Moffett Creek Capstone Project

Final Report 2018/2019





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Introduction

The Moffett Creek Capstone Project (MCCP), as part of the Southern Oregon University's Environmental Science and Policy program, was developed to conduct a large-scale assessment of the Moffett Creek Watershed to ascertain the magnitude of natural versus anthropogenic caused erosion and sedimentation and to what extent and scope the degradation of the watershed is occurring. This report summarizes efforts and findings from the Moffett Creek Capstone Project (MCCP). The overarching goal is to demonstrate the culmination of skills, methodology, and knowledge learned in the undergraduate curriculum. In addition, this project will attempt to answer the question; if implementation of restoration techniques can address anthropogenic impacts and reduce degradation, improving water quality for both Moffett Creek and the larger Scott River riverine system? The MCCP utilized mixed methods research using both quantitative and qualitative approaches, assessing anthropogenic versus natural impacts on water quality and quantity. Data collection, data analysis and modeling will provide information that can be used to evaluate the possible effects of potential restoration activities. The parameters that were utilized are groundwater and surface water levels, stream discharge, turbidity, stream channel configuration, and soil profiles. A social element to the project included a landowner survey to better understand the current attitudes and perceptions about restoration.

The Scott River Watershed is located in Siskiyou County, California and lies within the Intermountain West, a semi-arid region. The watershed is 813 square miles, has 274 miles of anadromous salmonid habitat and is a main tributary of the Klamath River, one of California's largest river systems. The region is ecologically diverse and features dramatic variations in elevation, hydrology, geology, and soil composition (Scott River Watershed Council 2005). Moffett Creek is a large sub watershed of the Scott River (Figure 1). The MCCP will focus on the upper Moffett Creek watershed which includes approximately 45,000 acres of mixed terrain (SHN 2003). Elevations within the basin range from 6,000 feet at Duzel Rock to 2,900 feet at the confluence of Moffett Creek and Soap Creek.

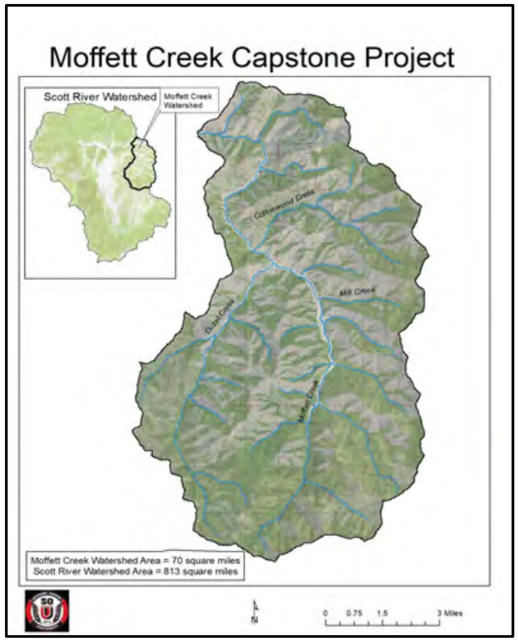

Figure 1: Moffett Creek watershed area as it relates to the larger Scott River watershed.

For over a century, a large majority of areas within the Moffett Creek watershed have experienced varying degrees of alteration due to human activities affecting many aspects of the natural physical, hydrologic, and ecological systems. The effects of human land use tend to alter one of three watershed components; water, soil or vegetation. Ecologically, both aquatic and terrestrial ecosystems have evolved within a natural range of disturbance frequency and intensity. Land use in the Scott River watershed have significantly, and in some instances, catastrophically disrupted the natural disturbance regime, causing imbalances both in the physical and biological systems (Environmental Science Associates 2009). Moffett Creek has been impacted by road construction, logging, overgrazing by cattle, channel straightening and leveling, floodplain modification, fire suppression, and recent prolonged droughts.

Surface water within the upper Moffett Creek has two distinct characteristics. Within the valley floor of the basin, the surface water connectivity is intermittent, with no surface flows for most of the drier months of the year. Perennial flows begin at approximately river mile 12 and persist through river mile 16. Furthermore, there are eleven man-made ponds located along the Moffett Creek channel that do present surface water on a more regular basis. According to the Scott River Adjudication Decree, the upper Moffett Creek and its tributaries have a total adjudicated right of 14.86 cubic feet per second (cfs), with a total area served of 966 acres (California State Water Resource Control Board 1980), however there are no known active diversions at this time. There is very little data recorded about the groundwater in historic records.

Cottonwood (*Populus fremontii*), alder (*Alnus rhombifolia*), and some willow (*Salix lasiandra*) are the predominant riparian species. There is a significant change along the riparian zone in the ratio of different species, the range of age classes, and percentage of cover from the lower section of the watershed to the upper. The reason for this change is not fully understood, as there are many factors that could influence riparian health and vigor; such as access to groundwater, impacts from ungulate browse, and nutrient and soil variations.

A large portion of the valley floor has been managed for cattle production. Siskiyou County is one of six counties within California to have an open range law. This law states the property owner is responsible for fencing of their property to keep livestock off the land. The only exception to this law applies to properties that are adjacent to federal lands and in such case, the owner of the livestock must provide adequate fencing to keep livestock off of federal property (County of Siskiyou 2005). Reports of cattle coming into the local basin from areas outside the Moffett Creek basin are common.

The economical as well as the social aspects of the area are strongly connected to post European activities such as timber extraction and cattle production. Currently, 31% of the Moffett Creek watershed is owned and actively managed for its timber resource by private timber companies (Siskiyou County Assessor 2015). Land uses for the past century has consisted mostly of logging, cattle and hay production and residential. Approximately 89% of the overall watershed ownership is private, with several landowners owning 15,000+ acres. It is estimated that approximately 63% of the watershed consists of mixed conifer, brush and woodlands, 28% of rangelands, 8% of croplands, and 1% of urban uses such as residential and roads (United States Department of Agricultural 1971). Recreational activities are few with the exception of hunting of blacktail deer (*Odocoileus hemionus columbianus*), black bear (*Ursus americanus*) and limited species of upland birds. These activities are managed by the California Department of Fish and Wildlife and take place primarily on private lands. Overall, the larger Scott River watershed consists of disadvantaged communities, with the mean household income averaging $38,524, based on Siskiyou County data (United States Census Bureau 2018). Historically, Moffett Creek was home to the Shasta Indian. Today, there is very little to show for their thousands of years of occupation, with the exception of a cemetery that was utilized from 1850 through 1950 (Figure 2).

Figure 2: Shasta Indian burial grounds located in Cedar Gulch within the Moffett Creek, circa 1850 to 1950.

Under section 303(d) of the Clean Water Act (CWA), the U.S. Environmental Protection Agency included the Scott River in the list of impaired waters for excessive levels of suspended sediment and elevated water temperature (North Coast Regional Water Quality Control Board 2006). These water quality parameters are known to impact the habitat and survival of salmonid species and the designated beneficial uses and are used to protect cold water, migratory fish and habitat.

In 2005, the NCRWQCB adopted the Action Plan for the Scott River Sediment and Temperature Total Maximum Daily Loads (TMDL). The Plan includes sediment and temperature TMDL's and describes the implementation actions necessary to achieve the TMDL's and attain water quality standards in the Scott River Watershed within 40 years of EPA approval of the water plan. Additionally, the plan set daily totals for these pollutants to be considered and incorporated into regulatory and non-regulatory actions in the Scott River Watershed (North Coast Regional Water Quality Control Board, 2006). Sedimentation from the Moffett Creek drainage has been identified as one of the main contributors to the Scott River's listing. SHN Consulting Engineers & Geologist, Inc. (SHN) completed the Moffett Creek Gross Sedimentation Assessment Version 1.4 Revised, prepared for the Siskiyou Resource Conservation District in 2003. In their report, SHN concluded significant erosion is attributed to natural geomorphic and topographic conditions, in addition to management or anthropogenic related activities in the Moffett Creek Watershed (SHN 2003).

According to the 2003 SHN assessment, "Moffett Creek and its two sub watersheds, Mill Gulch and Cottonwood Creek are contributors to sediment loading of the Scott River; leading to its listing as impaired". If sediment loading of Scott River can be reduced, it may have an impact on overall water quality of the Scott River. Nationally, 30% of sediment loading in rivers streams, and lakes may be attributed to natural conditions leaving 70% attributed to anthropogenic causes (Mid-America Regional Council, n.d.). To address the anthropogenic impacts, restoration practitioners should seek ways to implement restoration within a watershed that aim to reestablish natural processes. Consequently, there is a need for an updated study on Moffett Creek watershed as the 2003 SHN study was limited in scope and there are no peer reviewed scientific studies of the watershed available for analysis.

Methods

One of the first and most critical elements of this project was the formation of the necessary partnerships with local landowners, stakeholder and agencies. Two large landowners agreed to allow the MCCP to take place on their lands, totaling 18,065 acres. Additionally, there is 15,540 acres of federal lands (Figure 3).

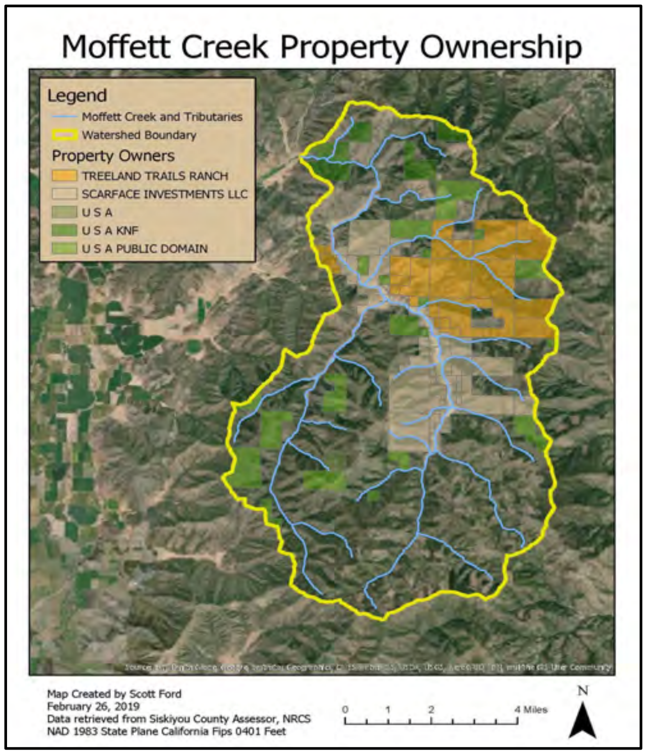

Figure 3: Property ownership for Moffett Creek Capstone Project area within Moffett Creek watershed.

Limited data exists for the Moffett Creek watershed especially relating to the hydrology of the basin, therefore the MCCP focused its initial efforts on establishing a monitoring plan that would help inform restoration efforts in the future. There were five main elements utilized to meet the objectives of this project:

1. Data collection methodology:
    a. A discharge station was established in the summer of 2018 and another established in January 2019 (Figure 6). A SonTek Flowtracker Handheld ADV Firmware Version 3.3 Software Version 2.20 is being used to record discharge from a location that is at the top of the watershed basin and within a confine canyon reach, downstream of the main Moffett Creek basin. These measurements were manually taken on a weekly basis.
    b. A groundwater and surface water monitoring network was established longitudinally down the valley floor of the Moffett Creek watershed using eight existing groundwater wells, one well within the Cottonwood Gulch drainage and one well down at the confluence of Moffett Creek and Soap Creek. Additionally, four surface water ponds are being measured using a staff plate

(Figure 6). Depth to groundwater will be measured using a Solinst 101B Flat Tape Water Level Meter. These measurements are taken from a reference point which was surveyed using a Total Station to get relative elevation. Manual readings were taken to help calibrate Onset U20L-04 HOBO Water Level Data Loggers which were also measuring water levels on a 15-minute interval. In order to get the groundwater elevation, an additional logger has been set up that will measure the barometric pressure which will allow us to calibrate the water surface level. To ensure that the best available concerning localized precipitation is obtained, a Data Logging Rain Gauge system that is a battery powered HOBO® Pendant Event data logger with a tipping-bucket rain gauge has been installed within the subbasin close to the confluence of Cottonwood Creek and Moffett Creek. This device collected rainfall, time, duration, and temperature data.

c. Turbidity sampling was done at different locations along stream reach to try to better understand sediment inputs for subwatersheds as it relates to the entire Moffett Creek drainage (Figure 4). A HACH Portable Turbidimeter Model 2100P was used to determine the concentration of suspended particles within the water column. Water samples were collected and measured at 5 locations. The locations for the sampling sites were established at the existing discharge measuring stations, and at the three bridges located on the mainstem of Moffett Creek.

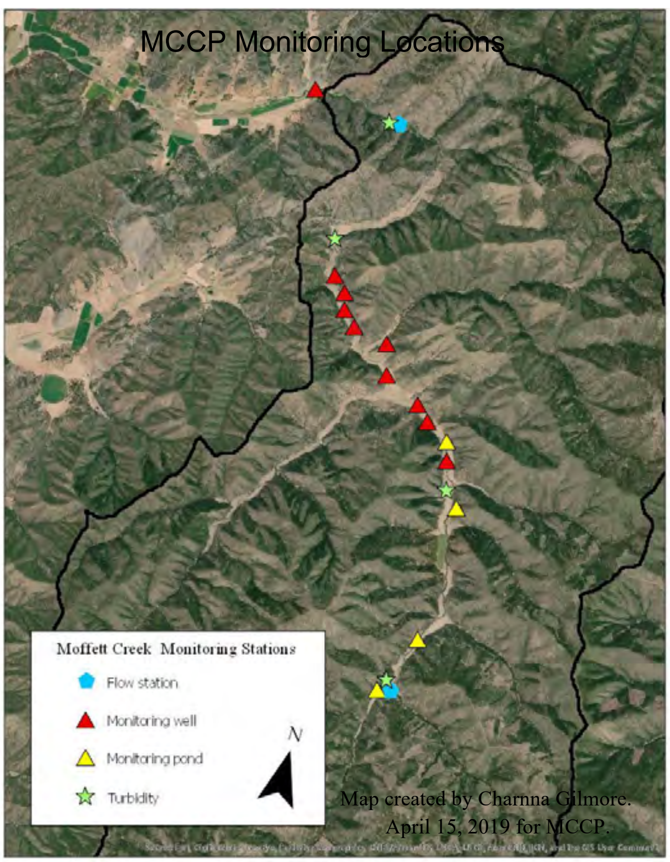

Figure 4: Moffett Creek Capstone Project monitoring locations.

   d. Historical photos from 1955 and 1965 were georeferenced and used to evaluate change over time, particularly within the valley floor and creek channel. Further evaluation was done utilizing normalized difference vegetation index (NDVI), which is a simple graphical indicator used to analysis remote sensing measurements to assess a change in vegetation regimes within the watershed.
   e. Soil data was gathered using the United States Department of Agriculture Natural Resources Conservation Service Web Soil Survey program. Soils for the Upper Moffett Creek basin were imported into ArcGIS Pro software in order to determine soil compositions and soil areas for each sub-basin.
2. Environmental Modeling
   a. STELLA™ software was utilized to create a dynamic computer model of the upper Moffett Creek watershed basin. The model used monthly time steps with a full run time of 2 years to allow for the assessment of changes to land use practices over time. The model was run with current, increased, and decreased impacts from anthropogenic factors to test how influential anthropogenic variables are on the overall sediment removed from the basin. Key state variables, or stocks, for this model were the various sub-basins of Moffett Creek, a stock for sediment outflow from the basin, as well as Moffett Creek itself (Appendix A).
3. Future Restoration Project Tools and Recommendations
   a. A Programmatic Environmental Impact Statement was prepared pursuant to the California Department of Fish and Game §1602 Streambed Alteration Agreements or Habitat Restoration and Enhancement Act of 2014 permitting, Clean Water Act §401 Certifications, a Clean Water Act §404 Nationwide Permits or Regional General Permits, and an Endangered Species Act Section 7 Consultation/Incidental Take Statement to assess the environmental impacts of proposed actions to implement restoration activities within the Moffett Creek (Appendix B).

Results

Soils and Geology: The underlying geology of the Upper Moffett Creek Watershed is located along the east central boundary of the lithotectonic belt of the Klamath Mountains physiographic province (Bailey 1966). This rock is primarily composed of marine phyllite, siliceous slate, tuff and crystalline limestone (SHN 2003). Portions of the basin also contain Silurian and Ordovician marine rocks which add sandstone, conglomerate, dolomite, and greenstone to the rocks already present. Mesozoic ultramafic rocks such as serpentine, peridotite, gabbro and diabase are present at the north end of the watershed. The United States Department of Agriculture's Natural Resource Conservation Service (NRCS) reports that the valley floor of the Upper Moffett Creek Watershed is mainly composed of various Bonnett gravelly loams with additional soil complexes on the surrounding hillsides (Figure 5) (United States Department of Agricultural 1971). Interestingly, Moffett Creek's water is very hard and is noted to be high in magnesium (Mack 1958). This would be consistent with visual mineral deposits within the stream channel and local knowledge and residents dealing with high levels of calcium, leading to infrastructure problems (Stevens 2019).

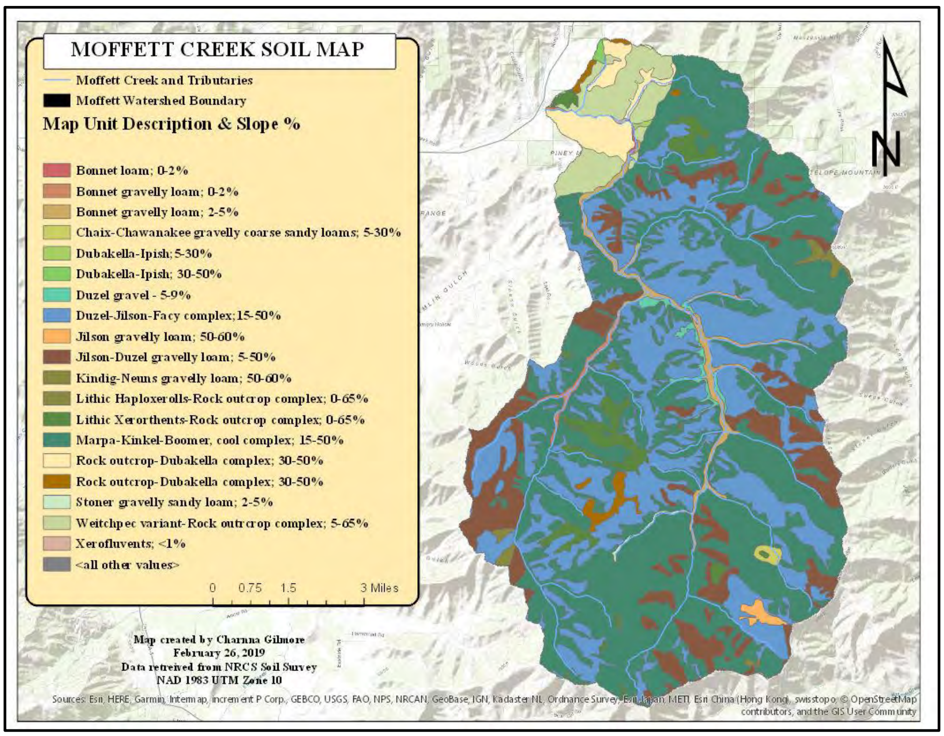

Figure 5: Moffett Creek soil map. Soil data acquired from the National Resources Conservation Service.

One area of interest within Moffett Creek lies along the valley floor and consists of deep, well drained soils that were formed by in residuum derived from metamorphic rock (United States Department of Agricultural 1978). In much of the area, significant incision has occurred due to anthropogenic impacts that may have be exacerbated by channel simplification (Figure 6).

Figure 6: Large cut bank on Moffett Creek.

This particular soil is classified as a Bonnett gravelly loam, 2 to 5 percent slopes. These soils consist of very deep, well drained soils from alluvial fan deposits and formed in mixed alluvium (Figure 7) (Appendix D).

Figure 7: Distinct soil horizons exist within the soil sample on valley floor in Moffett Creek watershed.

Soil Model: The Stella Model resulted in a combined sediment delivery of 1.9 tons/month from the five simulated sub-basins. While the amount of sediment delivered fluctuated with increased and reduced anthropogenic effects the effect was fairly small. The major finding of the model was that the amount of loose sediment being created in the upper areas of the sub-basins was much higher than the amount of sediment being delivered through Moffett Creek (Figure 8). This sediment creation means that while large amounts of loose sediment is being created from the soils there is not enough water in the watershed to remove it under normal conditions. During large precipitation events however, this loose sediment is carried out of the sub-basins with surges of water. While surprising, these results match what was observed in stream turbidity after large precipitation events.

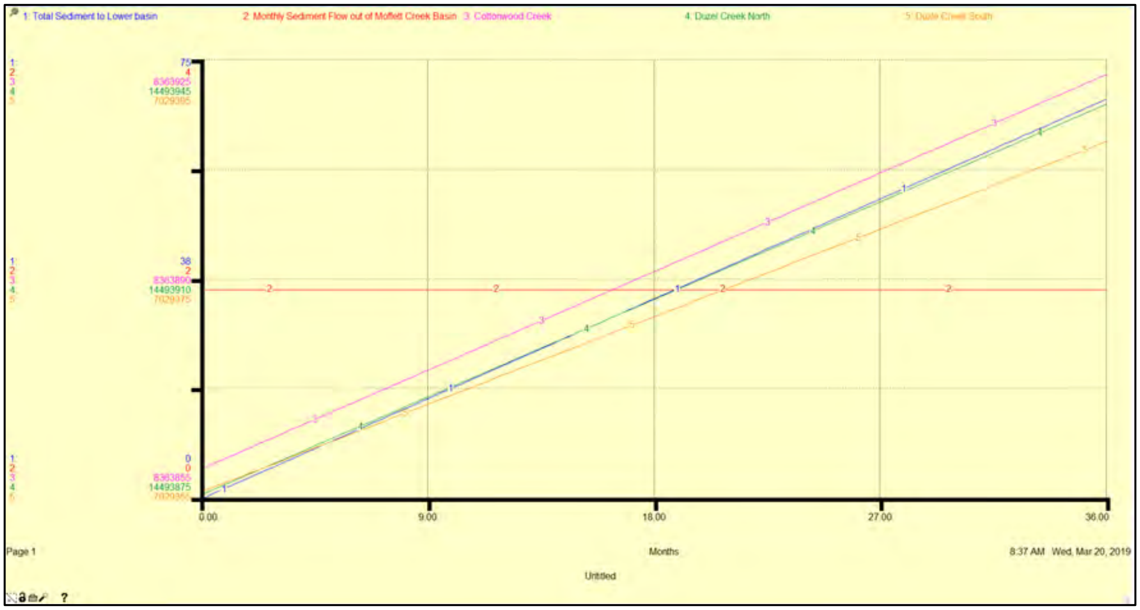

Figure 8: Stella model results. Line 2 is sediment delivered out of watershed. Lines 1, 3, 4, 5 are sediment amounts for each modelled sub-basin.

Discharge: The flow data that was collected for this project was analysis with a historic data set from 1958 to 1967, along with looking at the hydrography as it compared to the Scott River flow data for same period of time (USGS 1958-67). Similar trends were observed in the different years, however there was a noticeable in the difference cubic feet per second (cfs) between the historic data set and the 2018/2019 data set (Figure 9).

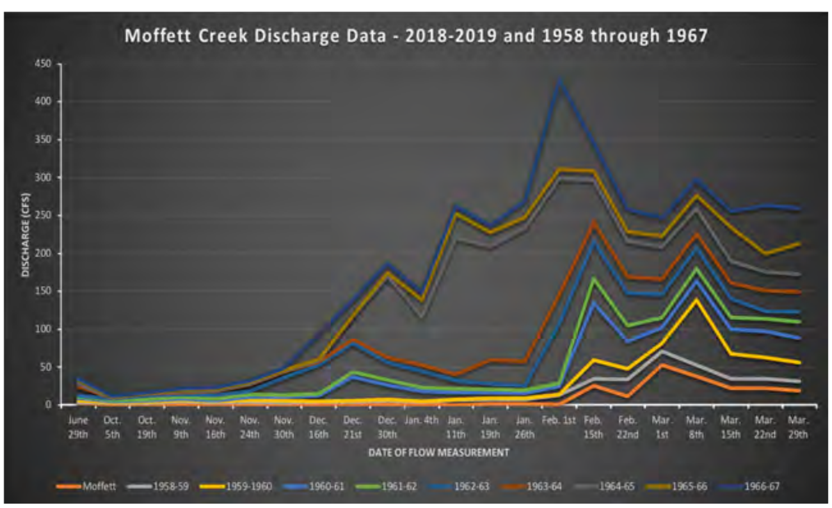

Figure 9: Moffett Creek discharge data from study period in 2018-2019 and historic data set from 1958-1967.

Peak flows measured on March 8, 2019 at 40.16 cfs as compared to flows recorded in February 1, 1967 at 423 cfs. Decadal precipitation data was also evaluated the data suggests a possible trend towards a drying regime (Figure 10) (California Department of Water Resource 2019).

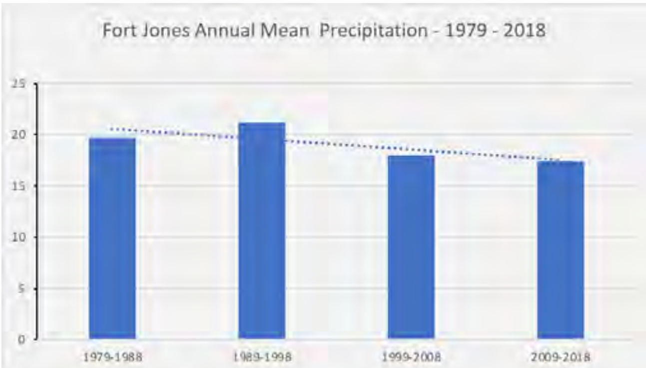

Figure 10: Fort Jones precipitation data from 1975-2018

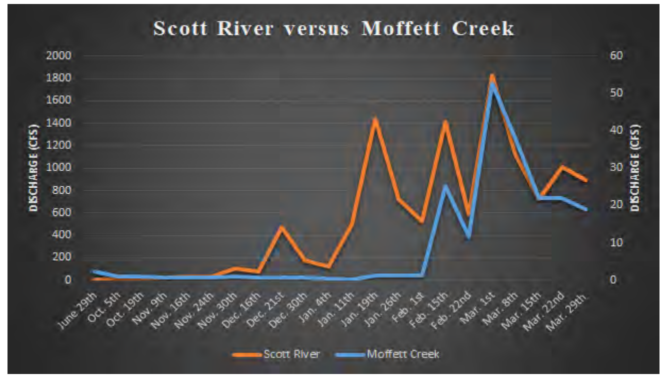

Figure 11: Moffett Creek and Scott River flow data from 2018-2019.

Data from the Moffett Creek flow station was evaluated against the flow data from the Scott River (USGS 2019). There is a strong correlation in the two hydrographs after the February 1, 2019 (Figure 11). This period was also the time when the surface of the groundwater increased substantially suggesting that the underlying aquifer may have gained some degree of recharge and therefore resulted in higher surface flows.

Water Surface Elevations: Over the past nine months, a groundwater and surface water monitoring network was established in order to better understand the hydrology of the basin. One of the goals of this project is to better understand the relationship between the groundwater aquifer and surface water flows (Figure 12).

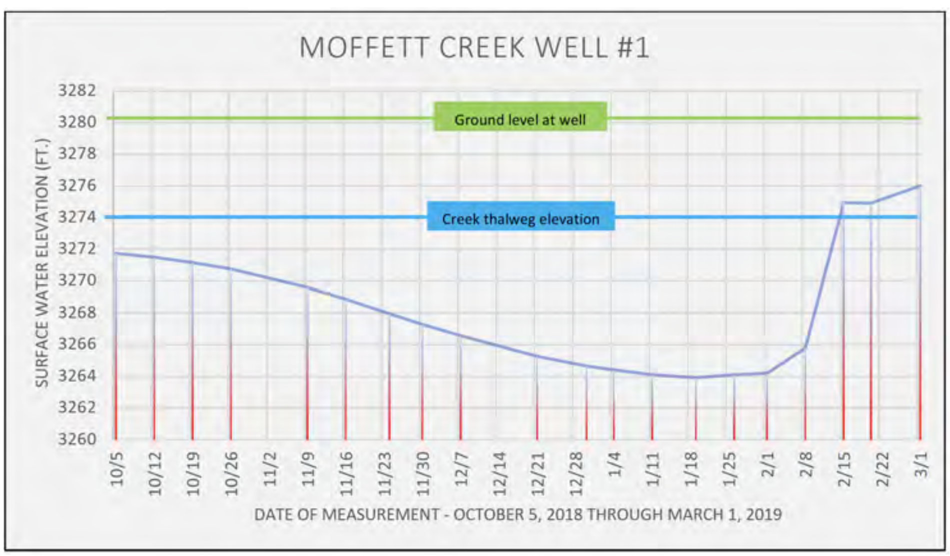

Figure 12: Moffett Creek well #1 surface water, creek thalweg and ground level elevations.

A cross sectional survey was performed at six well locations obtaining surface elevations of the well reference point, adjacent ground level, stream channel, thalweg, channel toes and banks. A full analysis was conducted on all groundwater and surface water monitoring sites to establish the relationship between water levels and creek channel/thalweg. As the Moffett Creek aquifer recharged, there was an observed increase in the surface of the groundwater elevation over a relatively short period of time, which resulted in visible surface water flow in creek (Figure 13).

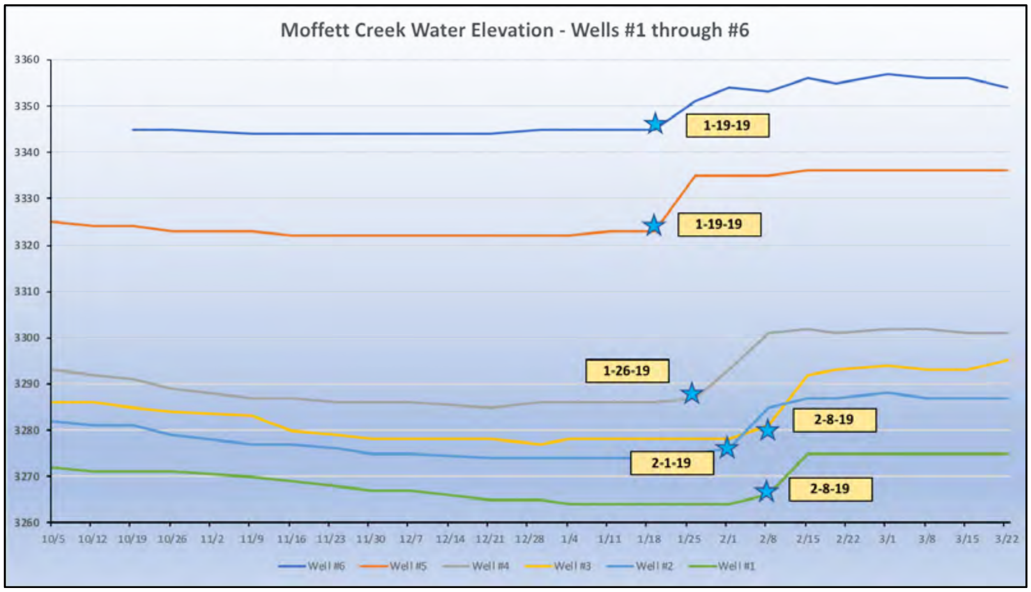

Figure 13: Groundwater data over time and when visible surface water was detected in creek.

Turbidity: One of the main questions that MCCP tried to answer was how much actual sediment is being transported through the watershed. Ultimately, this was more difficult to obtain than originally estimated. Although sampling did occur, the results were mixed. There were different events that produced high levels of suspended sediment and therefore the equipment was unable to take readings (Figure 14).

Figure 14: Moffett Creek flows during one of the first storms of the season. Photo taken 12/16/2018.

Direct observation and testing did determine that there were areas within the watershed that had higher inputs of suspended sediments. The highest turbidity reading was found at Station 5b on April 12, 2019 at 41.24 ntu (Table 1). This was a stark difference from Station 5c (Figure 15).

Table 1: Minimum, maximum, and mean turbidity readings (nephelometric turbidity units, ntu.) for Moffett Creek, stations 1-5, November 9, 2018- April 19, 2019.

	Station 1 Lower Transect	Station 2 First Bridge	Station 3 Second Bridge	Station 4 Scarface Bridge	Station 5a Upper Transect	Station 5b Upstream Branch	Station 5c East Branch
Min	0.31	0.44	0.39	0.89	0.42	0.38	0.57
Max	9.57	11.33	10.07	15.9	31.33	41.24	5.74
Mean	2.33	2.91	3.12	5.28	5.23	6.03	2.23

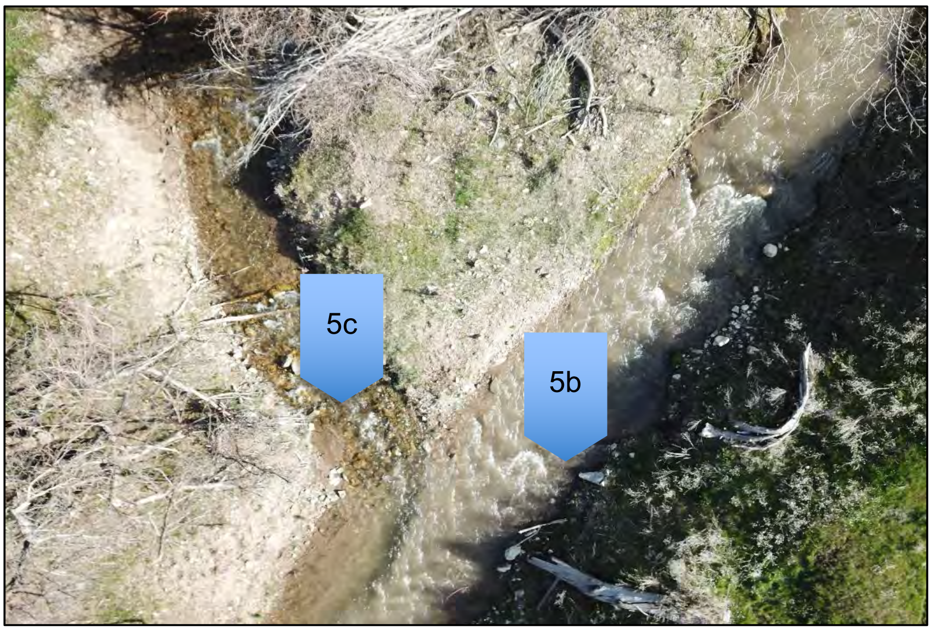

Figure 15: Turbidity stations 5b and 5c on April 12, 2019.

Remote Sensing: Historic aerial imagery of the Moffett Creek watershed from 1955 and 1965 were acquired from the Soil Conservation Service and subsequently georeferenced with current imagery from 2019 to display the relative changes in stream morphology. There was a noticeable loss of sinuosity in Moffett Creek from 1955 to 2019 (Figure 16). Consequently, this may have led to changes to the hydrologic regime including modified sediment transport as well as reduced depositional zones over the course of 65 years.

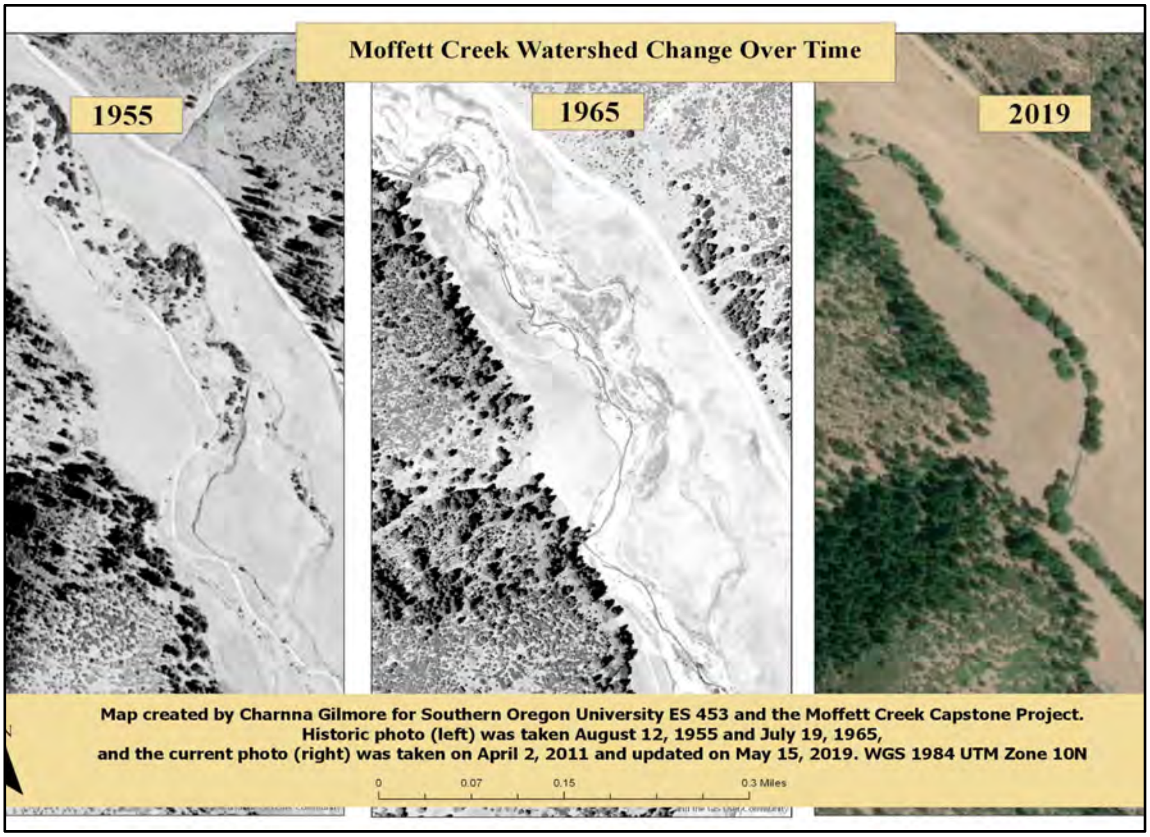

Figure 16: Channel configuration contrast within a reach of Moffett Creek from 1955, 1965 and 2019.

In order to better quantify these changes, Landsat data was used to analyze changes in vegetation via Normalized Difference Vegetation Index (NDVI) analysis. Sampled Landsat data was chosen to be from a midsummer (late June to mid August) seasonal period with date variation within that range due to cloud cover. Landsat scenes were chosen with 5-year intervals from 1975 to current in order to analyze the temporal change. Additionally Landsat data was used from each year in the past decade (2008-18) in order to get a more detailed view of the current behavior. This was done with the exclusion of 2012 due to errors in Landsat 7 data collection.

Landsat data for each chosen year was brought into ArcGIS Pro and combined into composite images of spectral bands. NDVI analysis was then performed on each composite. Average NDVI values were recorded for each year's image. Difference analysis was then run between the images to create maps of change in NDVI between images. This was done 3 ways. First, difference analysis was performed between each 5-year period. Then difference was analyzed for each decade (1975 was compared with 1985, etc) and finally the difference between each year from 2008 to 2018 was compared to improve resolution of current changes. Quantified results were then graphed to understand the trends in NDVI change from 1975 to 2018.

Further analyzation of NDVI for Moffett Creek from 1975 to 2018 shows an overall trend toward a reduction in the ranges of NDVI values for each year. Despite this change, average NDVI values show a stable, almost flat trend over time. These trends may indicate an overall loss in plant heterogeneity as similar plants will respond to environmental influences in the same manner. These changes may be a result of land use management, fire suppression and climate change.

Comparison of Moffett Creek NDVI between 1975 and 2015. There a shift in areas of vegetation away from the valley floors and into the upper reaches of the sub-basins. 1975 NDVI had a value range of 0.578595 to -0.9375. 2015 NDVI had a value range of 0.483987 to -0.00527933. These value ranges show that over time the difference between high and low vegetation has reduced. Areas in green and blue on the map indicate areas of relatively high vegetation while areas of orange and red indicate areas of relatively low vegetation. Yellow represents values near the middle of the range (Figure 17).

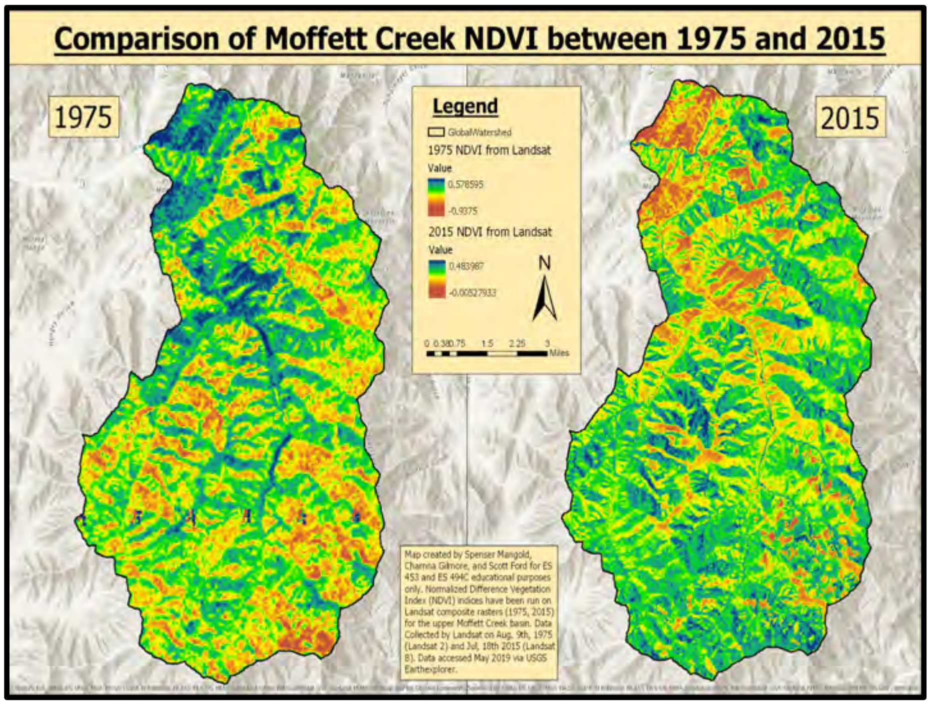

Figure 17: Moffett Creek NDVI map showing 1975 and 2015 comparison.

Difference Between 1975 and 2015 NDVI. Below is a map that uses the differences to help illustrate the visualize the change in NDVI between 1975 and 2015. Areas in green indicate an overall increase in vegetation over time while areas of red show a decrease in vegetation. Yellow areas indicate little change in vegetation over time (Figure 18).

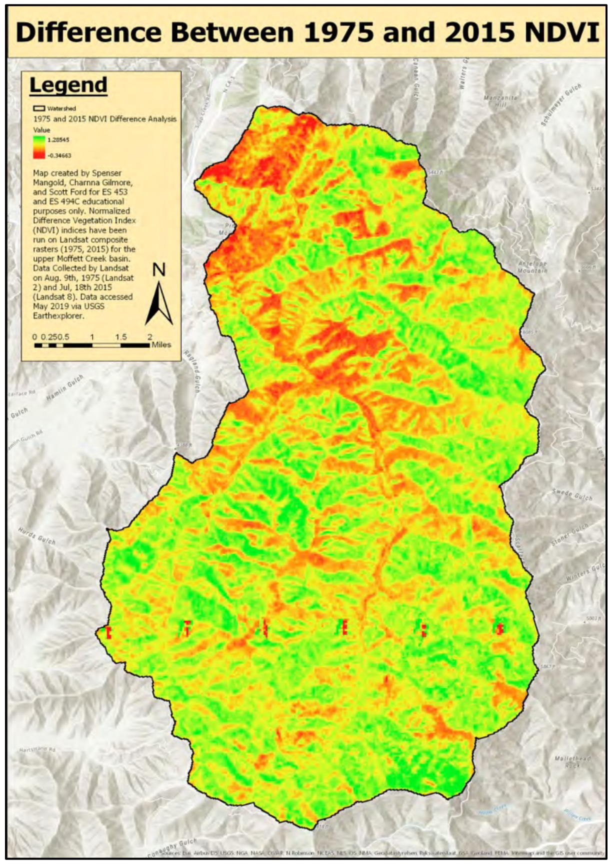

Figure 18: NDVI differences from 1975 to 2015 within the Moffett Creek watershed.

Discussion

An estimated 53% of all wetlands have been eliminated around the nation, with a much greater loss, over 90% within California (Dahl, 1990). Wetlands and floodplains play a critical role in the biological, geomorphic, and hydrologic cycles including groundwater recharge, all of which impact the overall ecological fitness of a watershed (Cluer and Thorne 2013). With the loss of floodplain accessibility, one of the byproducts is excessive sedimentation, and it is one of the leading causes of water quality impairment across the globe. It is estimated that nearly 20% of U.S. streams do not meet water quality standards set forth by individual states owing to high sediment levels and sediment loading from non-point sources (US Environmental Protection Agency 2006). Typical non-point sources of sediment from upland areas include runoff from agricultural lands, pastures, urban areas/construction sites, and forested lands, while stream banks and the streambed are considered in-channel sources (McCarney-Castle 2016). The amount of flow and sediments are controlled by hydrologic and geomorphic characteristics of the watershed; hence the watershed is the prime unit of sediment management (Owens et al. 2004; Narasimhan 2017). Locating the source of sedimentation is a critical first step in mitigating excess sediment in watersheds because it leads to a specific area to target for mitigation (Dutton et al. 2013; McCarney-Castle 2016). This is important because even relatively small changes in suspended sediment concentrations (SSC) can adversely affect aquatic biodiversity, especially affecting species with a narrow range of suspended sediment tolerance (Arismendi et al. 2016; Olsson and Hawkins 2017).

Riparian zones provide critical functions to overall stream health. Stabilizing creek banks and providing erosion control and sedimentation retention are two ecological services that Moffett Creek may benefit from as a result of establishing a healthier riparian area. The current riparian condition varies within the project area, however there are noticeable detrimental impacts from continuous and long term browse from cattle due to the lack of exclusionary fencing. Another factor that may limit riparian health, particularly in the lower reach of the watershed is the access to the water table by riparian roots. It is recommended that when planting riparian cuttings as a restoration tool, cuttings should be planted as much as 3-5 feet into the ground and sometimes deeper to ensure they are in the mid- summer water table (Hoag 2007). In some locations within the project area limited access to groundwater may reduce or slow a vigorous riparian growth (Figure 19). With prolonged durations in which the root zone does not have access may present challenges for natural recruitment and reduce the survival rate for future planting projects.

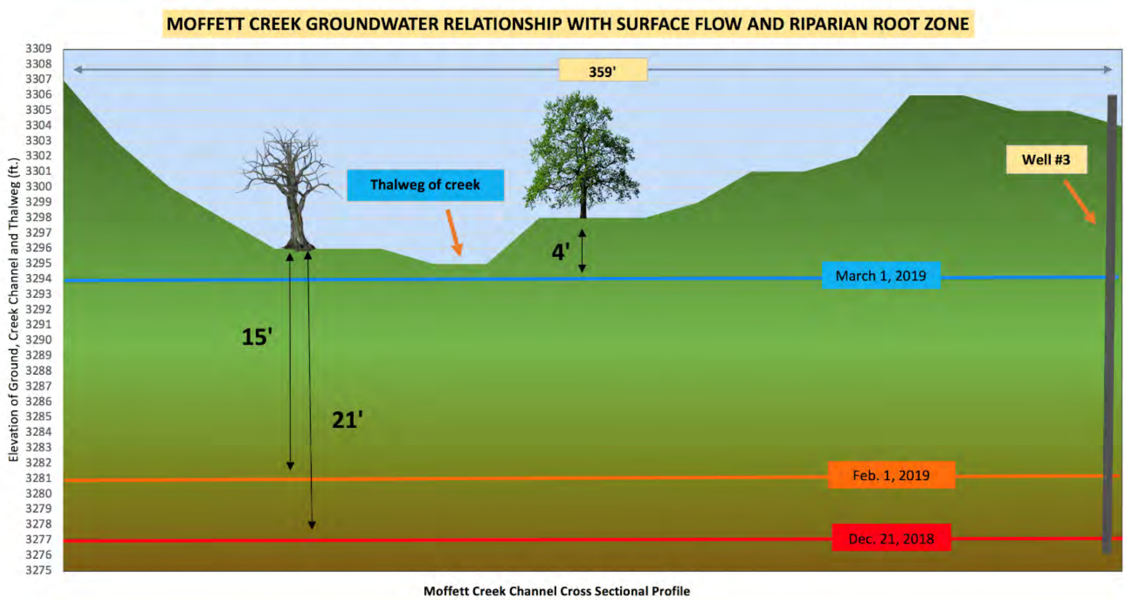

Figure 19: Relationship of groundwater at different time of the year as it relates to the thalweg of Moffett Creek at well #1.

Restoration within the Moffett Creek watershed and the larger Scott River watershed should focus on the concept of building ecosystem resiliency in advance of further impacts related to climate change, local droughts, and legacy as well as ongoing land use practices. In general, there are a variety of different restoration strategies that can be implemented, either as a sole action or in conjunction with complementary techniques. Restoration practices are most effective when addressing the root causes of the problem and not merely the observed symptoms. However, this can be extremely challenging when watersheds such as Moffett Creek have been highly modified by anthropogenic practices. Additionally, climate change ramifications are not fully understood, therefore comprehending the totality of impacts as they relate to restoration efforts is difficult (Beechie et al. 2013).

This information is important when trying to evaluate the ability for either natural recruitment of riparian plants and/or when designing a riparian plant restoration project. It is also important to try to discern the potential impacts of using tools such as beaver dam analogues or other methods designed to increase groundwater recharge. Ultimately, the goals of any future restoration plan within Moffett Creek should include the desire to increase groundwater recharge and ultimately prolong surface flows.

Stream morphology interacts with the flow and sediment regimes (discharge, seasonality and variability), channel boundary characteristics (bed sediments, bank materials and vegetation) and water quality (temperature, turbidity, nutrients and pollutants) to produce, maintain and renew habitat at a range of spatial and temporal scales. The potential for a stream to support resilient and diverse ecosystem services generally increases with its morphological diversity. Although restoration efforts targeted to increase diversity does not guarantee recovery of any particular target or iconic species, it may push a system towards recovery of some of the stream morphology (Palmer et al. 2005). Therefore, future restoration efforts should promote process-based activities that encourage natural recovery of the riverine systems with the goal of increasing groundwater levels that would support stream flows and riparian health. This generally involves the removal of features such as levees which are evident in a significant portion of Moffett Creek banks. To address the severe incision problem (Figure xx), MCCP will evaluate the installation of instream structures as a restoration technique to enhance stream complexity and to access adjacent floodplain habitat by the initiation of more natural processes. Site specific goals will be identified to include the control or limitation of erosion of a channels lateral and/or vertical profiles. Aggradation, which refers to the increase in land elevation in a river system due to the deposition of sediment and hydraulic diversity, including scouring and flow modification; could be desired outcomes and will be evaluated in the process.

Conclusion

The MCCP has played an important role in developing a better understanding of the Moffett Creek watershed. The established monitoring plan will serve as a foundational element to better inform those wishing to work in the watershed to address water quality issues. Furthermore, steps throughout this process have been crucial first step for determining possible restoration techniques to mitigate for excess sedimentation. It is recommended that these efforts continue beyond the extent and finalization of the MCCP. Potential limitations to future work in the Moffett Creek watershed include; frequency and timing of precipitation events, the episodic thunderstorms that tend to cause large amounts of sediment through the system, landowner permission and access, and limitation of data, in particular a flow station data recording station(s).

References

Arismendi, I. 2017. Suspended sediment and turbidity after road construction/improvement and forest harvest in streams of the Trask River Watershed Study, Oregon. Water Resources Research, 53(8), 6763.

Bailey, E.H. 1966. Geology of Northern California. *California Division of Mines and Geology*, Bulletin 190, p. 39-62.

Beechie, T., H. Imaki, J. Greene, A. Wade, H. Wu, G. Pess, P. Roni, J. Kimball, J. Stanford, P. Kiffney and N. Mantua. 2013. Restoring Salmon Habitat for a Changing Climate. River Res. Applic. 29: 939 – 960.

California of Water Resources. 2019. California Data Exchange Center. Fort Jones RS (FJN).

California State Water Resource Control Board. 1980. *Scott River Adjudication. Superior Court for Siskiyou County. Siskiyou County, CA*.

Cluer, B., Thorne C. 2013. A Stream Evolution Model Integrating Habitat and Ecosystem Benefits. John Wiley & Sons, Ltd.

County of Siskiyou. 2005. *Code of the West...The Realities of Rural Living. A Premier for Living In Siskiyou County California*. Yreka, California

County of Siskiyou. 2018. Planning Division - Zoning. https://www.co.siskiyou.ca.us/content/planning-division-zoning

Dahl, T., & U.S. Fish Wildlife Service.1990. Wetlands losses in the United States, 1780's to 1980's. Washington, D.C.: U.S. Dept. of the Interior, Fish and Wildlife Service.

Dutton C, Anisfeld S.C., Ernstberger H. 2013. A novel sediment fingerprinting method using filtration: application to the Mara River, East Africa J. Soils Sediment, 13, 2013, pp. 1708-1723

Environmental Science Associates. 2009. Scott River Watershed-Wide Permitting Program

Hoag, C.J. 2007. TN Plant materials revision how to plant willows and cottonwoods for riparian restoration. USDA-NRCS. Plant Materials Center, Aberdeen, Idaho

Mack Seymour. 1958. Geology and Ground-Water Features of Scott Valley Siskiyou County, California. Geological Survey Water-Supply Paper.

McCarney-Castle, K., Childress, T. M., & Heaton, C. R. 2017. Sediment source identification and load prediction in a mixed-use Piedmont watershed, South Carolina. Journal of Environmental Management, 185, 60–69. https://doi.org/10.1016/j.jenvman.2016.10.036

Mid-America Regional Council. (n.d.) *What is sediment pollution?* [Brochure]

Narasimhan, B., P.M. Allen, S.V. Coffman, J.G. Arnold, and R. Srinivasan. 2017. Development and Testing of a Physically Based Model of Streambank Erosion for Coupling with a Basin-Scale Hydrologic Model SWAT. Journal of the American Water Resources Association (JAWRA) 53(2):344-364. DOI: 10.1111/1752-1688.12505

North Coast Regional Water Quality Control Board. 2006. Action Plan for the Scott River Watershed Sediment and Temperature Total Maximum Daily Loads. NCRWQCB, Santa Rosa, CA.

Olson, J. R., and C. P. Hawkins. 2017. Effects of total dissolved solids on growth and mortality predict distributions of stream macroinvertebrates. Freshwater Biol., 62(4), 779–791.

Palmer, M. A., E. S. Bernhardt, J. D. Allan, P. S. Lake, G. Alexander, S. Brooks, et al. 2005. Standards for ecologically successful river restoration. Journal of Applied Ecology 42:208–217.

Scott River Watershed Council. 2005. *Initial Phase of the Scott River Watershed Council Strategic Action Plan*. Etna, California

SHN Consulting Inc. 2003. *Moffett Creek Gross Sediment Assessment, Siskiyou County, CA.* Prepared for Siskiyou Resource Conservation District.

Siskiyou County Assessor. 2015. Assessor's Office Parcel Search Online. Retrieved from: https://www.co.siskiyou.ca.us/assessor-recorder/page/assessors-office-parcel-search-online

Steven, R. 2019, January. Personal communication.

United States Census Bureau. 2018. Retrieved from: https://www.census.gov/quickfacts/fact/table/siskiyoucountycalifornia,ca/PST045217

United States Department of Agricultural. 1971. Watershed Investigative Report - Moffett Creek, Siskiyou County, California. Berkeley California 94704

United States Environmental Protection Agency. 2006. Summary of the Clean Water Act Retrieved from: https://www.epa.gov/laws regulations/summary-clean-water-act. Accessed Oct. 29, 2018R

United States Geological Survey. 1958-67. USGS 11518600 MOFFETT C NR FORT JONES CA. Retrieved from https://nwis.waterdata.usgs.gov/nwis/inventory/?site_no=11518600

United States Geological Survey. USGS 11519500 SCOTT R NR FORT JONES CA. Retrieved from https://waterdata.usgs.gov/ca/nwis/uv?site_no=11519500