WRPI: Water Resources and Policy Initiatives Final Report

Hydrologic and geologic review of the Hat Creek Basin and surrounding area

Sean Spencer
California State University, Fresno
WRPI Internship: May-July, 2018
Advised by Shawn Wheelock, Hat Creek Ranger District Hydrologist
Lassen National Forest

Table of Contents

Acknowledgements

This project was supported by Hispanic-Serving Institution's Education Program Grant no. 2015-38422-24058 from the USDA National Institute of Food and Agriculture. Additionally, I would like to express my gratitude for the support of my internship supervisor, Shawn Wheelock, the Hat Creek Ranger District Hydrologist of the Lassen National Forest. With his guidance and mentorship, this internship was an extremely educational, informative, and valuable experience.

Executive Summary

The Lassen National Forest is located in northeastern California and has three separate districts: the Eagle Lake Ranger District, the Almanor Ranger District, and the Hat Creek Ranger District in which this internship took place. In the Hat Creek Ranger District there are several projects being planned and implemented in order to care for the forests and grasslands in the district. In order to achieve this, the Hat Creek Ranger District must utilize the varied skillsets of its employees to build a robust and comprehensive plan for each project. This internship project was tasked to review and understand the hydrology and geology of the Hat Creek Basin and Lost Creek area in order to provide better background information for potential future projects by the Hat Creek Ranger District in the area. The Hat Creek Basin is an area that geologically has undergone faulting and periods of volcanism during the Quaternary. This interaction between the underlying geology, faulting, and the volcanic flows has led to displacement of the rock layers and created an environment promoting conduit-flow for the local springs and streams. Hat Creek Basin hosts several cold springs that originate from Quaternary basalts with varying discharges.

Water temperatures measured at these springs show a lack of deep groundwater circulation, implying aquifer volume is insufficient to account for high discharge rates. Large springs in the Hat Creek Basin show rapid flow decreases during drought periods which suggests the aquifer interconnectivity to the recharge area is at a high level, making long-term storage at the Hat Creek Basin aquifers unlikely.

Project Objectives

The Hat Creek Ranger District of the Lassen National Forest must understand the area comprehensively in order to implement robust project plans with the goal of maintaining a healthy and productive forest. In order to accomplish this, as a Hydrology Intern, I was tasked to review and understand the hydrology and geology of the Hat Creek Basin and Lost Creek area (a separate stream from the Lost Creek located in Lassen Volcanic National Park). In order to provide better background information for potential future projects, this in-depth review of scientific publications specifically looked at:

- The underlying geology of the Hat Creek Basin area
- Lost Creek and the geologic features that it interacts with
- The hydrologic dynamics between the streams/springs of the Hat Creek Basin area

In addition to this hydrologic and geologic review, the internship focused on exposure to the work and practices of the Forest Service, being immersed in several projects that are at various stages of planning or completion, and exploring potential future career paths through the Forest Service.

Project Approach

Due to the extensive geologic research done on the Lassen volcanic area, there are numerous research papers detailing the geology and hydrology of the Hat Creek Basin area. Using several highly cited papers I was able to compile a robust catalog of studies in order to best understand the hydrology and geology of the Hat Creek Basin area.

Project Outcomes

The Hat Creek Basin is within the Lassen volcanic area (Fig. 1), the southernmost point of the Cascade range, and is influenced by two region-wide geologic features: the extensional Basin and Range province and the subduction-created Cascade volcanic arc (Guffanti and Weaver 1988). The Lassen volcanic area is made up of hundreds of relatively small to intermediate volume volcanoes that frame a few large volume volcanoes (Clynne 1990). The Hat Creek Basin area is extensively covered by the Hat Creek basalt (Fig. 2). The Hat Creek Basalt is a relatively young lava flow that erupted between 15 and ~40 ka, erupting near the town of Old Station and flowed in a northerly direction. The Hat Creek basalt contains a high number of fractures and lava tubes, creating an environment that is highly permeable to groundwater flow (Anderson 1940). The Hat Creek Basin is bounded to the south by the Lassen volcanic area (Clynne 1990) and the Pit River forms the northern margin of the drainage basin (Rose 1996).

Throughout the Hat Creek Basin there are several normal faults with a northwesterly trend (Fig. 3), with the most dominant being the Hat Creek fault (Blakeslee and Kattenhorn 2013). The Hat Creek fault extends ~35 km from the town of Old Station northward to the Pit River and has

a vertical displacement in some areas of over 500 m (Muffler 1994). The east side of the Hat Creek Basin, the Hat Creek Rim, has Pliocene and Pleistocene basalt flows that are the same as those found beneath the Hat Creek basalt on the Hat Creek Basin valley floor (Macdonald 1964).

Water in the Hat Creek Basin typically flows in a northerly direction, following the local topography. The fractured and faulted volcanic rocks covering the valley floor promotes a very permeable medium for water to flow through, providing an area where the hydrologic nature of the surface water and groundwater becomes closely linked. Due to localized outflow of springs in the Hat Creek Basin, a system exists where the common springs and disappearing streams of the Hat Creek Basin deal with factors of structurally controlled discharge points and highly permeable rock layers (Rose 1996). This provides a hydrologic setting in the basin where some of the smaller disappearing streams and springs are difficult to specifically source. Two primary streams that flow through the basin are Hat Creek and Burney Creek. Hat Creek is spring-sourced from the southern extent near Lassen Peak while Burney Creek flows from the southwest, both flowing through the basin before joining the Pit River in the north (Rose 1996). The discharge at the springs in the Hat Creek Basin show a relatively rapid response to precipitation rates decreasing, which strongly suggests that decreases in hydraulic head are quickly spread throughout the system and indicates a high level of interconnectivity between the aquifers (Rose 1996). Research shows that the groundwater transport is quick throughout due to the aquifer interconnectivity. The large-volume springs in the basin are shown to have near-ambient temperatures, showing that inclusion of groundwater from deeper levels does not necessarily occur. Due to this lack of deep groundwater interaction and the high rate of spring discharge,

the estimated volume of the aquifers in the basin would be insufficient with regards to long-term storage and could carry less than 200 year aquifer residence times (Rose 1996).

Conclusions

The Lassen volcanic area has experienced several eruptive phases over the last ~7 Ma, and along with the extensional tectonic influences of the Basin and Range province, the geology and hydrology of the Hat Creek Basin and its associated streams and springs has endured changes to its system over that time. The influence of volcanism and the subsequent flows being fractured and permeable, along with the faulting of the basin area due to the Hat Creek Fault system, has promoted an environment that is extremely conducive to conduit flow of the local groundwater and has caused a high level of interconnectivity between the groundwater aquifers. This has led to an area where the Hat Creek Basin streams can disappear from surface view and the aquifers lack a deep underground mixing that can be found elsewhere. This environment paired with a high discharge rate has led to the hydrology of the Hat Creek Basin being heavily influenced by climate and drought. In the future with regards to cases of extended drought times, long-term storage of water in the Hat Creek Basin area is unlikely and must be accounted for when planning projects in the Hat Creek Ranger District of the Lassen National Forest.

Internship Assessment

This internship through WRPI and the Forest Service has given me the great opportunity to get a first-hand look at the potential career opportunities offered by the Forest Service. Through this internship and with the guidance of my supervisor Shawn Wheelock, I have greatly expanded

my working knowledge of hydrology and related field-work, as well as expanded my knowledge of how hydrology plays a pivotal role in several Forest Service related projects that are happening in the Lassen National Forest. This summer has been extremely productive and enlightening, making the Forest Service a potential part of my career in the future.

Appendix:

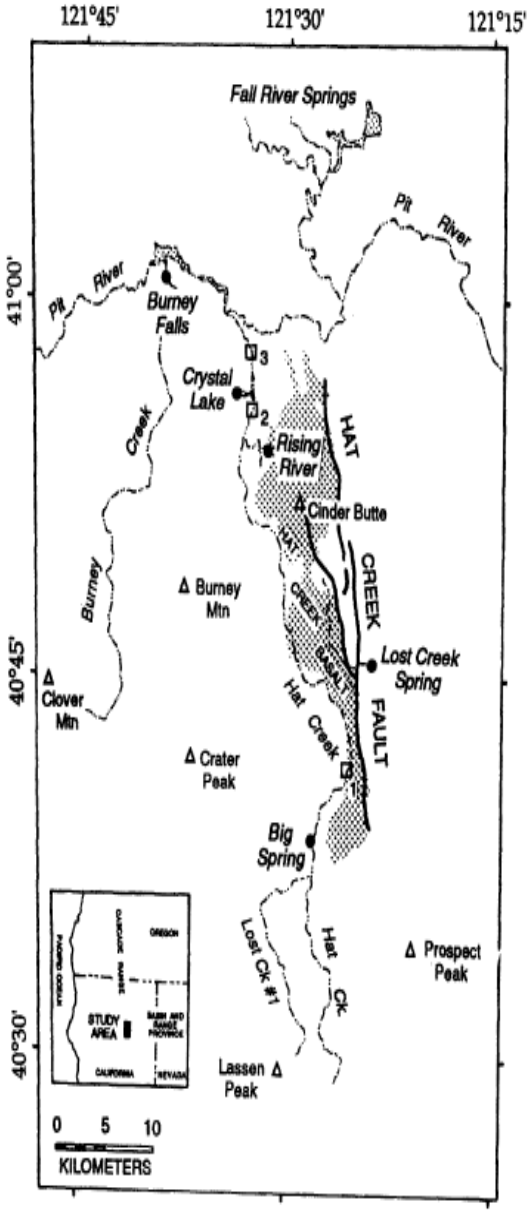

Figure 1 - Map of the springs and streams located in the Hat Creek Basin. Figure adapted from Rose et al., 1996.

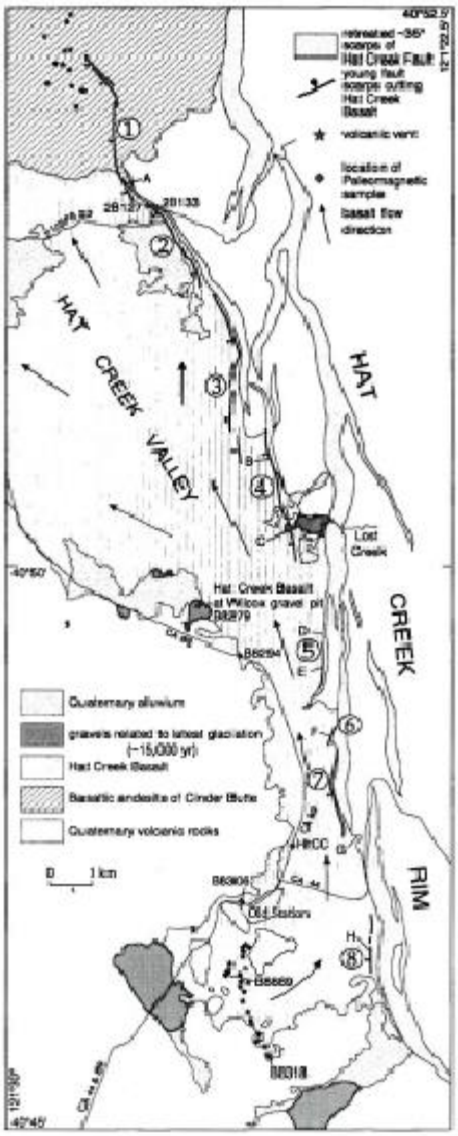

Figure 2 - Map of geologic features near the Hat Creek fault. Figure adapted from Muffler et al., 1994.

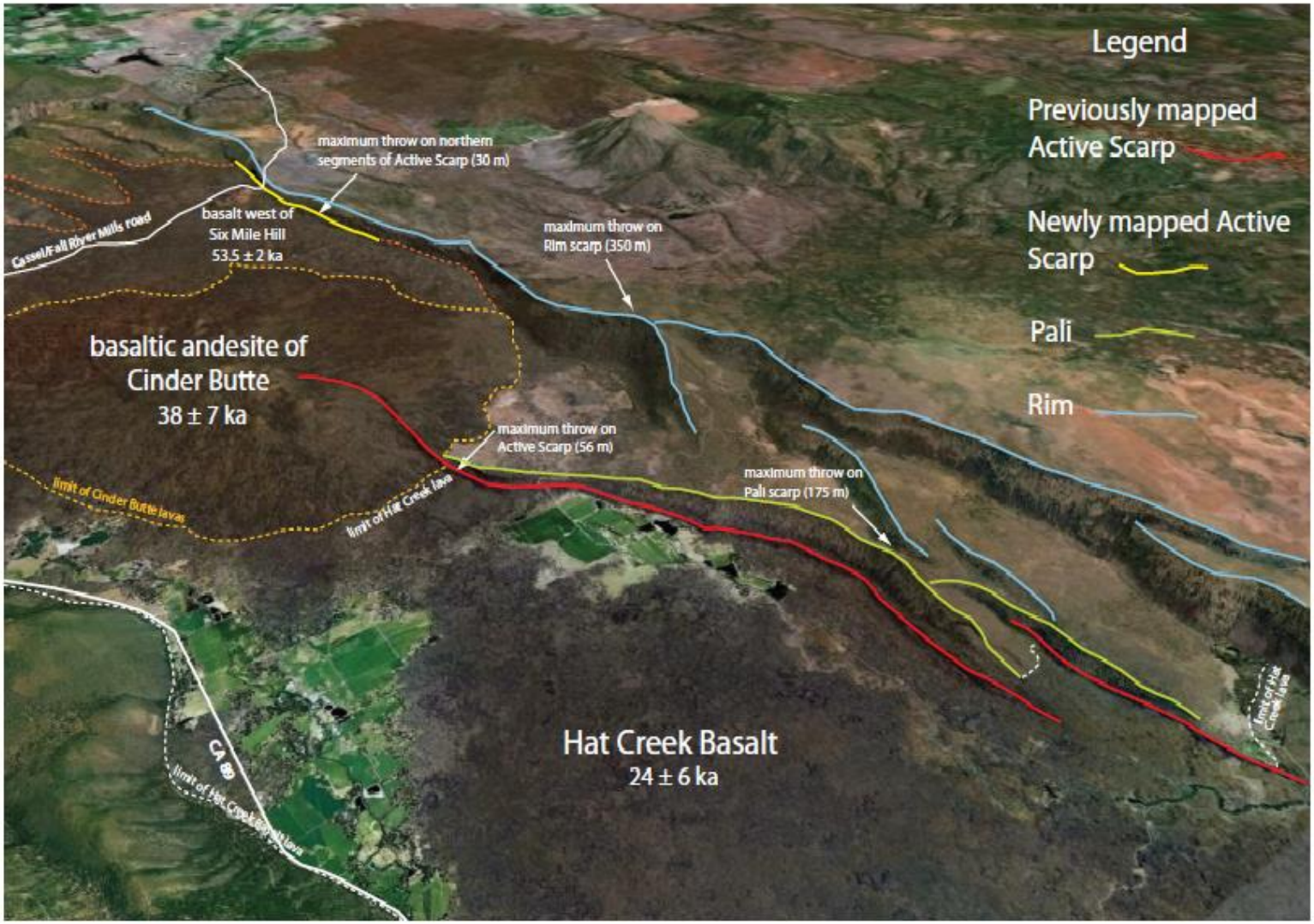

Figure 3 - Perspective view down and to the northeast of the Hat Creek Basin and Hat Creek fault system. Figure adapted from Blakeslee and Kattenhorn, 2013.

References:

Anderson, C. A. (1940). "Hat Creek lava flow." American Journal of Science **238**(7): 477-492.

Blakeslee, M. W. and S. A. Kattenhorn (2013). "Revised earthquake hazard of the Hat Creek fault, northern California: A case example of a normal fault dissecting variable-age basaltic lavas." Geosphere **9**(5): 1397-1409.

Clynne, M. A. (1990). "Stratigraphic, lithologic, and major element geochemical constraints on magmatic evolution at Lassen Volcanic Center, California." Journal of Geophysical Research: Solid Earth **95**(B12): 19651-19669.

Guffanti, M. and C. S. Weaver (1988). "Distribution of late Cenozoic volcanic vents in the Cascade Range: Volcanic arc segmentation and regional tectonic considerations." Journal of Geophysical Research: Solid Earth **93**(B6): 6513-6529.

Macdonald, G. (1964). "Geology of the Prospect Peak quadrangle." California: US Geological Survey Geologic Quadrangle Map GQ-345, scale **1**(62,500).

Muffler, P. L. (1994). "Late Quaternary normal faulting of the Hat Creek basalt, northern California." Geological Society of America Bulletin **106**(2): 195-200.

Rose, T. P. (1996). "Isotope hydrology of voluminous cold springs in fractured rock from an active volcanic region, northeastern California." Journal of Hydrology **179**(1-4): 207-236.