WRPI: Water Resources and Policy Initiatives Final Report

Groundwater Study for the Plum Restoration Project

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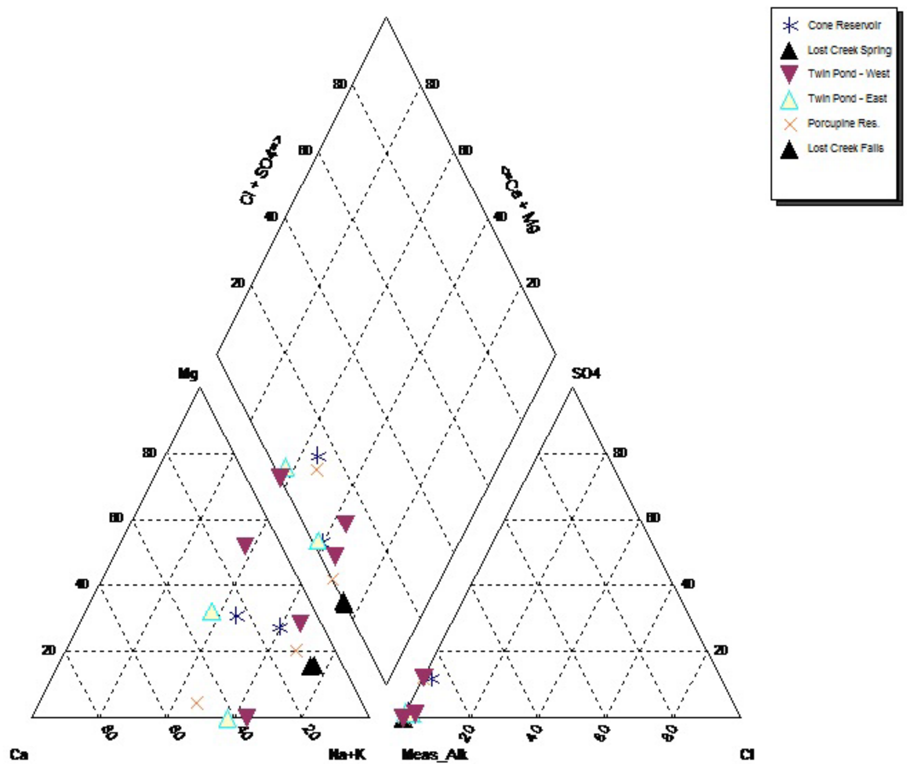

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Cover Figure: Piper plot showing major ion concentrations in mg/L. Separate points for the same sample ID are for different sample dates. Enrichment in several ions in the upper reservoirs is most likely due to evaporative forces, since these ponds are somewhat stagnant and in direct sunlight (with temperatures of 23C + in some cases).

Acknowledgements

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Executive Summary

The Hat Creek Ranger District (HCRD) is located in the Northern-most portion of the Lassen National Forest. Within the HCRD is the proposed Plum project area (Figure 1), which is currently undergoing the environmental analysis process as required under the National Environmental Policy Act (NEPA) of 1970. It includes, an approximately 18,253 acre analysis area that is currently being considered for a long-term landscape level restoration project. Both maintaining and restoring the natural hydrologic character of this area is a key component of this proposed project. Increased use of this area (timber harvest, infrastructure development, cattle grazing recreation, etc.) has led to increased stress on the already limited water supply. To effectively manage this scarce resource, it is vital to understand the origin of the many water bodies and springs throughout the project area.

Lost Creek Spring, an undeveloped spring located midway down the Hat Creek Rim, is one such source. The goal of this project was to determine, as well as possible with the limited resources at hand, the source of these waters. This was attempted through water sample collection and correlation from Lost Creek Spring, one point downstream, and three points that are potential upstream sources. Comparison of these samples, based on water properties such as total dissolved solids (TDS), temperature, conductivity/salinity, and major ions (Ca^+, HCO_3^-, Cl^-, SO_4^-, Mg^+ , $NO3^-$, $NH4^+$), suggests that the spring has a complicated source, that is most likely a mixture of

local surface infiltration and a regional aquifer surfacing at the graben's edge. However, several complicating factors, such as the area's underlying, highly heterogeneous geology partly due to the Lassen Volcanic Center's tectonic gradient superimposed on the regional tectonic gradient, make this a reasonable level of confidence difficult to achieve. Further testing is suggested to determine, with a higher level of confidence, the source of Lost Creek spring.

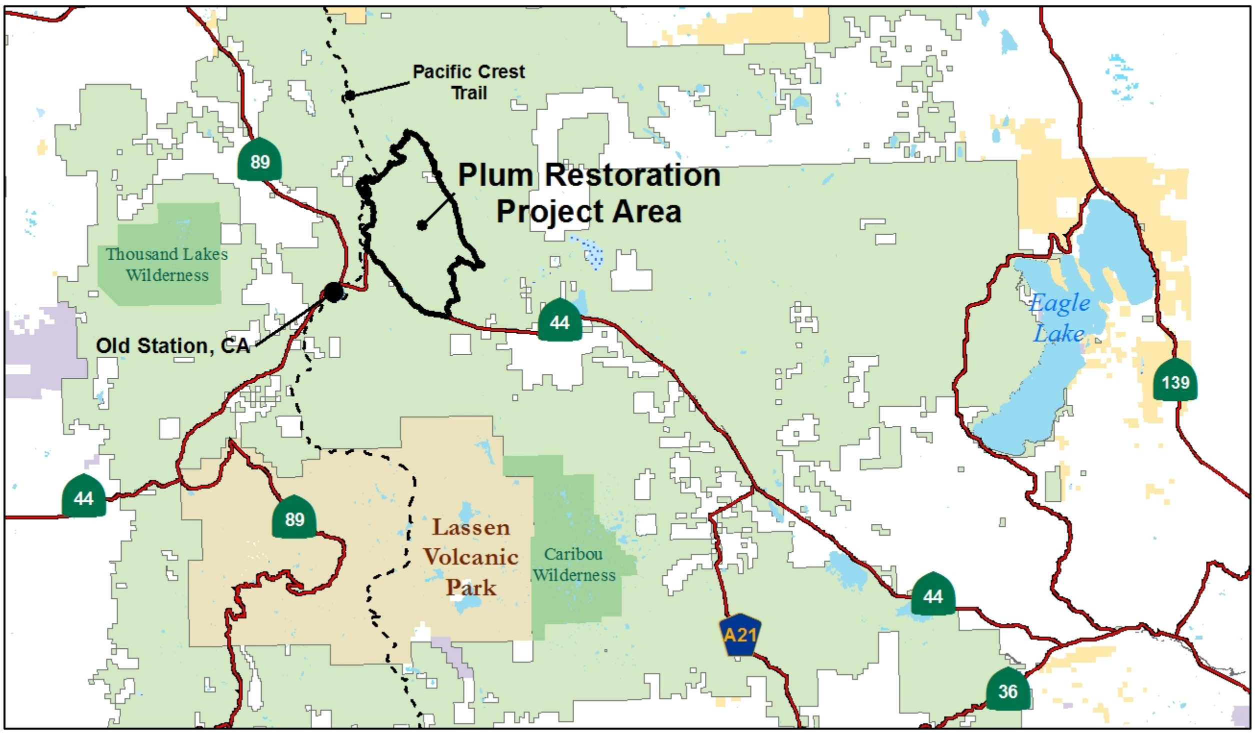

Figure 1: The Plum Restoration Project Area is an 18,000 + sq. km proposed restoration site, located within the Hat Creek Ranger District (HCRD) of Lassen National Forest (LNF). The project is a landscape level restoration project, aiming to restore functionality across many environmental and user access concerns. The Lost Creek Spring is located within the black outlined area. (USDA Forest Service, Lassen National Forest).

Project Objectives

The Plum Restoration project, a proposed landscape level restoration project in the HCRD, has as one of its key purposes to "improve the hydrologic function…" of the designated area, which includes assessing methods for restoring the ability of forest meadows, montane systems, and seasonal wetlands to retain water later into the summer. Knowledge of the source components for each water system is critical to designing management strategies to achieve water retention later into the summer. That water, redistributed into the system, should stay available to plants and wildlife late into the season. The goal of the project at hand is to assess potential sources for the Lost Creek spring.

The Lost Creek spring surfaces in a canyon, approximately midway between the Northern and Southern ends of the Hat Creek Rim, at 4390 ft. elevation. The spring is the primary source for Lost Creek Falls (shown as “Downstream 1” in Figure 2, elevation: 1279m), which provides water to a small, nearby hydroelectric power plant. This is distinct from the Lost Creek that originates within Lassen Volcanic National Park. Above the spring is an ephemeral stream channel, which was dry during this study period. Above the rim is a network of connected reservoirs (shown as “Upstream 1”, through “Upstream 3”). The network between Cone reservoir and Lost Creek falls is underlain by quaternary flood basalts, with a section of alluvial sediments underlying Twin Ponds, the uppermost reservoir. The underlying geology is a complex arrangement of fracture networks from primary cooling, with several later tectonic orientations imprinted over these (the Lassen Volcanic Center’s tectonic gradient is superimposed on the regional tectonic gradient). This had led to a high degree of secondary permeability.

The complex underlying geology, along with the large volume of water that emerges year-round between Lost Creek spring and Lost Creek Falls relative to the overlying rock column, suggests a more complicated mechanism. Several possibilities exist, including a regional western gradient that mixes with infiltration from the highly permeable basalts, before surfacing at and below the spring.

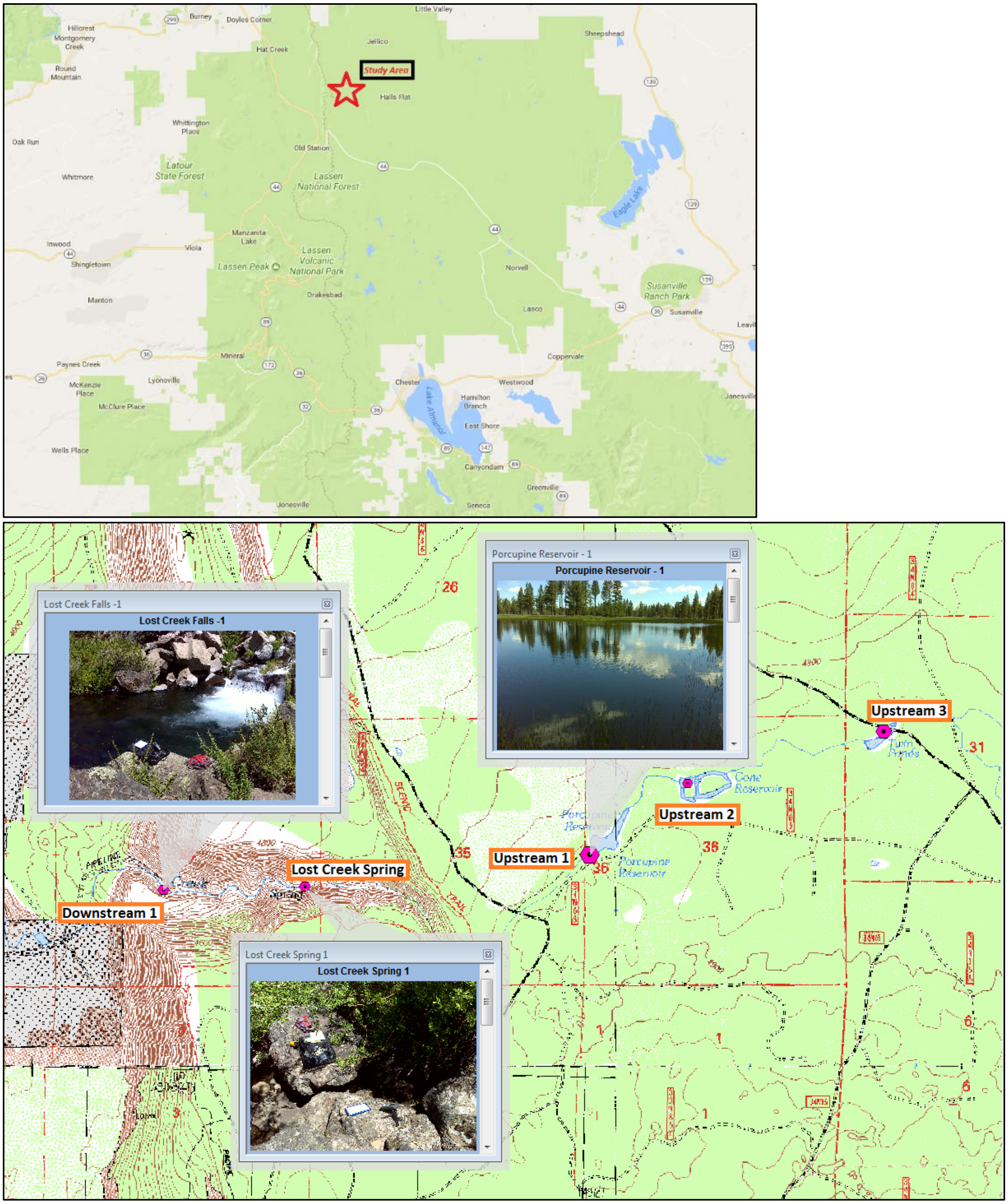

Figure 1: Top panel: Study area within Lassen National Forest. Bottom panel: Sample locations along the Hat Creek Rim. Sample point sizes are displayed as a function of TDS measurements at each site. Note: There was no overland flow during the study period between Porcupine reservoir and Lost Creek Spring, despite the presence of a stream channel indicator on the map.

The goals of this project were to:

- Determine source waters for the Lost Creek spring
- Gain familiarity with the AquaChem program, both in its application to the Lost Creek question, and beyond
- Add all new and existing data to ArcMap for continued analysis by the Forest Service, post-internship
- Explore potential career paths within the Forest Service

Project Approach

Since the presence of a regional flow system under Lost Creek spring is only hypothetical, the project took on an exclusionary approach, i.e. comparing sample parameters of known sites to potentially exclude a deep aquifer. Field measurements (including nitrate and ammonium) were taken with the YSI Professional Plus Multiparameter meter at all sites. Additionally, water samples using whirl-pack sample bags were taken at each site, and later analyzed for major Ions (Ca^+, HCO_3^-, Cl^-, SO_4^-, Mg^+ , $NO3^-$, $NH4^+$) with a YSI YPT950 photometer 9500. Samples were analyzed for Na^+ through a wet chemistry setup. This was done due to lack of available in-situ testing methods for Na^+.

Measurements and samples were taken once at each site during July, 2017, in addition to samples taken the previous year in June. Finally, a HOBO Water Temperature Pro v2 Data Logger was installed at the Lost Creek Falls site on 7/2015, prior to the beginning of this study. Data were taken from the logger, which has taken measurements every 4 hours since its installation.

Parameters of primary interest were TDS, temperature, salinity/conductivity, and major ions. TDS values of under 100mg/L can be a reliable indicator of the absence of groundwater [1]. Similarly, temperature values above a certain range, or that vary substantially throughout the year, are also indicators of a lack of groundwater input. Analysis of water types was done through the Waterloo Hydrogeologic program, AquaChem (https://www.waterloohydrogeologic.com/aquachem/).

Project Outcomes

TDS values across all measured sites were substantially lower than is typical for groundwater. Values below 100 mg/L are thought to not have the requisite time below ground to weather material and dissolve that material into solution. Sites with TDS above 100 mg/L, which is not a definitive signal of groundwater, were somewhat stagnant ponds with high temperatures. Higher TDS values at these sites are most likely due to evaporative enrichment of salts and organic matter. This effect was enhanced at the time of sampling by the absence of any significant storm since late spring.

Sample	Date	Correlation Coefficient	Points used for correlation	Water Type
Lost Creek Spring	7/12/2017	1	9	Na-HCO3
Lost Creek Falls	7/13/2017	0.999	9	Na-HCO3
Cone Reservoir	7/18/2017	0.992	7	Na-Mg-Ca-HCO3
Twin Pond - West	7/18/2017	0.969	8	Na-Mg-HCO3
Twin Pond - East	4/30/2016	0.884	9	Na-Mg-Ca-HCO3
Twin Pond - West	4/30/2016	0.877	9	Mg-Na-HCO3
Cone Reservoir	5/26/2015	0.872	7	Na-Mg-HCO3
Porcupine Res.	5/26/2015	0.858	7	Ca-Na-HCO3
Porcupine Res.	7/18/2017	0.857	9	Na-Mg-HCO3
Twin Pond - West	5/26/2015	0.85	6	Na-Ca-HCO3
Twin Pond - East	5/26/2015	0.835	5	Na-Ca-HCO3

Figure 3: Table showing correlation coefficients and water types from AquaChem.

A piper diagram plots all samples as somewhat similar water types, ranging from Na-HCO3 (Lost Creek Spring and Falls) to Na-Mg-HCO3 (Twin Ponds). However, the inconsistency in analysis techniques between ion measurements via photometer, and Na^+ measurements, is a potential source for error. Lost Creek Falls and Spring plot almost identically. Running a sample correlation matrix through AquaChem also correlates the two samples at r=.999 based on 9 sample parameters

(Figure 3). The parameters used for correlation include major ions, temperature, TDS, conductivity, DO, pH, and nitrate, and ammonium for the samples taken in 2017. This indicates that the same network that feeds the spring does indeed feed the falls, rather than a fracture network delivering water between the spring and falls, or some other unique geologic mechanism. Samples upstream also show high correlation coefficients of 83% or greater with the Lost Creek spring sample.

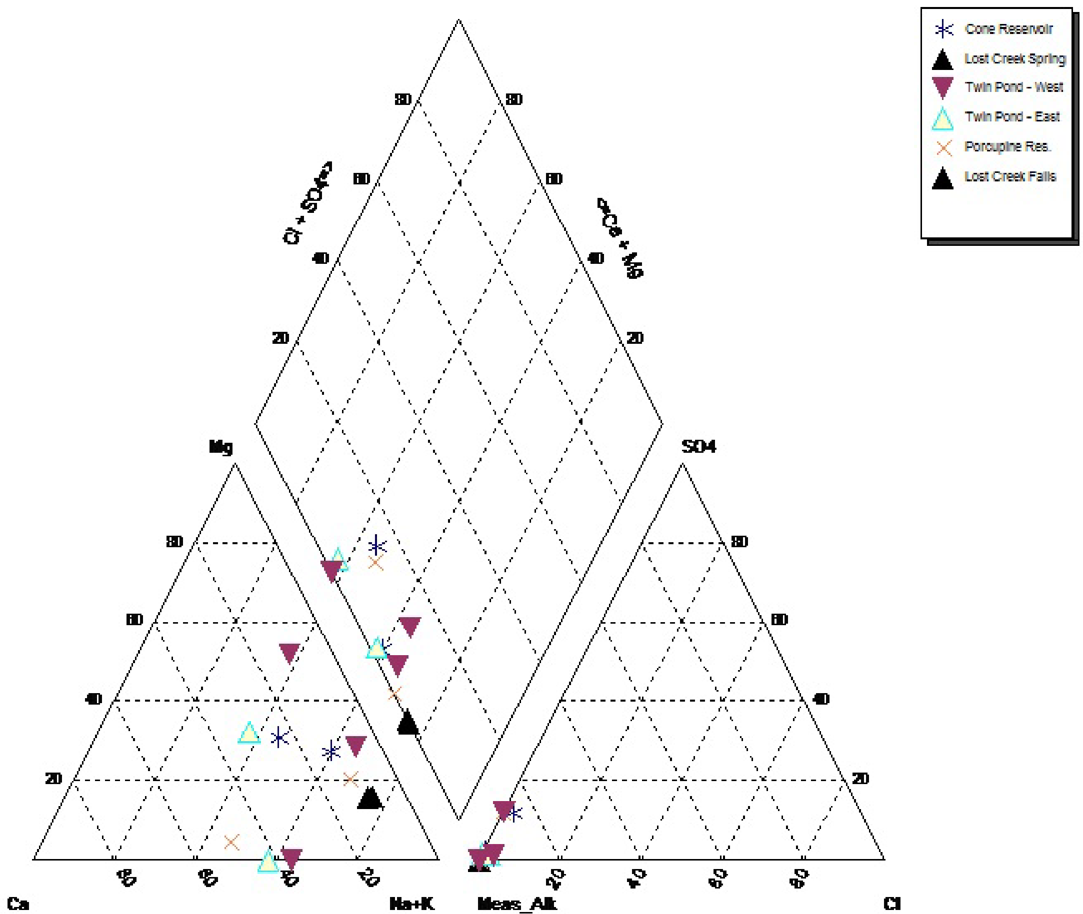

Figure 4: Piper plot showing major ion concentrations in mg/L. Separate points for the same sample ID are for different sample dates. Enrichment in several ions in the upper reservoirs is most likely due to evaporative forces, since these ponds are somewhat stagnant and in direct sunlight (with temperatures of 23C + in some cases).

Temperature data from Lost Creek Falls closely track seasonal patterns (Figure 6), with a yearly average temperature of 8.12 C (46.61 F) for 2015-2016, and 7.85 C (46.13 F) for 2016-2017. Temperature lows peak in mid-winter, and the temperature arc remains relatively stable throughout the spring, summer and fall months. Water temperatures that track seasonal changes can indicate a surface water source, mixing, or the influence of air temperatures on the probe. The overall temperatures are also slightly higher, but in line with a nearby groundwater spring. Big Spring, which is a groundwater driven spring in the Hat Creek Basin, had a temperature of 7.4C on 7/22/16 at its outlet, versus a Lost Creek Falls temperature of 8.5C on the same date.

Conclusions

The high correlation between samples, the related water types, and the measurements taken, point away from the influence of a deeper aquifer. However, the data collected are not a definitive confirmation of the spring's water source. For example, although low TDS values are suggestive of the primary component being surface water, they could also indicate fast moving groundwater (via fracture flow) that does not have ample time for minerals to dissolve into solution. As mentioned above, the groundwater around HCRD is primarily fracture flow dominated. The fact that the samples are well correlated could be due to surface reservoir infiltration draining and mixing with a deeper aquifer unit.

There are several ways to potentially resolve with more certainty the source of the waters which create Lost Creek springs and falls. A tracer test, accomplished by injecting a dye into the reservoir network, could also be done, although this method is somewhat costlier and time intensive. Additionally, testing for radon is a proven method for detecting groundwater. As uranium/radium decay in rocks, they produce radon, which dissolves into and travels conservatively with groundwater. However, radon volatizes easily once the water interacts with the atmosphere, leaving surface water with essentially zero concentrations. The presence of radon in any substantial amount at the spring should be a reliable indicator of a deep aquifer source.

Discharge measurements at several points throughout the year, both at Lost Creek Falls, and below the falls, would also lend perspective. If discharge remains relatively stable throughout the year, this could indicate the presence of a larger aquifer unit. Additionally, there exists an approximately 800 ft. deep production well on top of the Hat Creek rim, in the Halls Flat area, which can be pumped and analyzed. Gathering temperature gradients from the well, which is believed to be unscreened for its entire length, could lend insight into the vertical extent of the water bearing units, and the amount of surface water mixing.

Internship Assessment

The joint WRPI / Forest Service internship has allowed me a detailed look at the potential career opportunities within the Forest Service. Through this program, I have expanded my working knowledge of field hydrology and instrumentation, as well as engaged in many absorbing hydrologic projects. To be sure, I have grown my research skill set this summer, and now consider the Forest Service as a definite potential career pathway.

References:

State Water Resources Control Board, 2016, Groundwater Information Sheet: Salinity: http://www.waterboards.ca.gov/gama/docs/coc_salinity.pdf (accessed July 2017).

USDA Forest Service, Lassen National Forest, 2017, Plum Restoration Project Draft Project Description.

Appendix:

Station ID	Sampling Date []	Temp [°C]	pH	DO [mg/l]	El. Cond. [uS/cm]	TDS [mg/l]	Ca [mg/l]	Mg [mg/l]	Na [mg/l]	K [mg/l]	Cl [mg/l]	HCO3 & CO3 [mg/L CaCO3]	SO4 [mg/l]	NO3 [mg/l]	NH4 [mg/l]
Twin Pond - West	7/18/2017	23.3	8.83	5.1	161.8	108.55	6	17	72.68	1.8	4	180	2	2.7	0.05
Twin Pond - East	5/26/2015		7.67		80.2	57.6	12	0	17.5	2.7	0	60	1	0	
Twin Pond - East	4/30/2016	15	8.51	10.7	94.2	75.4	14	9	19	1.2	1	75	1	1.43	
Twin Pond - West	4/30/2016	15.1	8.83	11.9	99.3	79.3	4.4	13	17	1.3	0	75	0	0.49	0.03
Twin Pond - West	5/26/2015		7.48		127.7	88.9	10	0	18.4	3	0	60	8	0.46	
Cone Reservoir	5/26/2015		7.53		99.6	70.6	9	7	18.4	1.8	1.2	60	8	3.95	
Cone Reservoir	7/18/2017	23.4	7.18	4.4	236.5	-	14	18	72.68	2.1	1	210	4	1.98	0.07
Porcupine Res.	7/18/2017	19.1	6.1	2.1	182.8	134.55	12	13	81.88	0	0	190	0	1.65	0.05
Porcupine Res.	5/26/2015		7.45		118.3	83.3	18	1	18.4	2.5	0	70	9	0.66	
Lost Creek Spring	7/12/2017	7.9	7.54	11	80.3	77.35	6	7	60	2.2	4	120	0	0.31	
Lost Creek Falls	7/13/2017	8.7	7.55	11.3	83.6	78.65	7	7	61	2.2	0	130	0	3.4	0.34

Figure 5: Table showing values measured by YSI multimeter (Temp, pH, DO, Cond, TDS, NO3 & NH4) and by photometer (Ca, Mg, Na, K, Cl, HCO3 & CO3, & SO4)

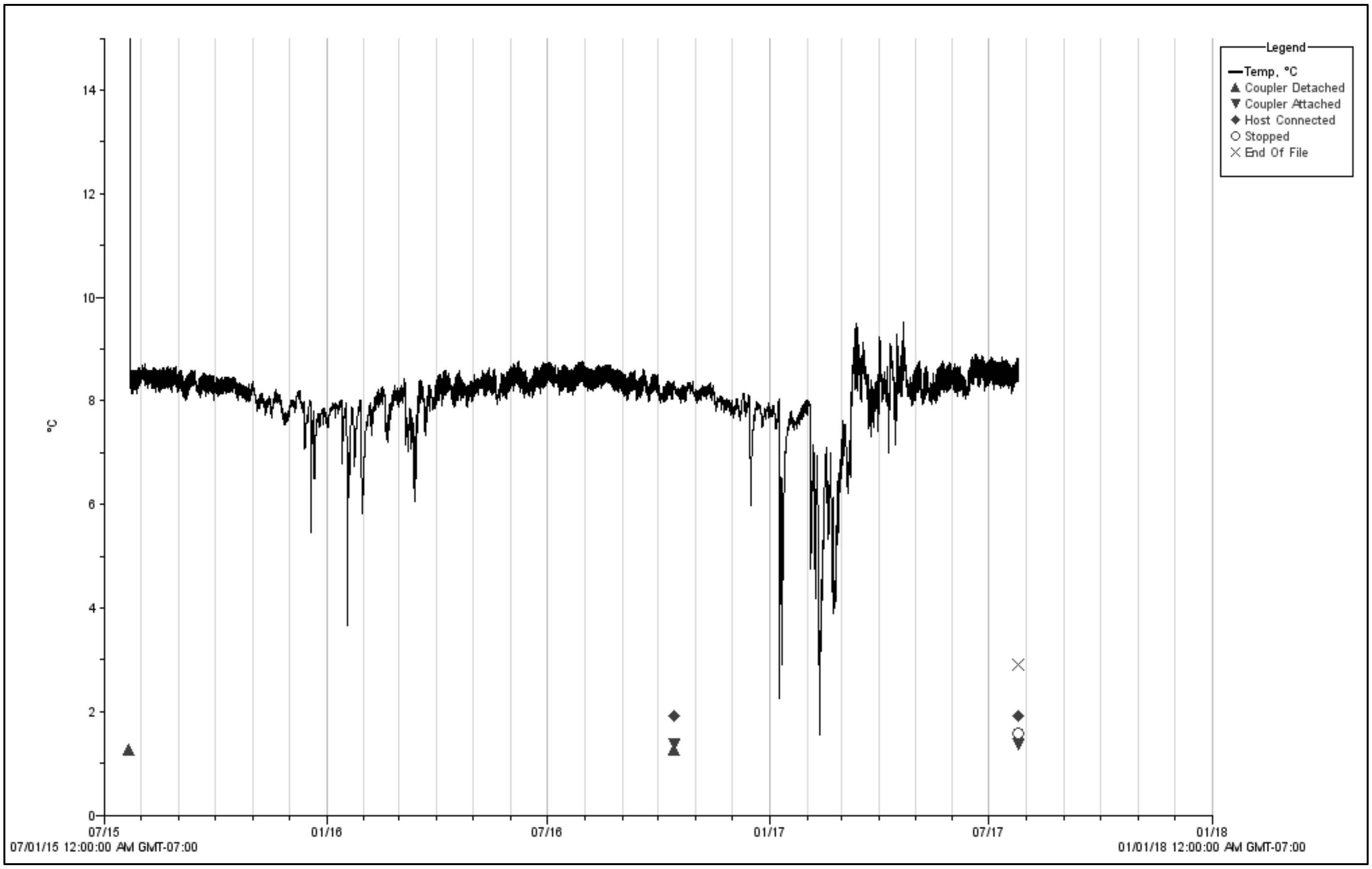

Figure 6: Temperature log at Lost Creek Falls for July 2015 to July 2017. The temperature closely follows seasonal patterns, with cold spikes arriving and peaking in the winter months, and relatively stable temperature arcs through the spring, summer and fall. This is indicative of a water source primarily composed of surface water.