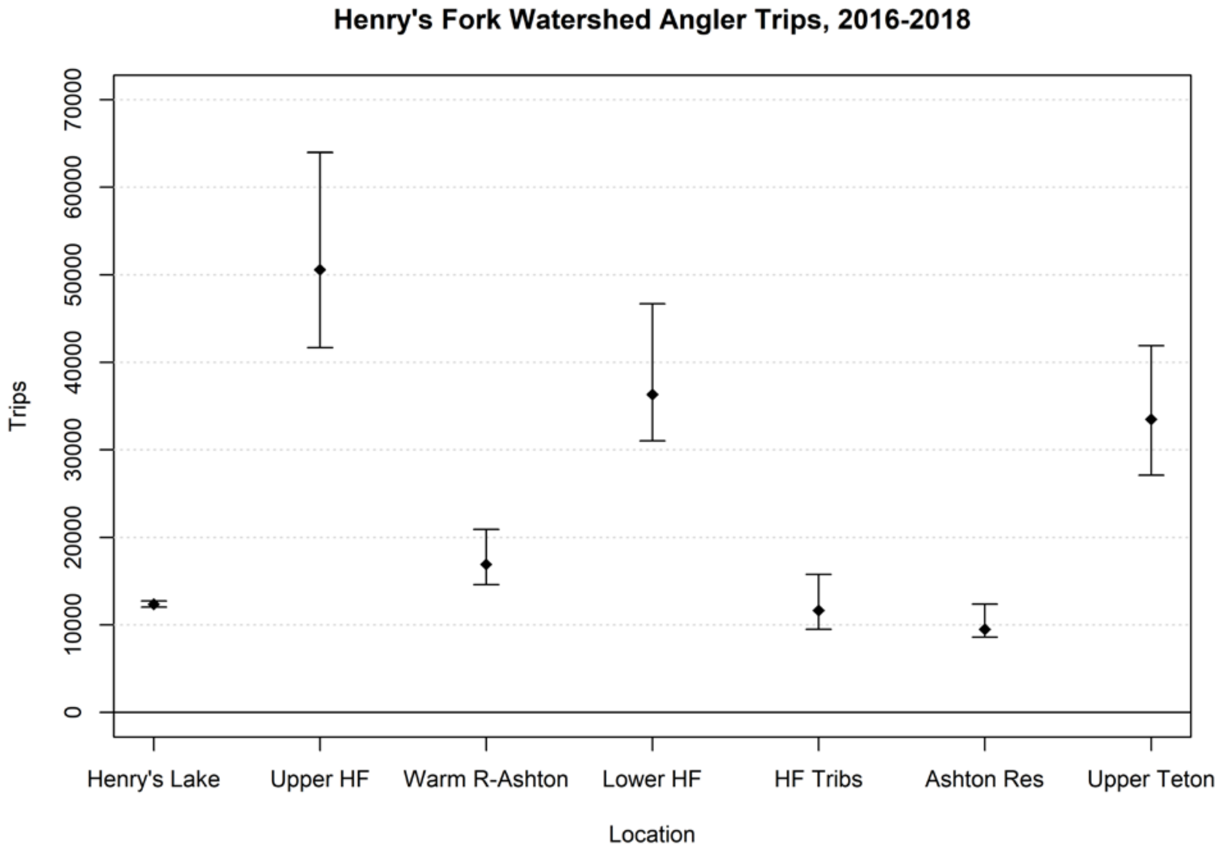


**Figure 15**. Angler trips on waters in the Henry's Fork watershed surveyed over a three-year period. Error bars are 95% confidence intervals. The lower Henry's Fork was surveyed in 2017.

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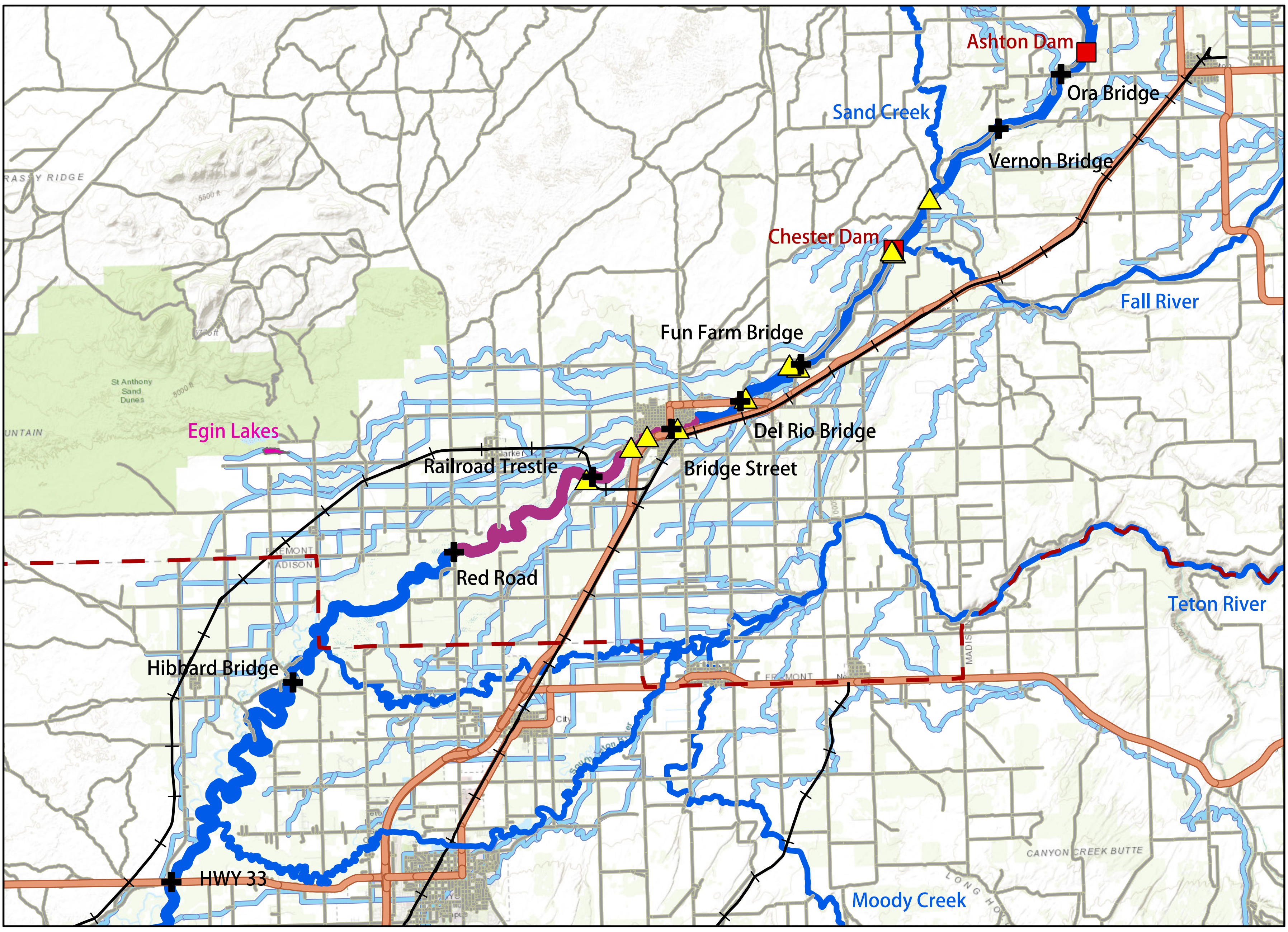
## Appendix A. Map

## Appendix B. Thermal Infrared Photos of Groundwater Inflow

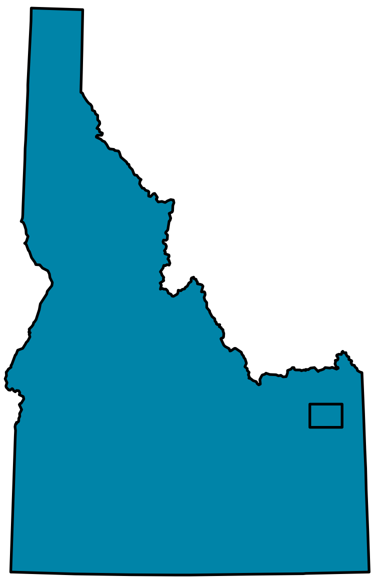
# Transportation and Canal Infrastructure Relative to the Lower Henry's Fork, Idaho




Flow

Christina Morrisett | December 2019 | Data courtesy of ESRI, USGS NHD, ISU

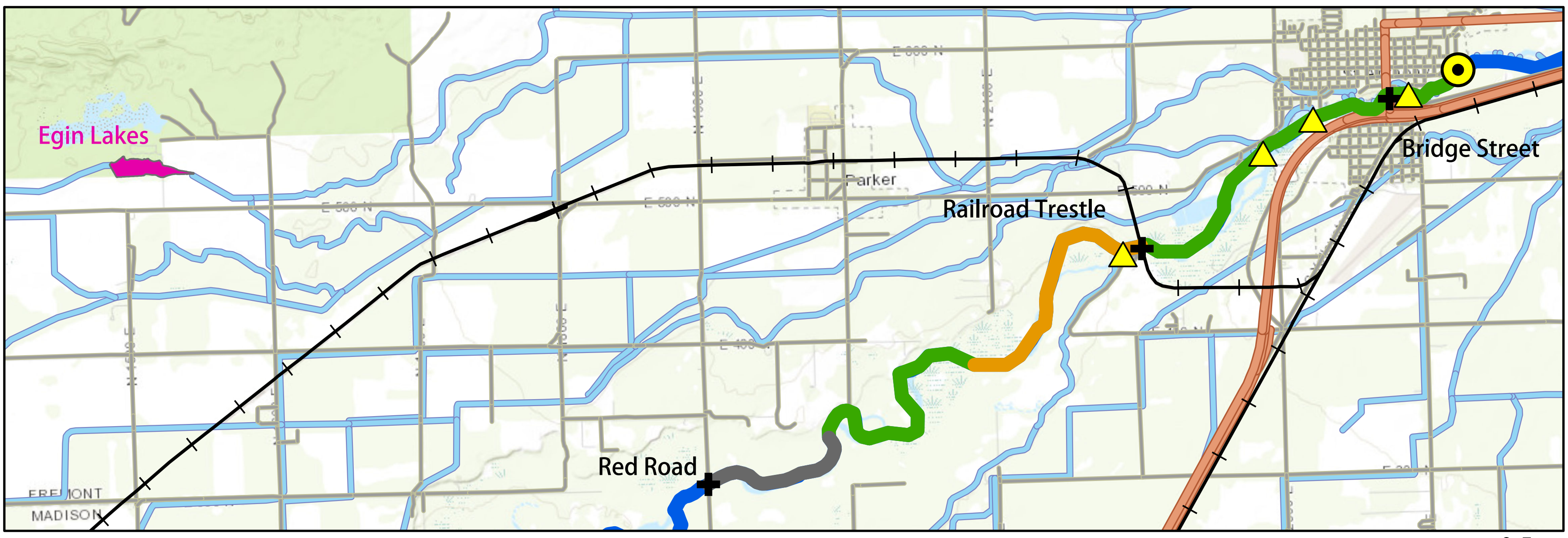
2 Miles



- Henry's Fork
- Tributaries
- Highway
- Streets and county roads
- Canals
- Railroad
- Dams
- Bridges over the Henry's Fork
- Canal diversions
- Managed aquifer recharge site
- Fremont-Madison County line
- 2019 flow measurement reach

## The larger study area

The lower Henry's Fork extends downstream from Ashton Dam. There are 10 canal points of diversion in this reach; Dewey is the northernmost and Consolidated Farmers is the southernmost. A managed aquifer recharge site, Egin Lakes, is located 4 miles northwest of the river near the St. Anthony Sand Dunes. There are nine transportation crossings over this reach, including a railroad trestle bridge. In 2019, we measured streamflow between St. Anthony and Red Road to identify gaining and losing reaches (results below).




0.5 Miles

## 2019 flow measurement reach

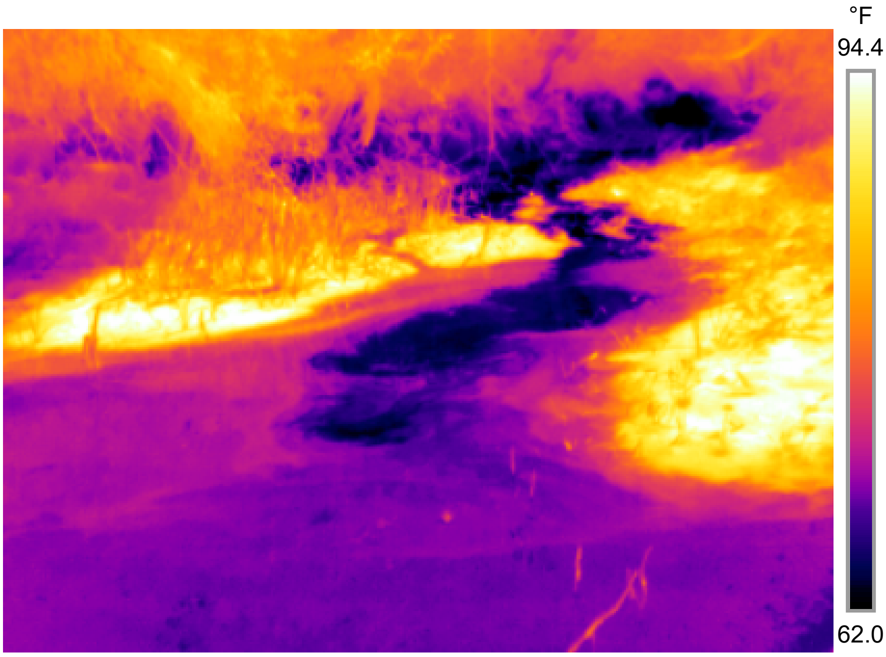
From June 28 to October 7, we took flow measurements with an Acoustic Doppler Current Profiler at four sites between the USGS gage at St. Anthony and Red Road. Reaches by gain or loss are shown above. Gains averaged 100 cfs and losses averaged 120 cfs.

- USGS gage at St. Anthony
- Gaining reach
- Neutral reach
- Losing reach

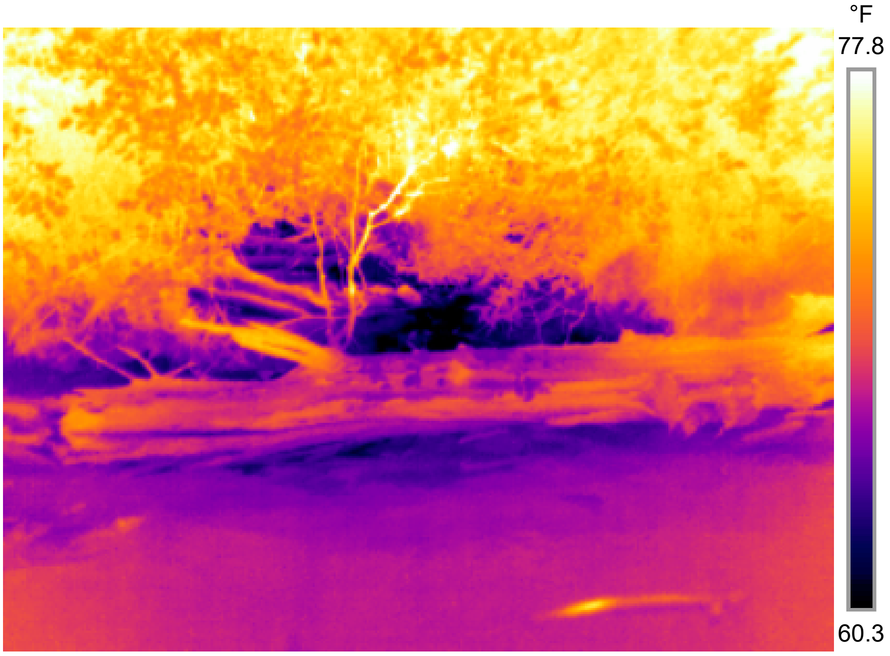
FLIR

Dates of Photo Collection:
07/17/2019 13:00-16:00
07/22/2019 10:00-15:00

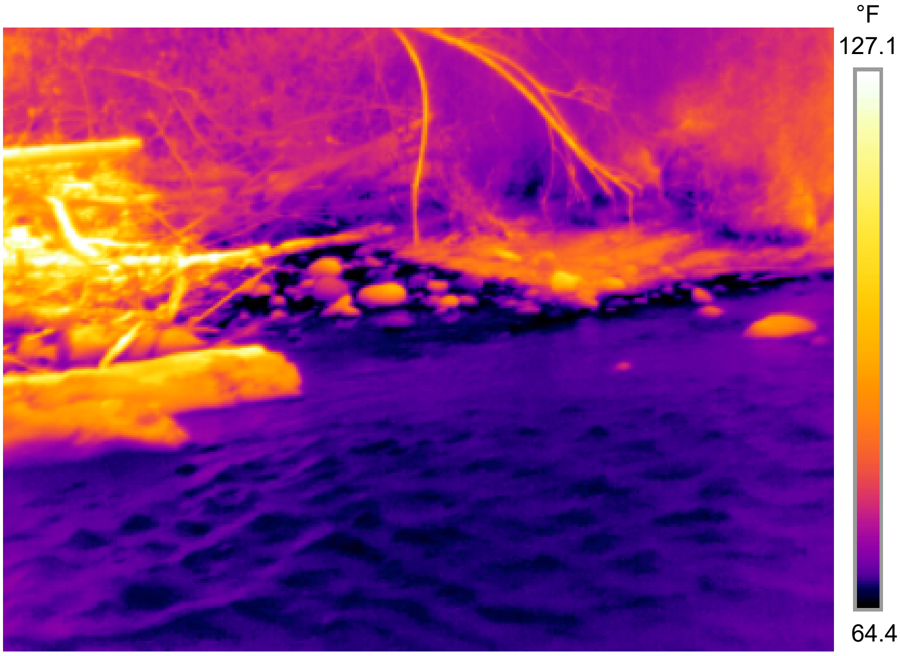
Site 1
Single Discharge Point
43°57.055' -111°43.168'



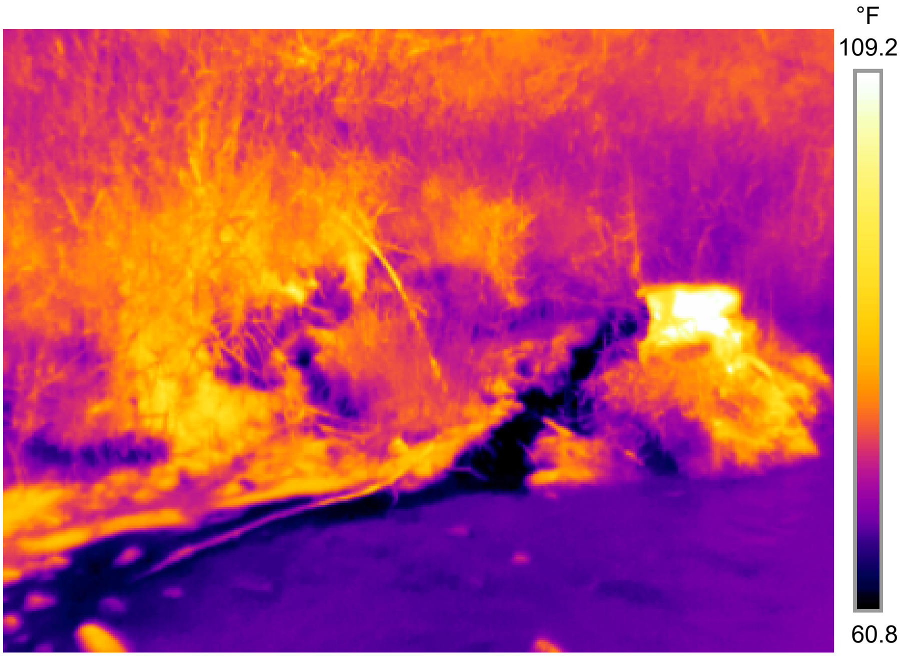

Site 2
Continous Wall Seep (Start)
Length: 107 ft.
43°57.066' -111°43.192'



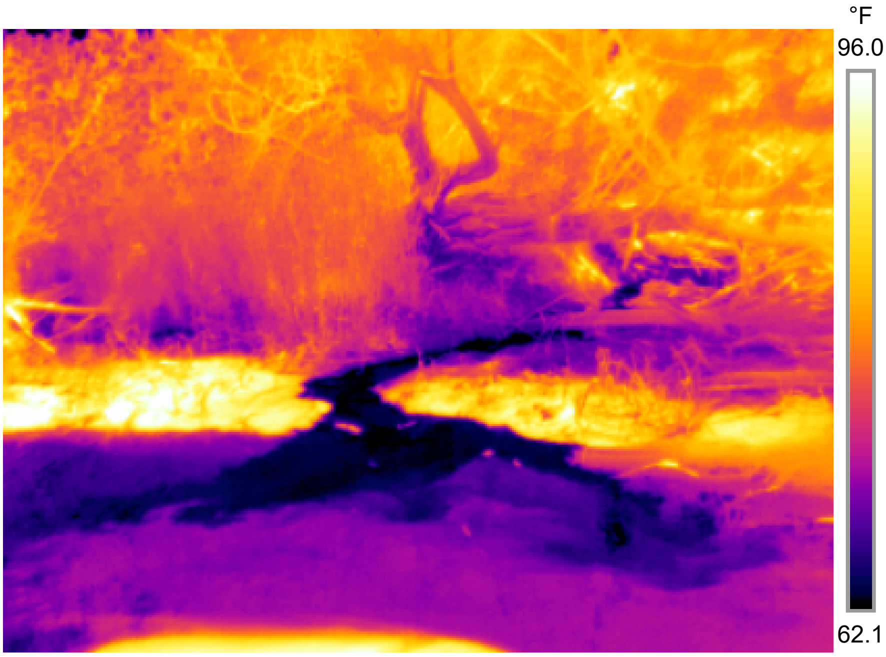

Site 2
Intermediary Section




Site 2
Continuous Wall Seep (End)
43°57.079' -111°43.210'



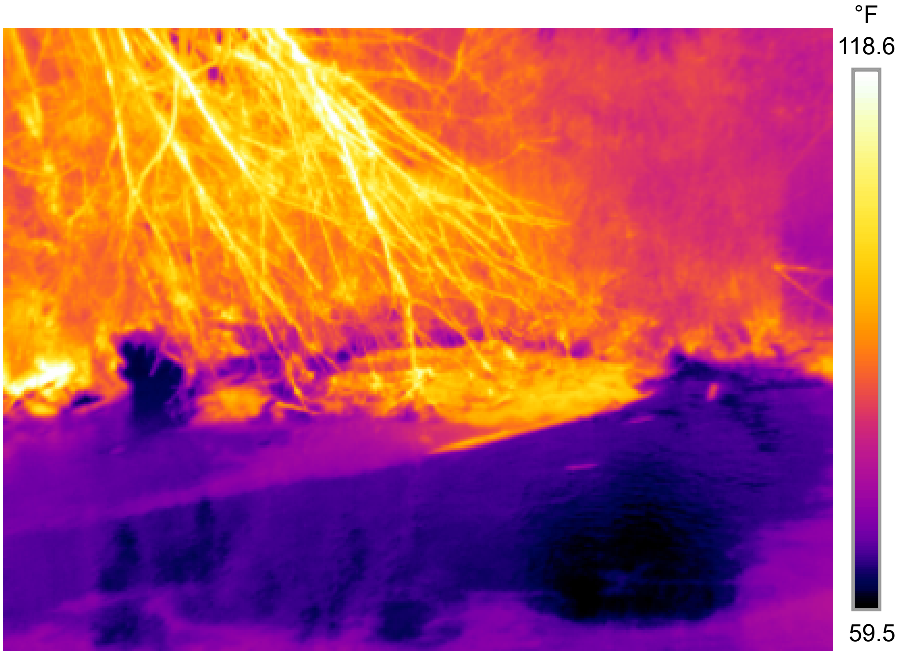

Site 3
Single Discharge Point
43°57.095' -111°43.238'



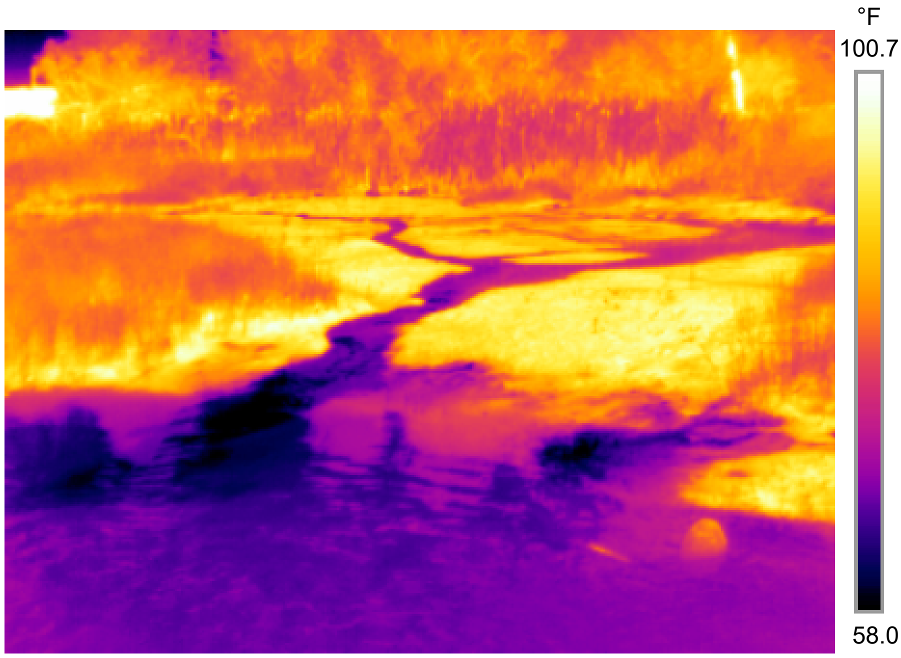

Site 4
Start of Continuous Wall Seep
43°57.079' -111°43.210'

Length: 10 ft.

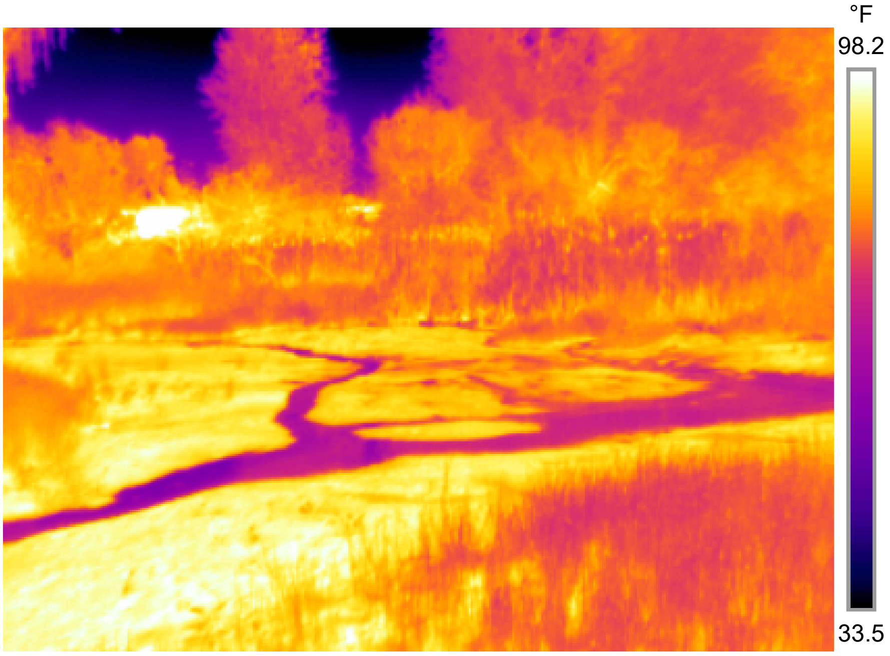
End of Continuous Wall Seep
43°57.097' -111°43.240'



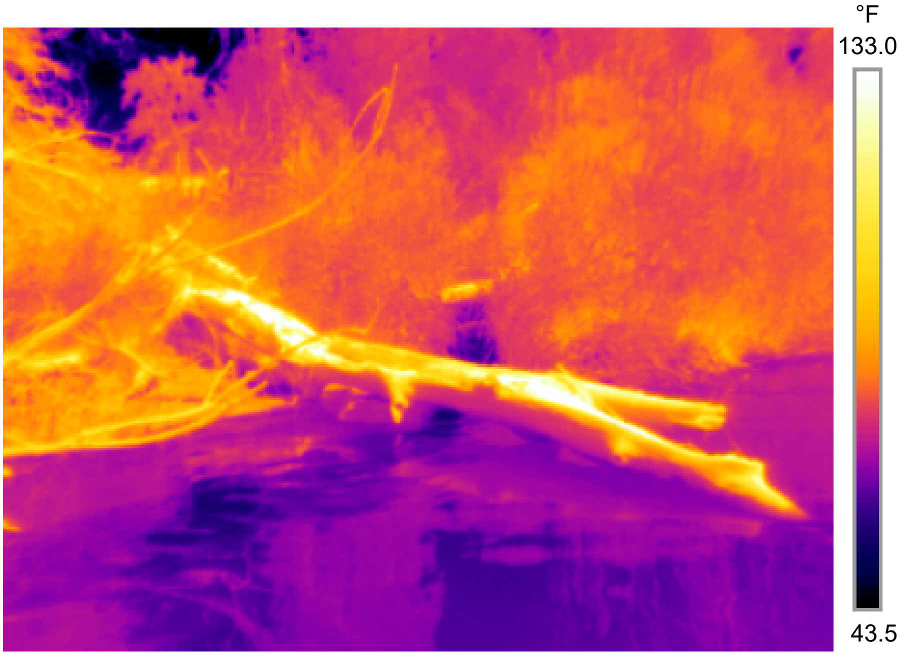

Site 5
Single Discharge Point
43°57.115' -111°43.322'



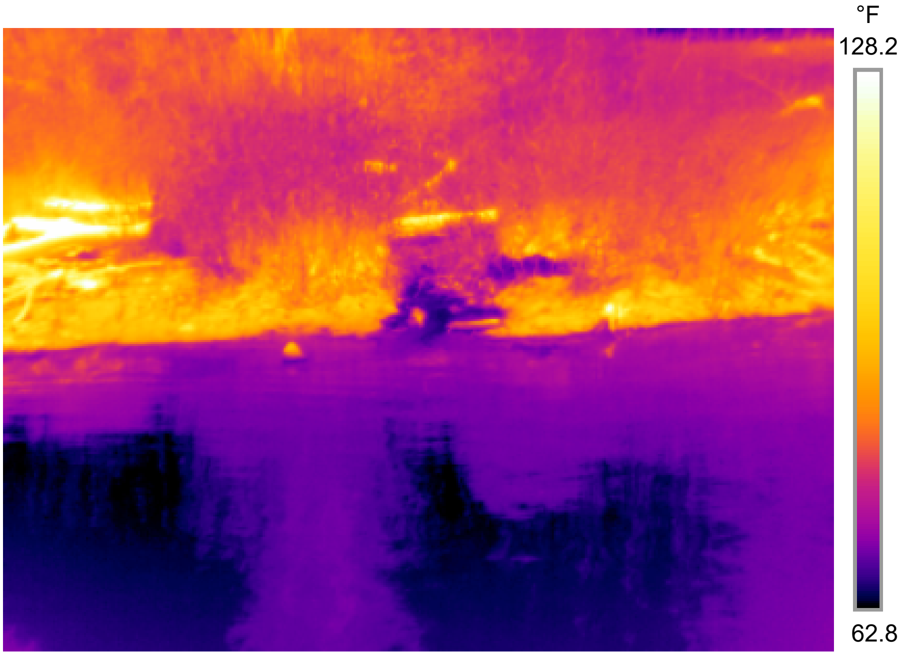

Site 5
Showing wetland-like habitat



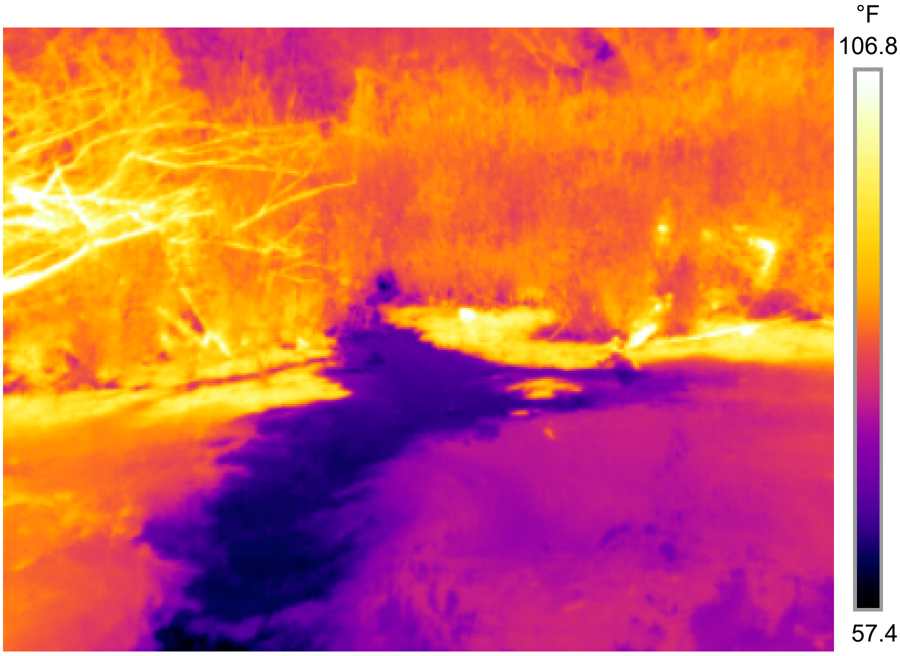

Site 6
Single Discharge Point
43°57.120' -111°43.340'



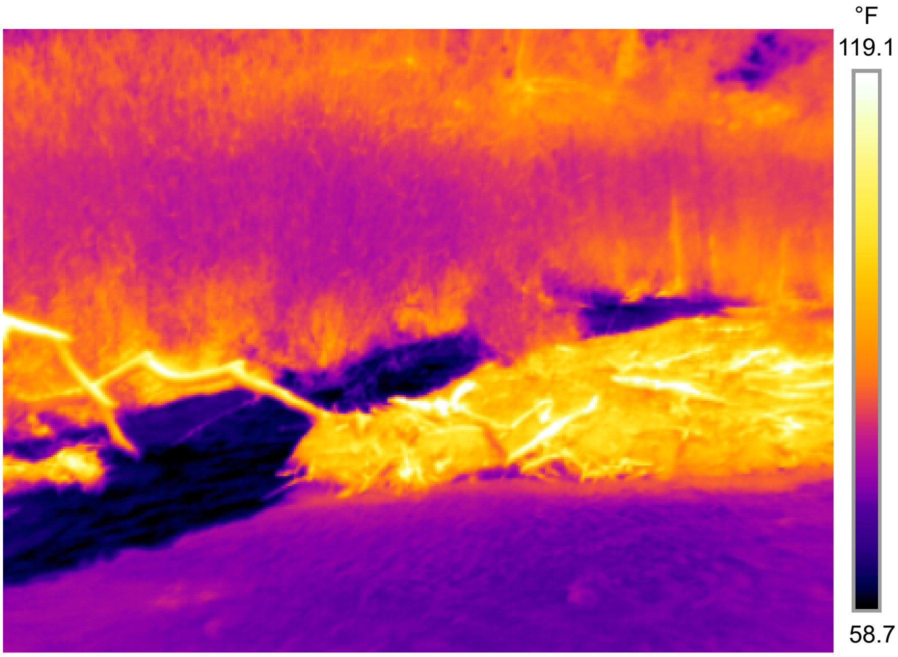

Site 7
Single Discharge Point
43°57.119' -111°43.370'



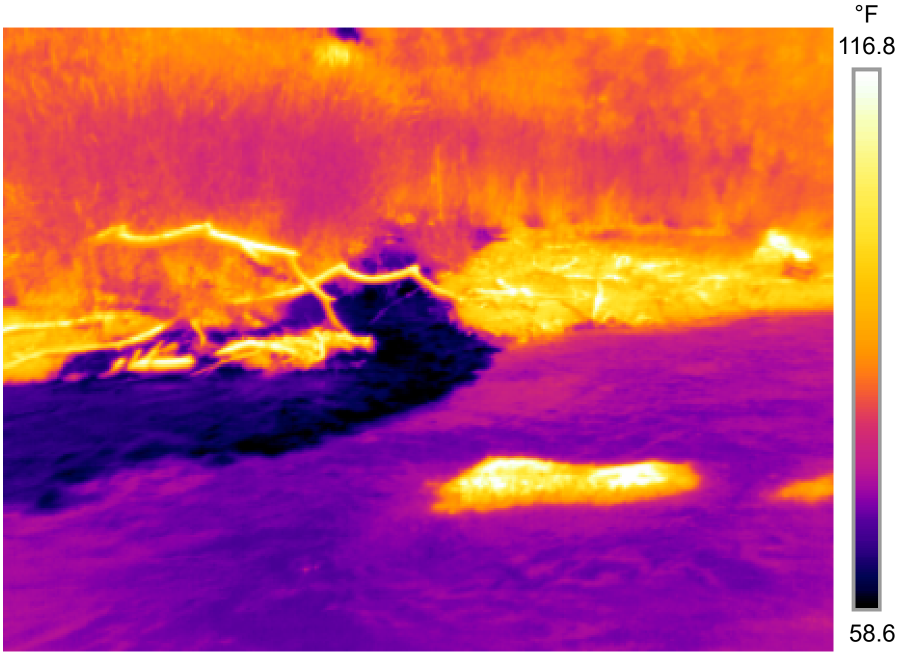

Site 8
Single Discharge Point
43°57.127' -111°43.445



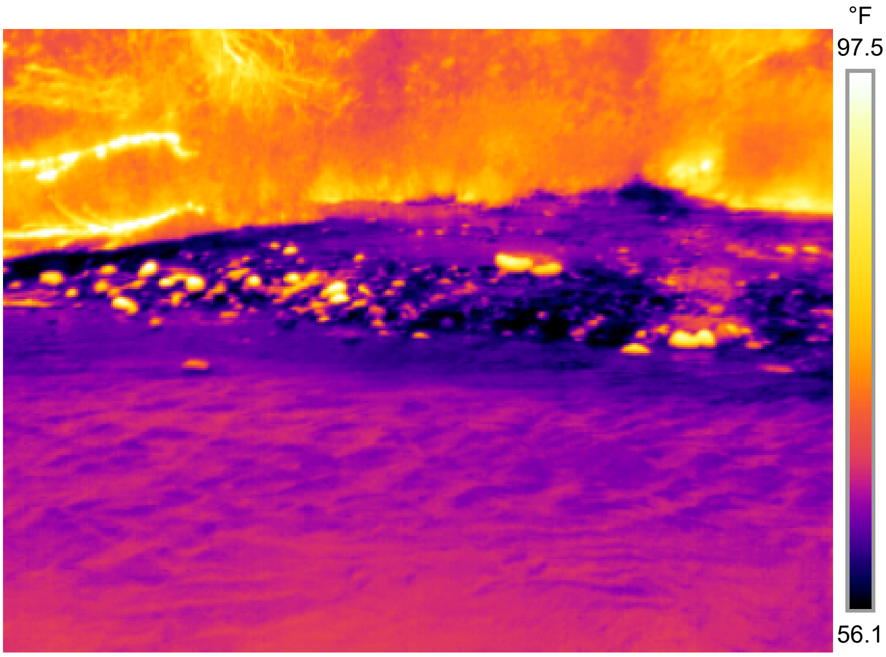

Site 9
Single Discharge Point
43°57.142' -111°43.524'




Site 9
Discharge flowing into the river

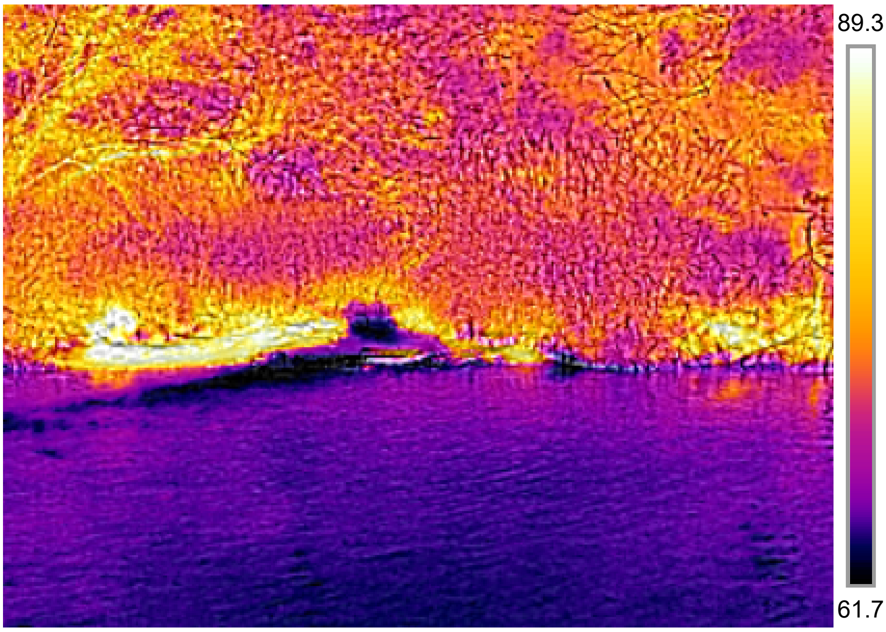



Site 10
Single Discharge Point
43°57.135' -111°43.575'

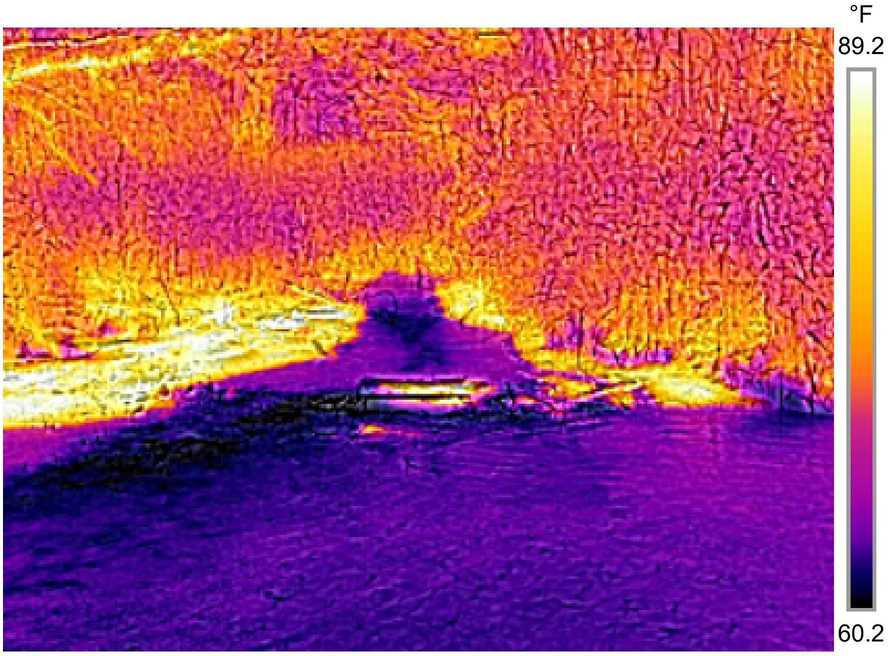



Site 11
Continuous Wall Seep (start)
Length: 184 ft.
43°57.137' -111°43.592'

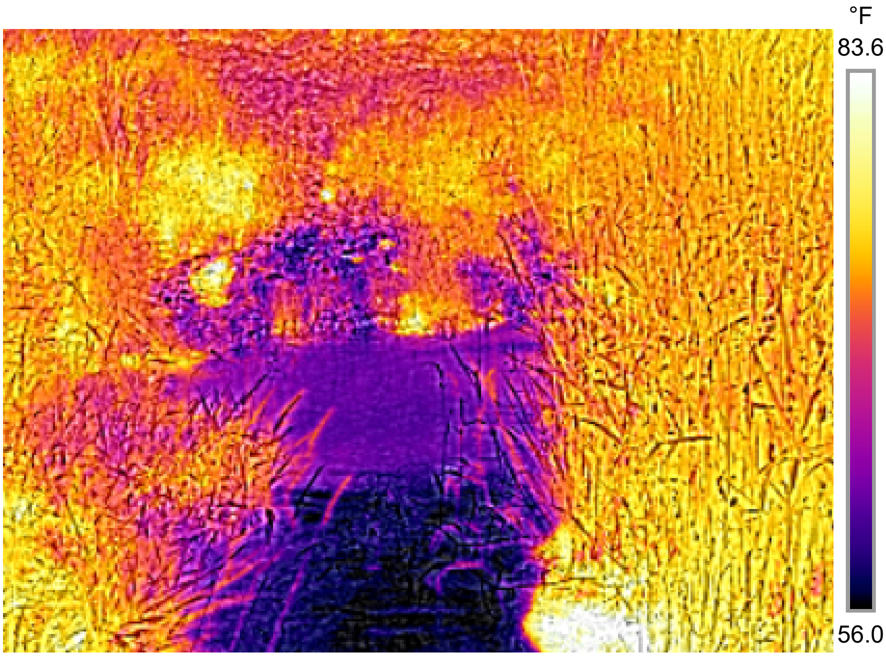
2/10/2000 10:12:43 PM



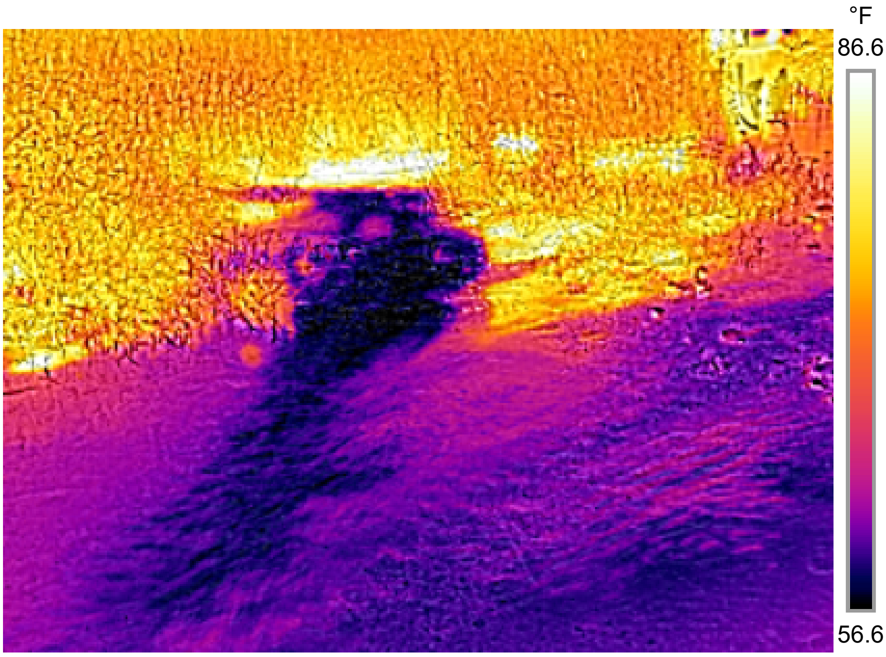

Site 11
Continuous Wall Seep (end)
43°57.118' -111°43.625'



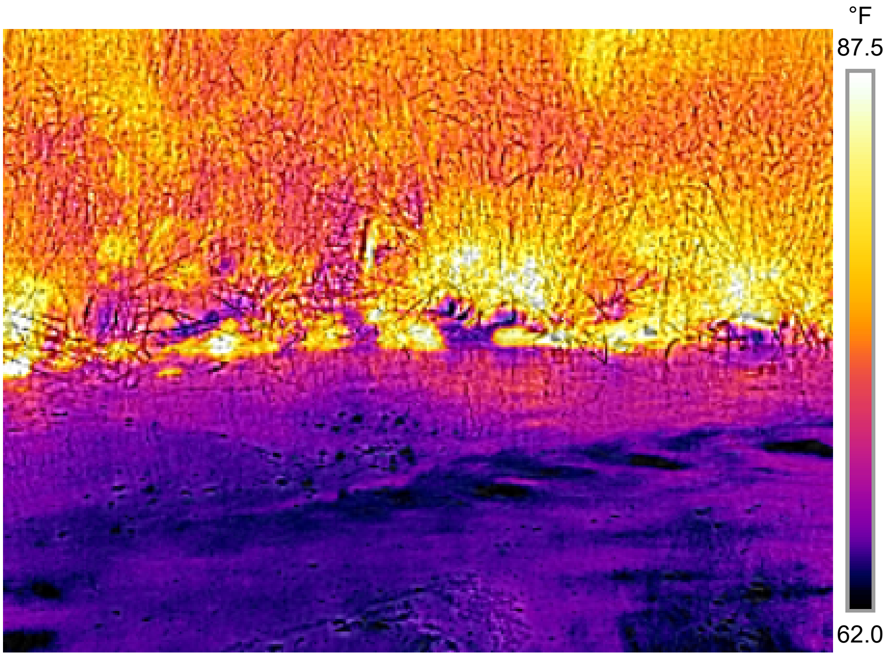

Site 12
Continuous Wall Seep (start)
Length: 24 ft.
43°57.117' -111°43.644'



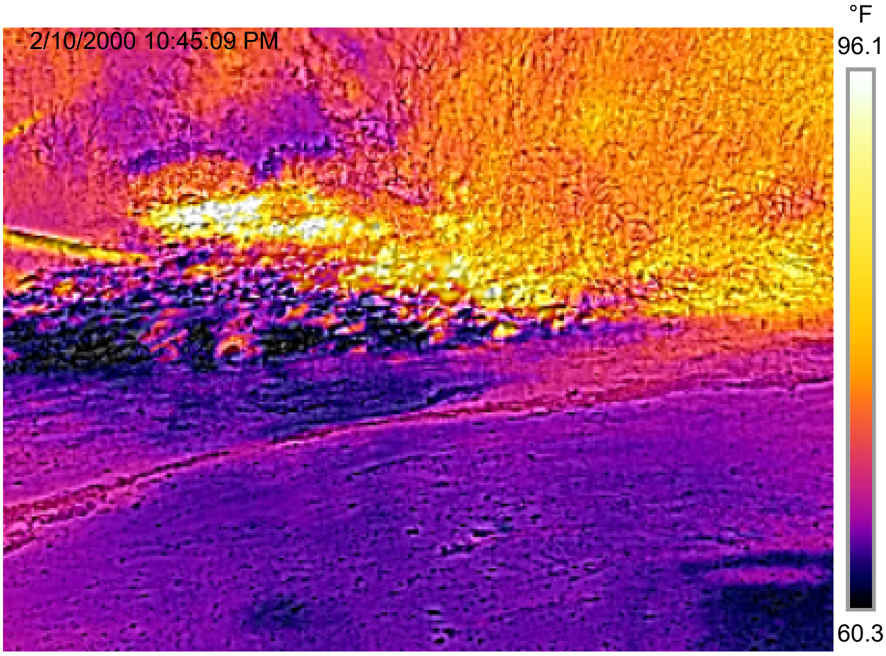

Site 12
Continuous Wall Seep (End)
43°57.115' -111°43.643'



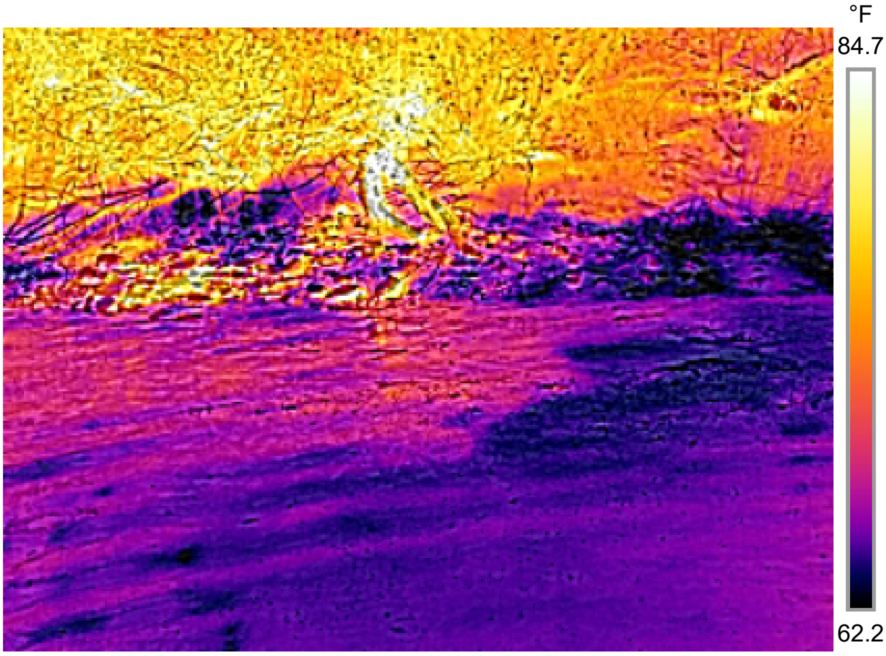

Site 13
Continuous Wall Seep (Start)
Length: 46 ft.
43°57.110' -111°43.653'



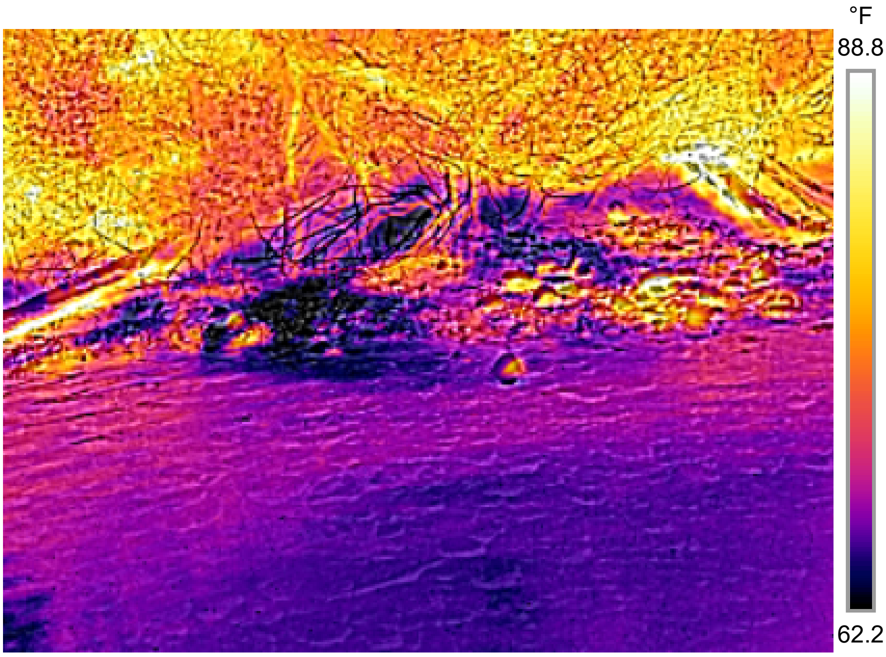

Site 13
Intermediary point showing discharge over gravel



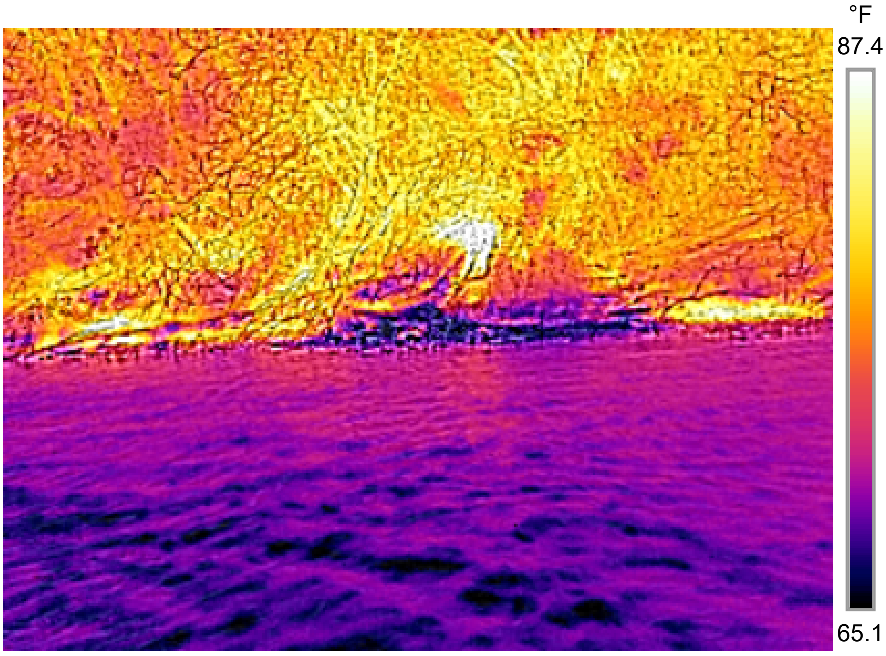

Site 13
Intermediary point showing
discharge over gravel




Site 13
Continuous Wall Seep (end)
43°57.104' -111°43.658'

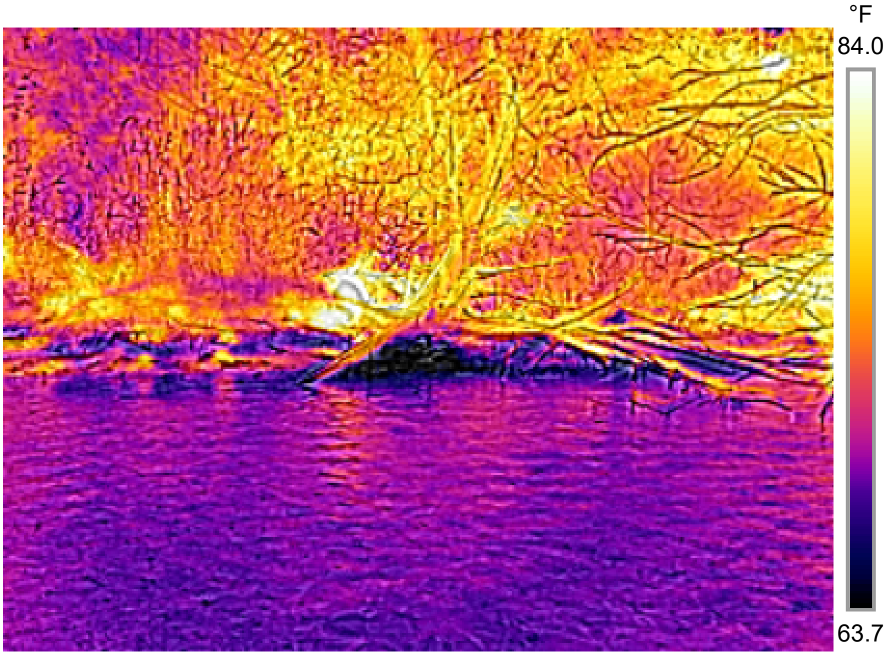



Site 14
Single Discharge Point
43°57.089' -111°43.664'

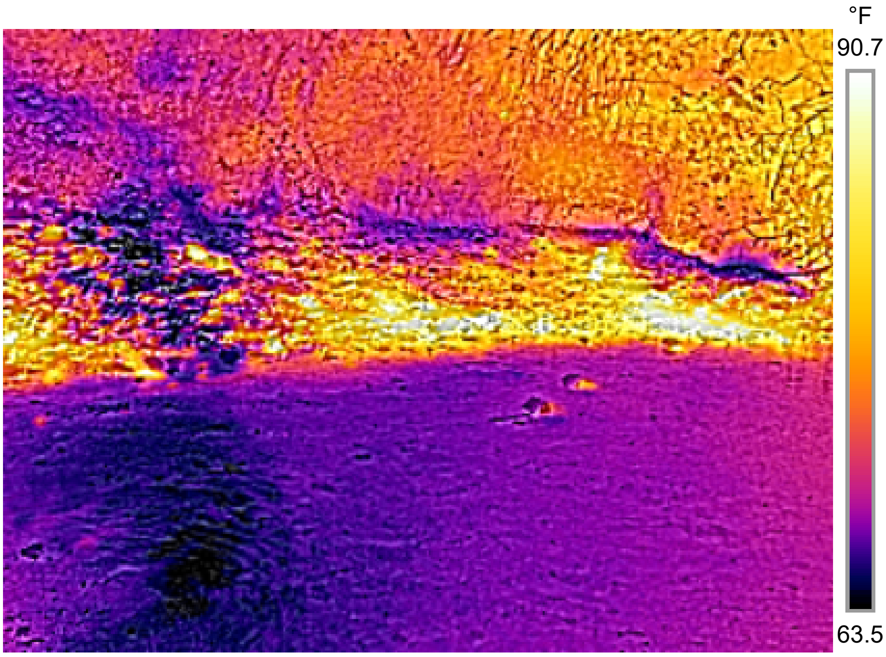



FLIR0023.jpg FLIR T450sc (incl W 62107435

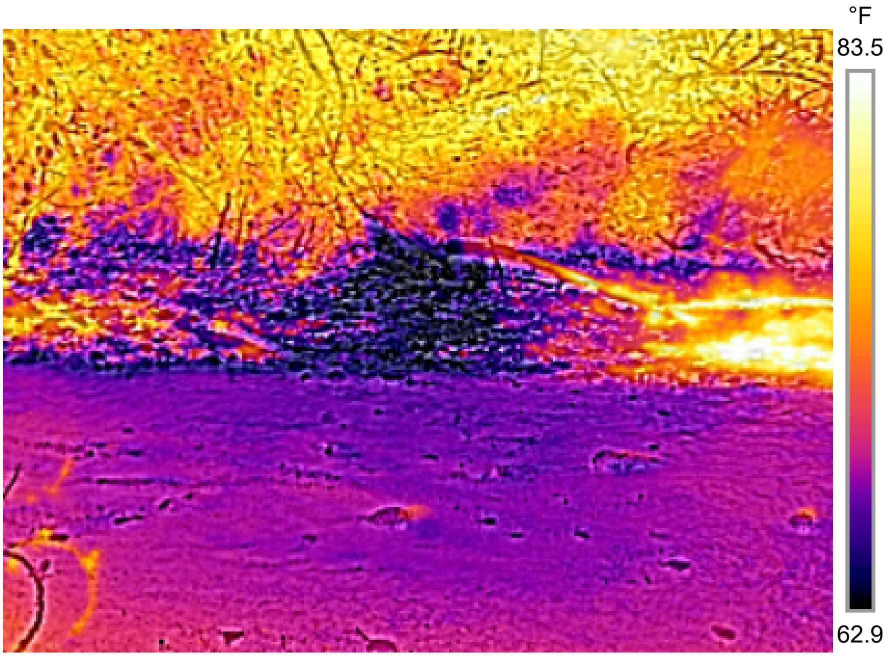
Site 15
Single Discharge Point
43°57.091 -111°43.676'



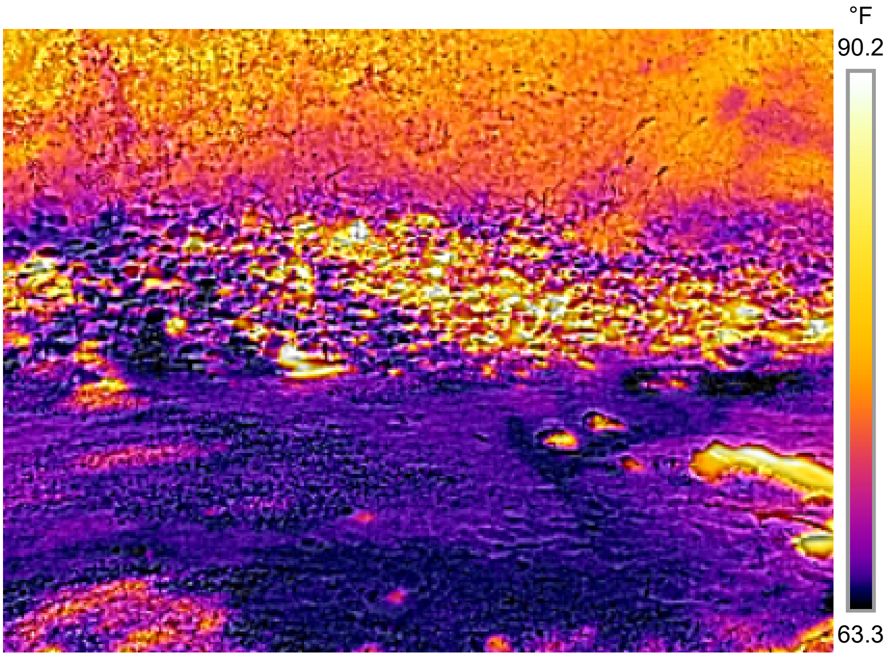

Site 16
Continuous Wall Seep (start)
Length: 978 ft.
43°57.084' -111°43.690'



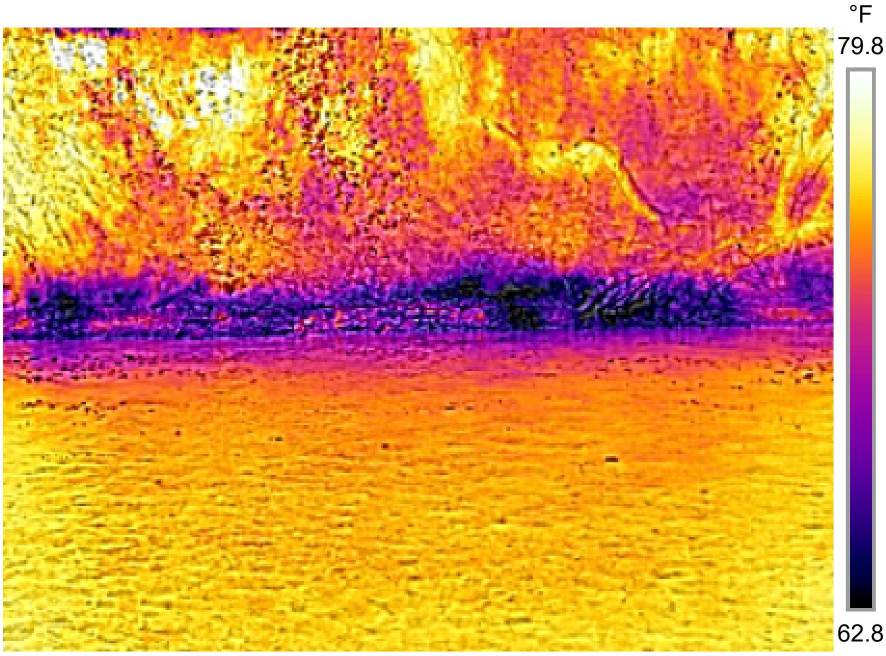

Site 16
Intermediary point showing
discharge over gravel




Site 16
Intermediary Section




Site 16
Intermediary Point




Site 16
Continuous Wall Seep (End)
43°56.934' -111°43.770'