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Factors Affecting Streamflow Timing on Sagehen Creek, California

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Abstract

Monitoring and understanding patterns in streamflow, especially in the western United States is extremely important. In California, and in the Sierra Nevada mountain range in particular, it is vital to predict and understand streamflow as it serves as a significant water resource for California. Mountain snowpack is the primary driver of flow for many rivers and streams throughout the mountain range. Melting snow in the spring fills streams and water management reservoirs so that people have access to potable water in the summer months when there is little precipitation. Over the past several decades, mountain stream gauges across the western United States have been experiencing earlier peak streamflow timings. This study looks at Sagehen Creek in the Sierra Nevada mountain range and analyzes key reasons as to why the peak streamflow has changed over time. Temperature, snow depth, snow-water equivalent (SWE) and precipitation are all factors that affect the size of snowpack, which ultimately will affect the response of streamflow. Temperature was found to have one of the biggest impacts on the snowpack surrounding Sagehen Creek. Average high April temperatures have been steadily increasing over the past two decades, leading to faster and earlier snowpack melting times. Snow depth, which is mainly dictated by temperature and precipitation was also found to play a huge role in affecting streamflow timing. Cool, wet winters around Sagehen Creek had deeper snowpack depths while warm, dry winters yielded shallower depths. SWE and precipitation are two other factors that played a lesser role in affecting the earlier time of the streamflow. April 1 st SWE and yearly precipitation both saw slight increases, which is the opposite of what is expected if the peak streamflow is trending towards earlier in the year.

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1. Introduction

Snowmelt's impact on streamflow is an important relationship to monitor and understand. In colder climates, melting snow contributes greatly to streamflow of nearby rivers and streams. As a result, the effect snowmelt has on runoff and streamflow is vital to some parts of the world (United States Geological Survey [USGS], 2016). One of the most significant effects this relationship has is on water management and water forecasting. In the western United States, many people rely on reservoirs that have snowmelt as their main source of water. Reservoir managers must carefully monitor the amount of water that flows into and out of the reservoir in order to make sure there is enough water to last through the summer season and to make sure large precipitation or melting events do not cause the reservoir to overflow (Harpold et al., 2017).

2. Literature Review

The effect snowmelt has on streamflow, especially in areas of the western United States, is well studied across literature. In areas of higher elevation, such as the Sierra Nevada mountain range in California, precipitation in the form of snow plays a vital role in the region's river and stream systems. In the western United States, most precipitation that falls on the mountains during the colder months forms snowpacks. These snowpacks stay frozen through the winter months and begin to melt as the temperature rises in the spring. The runoff from the snowmelt gets released into nearby rivers and streams and is essential for many water-supply systems. Sometimes, runoff from snowmelt can be responsible for most to almost all of the streamflow in a river (USGS, 2016). Another key factor in the amount of runoff that can occur is precipitation. Years with high precipitation amounts yield higher streamflows than years that saw little precipitation. The amount of precipitation that falls has an impact on the snowpack for the season. This, in turn, has an effect on the amount of runoff which ultimately has an effect on streamflow (USGS, 2016).

Recent studies show that changes in temperature and accumulation of snow are having an effect on seasonal snowpack. Decreases in the amount of precipitation falling as snow and decreases in snow-water equivalent are leading to smaller snowpacks that contain less water. Warmer temperatures are also contributing to earlier spring snowmelts. In a study done on Colorado river basins, 14 different regions of Colorado with 14 different gauges were tested. The analysis of the data showed that there is a strong correlation between snowmelt and streamflow timing. Over the 29 year study, it was found that the median for snowmelt shifted 2-3 weeks earlier in the year. The analysis also pointed to a trend of increasing air temperature during the time of the study, as well as a decline in SWE. Snowfall, SWE, air temperature, elevation and latitude were used as variables to try and see which factors had the biggest impact on the timing of snowmelt. Warm air temperatures had the biggest impact on earlier timings of snowmelt while SWE, latitude, and elevation were the biggest drivers of delaying the timing of snowmelt (Clow, 2010).

3. Data

To conduct this research, data will be collected from various sources. Temperature, snow-water equivalent (SWE), snow depth and precipitation will come from the Independence Lake SNOTEL (snow telemetry) site which is located just outside Sagehen Creek basin, but close enough that its data should be representative of snow conditions in the basin. Data from the Independence Lake SNOTEL site is provided by the Natural Resources Conservation Service (NRCS). Streamflow data is retrieved from the Sagehen Creek stream gauge. The gauge is run by the Unites States Geological Survey (USGS) and data for the gauge is from the USGS.

4. Methodology

This study will look at data pertaining to temperature, SWE, snow depth, and precipitation, with some data sets beginning in the late 1970s, some in the mid-1980s and some in the late 1990s and stopping in 2017. Within this time period, data will be organized and analyzed to see if 1) peak streamflow is occurring earlier in the year and 2) factors like temperature, SWE, snow depth, and precipitation have had an effect on recent streamflow.

5. Results & Conclusion

Since streamflow in the Sierra Nevada is of utmost importance in cases of water management, it is important to know what the trends in particular streams across the mountain range are and how the streams are responding to change. For Sagehen Creek, the timing of peak streamflow has been shifted earlier in the year over the past six decades (Figure 1). Every decade, the peak streamflow gets earlier in the year by an average of 3.3 days. So within the past 64 years, the timing of peak streamflow has changed by over 21 days. This is not inconsistent with other streams within the mountain range. On average, streams in the Sierra Nevada have been seeing earlier peak flows by about 10 to 30 days (Schwartz et al., 2017). Because Sagehen Creek's flow is heavily dependent on wintertime mountain snowpacks, any change in snowpack has a direct effect on the creek. Important factors and characteristics that affect snowpack include temperature, snow depth, SWE, and precipitation. The flow of Sagehen Creek responds to changes in each of these variables.

Over the past 22 years (the amount of years available that recorded high temperature data at Independence Lake), April temperatures have been increasing in the vicinity of Sagehen Creek (Figure 2). April temperatures are a good reference point for how much melting and how fast the melting will be in the spring. This is due to the fact that April temperatures gradually start to warm up during the month, kick starting the melting process. Although it is normal for April temperatures to increase, the rate at which they are increasing is dangerous to snowpack. The more snowmelt that occurs earlier in the spring, the less water that will be available for consumption in the summer. At Independence Lake, the average high April temperature over the past 22 years is 6.65 degrees Celsius. Out of those 22 years, average high April temperatures exceeded the mean in 12 years. In the most recent 10 years, 6 years were those that exceeded the average high, and 5 of those years featured back to back above average temperatures (2012 to 2016). Prior to this, there were no years that featured back to back above average temperatures for a period this long. Over the 22 year period, average April highs have increased by 0.67 degrees Celsius.

Snow depth of a snowpack is dependent upon precipitation and temperature. In the Sierra Nevadas, cold, wet winters yield deep snowpacks while warm, dry winters yield shallow packs. These conditions can often be influenced by the climate oscillations such as ENSO. This is true for the Independence Lake SNOTEL site. The years, 2006, 2010, 2011, and 2017 were all considered wet years in the Sierra Nevada and also reflect wet years at Independence Lake. Three out of four of these years presented with some of the highest peak snow depths (over 190 inches) dating back to 1999 at Independence Lake, which is due to temperature and precipitation. All four of these years had above average precipitation and all four of these years had below average April high temperatures (Figure 3). All four of these years were also in the negative phase of ENSO. Looking at 2007 through 2009 and 2012 through 2015, these years were all considered dry winters. Most of these years had small snowpacks (under 110 inches at peak depth) due to temperature and precipitation. All dry years experienced below average precipitation for the year and all but one year experienced above average April high temperatures. Over half of these years experienced their low snow depths while ENSO was in its positive or neutral phase.

April 1st SWE amounts are a good indicator of the size of future streamflows that occur due to melting. SWE is often one of the more significant factors considered when predicting streamflow. In the Sierra Nevada, April 1st SWE are on the decline. However, this is not true for Independence Lake. According to the graph of April 1st SWE at Independence Lake, SWE values have actually been increasing over the past 31 years (Figure 4). When the graph is fitted with a linear trendline, a positive slope is produced. Although the SWE is increasing, the past decade produced some of the smallest SWE amounts for the period of record. The reason for the increase may be attributed to the highest and third highest SWE amounts occurring within the past 10 years of data. These high values may be large enough to skew the data into producing a positive slope.

Precipitation and its relationship to streamflow and snowpack is important. Precipitation that falls on a river can directly contribute to streamflow. Large precipitation events can lead to peak streamflows depending on the intensity, duration, geographic, and geologic factors of a basin. Precipitation can also lead to the growth or decay of a snowpack, depending on the type of precipitation falling. At Independence Lake, there is approximately 39 years of precipitation data. When the total yearly precipitation data is plotted, it fits well with the findings of Knowles et al. 2006, in the fact that total yearly precipitation has not varied significantly. In the case of Independence Lake, yearly precipitation has actually been increasing steadily over the past 39 years (Figure 5). When the data is plotted and a linear trendline is applied, a slight positive slope is produced. The 39 year period yields an average annual total of 48.1 inches of precipitation, with 2017 being the wettest year and the late 1980s to mid-1990s having some of the driest years.

Based on the data, it is clear that the timing of peak streamflow on Sagehen Creek is gradually getting earlier in the year, with warmer temperatures and shallower, smaller snowpacks playing the largest role in why this change in timing is occurring. In addition to the earlier peak streamflow time, peak streamflow itself is also steadily decreasing (Figure 6). When the 64 years of peak streamflow data is plotted and a linear trendline fit to it, a substantial negative slope is formed. So, not only do these factors have an effect on peak streamflow timing, but they also have an effect on the amount and rate of water flowing in Sagehen Creek.

6. Figures

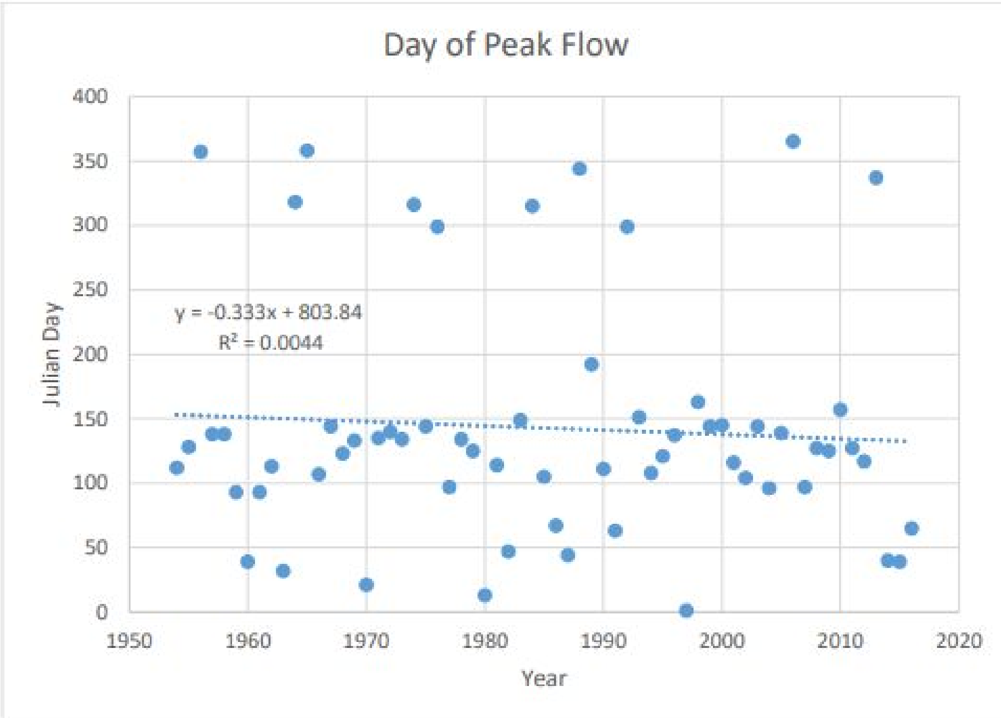

Figure 1: Graph of the day of peak streamflow from 1953 to 2017. Negative slope indicates that peak flow is trending towards earlier in the year.

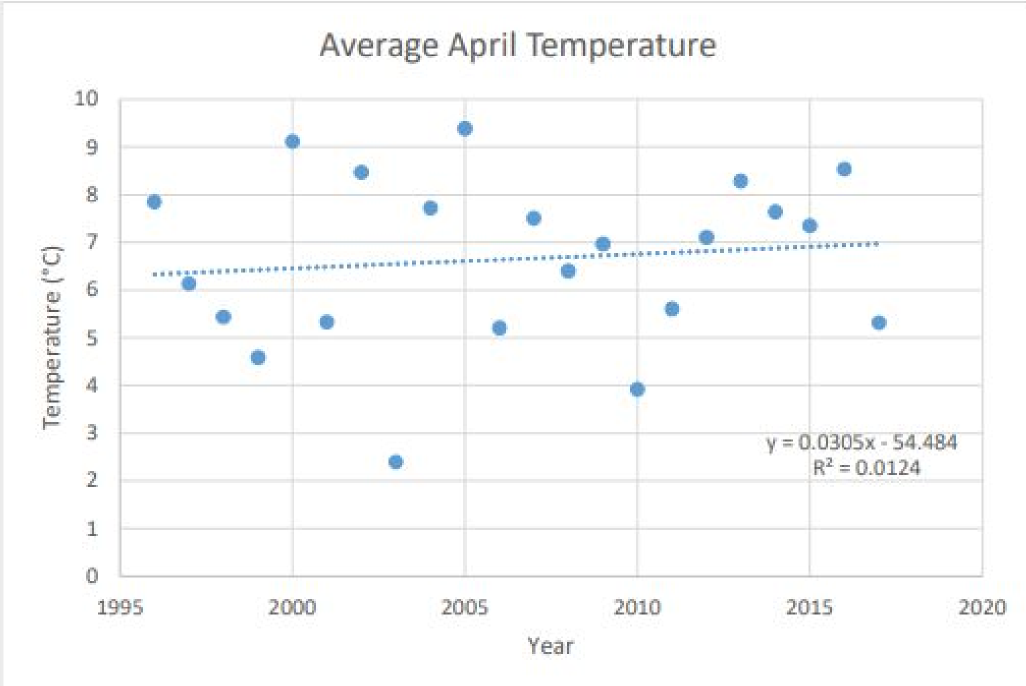

Figure 2: Graph of average high April temperatures at Independence Lake. Positive slope shows the increase in temperature over the past 22 years.

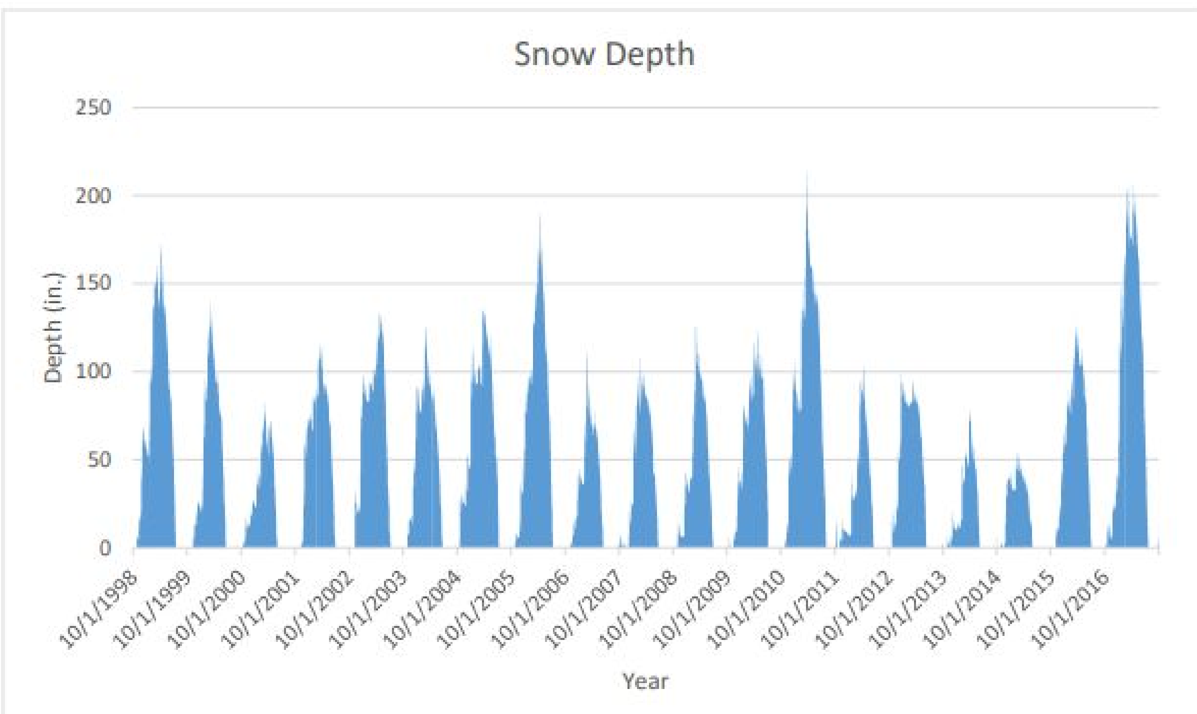

Figure 3: Graph of wintertime snowpack depth from 1999 to 2017.

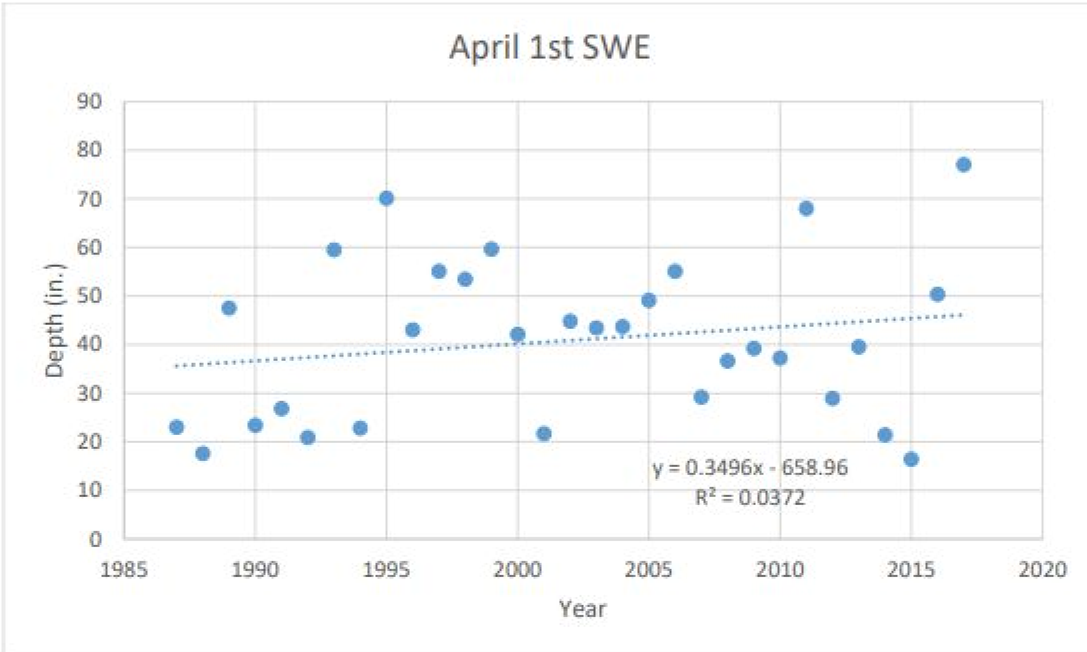

Figure 4: Graph of April 1st SWE. Positive slope indicates increasing SWE over the 31 years of data.

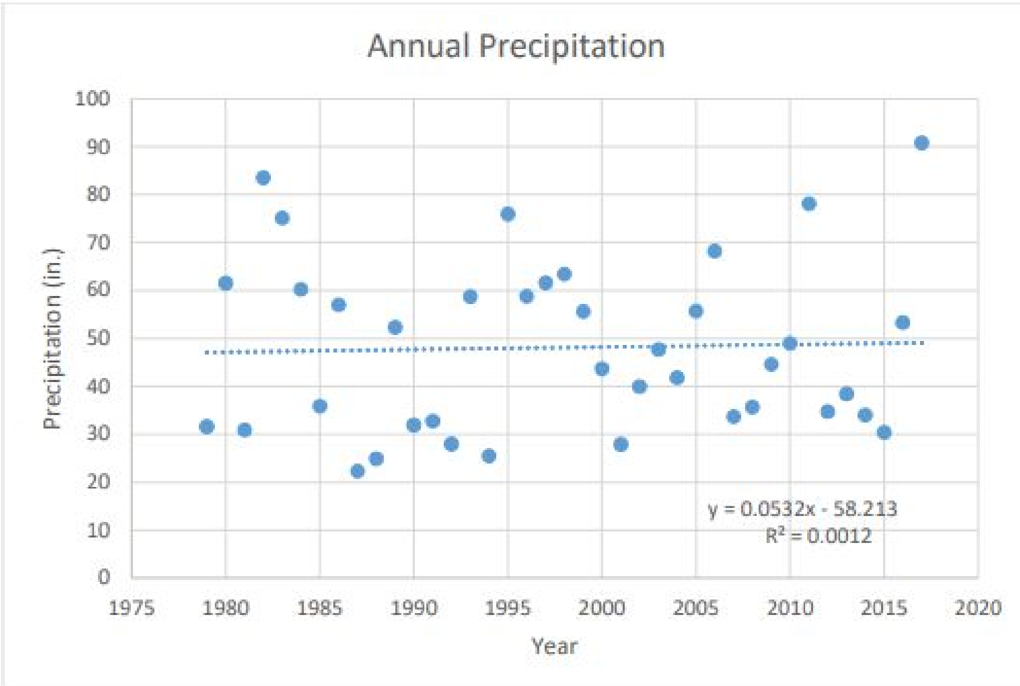

Figure 5: Graph of annual precipitation at Independence Lake. Positive slope shows increase in precipitation over the 39 year period.

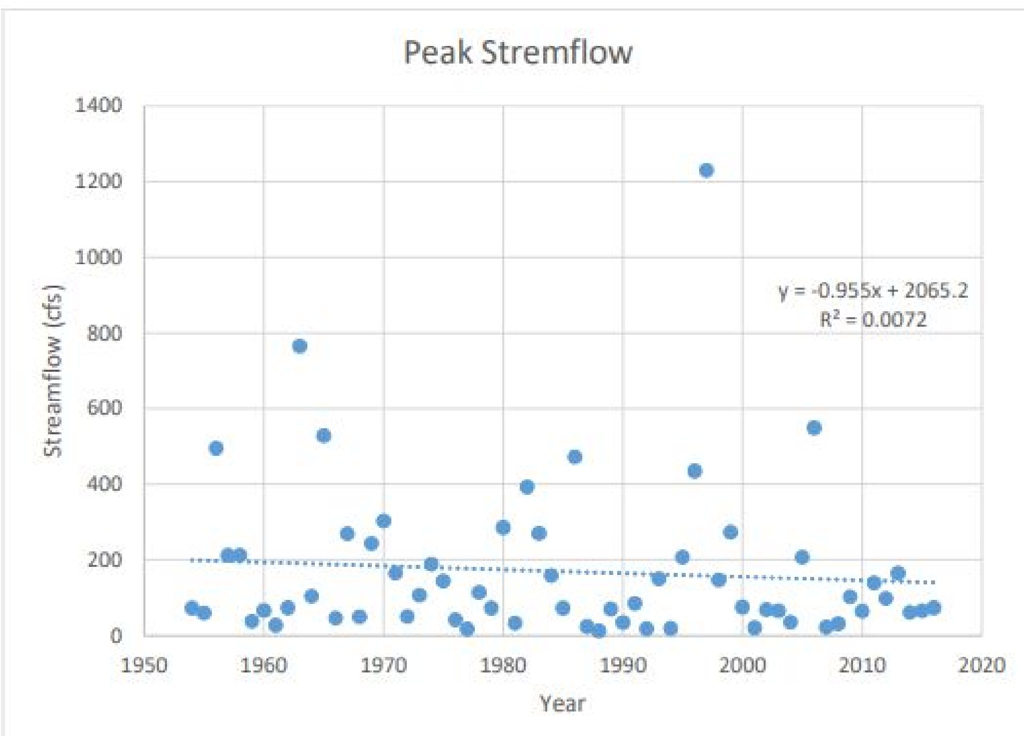

Figure 8: Graph of peak streamflow. Negative slope indicates that peak streamflow has been decreasing over the 64 year period.

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