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Water Resources on the Pacific Crest Trail: Thru-Hiker Experiences and Alternate Water Sources in 2019

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By

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of the Requirements for the Degree
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Riley Hine

20 May 2020

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A Thesis
Presented to
The Faculty of
Western Washington University

In Partial Fulfillment
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May 2020

Abstract

The Pacific Crest Trail (PCT) is a 2,650-mile long trail that connects Mexico and Canada through California, Oregon and Washington. For thru-hikers, water is a priority on trail that requires prior research and daily planning. Water resources fluctuate between seasons and years, requiring thru-hikers to adapt to variable resources. This case study examines how thru-hikers prepare for and experience water resources on the Pacific Crest Trail. Relying on thru-hiker interviews, online survey data, and analysis of water reports, this research uses a mixed-methods approach to examine water resource accessibility and variability on the PCT. Using a variation of Affordance Theory, informed by the Nature-Based Recreation Experiences Model and the Ecological Perception Model, this case study analyzes factors of perception, experiences, recreation, and the environment. With the increased popularity of the Pacific Crest Trail and thru-hiking in general, the stress put on trails and water resources are also growing. Findings from this research can inform management of trail use and maintenance. This study is reported in two manuscripts. The first study examines overall water resource variability on the PCT in 2019. The second study evaluates alternate water sources and water caches on trail to provide recommendations for where alternate sources should be placed.

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List of Acronyms/Glossary

Flip Flop/Flipped- When thru-hikers skip sections of trail or go back to skipped sections later

NOBO- Northbound thru-hikers

NPS- National Park Service

PCT- Pacific Crest Trail

PCTA- Pacific Crest Trail Association

SOBO- Southbound thru-hikers

SWE- Snow-water equivalent

USFS- United States Forest Service

Chapter 1: Introduction

1.1 Background

The Pacific Crest Trail (PCT) is a 2,650-mile long National Scenic Trail that connects the U.S.-Mexico border and the U.S.-Canada border through California, Oregon, and Washington (USDA Forest Service, 1982). The trail is split into five large sections known by hikers as The Desert, The Sierra, Northern California, Oregon, and Washington. The idea of the trail was originally proposed by Catherine Montgomery, a Bellingham, Washington professor, in 1926. Montgomery recommended that there should be a trail on the West Coast of the United States similar to the Appalachian Trail in the Eastern U.S. (Mann, 2011a). Clinton C. Clarke of Pasadena, California, officially started to promote the trail in 1932 and was deemed the "Father of the Pacific Crest Trail" (Mann, 2010). The PCT was first mapped starting in 1935 through the YMCA PCT relays. Forty teams of YMCA teenagers in small groups passed along a logbook starting at the southern terminus at Campo, California concluding at the Northern Terminus at Manning Park, British Columbia. By 1938, the PCT had been mapped (Mann, 2011b). Since then, the trail has been modified some, but follows closely to the original path. With the passage of the National Trails System Act in 1968, the PCT became a National Scenic Trail (NST) along with the Appalachian Trail (National Park Service, 2019). For the fiftieth anniversary of the act in 2018, there totaled eleven National Scenic Trails.

Per the National Trails System Act, the United States Forest Service (USFS) is the principal manager of the PCT as a National Scenic Trail (USDA Forest Service, 1982). In 1977, the Pacific Crest Trail Conference was created to organize volunteers and clubs associated with the trail. In 1993, the group was renamed to the Pacific Crest Trail Association (PCTA) and signed a memorandum of understanding that recognizes the PCTA as the major partner of the

federal government for the PCT (*Memorandum of Understanding*, 2014). The PCTA states that it is "the voice of the PCT, its steward, and its guardian, crucial to ensuring that the trail experience and the opportunities for outdoor recreation it affords remain in keeping with the original vision of its founders" (Pacific Crest Trail Association, 2020). This agreement also enables the PCTA to manage aspects of the trail, namely trail work and a volunteer network, and provide educational materials for trail users.

The Comprehensive Management Plan for the Pacific Crest National Scenic Trail was published in 1982 where the USFS identified issues that the trail was facing and would continue facing in the future (USDA Forest Service, 1982). One of these issues was water, given the highly variable nature of water resources in the Western United States. As water resources have become even more variable than could have been predicted in the 1980's, the USFS and the PCTA have had to incorporate alternate water sources on trail. These sources include faucets at campgrounds, water tanks filled by local fire departments, and more recently, water caches provided by trail angels (Pacific Crest Trail Association, 2020). Trail angels is a common term on the PCT for people who volunteer time and resources for hikers. These individuals are not paid for their acts, unless through donations by hikers. Their contributions range from food and snacks on trail, hosting hikers in their homes, providing hitchhike rides into town, and maintaining water caches (Pacific Crest Trail Association, 2020).

Thru-hikers are defined as individuals that hike an entire trail from one end to the other, without looping around (Pacific Crest Trail Association, 2020). In the case of the PCT, these are individuals that start at either terminus and complete a continuous hike to the other terminus in one season. On average, 90% of thru-hikers on the PCT attempt a thru-hike going Northbound (NOBO), starting at the southern terminus and finishing at the northern terminus. The remaining

10% attempt their hike starting at the northern terminus at Manning Park, BC, Canada and hike Southbound (SOBO) (Pacific Crest Trail Association, 2020). Thru-hikers, and section hikers planning on hiking more than 500 miles, are the only hikers required to obtain a permit. The popularity of the PCT has drastically increased since 2013 when the permitting system for those hiking over 500 miles was established. From 2013 to 2019, there has been an average of over 1,000 additional permits issued each year (Pacific Crest Trail Association, 2020). This increased interest in long-distance hiking is making it more difficult for hikers to obtain a permit date that gives them the best chance at completing a thru-hike safely. Thru-hikers need to plan their hikes around seasons, elevation changes, weather, and snowpack, which results in a short window of time where thru-hikers can safely attempt a continuous thru-hike. For Northbound thru-hikers this timeframe is from March/April to the end of September (before the snow falls in Washington State). For Southbound thru-hikers, this timeframe goes from the end of June/July (when the snow has melted in Washington State) to the end of November. For the 2019 season, the average start date for Northbound hikers was April 15, with an average finish date of September 19. Southbound hikers in 2019 averaged a start date of June 27 and an end date of November 3 (Halfway Anywhere, 2019).

Each year on the PCT brings different challenges in regard to environmental conditions. With the state of California experiencing extended droughts, the California section of the PCT reflects those issues. Dry years are relatively normal on the PCT, which result in longer dry stretches between water sources and thus more stress due to longer water carries. In 2019, there were record breaking snowpack levels, which filled up water tables and supplied water resources downstream with water further into the season, making it a very different year for water resource availability.

My research focuses on experiences of thru-hikers with water resources while on the PCT. The results of my research are discussed in two manuscripts. The first study examines how thru-hikers in 2019 perceived, prepared for, and experienced water resources on trail. This is done with thru-hiker interviews and online surveys. The second study looks at how thru-hikers perceive alternate water sources, specifically water caches, on the PCT, and how these sources were utilized. The study provides recommendations for where alternate water sources should be placed along the trail. The target journals for these manuscripts are the *Society and Natural Resources Journal, Journal of Ecotourism,* and/or *Journal of Parks and Recreation Administration.*

1.2 Perceptions and Experiences

In order to understand an individual's experience, it is necessary to understand how their perceptions impact that experience to tell us more about the conditions of water resources. The use of perceptions considers the individual and what factors may impact how that individual perceives an environment. Combining perceptions and experiences can show us the relationship between the built knowledge of an individual (knowledge gained through prior experiences and education) and the physical knowledge they obtain through participation and observation. "Perceptions and activities [experiences] are interrelated concepts regarding the search for information" as noted by Pierskalla and Lee (1998, pg 72).

Affordance Theory has been used to explain the interrelation of perceptions and experiences. This theory attempts to understand perceptions of natural environments and how this provides insight into preferences of recreation and the environment (Dorwart et al., 2009). Affordance Theory describes an affordance as an ecological concept described by a perceiver. Affordance Theory argues that perception drives action; a perception of the environment leads to

some course of action or response. Relating this to water resource perceptions of thru-hikers, if hikers perceive there to be high water scarcity in a certain section, they could respond by carrying more water for longer distances or searching for off-trail sources of water. If water is perceived to be abundant or reliable, hikers might carry less water and risk running out of water if some sources are dry.

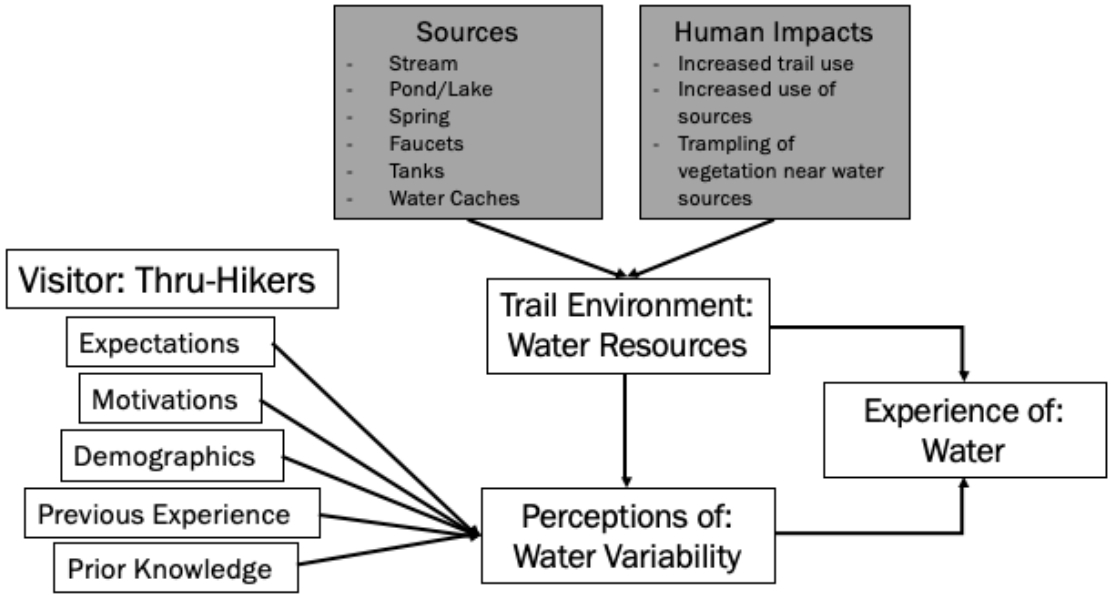
To further the ideas of Affordance Theory, Pierskalla and Lee (1998) created the Ecological Perception Model that aims to examine how a perception of the environment leads to a course of action (Pierskalla & Lee, 1998). The Ecological Perception Model explains that the environment, perceptions, and mode of activity (in this study, thru-hiking) "describe the process of realizing leisure affordances" (Pierskalla & Lee, 1998, pg 75). This model expands on perceptions driving action as described in Affordance Theory, and places mode of activity as an important element. Individual perceptions, the environment, and the mode of activity are all interrelated variables that together describe how an individual responds to various situations in the environment. For example, a horse-pack rider on the PCT may have a very different perception of a section that thru-hikers believe to be water scarce based on the difference of their mode of activity.

Dorwart et al. (2009) created the Nature-Based Recreation Experiences Model, furthering the ideas of the Ecological Perception Model, and examined attributes of the visitor that influence their perceptions of the trail environment. These influencing factors consist of norms, motivations, expectations, previous experiences, and social influences. These factors influence the perceptions of an individual, which then impacts what they experience. In relation to thru-hikers and water resources, an individual who has hiked the PCT before could have very different perceptions of water resources on trail compared to someone who has never hiked

before. If they had previously hiked the trail in a drought year, a year with abundant snowpack could comparatively be a very different experience as well.

Both models employ different aspects of using perceptions and experiences in studying the relationship between recreators and their environment. Constructs from Affordance Theory, the Ecological Perception Model, and the Nature-Based Recreation Experiences Model informed the conceptual model for my research (Dorwart et al., 2009; Pierskalla & Lee, 1998). The conceptual model in Figure 1.1 illustrates how the concepts of perception, experiences, and water resources relate to one another and the recreator.

Figure 1.1. Conceptual Model



Model Variables:

- *Visitors* in this model are thru-hikers who have decided to hike the PCT from one terminus to the other. The visitor has a wide range of factors including expectations, motivation, demographics, previous experience, and prior knowledge, that may influence their perceptions and experiences (Dorwart et al., 2009; Priskin, 2003). This study

focuses on previous experience as a main factor and examines the influence of those previous experiences on individual perceptions and experiences on the PCT.

- *Perceptions* are a key element in this research and model. Environmental perception is defined as a dynamic interaction between humans and an environment that is linked to the whole psychology of the observer and is immersed in the environment that is being experienced (Dorwart et al., 2009; Taylor et al., 1995). Perceptions are impacted by factors of the individual, which then will impact the experience the individual will have.
- *Experiences* are another important element in the model. Experiences are "the direct observation of or participation in events as a basis of knowledge" ("Experience", 2019). In this model, experiences are impacted by perceptions and trail environment elements. These experiences can also feed back into the factors of individual perceptions for future experiences.
- *Trail Environment: Water Resources* is the variable that this model uses to examine the relationship between perceptions and experiences in the environment. In this study, the term "water resources" is used primarily when talking about natural sources on trail. The term "water sources" indicates an alternate water source (i.e., faucet, tank, water cache) or overall sources of water including both natural and non-natural sources. Water resources on trail are impacted by human use, namely increased trail and source use, and trampling of vegetation near water sources.

The model highlights factors that impact a user's perceptions and how those perceptions impact their experience of water resources. The expected outcome of this model is an experience that is influenced by an individual's perceptions, the trail environment elements, and the relationship between those two aspects. In this study, prior experience is the primary perceptions

variable analyzed. This model informs the methodology of this study and the questions posed in the interviews and survey.

1.3 Methodology

This research utilized a mixed-methods approach consisting of qualitative interviews with 15 thru-hikers, online survey data collected from 747 thru-hikers who intended to complete the trail, and water report data collected from two secondary data sources for the PCT in 2019. Both the survey and interviews used nonprobability sampling methods, specifically opportunity and snowball sampling. The interviews were advertised through word of mouth and online PCT thru-hiker Facebook pages. Five survey questions (included in Appendix C) were developed, approved, and added to the Halfway Anywhere annual PCT online survey, the largest known data collection effort of experiences of PCT thru-hikers. Upon the closure of the survey, the administrator shared the raw data for the five developed questions, along with demographics such as gender, age, direction of hike, and completion status for the PCT. Two sources of data, the PCT water reports website (pctwater.org) and Guthook, a phone application, were combined and analyzed to create results for water condition reporting. The PCT water reports website is updated weekly by trail users through text, call, or email. The mobile phone application Guthook, is a paid for app that provides mile-by-mile information on camping, hazards, and water resources. The water resource information on the app is updated in real-time by user comments while on trail. Data from these two sources was obtained by collecting the reports and manually updating the conditions of the water sources. These sources are used frequently by thru-hikers and represent user reported data that is only corrected if another user provides updated or corrected information. Because of this, the data is known to not be completely accurate. However, given the immense amount of self-reported data within these two sources, the

sources can be considered reliable and adequately representative of the experiences of thru-hikers with water and the information available to them on trail.

Chapter 2 is the first manuscript: "Water Resources on the Pacific Crest Trail: Experiences of Thru-hikers in 2019." Chapter 3 is the second manuscript: "Alternate Water Sources on the Pacific Crest Trail: Water Resource Management for Trail Users." The final chapter is a discussion of the findings, limitations of the study, and recommendations for further research. The abstracts for the two manuscripts are below.

1.4 Study 1 Abstract

Water Resources on the Pacific Crest Trail:
Experiences of Thru-hikers in 2019

The Pacific Crest Trail (PCT) is a 2,650-mile long trail that connects Mexico and Canada through California, Oregon and Washington. For thru-hikers, water is an on-trail priority that requires prior research and daily planning. With water resources fluctuating between seasons and years, thru-hikers are needing to adapt to changing resources. This case study examines how thru-hikers prepare for and experience water resources on the Pacific Crest Trail. This research focuses on prior experiences as a main factor that influences perceptions and experiences. Through semi-structured interviews and an online survey, this research uses a mixed-methods approach to obtain an overall view of the experiences of water resources on the PCT. With the increased popularity of the Pacific Crest Trail and thru-hiking in general, the stress put on trails and water resources are also growing. Findings from this study can help to inform recreation managers on decisions of trail use and maintenance.

1.5 Study 2 Abstract

Alternate Water Sources on the Pacific Crest Trail:
Water Resource Management for Trail Users

The Pacific Crest Trail (PCT) is a 2,650-mile long trail that travels through the coastal US states of California, Oregon, and Washington to connect Mexico and Canada. As the trail has become more popular and drier conditions more prevalent in the Western U.S., long stretches of the PCT have limited natural sources of water. As a result, managers have implemented alternative sources of water, which include faucets, water tanks, troughs, and water caches. Trail volunteers, commonly known as trail angels, leave potable water along the trail in the form of water caches. This study examines these alternative sources of water on the PCT; thru-hikers experiences with, and opinions of, these (alternate water) sources; and provides recommendations on future water management on the PCT. This research used thru-hiker interviews, online survey data, and analysis of water reports, to obtain an overall view of what is happening with alternative water sources on trail. This study evaluates where alternate water sources should be placed based on differing criteria to help managers ensure access to water where is it most needed, while also protecting natural resources and the thru-hiking experience. This study recommends nine of the 28 caches present in 2019 continue to be maintained, an additional seven caches to be considered based on seasonal conditions, and 12 caches to be removed.

Chapter 2: Study 1

Water Resources on the Pacific Crest Trail:
Experiences of Thru-hikers in 2019

2.1 Introduction

The Pacific Crest Trail (PCT) is a National Scenic Trail that travels 2,650 miles through California, Oregon, and Washington to connect Mexico and Canada (USDA Forest Service, 1982). This research focuses on thru-hikers – individuals with the intent to hike the trail continuously from one terminus to the other. Thru-hikers can provide more complete information than section or day hikers, as they have hiked and experienced the entire trail. For hikers on long distance trails, water is an on-trail priority that requires prior research and daily planning. With natural water resources fluctuating between seasons and years, thru-hikers must adapt to changing resource conditions. If thru-hikers on the Pacific Crest Trail are unprepared for shifting water availability, they put their well-being at risk. The Western United States has been heavily impacted by severe droughts, flooding, wildfires, record breaking temperatures, and shifting seasonal weather. These changing conditions directly impact not only recreators in the American West but also how trails are managed. This research is a case study of the 2019 thru-hiking season that aims to understand how thru-hikers prepare for, perceive, and experience availability of water resources while on the PCT, which can inform future recreation management decisions.

2.2 Background

The Pacific Crest Trail was designated as a National Scenic Trail in 1968, along with the Appalachian Trail on the East Coast of the United States (National Park Service, 2019). The PCT travels through the coastal states of the Western U.S.: California, Oregon, and Washington. The southern terminus of the trail is at the U.S.-Mexico border and travels 2,650 miles to the northern

terminus just past the U.S.-Canada border (USDA Forest Service, 1982). The majority of the trail follows the crests of the mountain ranges through these states. The United States Forest Service (USFS) is the primary administrator of the PCT, who partners with other entities such as the Pacific Crest Trail Association (PCTA) to manage the trail (USDA Forest Service, 1982). Hundreds of thousands of people recreate on the PCT every year. The only permitted groups are long-distance hikers and horse packers attempting over 500 miles and thru-hikers attempting to hike the entire trail in a continuous footpath. Based off of directional permits issued each year, about 90% of thru-hikers on the PCT chose to travel Northbound (NOBO), while the remaining 10% go Southbound (SOBO) (Pacific Crest Trail Association, 2020). Given that thru-hikers need to plan their hikes around seasons, elevation changes, weather, and snowpack levels, there is a short window of time where thru-hikers can safely attempt a continuous thru-hike. For Northbound hikers this timeframe is from March/April to the end of September (before the snow falls in Washington). For Southbound hikers, this timeframe starts near the end of June through mid-July (after the snow has melted in Washington) and goes to the end of November. For the 2019 season, the average start date for Northbound thru-hikers was April 15 and their end date was September 19. Southbound thru-hikers in 2019 averaged a start date of June 27 and a finish date of November 3 (Halfway Anywhere, 2019).

2.2.1 Water Resources

Studies done on water resources in the Western U.S. find that water in the West is highly variable each year (Ingram et al., 2013; Lewis, 2003). In relation to precipitation, the state of California has the highest year-to-year variability of the Western states (Ingram et al., 2013). Snowpack levels in Western mountain ranges have also experienced an estimated 10% decline over the past century (Ingram et al., 2013). This means more creeks run dry later in the season,

which will impact thru-hikers. Examining the physical geography of the region shows us that topography is an important factor that impacts water variability. With the PCT travelling along the crests of mountain ranges, hikers are susceptible to more water variability than they would be at the base of the mountains (Lewis, 2003). Knowing the state of water variability in the region impacts thru-hiker's perceptions of how water will be on trail. How thru-hikers experience water is heavily determined by the climatic conditions of a given season.

The water crisis in the Western U.S. is much more complex than people perceive it to be. Some studies have called for linking perceptions, climate, hydrology, and management of the environment and natural resources in order to link human-environment interaction and natural resources (Li & Urban, 2016). There are many factors that impact water levels and availability, especially in the U.S. West. Mixed-methods approaches have been used to examine the social and environmental interaction of humans and natural resources such as water. These methods have included participant observation, historical and content analysis, interviews, policy analysis, and empirical data analysis (Hansman, 2019; Ingram et al., 2013; Lewis, 2003; Owen, 2017).

2.2.2 Alternate Water Sources on Trail

In response to variable water resources and more frequent drought years on the PCT, alternate water sources have been implemented on trail in various forms. In sections of Southern and Northern California and Southern Oregon, there are some sections of trail that do not have naturally occurring water resources for 20-30 mile stretches. Alternate water sources such as water tanks filled by fire departments and water caches supplied by volunteers called "trail angels" have been appearing on trail with higher frequency. Trail angels are people who volunteer time and resources for hikers on and off trail. Their contributions range from food and

snacks on trail, hosting hikers in their homes, providing hitchhike rides into town, and maintaining water caches (Pacific Crest Trail Association, 2020).

Water caches have become a topic of contention on the PCT. They were created in order to provide a safety net for hikers in long dry sections but have many associated issues. The PCTA states that water caches make the trail less safe (Pacific Crest Trail Association, 2020). People tend to start relying on the water caches, which puts hikers in danger when the caches are not regulated or reliable. The PCTA gives seven main reasons behind their stance against water caches, they: decrease wildness, decrease hiker preparedness, collect trash, become camping sites, cause harm to wildlife, are often illegal, and are unstudied (Haskel & Hendricks, 2015). The PCTA strongly urges all hikers to plan their hikes without using any caches and encourages trail angels to help in other ways. With such variable water resources, it is becoming more difficult to plan for, and predict, water resource availability on trail; water caches have become a small remedy for a much more complex and variable problem.

2.2.3 Water Resource Conditions of 2019 Thru-hiking Season

To understand the water conditions that thru-hikers experienced in the 2019 season, it is beneficial to recount the conditions of the PCT in 2019. In 2019, the mountain ranges the Pacific Crest Trail traverses were inundated with record breaking snowpack levels relatively late in the spring season. A total of 50-80% of the water supply in the Western U.S. is provided by the melting of winter snowpack (Ingram et al., 2013). By mid-February of 2019, the Sierra Nevada Range was already at 146% snowpack for the year (Voiland, 2019). By the end of March 2019, the Southern Sierra had recorded 154% snowpack, the Central Sierra had 160%, and the Northern Sierra had 151% (Skurka, 2019; CA Dept. of Water Resources, 2019). The snow-water-equivalent (SWE) is an important measure estimating water resource availability. The

SWE totaled 42.8 inches for the entire state of California by the end of March 2019, with snowpack at 156% of normal levels (CA Dept. of Water Resources, 2019). For reference, at the same time in March 2020, the SWE was only 10.6 inches with a 40% snowpack (CA Dept. of Water Resources, 2020). The high snowpack levels in the Sierra Nevada mountain range in 2019 recharged water resources along the PCT during the peak hiking season, resulting in greater water resource availability. As a result, the 2019 season experienced less water resource variability further into the hiking season than most years.

Another result of the high snowpack levels early in the thru-hiking season was that NOBO thru-hikers were unable to travel through the Sierra Nevada Range in a continuous footpath. Many hikers either stopped their thru-hike or broke their continuous path and "flipflopped" to go Southbound instead or skipped the Sierra Nevada section and rejoined the trail further north. Findings from a 2019 survey of over 800 PCT thru-hikers found that 37% of NOBO's and 13% of SOBO's reported that they flipflopped in 2019 (Halfway Anywhere, 2019). Of those that reported flipflopping in 2019, 86% said they did so because of snow; confronted with issues related to snow, 46% decided to flipflop sections, 39% skipped a section of the trail, and about 4% delayed their hike. Of individuals who did not complete their thru-hike in 2019, 22% attributed their noncompletion to snow conditions (Halfway Anywhere, 2019).

2.2.4 Permits and Trail Use

The popularity of the PCT has drastically increased in the last decade. In 2013, the PCT instituted a permitting system for individual thru-hikers and 500+ mile section hikers. Previously, one permit was issued for groups of up to eight people. With the trail increasing in popularity, along with the accessibility of long-distance hiking and gear in general, the

permitting system needed to more accurately count how many individual long-distance hikers were using the entire trail each year (Pacific Crest Trail Association, 2020).

Even with a narrower permitting system, the number of people in any given year using the trail and its resources is unknown. A total of 1,879 permits were issued in 2013; in 2019, the number of permits issued was 7,888 (Pacific Crest Trail Association, 2020). On average, the number of permits issued each year has increased by just over 1,000 permits annually. The largest portion and change in these permits was for thru-hikers. In 2013, a total of 1,041 thru-hiking permits were issued. In 2019 the number of thru-hiking permits issued was 5,441. That results in an average increase of 733 thru-hiking permits issued each year.

From the Halfway Anywhere survey, 82% of respondents started their hike on their permitted start date, while about one in five (18%) did not comply with their start date (Halfway Anywhere, 2019). Non-compliance with start dates results in larger concentrations of hikers throughout the entirety of the trail. According to the PCTA, overcrowding on the trail strains resources such as water, limits safe and responsible camping locations, and leads to higher concentrations of litter and improperly disposed human waste (Pacific Crest Trail Association, 2020).

2.2.5 Changes to Permit System

As a result of the large number of thru-hikers flipflopping sections in 2019 and many thru-hikers not starting on their permitted start date, stricter permitting requirements are being put into place for the 2020 season. Starting in 2020, a 15 people per day limit will be added to the northern terminus, along with the 50 people per day limit at the southern terminus that was established in 2013 (Pacific Crest Trail Association, 2019). The people per day limit is to try to spread out thru-hikers along the entire trail to prevent increased land and resource degradation.

The NOBO season start dates have also been tweaked. The timeframe to start the PCT at the southern terminus will now be March 1-May 31 (Kooyman, 2019). With a limit of 50 people per day starting at the southern terminus, the new date restrictions essentially limits the overall number of NOBO thru-hikers that will be allowed to attempt a thru-hike each year.

A final change for the 2020 season is strict requirements for travel through the Southern Sierra. A continuous path in one direction will now be enforced as well as a 35-day limit to complete this section (mile 701- 1,017). If the continuous footpath is broken by flipflopping, the permit will be invalid in that section, but will remain valid for all other parts of the trail (Kooyman, 2019). By implementing these limitations on thru-hikers starting at each terminus, land managers are attempting to ease crowding and land degradation along the entire PCT. These changes are an attempt to make long-distance trail users easier to manage with the growing popularity and use of the PCT.

2.2.6 Studies on Thru-hikers and Long-Distance Trails

Given the geographic range of long-distance trails, it is difficult to perform research on the entirety of these trails. Previous research examining thru-hikers on long-distance trails is fairly limited and has focused on motivation, recreation and leisure, and recreational benefits (Collins-Kreiner & Kliot, 2017; Goldenberg et al., 2008; Goldenberg & Soule, 2014; Hitchner et al., 2018; Littlefield & Siudzinski, 2012; Saunders, 2017; Seligman, 2011; Svarstad, 2010). Using Grounded Theory, a study in Norway found three categories of motivation for hiking in general: hiking as pure recreation, hiking as a critique of modern society, and hiking as a category of belonging (Svarstad, 2010). One of the only studies of thru-hikers on the PCT uses interviews to encapsulate experiences and benefits of thru-hiking (Goldenberg & Soule, 2014). Participants reported that, in addition to being outdoors for an extended amount of time, they

gained “environmental awareness, physical challenge, camaraderie, exercise, and solitude” (Goldenberg et al., 2008, p. 49). The most notable attributes were self-fulfillment, self-reliance, fun, and enjoyment of life (Goldenberg et al., 2008). However, there is a dearth of studies using mixed-methods to examine the human-environment interaction on long-distance trails.

Thru-hiker and long-distance trail user studies have used surveys, questionnaires, interviews, analysis of online blogs, and/or participant observation in order to understand the trail user (Collins-Kreiner & Kliot, 2017; Goldenberg et al., 2008; Goldenberg & Soule, 2014; Hitchner et al., 2018; Littlefield & Siudzinski, 2012). Most studies focus on one or two methods and call for using more mixed-methods to gather more detailed information (Hitchner et al., 2018; Littlefield & Siudzinski, 2012; Zarnoch et al., 2011). The research discussed here of the 2019 season thru-hikers on the PCT fills the gap between studies of recreators and studies of natural resources by using multiple methods to understand how people are adapting to variable water resources, especially when they rely on those water resources directly on trail for months at a time.

Affordance Theory has been used to explain the interrelation of perceptions and experiences of people in the natural environment. This theory attempts to understand perceptions of natural environments and how this provides insight into preferences of recreation and the environment (Dorwart et al., 2009). Affordance Theory describes an affordance as an ecological concept described by a perceiver. The theory argues that perception drives action; a perception of the environment leads to some course of action or response. Furthering the ideas of Affordance Theory, the Ecological Perception Model aims to examine how a perception of the environment leads to a course of action (Pierskalla & Lee, 1998). The Ecological Perception Model explains that the environment, perceptions, and mode of activity (in this study, thru-hiking) “describe the

process of realizing leisure affordances" (Pierskalla & Lee, 1998, pg 75). This model expands on perceptions driving action as described in Affordance Theory, and places mode of activity as an important element. Dorwart et al. (2009) created the Nature-Based Recreation Experiences Model, furthering the ideas of the Ecological Perception Model, and examined attributes of the visitor that influence their perceptions of the trail environment. These influencing factors consist of norms, motivations, expectations, previous experiences, and social influences. These factors are important to recognize in how they impact the perceptions of an individual, which then influences what they experience. Both models use different aspects of using perceptions and experiences in studying the relationship between recreators and their environment.

In order to understand an individual's experience, it is necessary to understand how their perceptions impact that experience to tell us more about the conditions of water resources. Combining perceptions and experiences can show us the relationship between the built knowledge of an individual (knowledge gained through prior experiences and education) and the physical knowledge they obtain through participation and observation. Constructs from Affordance Theory, the Ecological Perception Model, and the Nature-Based Recreation Experiences Model informed the methodology of this research (Dorwart et al., 2009; Pierskalla & Lee, 1998). This research focuses on prior experiences as the primary variable used to analyze individual perceptions.

2.2.7 Research Questions

The main research question guiding the case study research was:

- How do thru-hikers experience water resources on the Pacific Crest Trail?

Sub-questions included:

- Are there notable differences in water resource experiences between Northbound and Southbound thru-hikers?
- How do thru-hikers utilize water caches?

2.3 Methods and Sampling

This study utilized qualitative and quantitative data from semi-structured interviews of thru-hikers and online surveys. The main unit of analysis was thru-hikers on the PCT in the 2019 season who intended to complete the entire trail. Thru-hikers can provide more complete information about water resources than section or day hikers. Given there is incomplete information about thru-hiker completion rates (Pacific Crest Trail Association, 2020), it is difficult to conduct a random sample of the population. The only documentation of completed thru-hikes is a self-reported "2,600 miler list" on the PCTA website.

In order to obtain as much information as possible despite geography and population limitations, a purposive, non-probability opportunity and snowball sample was used to identify interview participants. Interviewees were recruited by posting requests for interviews on various PCT thru-hiking Facebook pages with a sequential opportunity sample. One of the Facebook pages was the official PCTA 2019 thru-hiker page, and the others were pages specifically for NOBO's or SOBO's in 2019. A total of 15 interviews were conducted, composed of seven Northbound hikers and eight Southbound hikers. Interviews were conducted over-the-phone and transcribed to enable thematic coding. The interviews were semi-structured to address how hikers researched, prepared, and perceived water resources on the trail and how they actually experienced water resources while hiking. Appendix A contains the interview question guide. Additionally, participants were asked to fill out an optional questionnaire that included

demographic questions about age, gender, education level, ethnicity/race, and logistical questions about their hike (found in Appendix B).

Survey data was collected through the well-known blog, Halfway Anywhere. Each year Halfway Anywhere administers an online survey for thru-hikers on the PCT asking questions on demographics, logistics, planning, gear, equipment, and overall experiences had on trail. This survey is meant to be a resource for future thru-hikers planning their hikes (Halfway Anywhere, 2019). The administrator of this survey added questions for this study (found in Appendix C) and provided the raw data for those questions and demographics. There were 747 responses from 2019 season thru-hikers, which included individuals who completed and did not complete their thru-hike.

2.3.1 Analysis Methods

The interviews were transcribed and coded thematically. This study utilized constant comparison and Grounded Theory to identify themes during the data collection process. Using Grounded Theory allowed flexibility to alter questions and allow codes to emerge from the data as data was being collected. Latent content analysis was used to look for categories and themes. Using a codebook informed by Hay, this analysis used three themes to start the coding process (Hay, 2010). The codes were conditions, perceptions, and strategies/tactics. From there, codes were created and logged into a codebook (Appendix D). The codes were then quantified to look for patterns of occurrence across all interviews.

The surveys were analyzed using Qualtrics stats iQ. Statistical analysis included descriptive statistics and relational tests (t-test). Although the study utilized a nonprobability convenience sample, this study found that conducting inferential statistics was beneficial. The

relational tests compared each survey question with the direction of the hiker (SOBO or NOBO) and to whether or not the individual completed their hike (finisher or non-finisher).

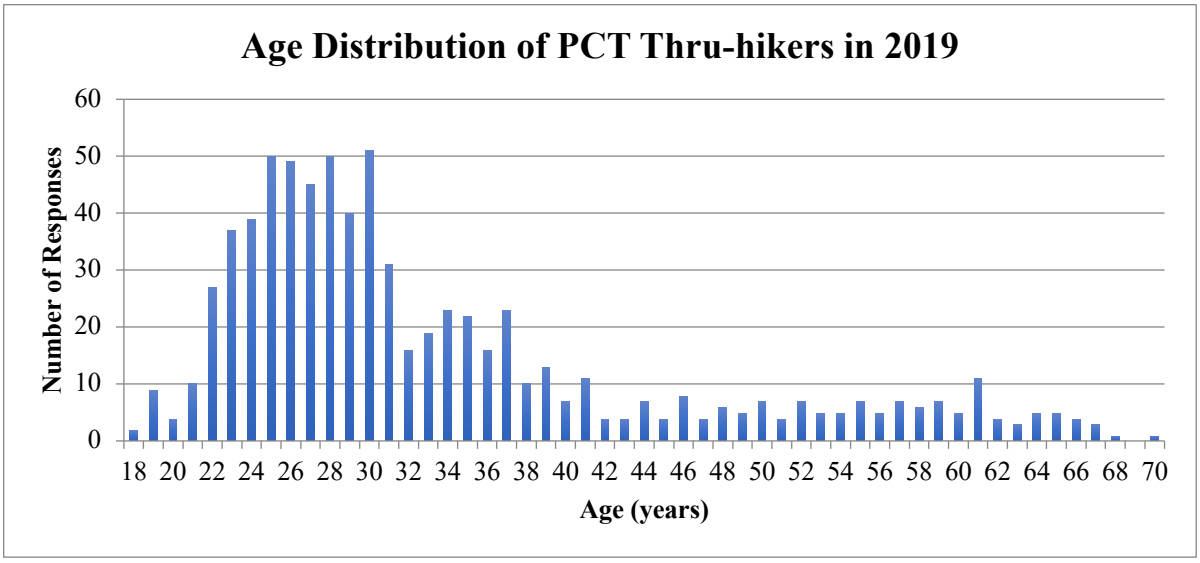
2.4 Results

The results section starts by presenting the survey and interview participant demographics, followed by the findings from the survey questions and interviews. The demographics are listed in Table 2.1. Of the responses from the survey data, 57% of people who intended to complete a thru-hike of the PCT in 2019 actually finished. For the interview participants, 87% finished their thru-hike and the remaining 13% finished the trail in two of the three states. Comparatively, from the PCTA self-reported "2,600 miler list", 909 thru-hikers reported completing a thru-hike in 2019, which is approximately 17% of the total thru-hiking permit holders (Pacific Crest Trail, 2019). Of the 43% of survey participants who did not complete the trail**,** 30% attributed their noncompletion to injury, 25% to personal reasons, and 22% due to snow conditions (Halfway Anywhere, 2020). The average age of thru-hikers was 34. The age distribution of survey and interview participants is displayed in Figure 2.1.

Table 2.1 Demographics Table from Survey Respondents and Interviewees

	Survey	Interviews
Gender		
Male	59.5%	53%
Female	39.9%	47%
Agender/Gender Queer/Non-binary/Transgender	0.4%	0%
Ethnicity/Race		
White/Caucasian	92.7%	80%
Mixed (2+ ethnicities)	2.4%	0%
Asian	2.2%	10%
Hispanic or Latino	2%	0%
Native American/American Indian Spanish/Native Hawaiian	0.5%	0%
African American/Black	0.1%	10%
Age		
18-19	1.5%	0%
20-29	46.8%	60%
30-39	30.2%	10%
40-49	7.7%	30%
50-59	8.1%	0%
60-69	5.6%	0%
70+	0.1%	0%
Direction of Hike		
Northbound (NOBO)	89%	47%
Southbound (SOBO)	11%	53%

Figure 2.1. Age distribution of PCT Thru-hikers in 2019



2.4.1 Survey Results

The final sample size of thru-hikers who intended to complete the PCT in 2019 was N=747. The survey questions are listed in Table 2.2.

Table 2.2. Survey questions and response options

Question	Response Options	N
1) While preparing, how reliable/unreliable did you think water resources were going to be?	1-5 where: 1= no variability 5= high variability	502
2) How prepared did you feel for water source conditions before beginning your hike?	1= very underprepared 2= somewhat underprepared 3= prepared 4= very prepared 5= totally prepared	738
3) How often did you utilize water caches?	1-5 where: 1= never 5= every opportunity	743
4) Overall, how much stress did water conditions cause you?	1-5 where: 1= None at all 5= A lot of stress	741

On average, respondents felt water sources would be moderately variable (Mean 3.4 +/- 0.7), with a confidence interval of 3.33-3.48 and a range of 1-5. People who completed their thru-hike had slightly higher values than people who did not complete the hike (p-value= 0.0468). In addition, Southbound thru-hikers had slightly higher mean scores on perception of water variability (Mean = 3.74) than Northbound hikers (Mean = 3.35) (p-value= 0.000215).

The average survey respondent selected just under 4 (Mean = 3.8, SD 1.1) for how prepared they felt for water source conditions before they began hiking. The confidence interval was 3.79-3.92. Neither hike direction (NOBO or SOBO) or whether or not they completed the hike were statistically related to how prepared the respondent felt for water source conditions. The same was found with how often water caches were used. While on average, the mean for

water cache use was 3.3 (SD = 0.7), there was no observed relationship between water cache use and hike direction or whether or not the respondent finished the hike.

On average, respondents reported that water conditions did not cause a lot of stress (Mean = 2.2, SD = 1.2). The confidence interval was 2.10-2.23. There was a full range of responses 1-5. Respondents who did not finish their hike had slightly higher values than finishing thru-hikers for how much stress water conditions caused them (p-value= 0.0000131).

2.4.2 Interview Results

From the thru-hiker interviews, a variety of themes and related codes emerged. The main themes present are perceptions, conditions, and strategies/tactics. Each of these themes had emergent codes that organized the data (Table 2.3). The most commonly occurring codes were water conditions (n= 60), water caches (n= 54), human intervention of water resources (n= 53), prior experiences (n= 38), and strategies and preparation (n= 52). The following section presents the results from the main themes and related codes present in the thru-hiker interviews.

Table 2.3. Description of themes and codes present in the thru-hiker interviews

Themes	*Codes*	*Brief Description Based on Transcripts*	*Example from Transcripts*
Perceptions	Prior Experiences	When mentioning previous experience that could influence perceptions, experiences on the PCT or strategies	"I had done lots of hiking and day hiking but no backpacking"
	Opinions on Environment	Overall mention of the environment and conditions of the environment	"There's a lot of cattle tromp through and defecate and everything in a high mountain stream."
	Opinions on Human-Environment Interaction	Mention of human interaction and interference/presence in the environment	"You've got to wonder if letting cattle venture up into high mountain streams should change given the state of water sources."
	Opinions on thru-hiking culture	Mention of the experience of thru-hiking and the thru-hiking culture	"[Water caches] maybe kind of took away a little from the experience. Like the kind of roughing it and doing it yourself attitude."
	Sense of Accomplishment	In relation to conditions, feeling like you accomplished something in your thru-hike	"It felt like an accomplishment like when we got to camp, or we made it over a big pass or a river crossing."
Strategies and Tactics	Strategies and Preparation	How individuals approached planning for water and hiking	"I was looking at maps frequently to see where my next water source was, how many miles away, how much did I have, [etc.]."
	Consequences	Outcomes of poor planning or unreliability of water sources	"There was another part of the desert where I ran out of water until I hit a cache."
Conditions	Water Conditions	When water conditions on trail are specifically mentioned	"Everyone I was hiking with was surprised there were a couple of long carries in Oregon."
	Human Intervention of Water Sources	When mentioning alternate/human water sources and needs for management of water sources	"I'm sure if there were one or two more well-maintained and operated caches nobody would complain."
	Water Caches	Whenever water caches are specially mentioned	"In the desert, I think half of the water sources I don't think I stopped at were water caches."

Prior Experiences

Four interviewees had very little backpacking/hiking experience, four had some backpacking experience, and seven people had a lot of experience. However, no matter their level of expertise, prior experiences were mentioned by every interviewee. Of the eight people who had little or some experience, they noted that they were nervous or had stress related to water resources planning and variability on trail. As one novice hiker noted, "[In] a lot of my prior experiences, I viewed water as something I didn't have to worry about. And that changed a lot for me on the PCT" (Interviewee 12). Of the seven interviewees who had a lot of experience, they all noted that their prior experience made them feel more confident and better prepared for water resource variability on their PCT thru-hike. "It helped me understand knowing how much I drink. Like per mile, on a hot day, on a cold day, in the morning… all of the different variables. I knew how much to carry. And then I think it helped me know how to be more efficient in how to plan around water" (Interviewee 2).

Strategies and Tactics

The theme of strategies/tactics included the sub codes of *strategies and preparation* and *consequences*. Every person interviewed talked about strategies and tactics related to planning for water and strategies used. Of the 15 thru-hikers interviewed, 100% used the mobile phone application Guthook for their water resource planning, compared to 93% of survey participants. Five people mentioned that they also looked at the PCT water reports, however they relied more heavily on Guthook. One interviewee who used both sources acknowledged their usefulness: "I used [the PCT water report] a little bit at first, but I did come to the conclusion that of those sources, the Guthook app was the easiest to use" (Interviewee 1). Furthermore, according to another interviewee comparing the sources, "The water report was there but people were

honestly so up to date on comments on Guthook that I think I only used the water reports like one time" (Interviewee 2).

In terms of how often thru-hikers were thinking and planning for water, the majority of interviewees noted that it was a frequent thought. One hiker described: "I was looking at maps frequently to see where my next water source was, how many miles away, how much did I have, trying to figure out what I could drink now, how much I had to save" (Interviewee 1). Another interviewee mentioned that while it was not a constant thought, "It was always the main factor that dictated when we would stop and how far we would go" (Interviewee 10). Twelve out of the 15 interviewees mentioned some sort of consequence related to poor planning. Every Northbound thru-hiker interviewed mentioned a consequence of poor planning of water resources. This included running out of water, filters not working properly, or relying on a water cache that was empty. When there were no updates on water sources, thru-hikers would get creative; "If we didn't have an update from Guthook for this current year, we would look at previous year's comments and look at what water was like then and base it off of that" (Interviewee 6).

Water Conditions

The main theme of conditions includes the codes of *water conditions, human intervention of water sources,* and *water caches*. Every code in this theme was mentioned in every interview. For more in-depth analysis of water caches and alternate water sources on the PCT, see the study "Alternative Water Sources on the Pacific Crest Trail: Water Resource Management for Trail Users" (Chapter 3 in this document).

In response to which sections people perceived there would be the most water scarcity, 14 out of 15 interviewees responded with the Desert/Southern California. Four people said that

this section was the only section that actually ended up being the most scarce. Many people added that Northern California and Southern Oregon had long dry sections that they were surprised by. As one interviewee summed up, "I wasn't expecting it to be quite so dry in Oregon and Northern California. But it wasn't necessarily shocking I would say. I hadn't really thought about it outside the Desert. It was kind of looming that water was going to be scarce down there" (Interviewee 14). SOBO thru-hikers had another take on how they viewed water resources and variability, "I wasn't super concerned about it, I mean I was for the desert, it was pretty much only the Desert. Prior to that my concerns were very minimal. But it was so far into the future I wasn't really thinking about it, I mean I wasn't sure I would make it that far" (Interviewee 15). The only sections that were noted as having water stress and variability were Southern California/the Desert, Northern California, and Southern Oregon.

All interviewees noted that they utilized water caches and the majority noted that they had relied on at least one water cache during their hike. There were contrasting opinions about whether water caches should still be used. Most people said that they liked water caches and that they were helpful. Those who were critical of water caches explained that thru-hiking the PCT is not supposed to be easy, the difficulty weeds out people who should not be on trail, trash and litter collect around caches resulting in environmental impacts, and people noted an increase in camping next to caches.

Thru-hiking Culture

The code of *thru-hiking culture* emerged from the data and provided support for individual opinions on human intervention of water sources and water caches. The code captured reflections related to the culture or traditions of thru-hiking, particularly on the PCT, and was mentioned by 14 out of 15 interviewees. Examples include references to how hard the trail

should be, the notion that thru-hiking is not supposed to be easy, and "purist" thinking around having to walk every mile of the trail in order to be considered a thru-hiker. It also captured thoughts about what the experience would be like for thru-hiking if there were changes in conditions (i.e., no water caches on trail). As one interviewee noted "As far as my 'purist' thinking on [thru-hiking], I don't think it's a cheat as much as I used to think" (Interviewee 9). Although, others felt differently: "[Water caches] are making it so much easier for people that don't have the skill to complete [the trail]" (Interviewee 5).

Related to more people being on trail, interviewees had issues with overcrowding. "Starting the trail it was hard to find camping sites for like the first three weeks because there were so many people" (Interviewee 11). With respect to water caches specifically, one interviewee noted "It would be really impossible for some people to start later in that March/April/May window of starting on the trail. I think having [water caches] there helped spread out the feasibility of start [dates] of doing the trail South to North" (Interviewee 6).

2.5 Discussion

Overall, water conditions were not much of an issue in 2019 for thru-hikers. Every interviewee said Southern California was their main concern for water conditions. Ten of the 15 interviewees also noted that Northern California and Southern Oregon were also areas that surprised them in addition to Southern California.

Overall, prior thru-hiking and long-distance hiking experience helped thru-hikers feel more confident and less stressed about water conditions. All interviewees mentioned prior experiences that impacted how they prepared, their mindset, and how their hike turned out. Many hikers that were from the Eastern U.S., most notably, were most surprised about water conditions and variability having not hiked much in the Western U.S. As a few interviewees voiced, if there

was a creek on the map, they assumed there would always be water, similar to how they are used to experiencing trail water resources on the East Coast.

For SOBO's, the experience and knowledge gained in the first 2,000 miles made the Desert section less stressful. Many attributed this to having their "hiker legs" and therefore knowing how much water they usually drink on trail, how many miles they usually complete, and how much water they need for camp. Overall their confidence after months on trail was enough to make them say that water conditions in the Desert were much better/less stressful than they had originally thought.

Thru-hikers relied on water caches in 2019, especially SOBOs in Southern California. Despite the 2019 season having high snowpack levels, which provided more abundant water resources longer into the thru-hiking season, hikers relied on alternate water sources. The majority of thru-hikers interviewed noted using 50-70% of the water caches they passed and every interviewee mentioned relying on at least one water cache. This universal reliance did not suggest consensus of opinions about the appropriateness and necessity of caches; findings showed a range of perspectives regarding their need, presence, and impact on trail.

Affordance Theory helps to explain the findings related to perceptions of water variability, which impacts individual actions and outcomes (Dorwart et al., 2009). Overall, Southbound thru-hikers initially thought that water resources would be more variable than Northbound thru-hikers. This can be attributed to SOBO's perceiving that they would need to plan more extensively for the Southern California section of the trail, assuming that after a dry summer in California, water resources would tend to be more variable in September-November. Another significant finding was that people who ended up finishing their thru-hike noted that they believed water resources were going to be more variable before they started their hike than

people who did not finish their hike. This suggests that people who had believed water resources would be more variable planned more extensively, which resulted in a higher number of those people finishing their thru-hike. Finally, people who did not finish their thru-hike noted feeling more water-related stress than people who did finish. This could be attributed to under preparedness that potentially could have been a deciding factor in those individuals stopping their hikes.

2.6 Conclusion and Further Research

From this research, it shows that preparation and education on water resources on the PCT is imperative. The PCTA should continue to educate future trail users and thru-hikers on the issues of water variability on the trail and the different resources available to thru-hikers to plan for water supply. Limiting the concentration of thru-hikers on trail by capping the number of permits per day at both the southern and northern terminus is a step in the right direction to combat degradation of the trail and its' resources. Thru-hikers value the traditional culture of thru-hiking, but also are aware of the need to adapt given the changing climate. Alternate water sources such as water caches are a way to provide a small solution to the larger problem, although they are not entirely sustainable. The PCTA and the USFS need to address the growing issue of water variability on trail and the related issue of water caches. The PCTA already has a strong stance on water caches but has taken only small actions to dismantle them. Thru-hikers are utilizing water caches and, although they are aware they should never rely on them, they end up relying on them in certain sections of the trail. This suggests that some sort of coordinated intervention needs to occur related to water resources for the health and safety of thru-hikers.

As an extension of this research, a longitudinal study examining hiker preparedness and experiences over several years would illustrate the impact of variable water conditions based on

multiple years varying snowpack levels. It would also be beneficial to study other trail users than just thru-hikers to understand more perspectives. A study comparing different years after new permit restrictions are put in place would also be valuable to test the impact of those changes.

This study focused on analyzing how prior experiences in particular impacted perceptions and experiences of water resources. This was only one of the many variables considered from the Nature Based Recreation Experiences Model through Affordance Theory. Future research could be done to study the other variables more thoroughly (norms, motivations, expectations, and social influences) (Dorwart et al., 2009). It is also important to study the demographics of the thru-hiking population. In 2019, the vast majority of PCT thru-hikers were white/Caucasian, cisgender individuals in their 20's and 30's. These demographic realities raise social justice concerns related to the accessibility of thru-hiking recreation on the PCT for more diverse groups.

A more in-depth study on how users utilize trail educational materials could be beneficial to the PCTA. In the Halfway Anywhere survey, it was found that 93% of respondents utilized the application Guthook in 2019 (Halfway Anywhere, 2019). Fewer people are using the PCT water reports that the PCTA recommends. A study looking into this resource and how it is being utilized could be valuable for the PCTA and for thru-hikers. It could also be beneficial to perform key-informant interviews with the PCTA or other managers on the PCT, as well as thru-hikers.

Overall, this study found that prior experiences influence thru-hikers perceptions and experiences of water resources while hiking the PCT. How water resources are perceived influence how extensive an individual prepares, which then can impact their completion of the trail. Seasonal climate conditions also influence how a thru-hiker prepares for the trail. Even

though hikers are told to never rely on water caches and alternate sources, thru-hikers still rely on them. Furthermore, this study found that there is a need for more research on alternate water sources on the PCT due to changing climate conditions. Water resources are showing patterns of higher variability and the PCTA is needing to find viable solutions to the lack of natural water resources. With the increased popularity of the trail, these issues should be addressed in order to keep the PCT and thru-hiking sustainable.

Chapter 3: Study 2

Alternate Water Resources on the Pacific Crest Trail:
Water Resource Management for Trail Users

3.1 Introduction

The Pacific Crest Trail (PCT) is a 2,650-mile long trail that connects Mexico and Canada through California, Oregon, and Washington (USDA Forest Service, 1982). The PCT follows the crests of the mountain ranges through these states. The PCT is used by hundreds of thousands of users every year. One of the only recorded user groups are thru-hikers who obtain a permit to hike the entire trail from one terminus to the other. Thru-hikers need to plan their hikes around seasons, elevation changes, and snowpack (Benner, 2015). With that, thru-hikers have a short window of time where they can safely attempt a continuous thru-hike. This timeframe is around March/April- September for Northbound hikers (which is about 90% of thru-hikers) and July-November for Southbound hikers (*Pacific Crest Trail Association,* 2020*)*. Water resources are seeing more variability due to climate change and increased trail use is generating more pressure on them. There are more trail sections experiencing longer dry stretches, requiring hikers to think more carefully about where and how they obtain water. A rising alternate water source on trail are water caches provided and maintained by trail volunteers (commonly called trail angels). PCT managers have not implemented a clear plan regarding alternate sources of water and where/if they should be placed. This study provides recommendations for where on trail alternate water sources might be considered, how current alternate sources are being utilized, and what thru-hikers think of these sources and human-intervention overall on the PCT.

3.2 Background

The Pacific Crest Trail travels through many jurisdictions including seven National Parks, 48 designated federal wilderness areas, State Parks, and private land. Per the National Trails System Act of 1968, the U.S. Forest Service (USFS) is the primary administrator of the PCT (National Trails System Act, 1968). In order to manage and protect the 2,650-mile long trail, the USFS has partnered with the Pacific Crest Trail Association (PCTA), the Bureau of Land Management (BLM), National Park Service (NPS), and California State Parks (USFS, 2019). In 1977, the Pacific Crest Trail Conference was established to organize volunteers and clubs associated with the trail. In 1993, the group was renamed to the Pacific Crest Trail Association (PCTA); the PCTA signed a memorandum of understanding with the federal agencies that recognizes it as the major partner of the federal government for the PCT management (Memorandum of Understanding Revision, 2015). The PCTA states that is it "the voice of the PCT, its steward, and its guardian, crucial to ensuring that the trail experience and the opportunities for outdoor recreation it affords remain in keeping with the original vision of its founders" (Pacific Crest Trail Association, 2020). This agreement also enables the PCTA to manage aspects of the trail, namely issuing permits, coordinating trail work and a volunteer network, and providing educational materials for trail users.

3.2.1 Water Resource Conditions & Management

In the Western United States, over the past century, snowpack levels have declined at an estimated 10% along Western mountain ranges (Ingram et al., 2013). On the PCT, this results in more water resources running dry during the thru-hiking season. The topography of the trail is an important factor when considering water resources because the trail traverses mountain crests, causing hikers to be more susceptible to higher water variability (Lewis, 2003). Melting

snowpack supplies a total of 50-80% of water supply in the Western U.S. each year (Ingram et al., 2013). During 2019, the PCT saw much higher percentages of total snowpack than most years recently and historically in this region. The state of California in 2019 saw an average total of 156% snowpack by the end of March (CA Dept. of Water Resources, 2019). The snow-water equivalent (SWE) is an important factor that influences water levels downstream for the year. In 2019, the 156% snowpack level equated to 42.8 inches of SWE. In March 2020, for comparison, the SWE was only 10.6 inches with 40% snowpack (CA Dept. of Water Resources, 2019-2020). The PCT in 2019 therefore had less variable water resources than a year with normal historical snowpack would see.

The USFS uses the Comprehensive Management Plan for the Pacific Crest National Scenic Trail, published in 1982, to monitor and manage the trail. One of the top issues that the trail was facing in 1982 and was estimated to deal with in the future was variable water availability (USDA Forest Service, 1982). As water resources have become even more variable over the past several decades, the USFS and the PCTA have had to incorporate alternate water sources on trail. These are discussed in the next section.

3.2.2 Alternate Water Sources

In response to variable water resources along the trail, the USFS, PCTA, and volunteers have begun to implement alternate sources of water. These include faucets at trailheads and campgrounds, tanks filled by local fire stations, troughs, and water caches. Water caches are maintained by volunteers, called trail angels. Trail angels is a common term on the PCT for people who volunteer time and resources for hikers. These individuals are not paid for their acts, unless through donations by hikers. Their contributions range from food and snacks on trail, hosting hikers in their homes, providing hitchhike rides into town, and maintaining water caches

(Pacific Crest Trail Association, 2020). Water caches were started by trail angels trying to help thru-hikers during the long dry stretches of trail. They are most prevalent in the first 700 miles in the Desert section of the trail. The PCTA has tried to implement more tanks along the trail filled by fire stations, but these tend to be costly and have many associated problems (e.g., animals dying in the water, the lid not being replaced, low water levels making water hard to obtain, etc.). As a result, trail angels tend to provide a large portion of the alternate water sources on trail through water caches. These range from very large and organized caches to gallons of water being placed at trailheads a few miles from a natural water source.

3.2.3 Water Caches

The PCTA's official stance on water caches is that they make the trail less safe (Pacific Crest Trail Association, 2020). Hikers are starting to rely on certain water caches, especially in the Southern California/Desert section of the trail. However, this creates issues and safety hazards because the caches are not reliable sources of water. These cache areas also tend to see more litter and trash around them as they are a stopping point for hikers to fill up water. Related to this, caches can also harm wildlife and vegetation around them. Caches have become camping areas as well, especially in long dry stretches of the trail. Many water cache areas are seeing degradation related to the increased camping, especially in the fragile desert ecosystems where most water caches tend to be placed (Haskel & Hendricks, 2015). The locations of caches are also often illegal. It is against the law to place trash or personal belongings (water caches fall into these categories) on public lands (Pacific Crest Trail Association, 2020). This means that caches, unless placed on the person's private property, technically are not allowed to be there. Finally, these locations have not yet been studied for degradation.

As a result of all of these factors, the PCTA is clear in their stance of not supporting water caches. They are receptive to different strategies given that long dry stretches of trail are increasing, especially with extended drought years. They have determined four main locations for alternate water sources such as water caches: two in Southern California, one in Northern California, and one in Southern Oregon. The PCTA strongly encourages trail angels to contribute to the trail and hikers in other ways than caches and asks thru-hikers to never include caches in their planning (Pacific Crest Trail Association, 2020).

3.2.4 Water Resource Preparation

With such variable water resources, it is becoming difficult to plan on water resources on trail, and water caches have become a small remedy for a greater issue. There are different methods and sources for thru-hikers to use to plan for water resources on trail. The PCTA's official water planning resource is the PCT water report from pctwater.org. The other main resource is the mobile phone application Guthook. In a survey of 2019 season thru-hikers, 93% of respondents noted that they used the application Guthook (Halfway Anywhere, 2019). These resources allow users to see where water sources are on trail by mile marker and the most recent updates of the conditions of sources by other users. The PCT water reports are updated once per week, whereas Guthook is updated in real time directly by user comments.

3.2.5 Thru-hikers and Permitting

Thru-hikers, and section hikers planning on hiking more than 500 miles, are the only hikers required to secure a permit. Thru-hikers are defined as individuals that hike an entire trail from one end to the other, without looping around. In the case of the PCT, these are individuals that start at either terminus and complete a continuous hike to the other end in one season. Approximately 90% of thru-hikers on the PCT attempt a thru-hike going Northbound (NOBO),

starting at the southern terminus and finishing at the northern terminus. The remaining 10% attempt their hike starting at the northern terminus at Manning Park, BC, Canada and hike Southbound (SOBO) to Campo, CA (Pacific Crest Trail Association, 2020). The popularity of the PCT has drastically increased since 2013 when the permitting system of one permit per individual was put in place (previously one permit could be used for groups of up to eight people). On average from 2013 to 2019, an additional 1,000 permits have been issued each year (Pacific Crest Trail Association, 2020). The southern terminus has had a 50 person per day limit since 2013. Starting 2020, a 15-person limit will be enforced on the northern terminus (Pacific Crest Trail Association, 2019). Also new, NOBO hikers have a shorter timeframe to start their hike at the southern terminus: March 1-May 31. Thru-hikers also will be required to complete a continuous hike of the southern Sierra section in 35 days (Kooyman, 2019). Many thru-hikers flipflopped due to snow conditions in the Sierra Nevada Range in 2019, which resulted in higher concentrations of hikers in other parts of the trail. These new limits should minimize environmental impacts, but will also reduce total foot traffic on the trail.

Given the factors of seasons, snowpack, and geography, thru-hikers have a relatively short window of time where they can safely attempt a continuous thru-hike. For Northbound hikers this timeframe is from March/April to the end of September (before the snow falls in Washington). For Southbound hikers, this timeframe starts near the end of June and July (when the snow has melted in Washington) to the end of November. For the 2019 season, the average start date for NOBO thru-hikers was April 15, with an end date of September 19; for SOBOs, the average start date was June 27 and the finish date November 3 (Halfway Anywhere, 2019).

With the increased use on the PCT and highly variable water resources, it is becoming urgent to find solutions to related issues such as overcrowding, environmental degradation, and

safety of thru-hikers. The PCTA notes that the water cache locations have not yet been studied (Pacific Crest Trail Association, 2020). This research, which examines water resources on the PCT, aims to fill the gap in knowledge of how water caches are utilized by thru-hikers and where caches and alternate sources are placed on trail. Based on the findings, recommendations are given on where alternate sources should be placed.

3.3 Methods and Sampling

This study utilized a mixed-methods approach, collecting data through interviews, surveys, and water reports. The main unit of analysis was PCT thru-hikers in the 2019 season. Given that there is only documentation for thru-hiking permits given out each year, but not for the number of thru-hike finishers, this study used a purposive, non-probability opportunity and snowball sample. Interview participants were recruited from three PCT thru-hiker Facebook pages on a volunteer basis, including the official PCTA thru-hiker Facebook page, and NOBO and SOBO specific pages. A total of 15 participants were recruited including seven Northbound hikers and eight Southbound hikers. The interviews, consisting of semi-structured and open-ended questions, lasted from 15-40 minutes and addressed water caches and opinions on human-intervention of water sources. An optional questionnaire addressing demographics was also provided. The interviews were transcribed and thematically coded using latent content analysis and constant comparison.

An online survey was the second method used in this study. Survey participants were recruited from the Halfway Anywhere blog, where the survey was administered. The site administrator agreed to add questions related to water cache use and water sources utilized on trail. A total of 747 responses were collected for the survey questions, which were analyzed using Qualtrics stats iQ using descriptive statistics and relational t-tests.

The final method for this study was content analysis of two online water reports; the PCT water report (pctwater.org) and the mobile phone app Guthook. The PCT water reports are free, weekly reports, publicly updated by users via phone, email, or text. Guthook is a paid for phone application that is updated by trail users in real time. The water reports were collected from April 2019 through November 2019 and water conditions for each month were recorded. Both reports were compiled into one spreadsheet. Each source listed the mile marker, the number of miles until the next water source, water source type (faucet, creek, water cache, river, etc.), and the status of the water source at the end of each month: flowing or attainable water (coded as 1); low flow, trickling, or stagnant (2); dry or unattainable water (3).

Table 3.1 outlines the trail sections analyzed for alternative water sources, along with the months where thru-hikers would be present in that section.

Table 3.1. PCT sections analyzed in water reports

Section	**Miles (from Southern Terminus)**	**NOBO months**	**SOBO months**
Southern California	0-761	April, May, June	October, November
Northern California	1,197-1,720	June, July, August	July, August, September
Southern Oregon	1,720-2,000	July, August, September	June, July, August

The water reports were analyzed comparing two scenarios outlined in Table 3.2: Best Case and 2019 Case. For the purpose of this study, “natural” sources are all resources that are naturally occurring on trail (rivers, streams, creeks, lakes, ponds, etc.). “Human” or “alternate” sources are all water sources that have been placed on trail through human intervention (e.g., faucets, tanks, troughs, water caches, etc.).

Table 3.2 Water report analysis scenario descriptions

Scenario	Description	Includes	Excludes
Best Case	All natural sources have attainable and safe drinking water	- All natural sources flowing - All faucets as running - All off-trail sources listed on either water report	- Water caches - Tanks, cisterns, and troughs
2019 Case	Sources as reported in 2019 thru-hiking months	- All natural sources as reported - All faucets as reported	- Water caches - Tanks, cisterns, and troughs

Geospatial analysis, using ArcGIS Pro and Excel spreadsheets, was done to analyze the spatial patterns of water sources, including identifying the number of miles between sources for both scenarios. The sources were listed as "dry" if they went dry or had been reported unattainable at any point for either NOBO's or SOBO's in their corresponding months. The average mileage completed each day on the PCT by thru-hikers in 2019 was 20.2 miles (Halfway Anywhere, 2019). Using the standard that a thru-hiker should come across at least one water source per day, the severity of need for an alternate water source is outlined in Table 3.3.

Table 3.3. Severity of need for an alternate water source by mileage between sources

Miles between Sources	Severity of Need
10-15	Low
15-20	Medium
20-25	High
25+	Very high

3.4 Results

3.4.1 Water Conditions

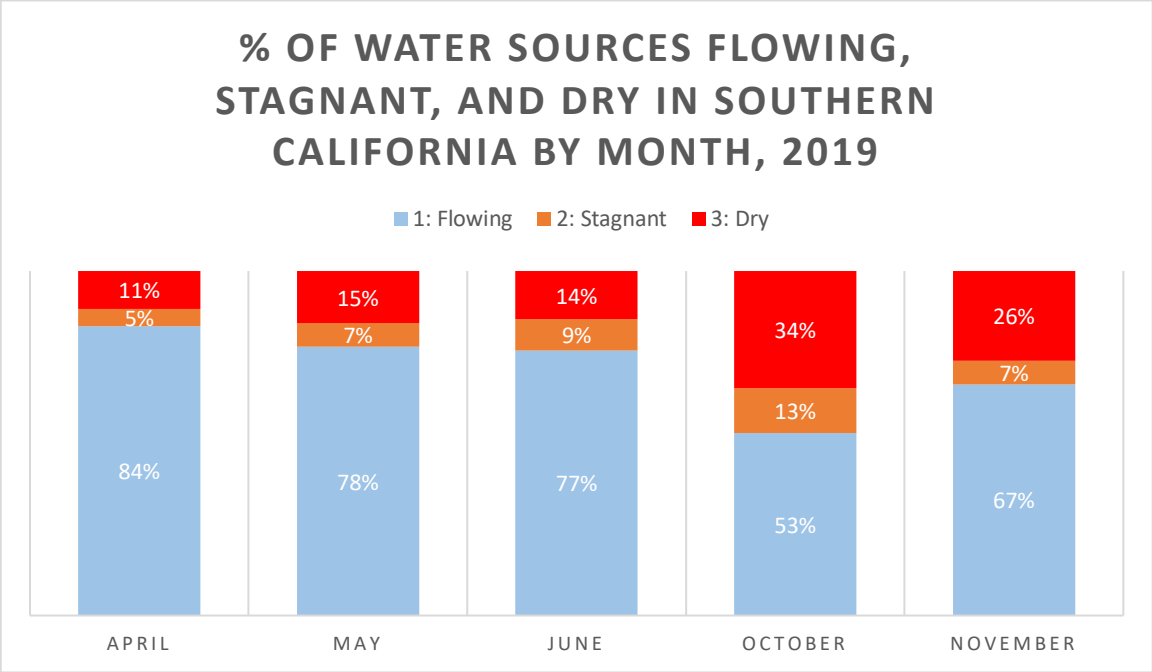
During the 2019 thru-hiking season, water resources in Southern and Northern California, and Southern Oregon were noted as the most variable sections that caused stress. Table 3.4 shows the results of quantifying how many sources fell into each category of need for an alternate water source. These calculations include all sources noted on both the PCT water reports and Guthook, including all natural sources, water caches, tanks, troughs, faucets, and off trail sources as reported. Not every source had an update for each month. Therefore, N is associated with how many sources had an update for that month. Each section saw a general upward trend in the proportion of sources that were categorized as a 2 (low flow, trickle, or stagnant) or 3 (dry, faucets off, or unattainable). The section with the most notable increases as the season progressed was Southern California. Particularly, during the months of October and November when SOBO thru-hikers were going through this section of the trail, there were the highest proportions of category 3 sources (dry, faucets off, or unattainable).

Table 3.4. Water sources by condition category during thru-hiking season

SECTION		1- FLOWING		2- STAGNANT		3- DRY		N
SOUTHERN CA	**Month**	**#**	**%**	**#**	**%**	**#**	**%**	
	April	166	84%	11	5%	22	11%	200
	May	184	78%	16	7%	35	15%	235
	June	162	77%	19	9%	30	14%	211
	October	95	53%	24	13%	61	34%	180
	November	81	67%	9	7%	31	26%	121
NORTHERN CA								
	June	194	94%	5	2%	8	4%	207
	July	208	86%	21	9%	12	5%	241
	August	188	83%	18	8%	21	9%	227
	September	162	81%	17	9%	20	10%	199
SOUTHERN OR								
	June	42	81%	3	6%	7	13%	52
	July	71	86%	5	6%	7	8%	83
	August	57	78%	6	8%	10	14%	73
	September	31	74%	5	12%	6	14%	42

Figure 3.1 displays proportionally how many sources were reported in each category during thru-hiking months for Southern California. Given the average SOBO thru-hiker finished their hike November 3 in 2019, the majority of SOBO thru-hikers were still present on trail traveling through the last 700 miles in Southern California during October. October saw 53% of sources attainable and 34% sources completely dry or unattainable.

Figure 3.1. Proportions of water sources in each category during thru-hiking months in Southern California



In Northern California and Southern Oregon, the trends were similar, with a great number of sources categorized as dry/unattainable in the months of August and September. As the thru-hiking season progressed, the water sources in each section had fewer sources flowing and gradually had more sources recorded as stagnant or dry/unattainable. The biggest range seen in Southern California was between April and October where there was a 31% drop in category 1 sources (flowing or attainable) (Figure 3.1). The biggest range for Northern California was between June and September with a 13% drop in category 1 sources (flowing or attainable). For Southern Oregon, the biggest range was a drop of 14% in category 1 sources between July and September.

3.4.2 Alternate Water Source Locations

Based off of the two scenarios described in Table 3.2 and the categorization of severity of need for alternate sources from Table 3.3, the three sections were analyzed and quantified to identify possible locations for alternate water source placement. Table 3.5 shows the results for

the best-case scenario. The most notable section was Southern California with eight low need areas (10-15 miles between sources), two medium (15-20 miles between), one high (20-25 miles between), and two very high areas (more than 25 miles between).

Table 3.5. Best Case Scenario: Number of alternate water source locations based on need

Section	Low need	Medium need	High need	Very High need
Southern California	8	2	1	2
Northern California	3	0	0	0
Southern Oregon	4	1	1	0

Northern California was the least severe section, resulting in only three low need areas (10-15 miles between sources). Southern Oregon also did not show any very high need areas, but did show one high need, one medium need, and four low need areas.

For the 2019 scenario, the results are split into the months that NOBO's or SOBO's would be traveling through the section, as listed in Table 3.1. Table 3.6 shows the results of the 2019 scenario of all sources as reported, excluding all tanks, troughs, and water caches.

Table 3.6. 2019 Scenario: Number of locations in each severity of need based on NOBO and SOBO months

	NOBO Months				SOBO Months			
Section	**Low**	**Medium**	**High**	**Very High**	**Low**	**Medium**	**High**	**Very High**
Southern California	10	4	0	4	11	5	0	4
Northern California	5	0	0	0	4	0	0	0
Southern Oregon	2	3	2	0	2	4	1	0

Southern California saw the most locations in need of an alternate source of water for both NOBO and SOBO months. Both NOBO months (April, May, June) and SOBO months

(October, November) in Southern California saw four locations that were categorized as very high need of an alternate water source (more than 25 miles between sources). No other section resulted in a very high need location. Northern California resulted in only low need areas (10-15 miles between sources). Southern Oregon saw the most range between low, medium, and high, although medium need locations (15-20 miles between sources) were most common. The water report data identified water source types, locations, and need for alternate water sources based on distance between sources. The following section provides the demographics of survey and interview participants and the results of the surveys and interviews regarding use and perceptions of alternate water sources.

3.4.3 Thru-Hiker Use and Opinions of Alternate Sources

Of the 747 survey responses**,** 57% of people who intended to complete a thru-hike of the PCT in 2019 actually finished the trail. A total of 87% of the interviewees completed their thru-hike. Table 3.7 displays the demographic information of the survey participants and interviewees.

Table 3.7 Demographics Table from Survey Respondents and Interviewees

	Survey	Interviews
Gender		
Male	59.5%	53%
Female	39.9%	47%
Agender/Gender Queer/Non-binary/Transgender	0.4%	0%
Ethnicity/Race		
White/Caucasian	92.7%	80%
Mixed (2+ ethnicities)	2.4%	0%
Asian	2.2%	10%
Hispanic or Latino	2%	0%
Native American/American Indian Spanish/Native Hawaiian	0.5%	0%
African American/Black	0.1%	10%
Age		
18-19	1.5%	0%
20-29	46.8%	60%
30-39	30.2%	10%
40-49	7.7%	30%
50-59	8.1%	0%
60-69	5.6%	0%
70+	0.1%	0%
Direction of Hike		
Northbound (NOBO)	89%	47%
Southbound (SOBO)	11%	53%

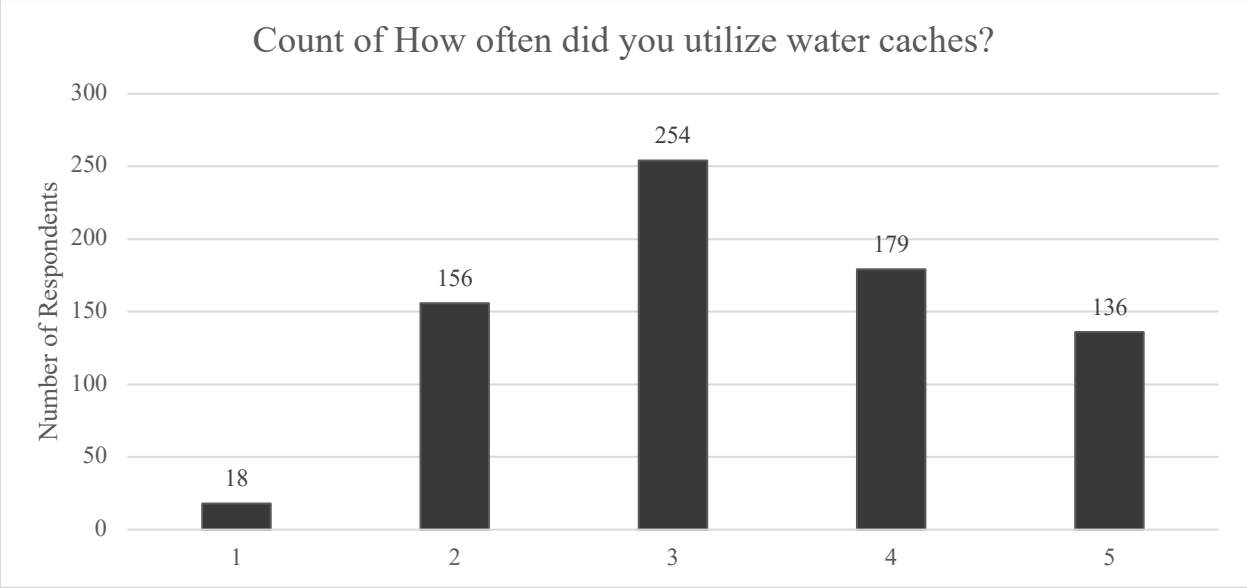
Two survey questions related to water sources and alternate water sources. In asking about top three water sources utilized on trail, natural sources were listed as the top sources, followed by faucets/pipes (33%) and water caches (24%). Table 3.8 shows the results of top water sources used by source and type.

Table 3.8. Percent of thru-hikers listing each source as one of their top three sources used on trail

Water Source	Natural or Human Source	Percent listed as one of the top three sources used
Streams and Springs	Natural	99.1%
Bodies of Water	Natural	52.9%
Faucets/pipes	Human	33.2%
Water Caches	Human	24.1%
Tanks and Troughs	Human	7.9%

For water cache use, respondents noted that they utilized water caches some of the time (Mean = 3.3, SD = 1.1, Range = 1-5). Respondents could select from 1= never, 2= very little, 3=some, 4=often, and 5= every opportunity. The distribution of responses is shown in Figure 3.2.

Figure 3.2. Responses for "How often did you utilize water caches?" n= 743



Most notable from this question is that 136 respondents noted that they utilized a water cache every opportunity they passed one. If the survey were representative of all thru-hikers in 2019, that would suggest that 18.3% (or almost 1,000) of thru-hikers utilized every water cache they came across.

From the water reports, 28 water caches were noted either from Guthook or the PCT water reports. They were primarily located in Southern California, with one in Northern California, and two Southern Oregon. No other water caches were noted on the reports. Appendix E contains the locations and names of the water caches found in this study.

Every person interviewed said they had used water caches during their thru-hike. The responses ranged from a few times total, to 50% of the time, to every time they came across one. Ten of the 15 interviewees said they utilized caches 50-70% of the time (or between 10-15 times total), which matches the findings from the survey. SOBO hikers used water caches more often than NOBO hikers did. In terms of relying on water caches, five of the seven NOBO interviewees noted that they relied on at least one water cache at some point on the trail. Four of the eight SOBO interviewees noted that they had relied on at least one cache, and all eight mentioned the reliability/unreliability of caches. “In some cases, we relied on them. I know Guthook says ‘Don’t rely on this source’ but we definitely would rely on water caches for water” (Interview 10). Of those interviewees who mentioned reliability of water caches, they noted that, even though they should not rely on them, without water caches, the trail would be much more difficult, and in some cases, some sections would be undoable; “I think in a lot of places they are pretty vital to people being able to do the trail. I think a lot of people would not attempt the trail if there were not those sources” (Interviewee 12).

Many interviewees mentioned the increased use of the trail and what that means for water sources on trail. “I think having [water caches] helped spread out the feasibility of start [dates]. I think with the current system, it definitely needs to keep up with water caches to keep up with the demand of people hiking the trail” (Interviewee 6). This perspective was mirrored by some respondents who said there should be fewer permits granted; “I believe without those sources in

the desert we would have to reduce the amount [of permits]" (Interviewee 5). With respect to the location and availability of alternate sources, one respondent noted "I think it would be better if the water cache was more based on the water conditions of the season" (Interviewee 6).

In regard to the concern of degradation and pollution around water caches, the majority of interviewees stated there were associated problems with collected liter around caches, or they mentioned camping around water caches themselves. "There are two water caches in particular I can think of where hikers huddle around to camp there" (Interviewee 4). This was a recurring theme in the interviews that thru-hikers mentioned trash collecting around caches and more concentrated camping.

As for human intervention of water sources and water caches, interviewees had differing opinions. The majority of interviewees did not see an issue with the caches and alternate sources. As one interview explained, "[I am] 100% for [water caches]. Just selfless people helping out people they will never meet. It's awesome" (Interviewee 11). Another interviewee noted, "It's just like kindness for the sake of kindness. People just doing something to help a bunch of crazy people out that are doing something [that] no one is forcing you to do[.] It made you feel like somebody knew we were out there and was trying to make sure we were going to make it okay" (Interviewee 10). However, some interviewees were not as supportive of caches. "I did see this year with the water availability, there were too many water caches and I did kind of feel like [they] kind of took away a little from the experience" (Interviewee 1). Another expressed, "I think water caches are enabling[.] They are deteriorating the feel of the trail. It's making it so much easier for people that don't have the skills to complete" (Interviewee 5).

All interviewees mentioned that they do not think there needs to be major changes in regard to alternate sources and human intervention of water sources on trail, other than some

small adjustments like the number or locations. There were differing opinions on whether or not the number of water caches in 2019 was adequate. “I think that maybe it’s a fairly appropriate amount where it’s at now. I definitely wouldn’t say there *needs* to be [more]. I’m sure if there were one or two more well-maintained and operated caches nobody would complain” (Interviewee 14). SOBO’s especially noted difficulty with water resources and not having alternate sources such as caches being maintained in Southern California when they passed through late in the season. “There just wasn’t very much water for us SOBO’s. So, I probably wager in the desert it was something like seven caches that I relied on. […] if there wasn’t water at that cache, I would have been pretty afraid” (Interviewee 15).

3.5 Discussion and Recommendations

Overall, thru-hikers in 2019 believed that the number and locations of the main water caches on the PCT are adequate. There were only a few interviewees that noted that there could be a couple more alternate sources placed on trail. The 2019 season was a high snowpack year resulting in a high Snow-Water Equivalent (SWE) for the PCT. Given this, if the number of water caches that were placed on trail in 2019 were also placed in drought years, the sentiment towards water caches may be far more favorable. Despite the relative abundance of water in 2019, every interviewee utilized water caches in 2019. The survey data also supports this; the vast majority of thru-hikers surveyed in 2019 also utilized at least one water cache, with 18% using every water cache they came across.

3.5.1 Water Cache Use and Opinions

Overall, the majority of thru-hikers interviewed noted that they appreciate water caches and utilize them. While most people said they support water caches, they also said there were downsides to them; they make the trail easier/less rigorous, turn into litter and trash collection

areas, and become de facto camping sites. The majority of thru-hikers interviewed stated that they only used about 50-70% of the water caches that they came across, which means in 2019 about half of the cache locations were not necessary. Neither water caches, nor tanks, are adequate long-term fixes for the issue of water variability on trail. However, without these alternate sources, many hikers would experience high water stress in some sections of the trail, most notably, the Southern California section for Southbound thru-hikers. This section needs to be monitored for water sources, especially in years when snowpack levels do not exceed the historic normal levels by over 50%, like what had happened in the 2019 season.

3.5.2 Recommendations for Alternate Sources

The three trail sections analyzed in this study are the only sections that the PCTA has deemed necessary for some sort of alternate water source: two in Southern California, one in Northern California, and one in Southern Oregon. The results of this study confirm these are the only sections thru-hikers came across water caches and/or experienced water stress. If all water caches were to be dismantled, it is critical that all faucets listed on the PCT water reports and on Guthook be maintained and kept running during the full thru-hiking season. Table 3.9 displays a comparison of the best case scenario analyzed in this study that included all faucets on versus the same scenario but with no faucets running.

Table 3.9. Best Case Scenario with and without faucets based on need of alternate water source

	Best Case With Faucets				Best Case Without Faucets			
Section	Low	Med.	High	Very High	Low	Med.	High	Very High
Southern California	8	2	1	2	11	6	2	5
Northern California	3	0	0	0	4	0	0	1
Southern Oregon	4	1	1	0	4	1	2	0

Without faucets all three sections have many more locations noted on the scale from low to very high need of an alternate source. The number of locations in very high need (over 25 miles between sources) went up from two to five without faucets in Southern California, and zero to one in Northern California. Southern Oregon is the only section that is only minimally affected by faucets being on or off. Without the faucet locations, water stress in these sections would increase.

Tanks have been placed on trail to try to mitigate some dry areas. From the water reports analysis and interviews, the tanks are seen as being as unreliable as water caches. Due to hygiene issues (e.g., animals dying in the tanks) and low water levels making water hard to reach, the tanks are not being utilized as much as they were intended to be. The PCTA has also stated that these tanks are expensive to maintain and fill (Pacific Crest Trail Association, 2020). If all tank locations and faucet locations were maintained where they currently are located, many water cache locations would be unnecessary.

In 2019 there were 28 water cache locations noted on either the PCT water report or Guthook. Based off of the mileage between natural sources, where current alternate sources are placed, and how early in the season some natural sources went dry, Table 3.10 gives recommendations for which current water caches should be maintained or removed.

Table 3.10. Recommendations for continuation of current water caches

	Mile	Location Name	Keep?	Notes
Southern California	15.4	Cottonwood Creek below Lake Morena	Depends on season	SOBO months only
	68.4	Rodriguez Spur Truck Trail	No	Stopped supplying for season after June
	77	Scissors Crossing	Depends on season	Over 30 miles between natural sources. Both noted issues of LNT and vandalism
	91.2	Third Gate Cache	Yes	
	143.1	Table Mtn Truck Trail AKA Sandy Jeep Road	Yes	Closed for season after 7/4. Would also benefit SOBO's
	145.4	Muir Wood (South) Cache	No	Other options
	209.5	Cabazon (under overpass)	No	Other options
	213.4	Mesa Wind Farm	Depends on season	Other options
	274.8	Cache	Not all season	SOBO months only
	347.3	Swarthought Canyon Road Cache	Yes, depends on season	SOBO months needed more
	370.4	Grassy Hollow Visitor Center	No	Keep faucet on and clean instead
	436.3	North Fork Ranger Station	Depends on season	Close to natural sources that may go dry (esp. SOBO months)
	465.6	Bouquet Creek (usually dry) Cache	No	Other options. SOBO months maybe
	485.7	Lake Hughes Road	No	Other options. Closed by July.
	499.5	RD0499 Unpaved Road	No	Keep up tanks nearby instead. Closed by June.
	510.9	Pine Canyon Cache	No	Other options
	549	Mile 549 "Lounge"	Yes	Breaks up a potentially very long carry
	558.2	Oak Creek Cache	No	Other options
	558.5	Tehachapi-Willow Springs Road	Yes- depends on season	Potentially very long carry without either. Depending on season, at least one should be placed
	565.1	Cameron Canyon Road	Yes- depends on season	
	566.5	Highway 58	No	Other options
	615.9	Kelso Valley Road	Yes	Large caches that can get depleted quickly. In long dry stretches
	630.8	Bird Spring Pass	Yes	
	651.3	Walker Pass Trailhead Campground	No	20-mile carry without either
	652	Hwy 178 (Walker Pass)	No	

Northern CA	1393.6	Cache 22	Yes	All season
Southern OR	1848.4	Unpaved Forest Road 961	Yes	4 natural sources spread far apart. Very long carry if some went dry
	1878.3	OST Junction-Windigo Cache	Yes	

This analysis located nine areas that should have a water cache maintained during the thru-hiking season (compared to the four locations noted by the PCTA). Six of these locations are in Southern California, one in Northern California, and two in Southern Oregon. Based on these recommendations, seven locations are noted as dependent on seasonal conditions, or only necessary during the SOBO thru-hiker months. A total of 12 water cache locations are recommended for removal, based off of being near natural sources that did not go dry early in the season, or being near other bigger water caches, tanks, or faucets.

3.6 Conclusion

The main section of the PCT that needs to be monitored is Southern California from mile 0-750. This was continually reported as one of the sections that thru-hikers felt the most water stress and variability. This research found that the locations of water caches in Northern California and Southern Oregon coincide with the PCTA's recommendations for alternate water source needs in those sections. In addition to the two Southern California locations the PCTA approves of water caches, this study identified four additional locations in Southern California.

Not all of the water sources were on both Guthook and the PCT water reports. If users are only using one of these reports, they may be unaware of many other water source locations, on and off trail. For example, many sources listed on the PCT water report, but not on Guthook, were off trail sources. Given that 100% of people interviewed and 93% of thru-hikers surveyed

used Guthook, this may be a gap in knowledge of all nearby water source options. Utilizing many of the off-trail sources broke up long dry sections, especially in Northern California.

Water caches are small solutions for the overall issue of water resource variability on the PCT but the issue may need a more permanent solution. On the Continental Divide Trail (another National Scenic Trail), they have implemented paid for water caches in the dry section of the trail in New Mexico (Continental Divide Trail Coalition, 2020). There are still issues with this system, but it may be worth considering as dry sections get longer and hikers are putting themselves at risk to get through the dry sections. With more supervision and monitoring of water cache locations, the environmental degradation associated with caches could also be monitored. Trail angels are spending a lot of money to keep these caches stocked and have begun to ask for donations from thru-hikers to keep the caches maintained. The PCTA has the opportunity to become more involved in water cache operations, if they were to see the caches as necessary to thru-hiker safety. Overall, thru-hikers are using water caches. Many thru-hikers are relying on them, especially in Southern California and if they are hiking Southbound. Even with all of the information and educational materials offered by the PCTA, there are no other options for many thru-hikers than to rely on some water caches. Many water cache locations are unnecessary, but there are areas even in very high snowpack years like 2019 that thru-hikers relied on them.

Chapter 4: Conclusion

4.1 Overall Discussion

Water is a constant consideration for thru-hikers on the PCT. Their days revolve around current sources, how much water they have, where they are headed, and the conditions of water sources along the way. Overall, this study found that thru-hikers did not have many issues with water resources in 2019. Southbound thru-hikers experienced more variable water resources than Northbound thru-hikers. Thru-hikers relied on some alternate sources of water, primarily water caches in the Southern California section of the trail. This study found that there were 28 water caches on the PCT in 2019 in various locations of Southern and Northern California and Southern Oregon. By analyzing the necessity of water cache locations, this study recommends nine of the 28 caches continue to be maintained, an additional seven caches to be considered based on seasonal SWE conditions, and 12 caches being removed. The majority of thru-hikers interviewed for this study utilized 50-70% of water caches on trail. Every thru-hiker interviewed relied on at least one water cache, and used the other water caches for convenience. My recommendations would maintain a minimum of 32% and a maximum of 57% of water caches that were present in 2019 (Table 3.10).

This study also recommends that the PCTA continue their educational and preparation materials for thru-hikers, in relation to water resources. Preparation and perceiving water resources as being variable produced a higher number of finishing thru-hikers. Continuing to educate thru-hikers on the importance of spreading out start dates at each terminus, abiding by their start date and permit conditions, and responsibly following Leave No Trace (LNT) principals is imperative to sustaining thru-hiking on the PCT. Limiting the concentration of thru-

hikers on trail will help to decrease environmental degradation and detrimental impacts on water resources.

The PCTA and thru-hikers find value in the traditional culture of thru-hiking. This includes the notions that the trail is not supposed to be easy, thru-hikers need to be adaptable and tough, and they should be self-sufficient. This culture is still valued, but there is sentiment that this culture may need to adapt with the changing climate. Alternate water sources such as water caches and tanks are making the trail safer as the quantity and severity of dry sections on the PCT are increasing. Neither water caches nor tanks are ideal solutions to the issue of water scarcity on trail. Both have related issues, whether it be cost, environmental impacts, or thru-hiker reliance on these non-dependable sources. As managers of the PCT, the PCTA and USFS need to address water scarcity and variability issues on the PCT in addition to the related issues of water caches. The current alternate water sources on the PCT are not realistic solutions for the long-term. As the Western U.S. and the PCT are experiencing more severe and frequent droughts, these issues related to hiker safety need to be addressed sooner rather than later. Thru-hikers know they should never rely on water caches and to plan their hikes without the use of water caches, yet these alternate sources are still needing to be relied on. Educational materials on water resources will not be enough to help thru-hikers when they need to hike over 30 miles without crossing naturally occurring water. This research suggests that PCT managers need to intervene with water resources for the health, safety, and sustainability of thru-hiking on the Pacific Crest Trail.

4.2 Limitations

This study was conducted on thru-hikers and water conditions in 2019. The results reflect a limitation of generalizability for other years on the PCT. The questions asked in interviews and

the survey were formatted in order to gauge the general opinions of alternate water sources in addition to what was experienced during the 2019 season. The actual numbers found in this study may not be significant for following years, but the patterns and opinions on intervention show practical significance.

The purposive sampling for the interviews and surveys produce low generalizability for this study. Given there is no documentation for finishing thru-hikers each year (only the permits issued), a random sample cannot be obtained. The PCTA estimates that 10% of thru-hikers go Southbound and 90% go Northbound. The survey results of this study match that statistic. Additionally, both of the water reports analyzed in this study are user reported and updated. Inherently, there are issues of reliability and updated information for both of these sources.

4.3 Further Research

To further this research, it should be repeated in other years. Doing a comparison of years that did and did not have the same level of snowpack would be beneficial to testing if the patterns found in this study apply to other years as well. A longer-term study on the water reports would be able to show water variability through the years, rather than only through one season. It could also be beneficial to perform key-informant interviews with the PCTA or USFS in addition to thru-hikers.

To further the recommendations for alternate water sources on trail, there should be more studies done on water caches themselves. It would be valuable to perform a study on whether or not caches show increased degradation to the surrounding areas. Trail angels could also be interviewed in regard to water caches to see how some of the larger caches have developed and the issues that they face. Since trail angels are the suppliers and maintainers of water caches on

the PCT, it would be valuable to hear their side of the story in comparison to what thru-hikers and the PCTA say about water caches.

This study focused on analyzing how prior experiences in particular impacted perceptions and experiences of water resources. This was only one of the many variables considered from the conceptual model (Figure 1.1) through Affordance Theory. Other studies should be done to study the other variables more thoroughly (demographics, norms, motivations, expectations, and social influences) (Dorwart et al., 2009). It is also important to note the social justice aspect of this study, given the demographics. In 2019, the vast majority of PCT thru-hikers were white/Caucasian, cisgender individuals in their 20's and 30's. These demographics come as a concern for social justice issues and raises concern about the access to thru-hiking recreation on the PCT.

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Appendix A: Interview Guide

Prior Experience and Motivation Questions

- How long were you on the PCT?
- Do you have previous backpacking experience?
- Why are you hiking the PCT?

Topic Questions

- What were the greatest environmental hazards you faced on trail?
- How was water on trail?
- How frequent was water on your mind while on trail?

Preparation and Perception Questions

- Did you use any water guides or resources to help with water?
    - Which were the most helpful?
    - Which were the least helpful?
- How did you prepare for water resources?
- Did you feel prepared for water resources?
- Before going on trail, what did you think water resources were going to be like?
- Which sections did you think were going to be the most difficult in terms of getting water?
- Is there something you wish you would have known while preparing for water supply?

Experience Questions

- How did your experience with water compare to what you had thought?
- How often did you utilize a water cache?
- What is your opinion of water caches and "human" sources of water on trail?
    - How would the trail be different without human sources of water….is it doable?
- In which sections was water the most scarce?
    - Desert, Sierra, Northern California, Oregon, Washington
- Did you ever run out of water?
    - About how many times?
    - Where?
- Given the snowpack this year in California, how do you think your experience was different than it would have been in a year with "normal" snowpack?
- How do you think your prior experiences helped how you viewed and experienced water on trail?

Concluding Questions

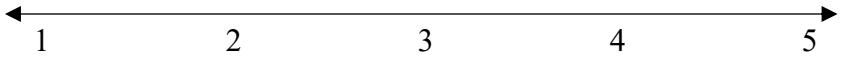
- Overall, what was your experience in regards to water on the trail?
    - If you had to rank it 1-5, 1 being very low stress and 5 being very high stress, where would your experience be?
    - Do you think this was a common experience amongst Northbound hikers/Southbound hikers?
- Do you think there needs to be more human intervention of water sources on the trail?

    - Why or why not?
    - Is there anything else the PCT Association could do in regards to water resources and management?
- What is the single most important thing you think I should know about water resources on the Pacific Crest Trail?

Appendix B: Interview Questionnaire

- Did you hike Northbound or Southbound?
- Gender:
    - Female
    - Male
    - Prefer not to say
    - Prefer to self-describe_____
- Age:_____
- Ethnicity/Race:_____ or prefer not to answer
- Education Level
    - 12th grade or less
    - Graduate high school or equivalent
    - Some college, no degree
    - Associate degree
    - Bachelor's degree
    - Post-graduate degree
    - Prefer not to answer
- Where are you from? State/country?
- What was your start date?
- What was your end date?
- About how much money did you spend on your thru-hike?

1) While preparing for your thru-hike, how did you think water resources were going to be? 1 being no variability, 5 being high variability



2) Which section did you think was going to be the most scarce?
    - The Desert
    - Sierra
    - Northern California
    - Oregon
    - Washington

3) Which section was water the most scarce?
    - The Desert
    - Sierra
    - Northern California
    - Oregon
    - Washington

4) Which sources of water did you rely on the most during your hike? Select top 3 sources.
    - Streams/Springs
    - Bodies of water (ponds, lakes, etc.)
    - Pipe/Faucet (i.e. at a campground)

- Water tank or trough
- Water cache
- Other. Please explain:_____

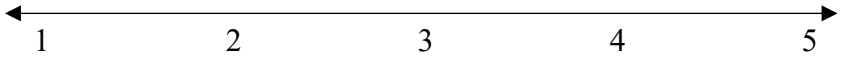
5) How prepared did you feel for the water conditions before beginning your hike?
   A) Very under prepared
   B) Somewhat underprepared
   C) Prepared
   D) Very Prepared
   E) Totally Prepared

6) How often did you utilize a water cache? 1= never, 2=very little, 3= some, 4=often, 5=every opportunity
   A) Never
   B) Very Little
   C) Sometimes
   D) Often, but not always
   E) Every opportunity

7) Overall, how much stress did water conditions cause you?
   A) None at all
   B) Little stress
   C) Some stress
   D) A lot of stress

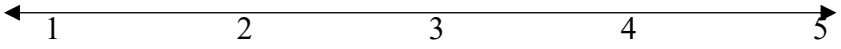
Appendix C: Survey Questions

1) While preparing for your thru-hike, how did you think water resources were going to be? 1 being low variability, 5 being high variability

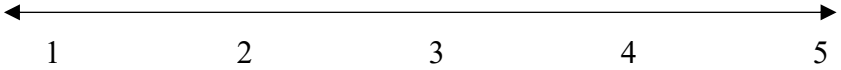


2) Which sources of water did you rely on the most during your hike? Select top 3 sources.
   - Streams/Springs
   - Bodies of water (ponds, lakes, etc.)
   - Pipe/Faucet (i.e. at a campground)
   - Water tank or trough
   - Water cache
   - Other

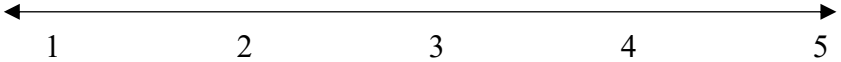
3) Did you feel you prepared enough for the water conditions? 1=underprepared, 5=overprepared



4) How often did you utilize a water cache? 1= never, 2=very little, 3= some, 4=often, 5=every opportunity



5) What was your overall experience of water conditions? 1=low stress, 5=high stress



Appendix D: Thematic Codebook

Theme: Perceptions

- **Code: Prior Experiences**
  - Description: When mentioning previous experience that could influence perceptions, experiences on the PCT or strategies
  - Example: "I had done lots of hiking and day hiking but no backpacking"

- **Code: Opinions on the Environment**
  - Description: Overall mention of the environment and conditions of the environment
  - Not for human-environment interaction
  - Example: "There's a lot of cattle to tromp through and defecate and everything in a high mountain stream"

- **Code: Opinions on Human-Environment Interaction**
  - Description: Mention of human interaction and interference/presence in the environment
  - Example: "You've got to wonder whether letting cattle venture up into high mountain streams should change given the state of water sources in general"

- **Code: Opinons on Thru-hiking Culture**
  - Description: Mention of the experience/culture of thru-hiking
  - Not for accomplishment or water impacts
  - More for social/emotional/mental experience
  - Can be used for what thru-hiking could be like if water sources were to change/human sources changed
  - Example: "[water caches] maybe kind of took away a little from the experience. Like the kind of roughing it and doing it yourself attitude"

- **Code: Sense of accomplishment**
  - Description: In relation to conditions, feeling like you accomplished something in your thru-hike
  - Example: "It felt like an accomplishment like when we got to camp or we made it over a big pass or a river crossing"

Theme: Conditions

- **Code: Water Conditions**
  - Description: When water conditions specifically are mentioned
  - Example: "I think everyone I was hiking with was surprised that there were a couple of long carries [for water] in Oregon"

- **Code: Human Intervention of Water Sources**
  - Description: When mentioning human sources and needs for management of water sources

    - Example: “I’m sure if there were one or two more well-maintained and operated caches nobody would complain

- **Code: Water Caches**
    - Description: When water caches are mentioned
    - Example: “In the desert I think half of the water sources I don’t think I shopped at were water caches”

Theme: Strategies and Tactics

- **Code: Strategies and Preparation**
    - Description: How they approach planning for water and hiking
    - Includes when they talk about apps used and strategies
    - Example: “I was looking at maps frequently to see where my next water source was, how many miles away, how much I had, [etc.]”

- **Code: Consequences**
    - Description: Outcomes of poor planning or unreliability of water sources impacting the person poorly
    - Example: “There was another part of the desert where I ran out of water until I hit a cache”

Appendix E: Water Cache and Tank Locations

Section	Mile	Location	Type
Southern CA	15.4	Cottonwood Creek below Lake Morena	Water Cache
	68.4	Rodriguez Spur Truck Trail	Water Cache and Tank
	77	Scissors Crossing	Water Cache
	91.2	Third Gate Cache	Water Cache
	143.1	Table Mtn Truck Trail AKA Sandy Jeep Road	Water Cache
	145.4	Muir Wood (South) Cache, on private land about 50 feet off trail	Water Cache
	209.5	Cabazon	Water Cache
	213.4	Mesa Wind Farm	Water Cache
	347.3	Swarthought Canyon Road Cache	Water Cache
	436.3	North Fork Ranger Station	Water Cache/Station
	370.4	Grassy Hollow Visitor Center	Faucet, Cache
	465.6	Bouquet Creek (usually dry)	Water Cache next to creek
	485.7	Lake Hughes Road	Water Cache
	499.5	RD0499 Unpaved Road	Water Cache
	510.9	Pine Canyon Cache	Water Cache
	549	Mile 549 "Lounge"	Water Cache
	558.2	Oak Creek	Water Cache
	558.5	Tehachapi-Willow Springs Road	Water Cache
	565.1	Cameron Canyon Road	Water Cache
	566.5	Highway 58	Water Cache
	615.9	Kelso Valley Road (middle of long dry stretch)	Water Cache
	630.8	Bird Spring Pass (Long dry section)	Water Cache
	651.3	Walker Pass Trailhead Campground	Water Cache
	652	Hwy 178 (Walker Pass)	Water Cache
Northern CA	1393.6	Cache 22	Refillable Tank
Southern OR	1848.4	Unpaved Forest Road 961	Water Cache
	1878.3	OST Junction	Water Cache