Riparian Vegetation

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INTRODUCTION

Authors

This document was created by staff of the Watershed Research and Training Center.

Audience

This Riparian Vegetation Assessment is a portion of a larger Watershed Assessment of the South Fork Trinity River Watershed (SFTR). It was designed to develop a riparian vegetation plan that includes the most appropriate and effective locations for planting vegetation in riparian areas as well as developing appropriate silvicultural prescriptions for benefits to coho salmon habitat.

Geographic Focus

This study encompasses the entire 2,414km^2 (932 square miles) SFTR watershed. However, it focuses on the most heavily degraded areas, especially those that have been damaged by anthropogenic activities. The smaller size of lower-order tributaries also allows restoration activities to have a greater impact on water temperature and large woody debris supply than at mainstem sites. The extent of the sediment and instability issues on the mainstem SFTR make restoration on the mainstem less feasible. Therefore, the majority of potential riparian restoration sites are located on Hayfork Creek and its tributaries.

Pertinent Historic Land Use

The discovery of gold in the Trinity River watershed in 1848 resulted in the migration to the SFTR watershed by European settlers. Miners worked the land and streams looking for gold. Gold mining destroyed much of the stream habitat and vegetation in the Hayfork Valley, especially the large dredges that worked Hayfork Creek and its tributaries in the early 1900s. Today, there are a total of 367 mines registered in the SFTR watershed, 48 (13%) of which are within 100m of a waterway. Not included in this calculation are the numerous placer mining claims on the SFTR and its tributaries.

Cattle ranching and agriculture entered into the Hayfork Valley during the mid-1850's to take advantage of the vast meadows and water sources, and to support the growing mining and logging communities. Today, the number of cattle in the area has decreased, yet grazing has been centralized around the depleting water sources including streams and wet meadows. Cattle grazing reduces the amount of vegetation cover, especially forbs, and compacts the soil which results in significant surface erosion (Tetra Tech 2000). Reduced vegetative cover also impacts stream flow, increasing downcutting, and resulting in lowering of local water tables (USFS 1994).

Forest structure, particularly in riparian areas, has been altered due to land use practices such as clear-cut logging (Harr&McCorison 1979), fire suppression, stream diversion and road construction (USFS 1999a). By 1977, 52% of forested areas within the South Fork Trinity River basin had been logged and 92% of all roads were associated with timber harvests (California Department of Water Resources (DWR 1979). Since that time an undetermined, but substantial, amount of additional land has been affected by further logging and road construction (NMFS 2014). Altered disturbance regimes increased timber density and led to changes in species composition, such as the conifer encroachment in areas historically dominated by oak woodlands. The increased fuel base along with drought and warming climate has set the stage for extreme and sometimes devastating fires that burn huge expanses of land including riparian areas.

Floods and sediment have impacted the riparian vegetation, primarily along the mainstem SFTR. The December 1964 flood caused numerous landslides and debris flows, which delivered considerable quantities of sediment in some reaches leading to channel aggradation and widening, and decreased depths and number of pools. The floods scoured vegetation and soils from stream banks and floodplains leaving deposits of sediment in its wake (NMFS 2014).

Need for Project

Availability of water resources under warming climate scenarios is expected to be most limited during the late summer (Vano et al. 2015). Van Kirk and Naman (2008) found that mean late summer discharge of the South Fork Trinity River was significantly lower (18%) in the warm period from 1977 to 2005 than the cold period from 1966 to 1976. Late-summer flow in the South Fork Trinity significantly declined relative to the other studied rivers in the Lower Klamath Basin (Upper Trinity, Salmon River and Indian Creek). Only the Scott River had a greater decline than the SFTR (Van Kirk and Naman 2008). Consistent with other studies Van Kirk and Naman (2008) concluded that the decrease in flow is likely due to a combination of increasing water utilization, land use changes and their alteration of riparian vegetation, and climate change, which has resulted in a decrease in snowpack in the region (Van Kirk and Naman 2008).

Low flows during the driest months of the year, from July through September, exacerbate rising water temperatures leaving unsuitable habitat for over-summering salmonids. In 1998 it was first formally recognized that temperature is a limiting factor for fish populations in the SFTR when the North Coast Regional Water Quality Control Board (NCRWQCB) added temperature impairment to its 303(d) list for the SFTR (U.S. Environmental Protection Agency, 1998).

As emphasized in the historic land use section above, the riparian zones of the SFTR have been modified extensively from pre-European settlement conditions. The majority of water diversions and water quality issues (high water temperatures, high nutrient loads, low dissolved oxygen) in the South Fork Trinity River basin occur in the Hayfork sub-basin, where depleted summer flows and lack of riparian shading have adversely affected salmonid production in Hayfork Creek (PWA 1994). The upper reaches of Hayfork Creek are too warm for rearing coho salmon, without thermal refugia from coldwater springs or groundwater. The loss of riparian canopy and wide channels contribute significantly to increased water temperatures, which can exceed 27 °C in Hayfork Creek (PWA 1994). Studies have shown that water temperatures exceeding 24°C can be lethal unless salmonids can find areas of cooler water during summer low flow conditions (see Appendix 2 of this report "Stream Temperatures in the SFTR"). Flow depletion, lack of riparian cover, and water pollution all affect the ability of Hayfork Creek and its major tributaries to produce salmon and steelhead. Because of its high water temperature, Hayfork Creek increases temperature problems in the main stem South Fork Trinity River in some years, whereas it formerly provided a moderating influence (PWA 1994).

Changes in riparian vegetation have a significant influence on stream temperatures (Moore et al. 2005). To mitigate stream temperatures for the benefit of coho salmon habitat, this plan outlines appropriate and effective locations for planting vegetation in riparian areas as well as appropriate silvicultural prescriptions.

Goals and Objectives

The following are recommendations for riparian management derived from the NMFS coho recovery plan:

- Developing appropriate silvicultural prescriptions for benefits to coho salmon habitat to "reduce water temperature and increase dissolved oxygen" (SFTR 10.1.11): Increase conifer riparian vegetation by determining appropriate silvicultural prescription for benefits to coho salmon habitat. Thinning, or releasing conifers, guided by prescription. Planting conifers, guided by prescription (NMFS 2012).
- Planting vegetation in riparian areas to "reduce delivery of sediment" (SFTR 8.1.19) to streams and plant vegetation to stabilize stream bank (NMFS 2012).

In developing the Riparian Vegetation Restoration Assessment the WRTC originally anticipated creating an assessment that would result in a prioritized suite of project, including 20 sites for revegetating riparian areas and another 20 streams for unique riparian silvicultural prescriptions. After compiling the results of scientific studies pertinent to the different aspects of silvicultural treatments in riparian buffer zones we changed this objective and decided to focus on an evaluation of existing and potential plant species composition, guidelines for prioritizing riparian planting sites and site specific planting recommendations (see introduction to "Riparian Revegetation Assessment").

REVIEW OF RIPARIAN MANAGEMENT PRACTICES

Forest structure, particularly in riparian areas, has been altered due to changes in disturbance regime and land use practices such as clear-cut logging (Harr & McCorison1976), fire suppression, stream diversion, and mining and road construction (USFS 1999a). Riparian forest cover affects a stream's water budget through many factors such as age and species specific evapotranspiration rates, hydraulic redistribution through live and dead roots (transporting shallow surface moisture to deeper layers and accessing water resources within the unsaturated zone), buffering effects of a canopy on snowmelt and rain runoff, and the creation and maintenance of soil organic matter.

In order to be able to improve or restore riparian forest conditions for salmonids through silvicultural treatments, we conducted a literature review and compiled the results of scientific studies pertinent to the different aspects of silvicultural treatments in riparian buffer zones. This information will help evaluate the suitability of a treatment approach for various sites in the SFTR and the tradeoffs of these treatments. We wanted to answer the following questions:

- How has water yield of forests changed with changes in disturbance regimes, forest structure and species composition pre and post clearcutting and/or high-grading logging activities?
- Are untreated riparian reserves more susceptible to high severity wildfire than pre fire suppression? Are riparian reserves acting as "fire wicks"? Do riparian reserves need management, in some cases, in order to avoid high severity or stand replacing fire? Where and when are current conditions different from historic conditions and fire behavior?
- What are the interactions between stream-shading by riparian vegetation and water use/evapotranspiration by riparian vegetation?
- Is current riparian forest structure different than pre and post intensive logging practices of the past? Could riparian thinning treatments aid in the recruitment of large woody debris for habitat structure?
- How does benthic macroinvertebrate production change with changing riparian forest and tree types?

Effects of Changing Forest Age Structure and Density on a Forest's Water Yield

By 1977, 52% of forested areas within the South Fork Trinity basin had been logged. An additional 4% of the old-growth had been lost to fire. Since that time, an undetermined, but substantial, amount of additional forest has been affected by logging, road construction and wildfires (NMFS 2014). In many areas, uneven-aged and old-growth forests have been replaced with young, dense forests that now dominate forested landscapes. A positive correlation has been established between a forest's age structure and a forest's water yield. Younger trees have a higher ratio of sapwood to basal area than old-growth, therefore more water is consumed through transpiration and thus younger forests yield significantly less water (Moore et al. 2004, Stubblefield 2012). The correlation between transpiration rates and water yield has been the primary means of measuring the efficiency of a forest's water use (Stednick 1996). It reflects how much water individual trees or forest stands consume, and therefore, how much water is returned to bordering streams. Research in the Mattole River watershed has confirmed that as young pole stands of Douglas-fir grow into young sawtimber stands they consume more water than older uneven aged stands (Stubblefield 2012).

Thinning has been used as a treatment to reduce the overstory demand for water and increase water yields in streams. Studies throughout the US confirmed that a reduction in forest cover increased runoff, and therefore increased water yield directly after harvest while afforestation decreased water yield (Bates & Henry 1928, Hibbert 1967, Bosch & Hewlett 1982, Stednick 1996). Bosch and Hewlett (1982) recorded the maximum increase in water yield in the first five years after treatment for 94 paired watershed studies. As a forest regenerates following treatment, increases in streamflow decline due to the higher sapwood and leaf area of new growth (Bosch & Hewlett 1982). Sprouts and saplings are increasing water use at a stand level. The rate of decline varies between catchments, but appears to be related to the rate of forest recovery. Overall, the response to treatments was variable between forest type and location. Seasonal distribution of streamflow response to treatment has been found to be variable; response in streamflow may be almost immediate or considerably delayed, depending on climate, soils, and topography (Hibbert 1967). In addition to transpiration rates, a "release effect" following thinning has been studied especially for coniferous tree species. Increased growth in sapwood, root, and leaf area after thinning is a result of increased water availability (Black et al.1980, Aussenac and Granier 1988). By decreasing inter-tree competition, more water becomes available within the soil profile, and is then used by the remaining trees allowing increased growth. During the first years following treatments, open canopy permits increased throughfall precipitation and exposes more soil to evaporative water loss, although it has been shown that overall water availability is still increased (Aussenac and Granier 1988).

In their review of studies from western forests, Rhodes & Frissell (2015) conclude that the maintenance of potential increases in water yield would require removing large percentages of canopy cover (about 25% of watershed area) with a return frequency of 10 years. These findings provide a useful benchmark, as we know that current watershed-scale forest density is considerably higher than was present under recent historical climate, land-use and disturbance regimes. Yet we don't think that generalized numbers are appropriate for such large areas and diversity such as "Western Forests". In the Klamath ecoregion there are some of the most diverse conifer forests in the world so site specific decision making is necessary concerning the percentage of canopy cover to be removed and which succession of treatments is needed to sustainably increase stream water yield.

As further evidence that thinning can increase in-stream flows, a thesis study conducted on a tributary to the lower Klamath River (Wick 2016, in publication) showed that a 50% basal area reduction of red alder (*Alnus rubra)* on one side of the stream resulted in a doubling of July water discharge between 2014 and 2015. In August 2015, discharge increased by an order of magnitude, and remained significantly higher in September, post-treatment. At the same time, water temperature increased significantly during the day over the reach length. The increase in discharge appeared to mitigate and modulate water temperature increases during the day. This may benefit salmon habitat during extreme low-water drought events, including annual seasonal oscillations and perhaps even decadal precipitation variability, by increasing available stream discharge.

Pertinent Conclusions: In the SFTR, there are many forest sites with altered structure and resulting increased water use, e.g. in unmanaged clearcuts and/or plantations and areas where fires have burned at high severity in the recent past.

Thinning can be used as a treatment to reduce the forest overstory demand for water (and thus increase streamflows), however the response to treatments is highly variable and difficult to predict given current data and scientific methods, so any riparian thinning prescription needs to be site specific and carefully considered in order to avoid unintended consequences. Thinning riparian vegetation can result in significant short term streamflow increases, however it often results in higher stream temperatures. As a recent example, for the Gemmil Project in the Upper Hayfork Creek watershed, Forest Service specialists proposed a thinning from below in a mixed conifer riparian reserve retaining 60% canopy closure of the conifers. Integrating mechanical or manual riparian thinning in this way may well pose an opportunity for increasing flows in targeted stream reaches across the SFTR watershed.

Any thinning treatments would then need to be maintained over time to maintain streamflow increases. Meaningful streamflow gains would also require scaling up beyond treatments in the riparian zone to the watershed and landscape-scale. In terms of both riparian treatment maintenance and scaling up, prescribed fire and/or use of natural wildfire ignitions are the most suitable and cost effective treatments for landscape-scale forest density reduction and maintenance of lower density conditions at the site-level. Restoring fire in the SFTR to its natural 5-30 year return interval would have many additional benefits.

Effects of Species' Specific Transpiration and Interception Rates on a Forest's Water Yield

In forested landscapes dominated by evergreen tree species, such as much of the Northern California mountain ranges, transpiration is not constant through the year (Vinukollu et al. 2011). The response of trees to solar irradiance, temperature, humidity, and subsurface moisture influences the timing of water flux to the atmosphere. Sap flow measurements show differences between needleleaf and broadleaf evergreen and deciduous trees in seasons of peak transpiration. Douglas-fir (*Pseudotsuga menziesii*) maintain significant transpiration through the winter rainy season and transpire maximally on clear-sky days in the spring (June) when soil moisture is high, followed by a sharp decline in transpiration with the low surface soil moisture conditions in the summer dry season (August and September). In contrast, Pacific madrone (*Arbutus menziesii*), and to a lesser extent other broadleaf evergreen species (*Quercus wislizeni, Notholithocarpus densiflorus, Umbellularia californica*), transpire maximally in the summer dry season (Link 2014, data from South Fork Eel River watershed) when atmospheric evaporative demand is highest. The difference in transpiration seasonality arises from different sensitivities to atmospheric evaporative demand and root-zone moisture. The root-zone moisture value determines when different species become water stressed. Shallow rooted Douglas-fir (Granier 1987, Humphreys et al. 2003, Moore et al. 2004, Jassal et al., 2009) and many other species in the *Pinaceae* family (Martinez-Vilalta et al. 2004) reduce transpiration in response to relatively moderate soil water deficits. In contrast, some broad-leaved species, e.g. the deeper rooted Pacific madrone (Link 2014) maintain high rates of transpiration even as the subsurface dries (McDowell et al. 2008). Evapotranspiration rates also depend on the rate of stomatal closure in response to increasing atmospheric evaporative demand. Douglas-firs close their stomata more rapidly in response to increasing vapor pressure deficit (Link 2014) than do certain co-occurring broadleaf species (*Berberis nervosa*, *Chrysolepis chrysophylla*, and *Cornus nuttallii* (Marshall & Waring 1984); *Populus trichocarpa* and *Alnus rubra* (Bond & Kavanagh 1999). Stubblefield's (2012) study on mixed Douglas-fir forests of different age structure also included a small sample of tanoaks. In 2008, the smaller of the two tanoaks had slightly less season water use than a similar sized Douglas-fir, but the big tanoak (DBH 52 cm) had more than twice the amount of water use compared to a similar sized Douglas-fir (DBH 55cm). In Link's (2014) study, broadleaf species also showed a greater relative increase of evapotranspiration with increasing solar radiation than did Douglas-fir. This species difference might arise in part because of different tree heights on the studied hill slope. Douglas-firs did not seem to use groundwater to alleviate water stress during the dry season. Trees downslope, where the water table is 5m below ground year round, declined at a similar rate to upslope Douglas-firs (with similar soil moisture) in the dry season, suggesting water limitation during the dry season until unsaturated zone moisture was replenished by rains. Research using stable isotopes to investigate the water sources of different tree species suggests that needleleaf species and broadleaf species use isotopically distinct water sources within the unsaturated zone (Oshun et al. 2012).

Overall, coniferous forests tend to have the greatest response to thinning treatments on water yield. In Bosch & Hewlett's (1982) review they found that pine forest types caused on average a 40mm change in water yield per 10% change in cover and deciduous hardwood and scrub ~25 and 10mm, respectively. However, if Douglas-fir becomes more prevalent in areas where it is encroaching on stands formerly dominated by broad-leafed trees, their suppressed transpiration in the dry season could decrease the regional summertime evapotranspiration, but might increase the land surface temperature (Link et al. 2014). The effects on streamflow of conifer encroachment into oak woodlands have not been well-studied, but mechanical removal of encroaching Douglas-fir has been shown to decrease interception of precipitation and increased shallow soil moisture (Devine & Harrington 2007).

Pertinent Conclusions: Douglas-fir and many other species in the *Pinaceae* family reduce transpiration in the summer dry season (August and September). Conversely, Pacific madrones (*Arbutus menziesii*), and to a lesser extent other broadleaf evergreen species, transpire maximally in the summer dry season. This leads us to two potential interventions based upon current conditions in the SFTR.

First, areas that are experiencing conifer encroachment, such as oak woodlands and glades, are likely experiencing reduced availability of water in the soil zone and associated stream flow declines. Restoring structure and species composition in oak woodlands and glades could thus increase forest resilience and water availability.

Second, areas that were formerly dominated by Klamath mixed conifer and mixed conifer-broadleaf forest that have been converted to vigorous broadleaf stands after logging and/or stand replacing fire are likely utilizing more water during the late-summer months of August and September than they did historically. Restoring species composition to more conifer dominance could help to increase water yield when fish need it most.

Changes in Wildfire Regimes in Riparian Reserves and Re-introduction of Prescribed Fire

Fire is a significant disturbance factor within the South Fork Trinity River basin. Prior to the initiation of organized fire suppression in the early 1900's, low intensity surface fires of relatively short intervals of 5 to 30 years were typical throughout the basin (USFS 1999b). The suppression of fire and strictly custodial riparian management, along with associated higher accumulations of fuels in streamside areas relative to uplands and lower pre-fire moisture levels due to drought, led to a transition to a fire regime with more frequent, high severity fires and vegetative community changes (USFS 1999b). Several large, intense wildland fire complexes, such as 1987, 2008, and 2015 have burned in the South Fork Trinity basin since fire suppression commenced; each complex burned hundreds of thousands of acres. Few fire history data are available from riparian zones, but available data suggest that fire-return intervals, and possibly fire behavior, are more variable within riparian zones than in adjacent uplands (Skinner 2002, 2003). Skinner (2002, 2003) found historic median fire-return intervals were generally twice as long on riparian sites adjacent to perennial streams than on neighboring uplands in the Klamath Mountains ecoregion. Skinner argues that his data is probably not representative of riparian areas associated with ephemeral and intermittent streams, which probably have a fire regime similar to the surrounding uplands (Skinner 2003). He concludes that intact riparian areas along perennial watercourses used to serve as effective barriers to the spread of many low-intensity and some moderate-intensity fires and influenced patterns of fire occurrence beyond their immediate vicinity. Consequently, by affecting fire spread, riparian areas are a key spatial feature that also contributes to the structure and dynamics of upland forest landscapes (Skinner 2000, 2003). In their study of two Oregon fires, Halofsky and Hibbs (2008) found that understory fire severity (percent exposed mineral soil and bole char height) was significantly lower in riparian areas compared with adjacent uplands in both fires, however, overstory fire severity (percent crown scorch and percent basal area mortality) was similar in riparian areas and adjacent uplands. Overstory fire severity was higher in riparian areas with a greater number of small stems (fine fuels). Understory fire severity was lower in areas with greater riparian deciduous hardwood basal area.

Due to the altered forest structure, Van de Water & North (2011) found that riparian forests in the Sierra Nevada were significantly more fire prone under current than reconstructed conditions, with greater basal area, stand density, snag volume, duff loads, total fuel loads, canopy bulk density, surface flame length, crown flame length, probability of torching, predicted mortality, and lower torching and crowning indices.

High riparian fuel loads, especially if uplands have been harvested or actively managed for fuel reduction, can influence fire spread by serving as 'wicks' and riparian forests could act as fire corridors (Skinner 2003). This fire behavior was documented during the Angora Fire in Tahoe National Forest in 2007. Dense stands of trees and heavy loads of LWD in the Angora Stream Environment Zone likely contributed to the rapid fire spread upslope to Angora Ridge (Murphy et al., 2007). The build-up of streamside fuels is a concern in most riparian vegetation types; however, in conifer dominated watersheds, recent beetle and fungus infestations have resulted in considerable canopy mortality, affecting fuel loads in both upland and riparian areas (Dwire et al. 2011). There is limited published information available to managers on the necessity or ecological effects of fuel reduction treatments in riparian ecosystems. Because riparian plant communities may differ considerably from upland vegetation, the application of FRCC (Fire Regime Condition Class) ratings, derived for dominant upland vegetation types, is questionable for some riparian areas (Stone et al. 2010). In addition, riparian fuel conditions can be difficult to define for many reaches due to human disturbances.

There are legitimate concerns about causing excess erosion when reducing fuel loading in riparian zones. In a recent study in the Tahoe Basin, Harrison et al. (2015) found that the use of mechanical treatments or prescribed fire treatments that mimic the patchy burn mosaic of historic fire regimes, leaving sufficient organic matter to trap sediment but having sufficiently low fuel loading and/or enough fuel discontinuity or patchiness to limit fire spread, did not significantly increase erosion.

Further, Beche et al. (2005) found that patchy low to moderate severity prescribed fire that burned less than 20% of the area of a first-order Sierra Nevada watershed had no lasting effects on macroinvertebrate communities, large woody debris volume and recruitment or fine sediment in pools.

The treatment reduced pre-fire fuel loads in the riparian zone up to 80%. They concluded that the recovery of streams post-fire is largely dependent on the recovery of the riparian zone, which is usually more rapid than upland recovery. In an experiment in Idaho, Arkle & Pilliod (2010) reached similar conclusions: they found no detectable changes in periphyton, macroinvertebrates, amphibians, fish, and riparian and stream habitats for 3 years after prescribed fire treatment, compared to data in four unburned reference streams. They noted that the extent and severity of riparian vegetation burned during prescribed fires in ponderosa pine forests may be too low to generate the fire induced changes that have been observed after low-severity wildfires.

Stone et al. (2010) surveyed USFS Fire Management Officers in 11 western states and 55 different National Forests and found that in the districts surveyed, prescribed fire treatments in riparian areas were often conducted to reduce fuels in upland areas; riparian areas were affected because they either occurred within the treatment area or because prescribed fire was allowed to move into adjacent streamside areas during upland project implementation. Projects that directly target riparian areas tended to be small, with over 90% being less than 120 ha (300 acres). This pattern may reflect the relatively small proportion of the landscape that riparian areas occupy. Mechanical treatments were most often used in areas where managers were unable to treat with fire. As in upland projects, treatment combinations were used to target different fuelbed strata and thus achieve multiple objectives. Fuel reduction treatments were used to protect the many campgrounds, picnic areas, roads, structures, and private in-holdings that are located in riparian floodplains.

Research from other fire-suppressed areas of California (albeit at higher elevations where snow is more prevalent than in the SFTR basin) suggests that re-introduction of fire can alter vegetation enough to increase streamflow. For example, preliminary results from the snowmelt-dominated Illilouette Creek in Yosemite National Park indicate that following 40 years of letting lightning fires burn, forest heterogeneity has increased (i.e., a mix of open areas and varying levels of density), water yields (i.e., streamflow per unit precipitation) are increasing, and wetland vegetation is replacing former dry-adapted vegetation (Boisrame et al. 2014). Of all streamflow sites evaluated by Asarian and Walker (in press), the Salmon River had the highest percent areas burned by wildfire and was the only site unregulated by dams that had an increasing precipitation-adjusted streamflow for July, August, and September. The Salmon River was also the only gage where Sawaske and Freyberg (2014) found a decreasing trend in the rate of baseflow recession."

Pertinent Conclusions: Riparian forests are generally less prone to high severity fire than neighboring uplands, however, under current conditions they are generally more fire prone than under historic conditions. Currently, "fire wick" behavior is not pertinent in the SFTR watershed because so little logging is occurring. Under current conditions wildfires now have more potential to burn riparian areas in high severity due to past human wildfire suppression activities, associated changes in species composition and former logging practices, especially in headwall "chimney" areas. Areas such as Little Creek, Cold Camp Creek, Flume Gulch in 2008, and Grapevine Creek in 2003 were some of the riparian areas that burned high severity in potentially uncharacteristic wildfire (though it should be noted that these may have all been human started fires including suppression-operation back-burns). Thinning treatments and prescribed fire in riparian reserves in low order streams, especially if adjacent upland sites have been harvested or actively managed for fuels reduction, should be considered to limit this “chimney” fire behavior. Treatments in these riparian areas could make them more resilient to wildfire. This being said, review of 2008 and 2015 wildfires within the SFTR watershed shows a consistently lower burn severity in riparian zones compared to adjacent upland sites.

Stream Shade and Stream Temperature

Forest canopies, topographic shading and groundwater can all affect stream temperatures.

Forest canopies affect the microclimate and stream temperature because they intercept the transmission of radiation. Intact canopies reduce diurnal air temperature compared to open areas and reduce the soil temperature range. Over very small streams, the effect of openness to the sky can be dampened by bank sheltering, particularly for narrow incised streams. Shallow streams warm up quicker and are thus more affected by removal of shade than deep streams.

Thinning treatments can increase solar radiation in the riparian zone as well as wind speed and exposure to air advected from clearings, typically causing increases in summertime air, soil, and stream temperatures and decreases in relative humidity (Moore et al. 2005).

Stream temperature increases following thinning treatments are primarily controlled by changes in insolation but also depend on stream hydrology and channel morphology. Stream temperatures recovered to pre-harvest levels within 10 years in many studies but took longer in others (Moore et al. 2005). A range of other studies has demonstrated that streams may or may not cool after flowing from clearings into shaded environments. In our Stream Temperature Analysis the WRTC found that Hayfork Creek does cool downstream of the creek’s middle reaches within the Hayfork Valley where riparian canopy is poor and streamflow is depleted due to water diversions, but cooler temperatures within the lower Hayfork Creek Canyon are likely due to topographic shade, lack of stream diversions, and inflow from cooler tributaries rather than solely vegetative shading (see Part 2 Stream Temperature Analysis).

Where downstream cooling does not occur rapidly, the spatial extent of thermal impacts is effectively extended to lower reaches, which may be fish bearing. In addition, warming of headwater streams could reduce the local cooling effect where they flow into larger streams, thus diminishing the value of those cool water areas as thermal refugia.

In Wick’s (2016, in publication) thesis study the 50% basal area reduction of red alder on one side of the stream resulted in a significant water temperature increase during the day over the reach length, with a maximum increase in temperature over the treatment reach of 3.5°C (2015), however temperature maxima were within thermal tolerances for cold-water adapted salmonids, in part due to the cool coastal climate at the study site (see above, Effects of Changing Forest Age Structure). Canopy removal involves removal of an insulating layer, which both causes an increase in direct solar insolation on the water surface, resulting in daytime water temperature increases, as well as nighttime water temperature reductions due to radiative heat loss from the water to the cooler sky at night. Moore et al. (2005) concluded that “further research is required on riparian microclimate and its responses to harvest, the influences of surface/subsurface water exchange on stream and bed temperature regimes, and methods for quantifying shade and its influence on radiation inputs to streams and riparian zones".

Only vegetation of a certain height is effective in shading: when direct radiation comes from >30 degrees above the horizon most of it can be absorbed within the water column and by the bed and thus is effective at stream heating. Vegetation must block radiation within this sector of the sky to be effective (Moore et al. 2005). Peak daytime net radiation over a stream without blocking from canopy can be more than five times greater than that under a forest canopy during the summer. Removal of riparian vegetation may increase stream temperatures up to the ambient air temperature, depending on the natural extent of shading and the proportion of canopy removed. Thus, temperatures typically observed only in downstream reaches may occur in tributary streams.

Groundwater is cooler than the stream's daytime temperature in summer. Forest thinning can increase soil moisture and groundwater levels. Increases in groundwater volume could promote cooling, or at least ameliorate warming, but cutting could increase groundwater temperature due to greater flow volume with decreased interception losses; further research is needed.

Pertinent Conclusions: Riparian forests keep streams (including air, soil and water) cool by intercepting radiation, reducing advection, increasing relative humidity, and sometimes even stabilizing streamflow by reducing evaporation. Removal of riparian canopy typically leads to increased stream temperatures, but also leads to decreased minimum temperatures at night. Mainstem Hayfork Creek in the Hayfork Valley has seen major riparian forest removal through past mining and ranching activities, leaving some sites completely without vegetative shading. Greater regulatory safeguards and better enforcement of existing laws should be considered to protect riparian forests in valley bottom (5+ order) streams such as Hayfork Creek, even on smaller scale private lands.

Riparian Reforestation (Planting) Influence on Stream Temperature

A thermal modeling study on the North Fork Salmon River investigated the thermal benefits of two reforestation scenarios in riparian areas (Bond et al. 2015). They modeled how different elevated air temperatures would increase mean stream temperature. Both reforestation simulations reduced mean daily maximum temperatures while daily minimum temperatures were essentially unchanged. However, in the full reforestation scenario there was more than double the cooling effect on mean daily stream temperatures compared to the partial reforestation scenario. Areas identified for simulated reforesting consisted of denuded gravel bars from historic hydraulic gold mining and areas of low vegetation in the study reach. The "partly forested" treatment simulation increased bare areas to small mixed stand conditions (70% density) and "willow/shrub/rock" (45% density) to small conifer stand conditions (height increased to 12m,still 45% density). The "fully forested" treatment increased bare and "willow/shrub/rock" areas to large mixed stand conditions (24m height and 70% density) and small conifer stand areas to large conifer stand conditions (27m height, 70% density). Reforestation thermal profiles highlight the buffering potential of riparian forest during daily maximum temperatures. Reduced streamflow raised peak stream temperatures in all simulations. The cooling effect of reforestation increased as the simulated stream discharge was lowered. Cooling effects in the different flow scenarios were similar across increased air temperature scenarios. Warming could be mitigated by reforestation in all scenarios.

Pertinent Conclusions: Modeling of riparian reforestation indicates that stream warming could be mitigated by reforestation. Under severe drought (low flows) and/or with only partial reforestation success, less reductions in warming would occur. Recent decreases in streamflow have led to increasing stream temperatures, particularly in the most degraded riparian sites on Hayfork Creek, but could be mitigated by riparian reforestation. See

Table 4 for fifty of the prioritized riparian reforestation sites in the SFTR.

Light-limited Sites are Productivity Limited Sites – Thinning Influence on Salmonid Production
In a study of six streams in the Smith and Klamath River basins, red alder (*Alnusrubra*) and other hardwoods were removed along both banks of a 100-m reach to increase incident radiation and compared with 100-m control reaches with an intact canopy (Wilzbach et al. 2005). Study sites on the six streams were located in stands of 30- to 60-year-old conifers (coastal redwood, Douglas-fir, and Sitka spruce) with riparian vegetation dominated by red alder. Cut and uncut riparian reaches did not differ in winter or summer mean temperatures or maximum weekly average temperature. Downstream patterns in temperature during the late summer period in the first year of the study did, however, reveal the persistence of slight temperature increases below reaches with cut riparian canopies. They concluded that in light-limited settings where temperature gains associated with canopy opening are not problematic for aquatic resources, gains in salmonid production might be achieved by selective trimming of riparian hardwoods. Total density, biomass levels and specific growth rates of cutthroat trout (*Oncorhynchusclarki*) and rainbow trout (*Oncorhynchus mykiss*) responded positively to canopy removal. Canopy opening increased primary production, which appears to be the most important trophic pathway for increasing the availability of aquatic macroinvertebrates particularly important in sustaining salmonid growth during spring and summer (Bilby & Bisson 1992). That is the basis of the finding that increased summer primary biomass in logged streams often supports higher salmonid production than light limited forested streams (e.g., Wilzbach et al. 1986, Hawkins et al. 1983). Increased light from canopy opening may also increase foraging efficiency of the fish (Wilzbach et al. 1986). The magnitude of temperature increase from canopy removal varies by site and harvest treatment (Johnson and Jones 2000). The spatial scale and extent of canopy opening are relevant since multiple canopy openings within a watershed have the potential to cumulate thermal loadings downstream (Murphy and Meehan 1991).

Nutrient limitation of Pacific Northwest streams may be exacerbated by a declining nutrient supply from carcasses of spawned adult salmon, as salmon stocks have sharply declined. Gresh et al. (2000) estimated that current salmon returns provide only 6–7% of the historical subsidy of marine-derived nitrogen and phosphorus once delivered to regional rivers.

Pertinent Conclusions: Gains in salmonid production can be achieved through riparian forest thinning. Canopy opening increases primary production, which increases the availability of aquatic macroinvertebrates, which improves salmonid growth. Areas such as upper portions of the Big Creek, Salt, Rattlesnake, and Tule Creek watersheds (4^{th} and 5^{th} order streams), could see increased salmonid growth and production with thinning treatments. However, thinning treatments might have a negative impact on salmonids by increasing downstream stream temperatures.

Long Term Recruitment of Appropriate LWD

Removal of trees from riparian areas from timber harvesting, mining, road construction, fire suppression, and channel clearing following flood events has altered the amount and rate of recruitment of large woody debris especially into Hayfork Creek and its tributaries. This lack of LWD has affected the number and structure of pools, complexity of salmonid habitat, sediment routing, and probably decreased smolt production. For example only 7% and 18% of the stream surface area in Salt Creek and Big Creek, respectively, is in the form of pools (USFS 1999b). The U.S. Forest Service assessed riparian areas and identified watersheds (within the SFTR) that have more than 15 percent of their riparian zone acreage with low LWD recruitment potential and low shade. From least (17 percent) to greatest (30 percent) were Butter, Corral, Upper S.F. Trinity, Plummer, Lower Hayfork, Eltapom, Rattlesnake, Hidden Valley, Upper Hayfork, and Salt. Grouse Creek and Eltapom Creek in the Grouse Creek HSA, Naufus, Indian Valley, Dobbins, Rattlesnake, and Salt Creeks also showed signs of low LWD recruitment. The Upper South Fork, by comparison, has a riparian forest composed largely of Douglas fir and White fir, with canopy closures ranging between 70 percent and 80 percent. Future LWD recruitment in these stands is excellent, with some of the highest recorded volume measurements in the Trinity Basin (USFS 1999a). This information might be outdated, but recent data on instream LWD is limited and apparent lack of LWD is likely adding to a lack of channel complexity and floodplain connectivity.

In a study of Northern California streams, Benda and Bigelow (2013) found that 90% of wood recruitment occurs within 10 to 35 m of channels in managed and less-managed forests. Local landsliding extends the source distance. The recruitment of large wood pieces that create jams (mean diameter 0.7 m) is primarily by bank erosion in managed forests and by mortality in unmanaged forests. Formation of pools by wood is more frequent in streams with low stream power. Forest management influences stream wood dynamics, where smaller trees in managed forests often generate shorter distances to sources of stream wood, lower stream wood storage, and smaller diameter stream wood.

Pertinent Conclusions: Many SFTR subwatersheds have been identified as having low LWD recruitment potential and low shade. Historic logging in portions of Rattlesnake and Salt creeks has created unnaturally dense timber stands. High levels of competition in these stands limits individual tree growth and inhibits trees from growing into the appropriate size classes necessary to function as LWD in large stream systems. In these heavily managed stands, thinning within the 10-35m zone could improve the rates of tree growth and lead to more appropriate sized LWD available to the stream sooner.

Macroinvertebrate Food Production

The distribution of aquatic organisms is directly related to riparian vegetation type. The leaf litter produced by riparian trees determines shredder insect populations. Of the organic material that falls or slides into first-order streams every year, less than 50% may be flushed downstream to higher-order streams (Anderson 1979). Due to its nitrogenfixing capacity alder has the highest nutrient value in the riparian zone (Anderson 1979, Short 1980). Maple, willow, and cottonwood have moderate nutrient values. Oaks and conifers contribute the least to nutrient exchange because they don't produce nutrients that are readily bio-available. However, oaks are an excellent stream shade source. Deciduous forest inputs increase in late summer and peak in the fall. Coniferous forest and evergreen deciduous forest streams show a more even distribution of inputs throughout the year. Seasonal quality of the inputs varies in terms of nutrient content. Spring and early summer inputs, although quantitatively smaller, consist primarily of high-nutrient pollen, flower parts, and insect frass. In Oregon, inputs of wood and lichens came predominantly in the winter and spring (Sedell et al. 1974). Although leaf litter has received the greatest attention by stream ecologists, woody debris represents over 70% of the inputs to a coniferous forest stream and also a large fraction in deciduous forest streams (Anderson 1979).

Shade conditions inversely influence biotic and nutrient exchange. Too much shade means a very low macroinvertebrate productivity level (see above "Light-limited Sites are Productivity Limited Sites"). The most sensitive hydrologic areas may be steep, headwater areas.

Pertinent Conclusions: Riparian vegetation types (alder, cottonwood, willow, etc.) offer more nutrient value and macroinvertebrate production than oaks and conifers. Thinning riparian stands, especially where conifers and oaks have outcompeted riparian vegetation types, could lead to improved macroinvertebrate production. **There are tradeoffs between the individual management strategies. For example, if a site is converted from alder to conifer to manage for LWD recruitment, this will lead to a reduction in the amount of nutrient exchange.**

RIPARIAN REVEGETATION ASSESSMENT

The more research and literature review we conducted, the more it became apparent that riparian planting is straightforward and effective for fisheries restoration, while silvicultural prescriptions have many trade-offs and effects of treatments could easily become counterproductive.

Additionally, Jeff Paulo, the former USFS silviculturist who had previously worked on USFS riparian silviculture prescriptions and has vast knowledge about the SFTR watershed, had been working as a WRTC employee in 2013 when this FRGP proposal was written. However, Jeff fully retired and was unavailable to consult on this project by the time the funding was available. We attempted to collaborate remotely but it was not productive. Ultimately, we determined that riparian silviculture prescriptions were too risky and required more attention than our current staffing or funding levels allowed and we focused the majority of our efforts on designing appropriate riparian revegetation restoration work.

Numerous studies and assessments have noted on the one side the lack of riparian vegetation and the extent of damaged riparian sites as a detriment to salmonid populations and on the other side the multiple benefits to riparian ecosystems from revegetation. Revegetation enriches the topsoil and increases long-term ecosystem productivity; it helps to control and prevent erosion; improves biological diversity, enhances ecosystem resilience to disturbance; accelerates plant succession on recently disturbed areas, leading to more favorable plant cover and more "mature" ecosystems; and improves wildlife habitat and improves aesthetics.

Past Revegetation Projects

Six Rivers National Forest and the Pacific Southwest Research Center (USFS)
First afforestation efforts began in the late 1980's and were turned into a more serious endeavor in the 1990's with the onset of the Northwest Forest Plan and emphasis on ecosystem restoration. Six Rivers

National Forest and the Pacific Southwest Research Center managed a project that focused on plantings on flood deposit terraces and on streamside landslides to provide stream shading and bank stabilization (C. Cook,2011, pers.comm.). On large terraces of the SFTR, 510 gray pine and Jeffrey pine were planted; on landslides, a mix of 16,000 conifers and hardwoods were planted (Jeffrey and gray pine, Douglas-fir, red alder, redbud, white and black oak, canyon live oak) and also some brush and grass species. There was an overall 10% survival rate. As general project findings, Cook &Furniss (2011, pers. comm) noted that planting costs were high (CCC crews were hired), logistics were very difficult to plan taking into account varying distances to sites, types of vegetation, and most suitable timing. "Restoration is the art of the possible… strategically focus on what can be done and experiment!" (C. Cook, 2011, pers. comm).

NRCS and TCRCD projects of the 1990's

In the 1990's the Coordinated Resource Management Plan (CRMP) group conducted a large riparian restoration initiative, especially in areas of the Hayfork Valley (Patrick Truman & Associates et al. 1996). WRTC staff have discussed past riparian restoration projects with a number of the organizations and personnel who worked on these projects—gathering information about what worked well and what did not. Jim Spear of the NRCS, John Condon of the TCRCD, and a number of other personnel (including Noreen Doyas, Carolyn Rourke, Linda Peak, Tim Viel and Randi Paris). While little post project data was ever collected, discussions indicated that the most successful projects were probably the riparian fencing projects, and to a lesser degree the riparian planting projects. For example, the Big Creek Ranch had extensive riparian fencing installed with conservation funding in the 1990's and is today one of the best examples of riparian vegetation within the watershed.

The Coordinated Resources Management Plan in 1996 also provided information which indicated that approximately 14 parcels were planted within the riparian zone and at least five parcels were fenced to exclude livestock from riparian areas in the Hayfork valley (Patrick Truman & Associates et al. 1996).

The WRTC conducted a small study to determine survival rates at a particular riparian planting project on Carr Creek. The following species were planted and then maintained with watering by NRCS and TCRCD staff: Of 11 Oregon ash, all had survived 20 years after the planting, most had some drought related crown dieback and two of them had severe dieback. Of 20 Ponderosa pines all had survived and had more than 50% green healthy needles.

Figure 1: Oregon Ash 2014, 20 years after planting by the Trinity County Resource Conservation District in riparian restoration efforts on Carr Creek. Field technician Donna Rupp of the TCRCD.

A side note on this Carr Creek project, several landowners have indicated that this NRCS and TCRCD project created a thick cover of willow that engulfed the stream (Figure 2). When we reviewed the planting documents, it appeared that no willow, cottonwood, or alder varieties were planted. It is curious as to why willows colonized so successfully after the planting work; possibly due to other factors like changing hydrology or beaver eradication.

Figure 2: Thick willow has grown in on the Carr Creek planting site 20 years after the restoration project of 1994. Field technicians Theresa Krebs and Donna Rupp assessing riparian vegetation.

WRTC projects: 2010-2015

The WRTC has conducted several riparian vegetation planting projects from 2013-2015 with varying degrees of success. The Hayfork Community Wetland and Stafford Fire ignition sites were selected due to restoration need and community interest. The plantings were implemented through a partnership with the USDA Forest Service, local schools and interested community members. Native woody species were planted at both sites. Due to 5 consecutive years of severe drought, the plantings had a viability rate of less than 25% over all. This high mortality rate was experienced even with dry water (a plant based cellulose gel which slowly releases water into the soil) application and watering.

Hayfork Community Wetland Enhancement

The Hayfork Community Wetland Enhancement project is an ecosystem restoration project designed to restore a series of wetlands that would provide habitat for amphibians, reptiles, birds, bats, and crustaceans. It also involves use by Hayfork High School as an outdoor classroom and recreational use by the community of Hayfork. Several phases of vegetation seeding and planting have occurred at this site after restoration activities occurred.

A native grass and forb mixture was spread and covered with 2.5cm of rice straw immediately after the phase 1 ground disturbance (wetland enhancement with heavy equipment) occurred. The seed mix contained Califonia wild rye *(Elymus glaucus)*, California brome *(Bromus carinatus)* and rock penstemon

(*Penstemon deustus).* In addition, *Scirpus microcarpus* was collected on site then spread in the low lying newly constructed wetland areas.

In February of 2015 forty volunteers assisted Watershed Center employees in a community wetland work day. 91 riparian shrubs and trees were planted (Figures 3 and 4, Table 1). While some volunteers were planting nursery sourced woody species, others were collecting native wetland obligates (willow, cottonwood, sedges, etc.) from source wetlands, to be relocated to the enhanced wetlands. Source wetlands were those with a high diversity of desirable native wetland obligates. Relocation and seeding of desirable wetland species was completed in an effort to provide diversity in the enhanced wetland features and to inhibit invasive species from connected areas from invading the restored sites.

In December 2015, 96 Oregon white oak (*Quercus garryana)* acorns were planted on the mounds above the constructed wetlands. Acorn plantings only occurred on mounds which experienced tree and shrub mortality to the extent that surviving tree and shrub saplings occurred more than 10m apart. We assume that the mortality was due to severe drought conditions. Each hole received 3 acorns. The acorns were collected from Hayfork Park and Hayfork fairgrounds and sprouted for planting.

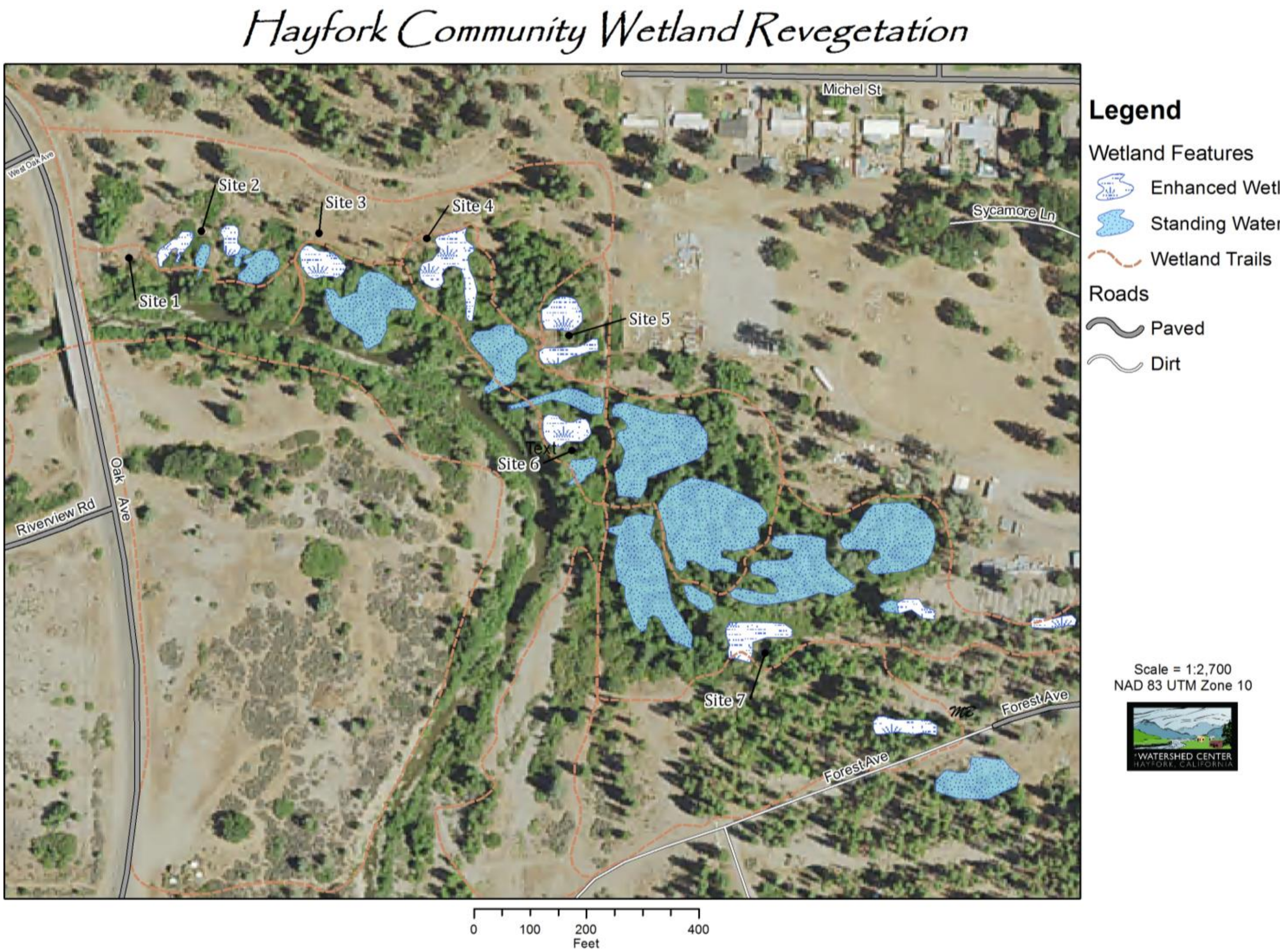

Figure 3: Hayfork Community Wetland Project Site Map

Table 1: Species Planted in the Hayfork Community Wetland.

Planting Site	Ceanothus	Mock Orange	Live Oak	Ghost Pine	Nine Bark	Redbud	Wild Grape
1	3		1	2		2	
2	1	1		1			1
3	3	3	1	4		6	1
4	4	4	4	3	1	2	
5	4	6	2	2		1	2
6	5	2	3	2		3	
7	2	3	2	2		2	
Total	**22**	**19**	**13**	**16**	**1**	**16**	**4**

Figure 4: Volunteer planting effort in the Hayfork Community Wetland, February 2015.

Stafford Ignition Site Planting

The Stafford ignition site was chosen due to wildfire impacts on Hayfork Creek. The Stafford Fire burned 4,403 acres in the summer of 2012; 903 acres were burned at high severity. This high intensity wildfire decreased riparian vegetative cover along approximately 6 miles of Hayfork Creek and an additional 22 miles of its tributaries (Figure 5). Due to a variety of conditions on site, planting design was implemented in two phases with guidance from James Lee, Riparian Ecologist.

Phase 1 occurred in March 2014. Prior to phase 1 of the planting efforts, the Forest Service Silviculture crew pre-dug 73 holes adjacent to a nurse feature that can provide afternoon shade. Five Valley High School students, community members, and a Riparian Ecologist assisted Watershed Center staff with planting conifers. Two year old Douglas-fir, incense cedar, and ponderosa pine saplings were planted. Dry water (a plant based cellulose gel which slowly releases water into the soil) was placed in a PVC tube, and placed in each hole at a 45˚ angle, to deliver 3 months of moisture to the roots. Starting four months post planting, the saplings were watered once per month. Even with dry water and irrigation, extreme drought resulted in 100% mortality of the incense cedar and 85% mortality of other conifer saplings.

Phase 2 occurred in March 2015, immediately above Hayfork Creek. This area historically had oaks and other hardwood species; however, wildfire and mining impacts have left it without overstory shade. Some re-sprouting of fire impacted hardwood trees was observed, but not enough to provide sufficient shade to the creek. Hayfork Elementary School kindergarteners assisted Watershed Center staff in planting Oregon white oak acorns. 50 holes were planted at a rate of 3 acorns per hole. All acorns planted were previously collected from the Hayfork Valley.

Figure 5: Stafford Fire "Ignition Site" Revegetation Project Map.

Figure 6. Stafford Fire "Ignition Site" Revegetation Project. a) Douglas-fir seedling with deer protection and dry water tube. b) Ponderosa pine seedling strategically placed near nurse feature for afternoon shade generation.

Study Design and Methods

Visiting reference sites and assessing past riparian projects helped us to develop a set of methods to prioritize which planting sites in the SFTR watershed would be most appropriate and practical to decrease stream temperatures. The methods included a "cover, no-cover" analysis of the whole watershed to determine the riparian areas with little or no riparian vegetation, the coho habitat intrinsic potential modeling, a solar insolation model to determine ranges of average annual solar radiation at each site, and an evaluation of appropriate plant species. Last, we field verified model results in 10 randomly chosen and 10 known sites in need of restoration.

All modeling results and products including: solar insolation, "cover, no-cover" and the evaluation of appropriate plant species, are submitted on a disk with this report as an appendix.

Reference Site Selection

As a first step, we visited sites that showcase reference riparian conditions to assess which state the disturbed sites could be restored to. Some of the reference sites visited were: Big Creek Ranch as an example of riparian valley vegetation (actively managed with fencing) with cottonwood and Ponderosa pine, Hayfork Creek near Natural Bridge as an example of alder and mixed conifer on different flood plains, the SFTR at the Ostrat Place as an example of floodplain and terraces on one bank and canyon on the other with late serial Douglas-fir forest, and Hayfork Creek downstream of the Hayfork Valley.

"Cover/no-cover"Aerial Photo Interpretation

Using 2014 national aerial imagery (NAIP) and PLSS Township, Range and Section data, all perennial streams within the entire SFTR watershed basin were analyzed for vegetation cover, section by section. The defined riparian zone width was calculated as the perennial streamflow line buffered 100m on each side to represent the inner riparian area. The entire length of each perennial stream riparian area was viewed from the headwaters to the confluence, at a scale between 1:2000 and 1:4000. Non-vegetated areas (later referred to as 'no cover') were defined as areas which appear to host less than 25% overstory vegetation. Areas identified with less than 25% cover and greater than 0.25 acres in size were digitized as polygons. Rock outcrops greater than the 0.25 acre threshold were excluded from the study as well as non-vegetated areas within 8m (25 ft) of the road center line. A total of 995 polygons were generated.

Solar Insolation Model

A variety of models were assessed to determine the best fit for project objectives including Lee Benda and Associates' NetMap model and a solar insolation methodology from Derek Olson at The Nature Conservancy in Oregon (2014, pers. comm.). Ultimately, a combination of models were used, but the primary methodology used was based on Daryl Van Dyke's work for USFWS in Shasta River, Siskiyou County (2014, pers. comm.). Following Van Dyke's method, we prioritized planting areas based on degree of solar insolation. In exposed areas where solar radiation is high, the stream potentially heats up the most and vegetative shading is most needed. Solar insolation is the intensity of incoming solar radiation on an area measured in watt hours per square meter (Wh/m^2). It varies across the topography of a landscape with south-facing slopes having the highest solar radiation while north-facing slopes have the lowest values. Elevation values were not included in the model. Resulting solar radiation values only account for topography, they do not reflect shading by existing riparian vegetation.

The solar radiation/insolation modeling for the entire SFTR watershed was calculated using a Spatial Analyst Area Solar Radiation tool. The data was based on a 10m digital elevation model (DEM). Raw National Elevation Data was downloaded in degree x degree rectangles then combined using the combine tool in spatial analyst resulting in a complete dataset that covers the entire assessment area. This new DEM mosaic dataset was then smoothed out using the Focal Statistics tool, with the annulus neighborhood option. The annulus neighborhood option reconditions individual pixel values using a doughnut shaped neighborhood statistic. This tool effectively smoothes out the visual terracing effect within the areas of extreme topographic gradients. Default parameters were used within the Area Solar Radiation tool when appropriate. The whole year time frame was specified, in addition to the central latitude of the SFTR watershed. The other GIS input values assigned are listed in Table 2. We chose to use geometric intervals otherwise known as smart quantiles to symbolize the data because this creates balance between changes in middle values and extreme values, is visually appealing and is cartographically comprehensive.

Table 2: Other Geographic Parameters Assigned in the Solar Insolation Modeling.

GIS Input	**Value Assigned**
input raster	Smooth DEM
Latitude	40.6213002850091
sky size/resolution	200
time configuration	Whole Year with monthly interval
day interval	14
hour interval	0.5
create outputs for each interval	false
z factor	1
slope& aspect	From dem
calculation direction	32
zenith divisions	8
azimuth divisions	8
diffuse model type	Uniform sky
diffuse proportion	0.3
transmissivity	0.5

The final product was an annual solar insolation value for each 8m^2 pixel in the entire SFTR watershed. Radiation values are one important parameter for prioritizing restoration sites but are not necessarily reflected in stream temperatures. Other factors which influence stream temperatures are shading by existing riparian vegetation, cold water spring influxes, substrate type, anthropogenic disturbances like warming caused by water diversions. In Figure 7 we overlaid stream temperature on solar radiation: for example, the highest values of solar radiation (830,324 - 972,097Wh/m^2) occur in the upper reaches of Hayfork Creek but because of cold water influx, shading through intact riparian vegetation as well as an absence of water diversions, stream temperatures are comparatively low. Reaches farther down Hayfork Creek are characterized by many anthropogenic disturbances (e.g. mining tailings and water diversions) and a lack of riparian vegetation - there the stream heats up despite cold water influxes and medium solar insolation (737,738 – 772,457Wh/m^2). In the Hayfork valley there is even less riparian vegetation, less cold water influxes and the highest number of diversions, reflected in the hottest stream temperatures with medium solar insolation (772,458 – 801,391Wh/m^2).

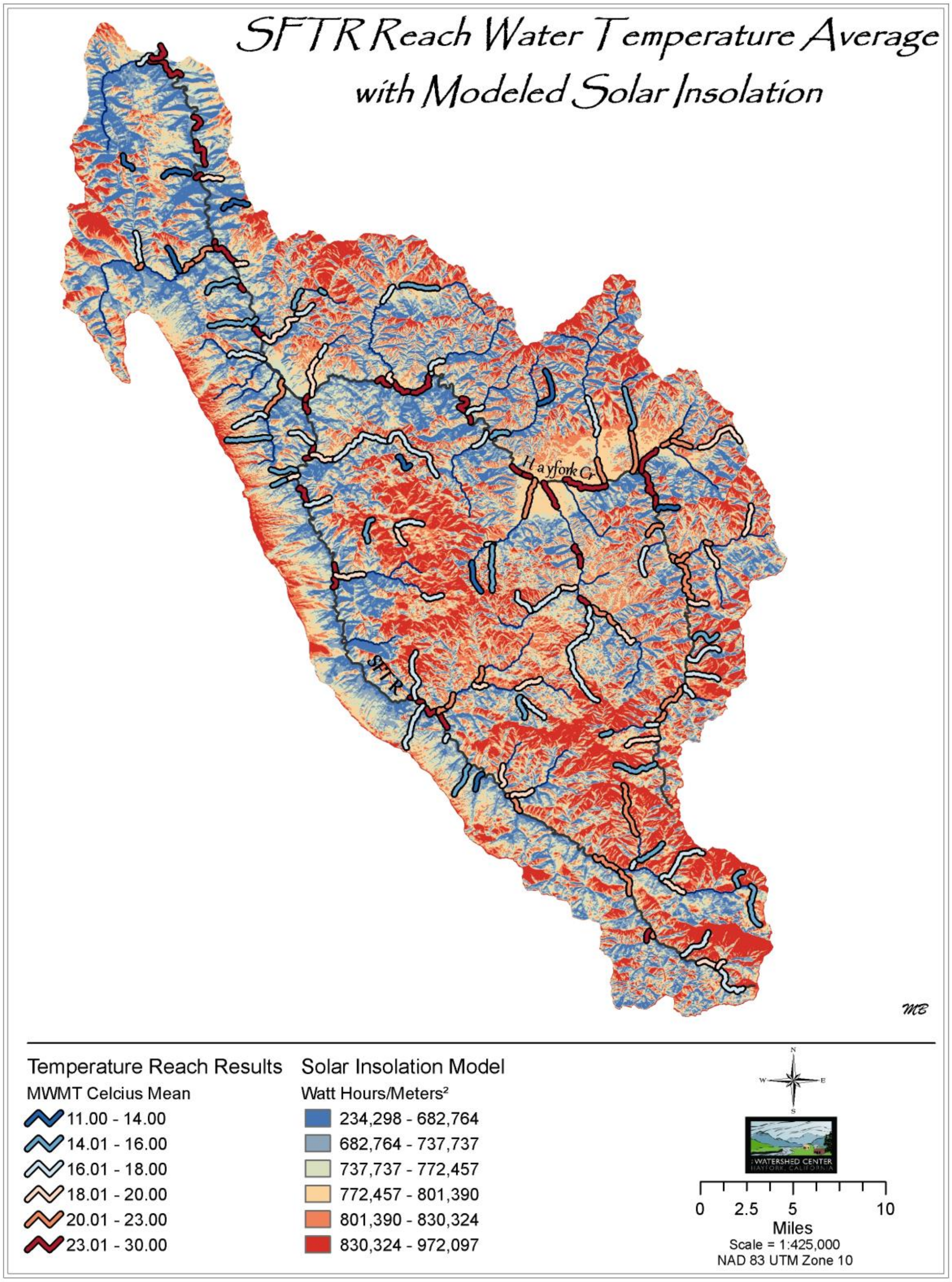

Figure 7. Mapped results of the Solar Insolation Model overlayed with stream temperature reach results from Appendix 2: Stream Temperature Analysis. MWMT is the maximum floating weekly maximum water temperature.

Hydrology Analysis

The task to evaluate hydrologic conditions in terms of streambank stabilization and groundwater availability to ensure plant survival was intended to determine the viability of specific sites. When the grant proposal was written, it was anticipated that consultants from Stillwater Science would conduct a Riparian Vegetation Assessment including the hydrology analysis, but this wasn't financially feasible. Instead we worked with James Lee who has more local experience and conducted a first site specific hydrology analyses on site visits to 20 priority restoration sites. The collected data (e.g height above stream surface, substrate type and detailed site descriptions) is available in the Field Verification Sites Visited section of this document. A broad scale hydrology analysis would not be useful for evaluating planting sites. Site specific testing (digging pits) in high priority sites (which is time and cost intensive) will be an open future task.

We identified wetland areas within the SFTR watershed above and beyond typical riparian reserve areas. In a later stage, wetland polygons can be used as additional information for prioritizing planting sites: areas adjacent to wetlands will receive a higher priority to ensure habitat connectivity and buffer wetland areas. We used high-resolution world imagery by Esri to visually identify wetland areas. Starting with the northwest boundary and moving through to the southeast boundary, the landscape was analyzed systematically by township, range and section at a scale less than or equal to 1:4000. When a wetland area was identified, the area was digitized.

Evaluation of Appropriate Plant Species

Review of literature about appropriate riparian plant species lead to the need for a consolidated source of information. We developed a plant database that contains information about the shade tolerance, soil moisture preference, habitat type and value, elevation range, propagation methods, and many more pertinent attributes for planting and growing more than 73 different appropriate riparian species of woody plants (submitted with this report as a deliverable, Appendix 3A). The main resources to guide the selection of appropriate plant species and definitions of their traits included: the Manual of California Vegetation (CNPS 2016), the CalFlora "What Grows Here" website, the Jepson Manual (2012), the Field Guide to the Common Riparian Trees and Shrubs of the lower Trinity River (Bair 2007), and the California Salmonid Stream Habitat Restoration Manual (CDFW 2003). Information from these publications was supplemented with personal observations and professional judgment. We believe this to be a comprehensive list of riparian vegetation that is found in the South Fork Trinity River watershed basin. The woody species featured in this table serve as an inclusive list of trees and shrubs that could be planted to benefit stream ecology and Coho salmon. Each planting prescription should be site specific and further research is needed regarding seed collection as well as feasibility and survivability.

Prioritization Framework Methods

The following steps were used to prioritize the riparian vegetation restoration sites:

1. The "cover, no-cover" analysis yielded a feature class with 995 polygons. These polygons symbolize the sites that are the starting point for the prioritization.
2. Intrinsic Potential: The "no-cover" polygons were spatially joined to the COHO intrinsic potential (IP) linear feature class. IP rating is classified into 3 classes, with class 3 having the highest intrinsic potential for coho habitat (NMFS 2014). An IP rating based on the nearest IP line

segment was assigned to each feature. To accomplish this, the "Coho IP Curve" values were broken into 3 classes which are as follows: 0.00-0.33 = 1 (low), 0.34-0.66 = 2 (moderate), and 0.67-0.99 = 3 (high). The 3 class breaks were modeled after the layer file class breaks provided by the North Coast National Marine Fisheries Unit (NMFS 2014).

3. Distance: All sites that were more than 300 meters from a stream with Coho IP were removed from the original “no-cover” feature class. This resulted in a feature class containing 858 potential restoration sites.
4. Solar Insolation: A solar insolation rating was assigned to each “no-cover” polygon in a similar fashion. First the zonal statistics tool was used with the solar insolation raster as the value input (in Watt Hours/ Meter^2) and “no-cover” polygons as the zones. The resulting values were interpolated into the “no cover” polygons. Solar insolation values were separated into 6 classes as follows: 548356- 596305 Wh/m^2 = 1 (coolest), 596305 - 644254 Wh/m^2 = 2 (moderately cool), 644254- 692203 Wh/m^2 = 3 (moderate), 692203- 740151 Wh/m^2 = 4 (moderately warm), 740151- 788100 Wh/m^2 = 5 (warm), and 788100- 836049 Wh/m^2 = 6 (Hot). Values were rounded to whole numbers in this document for simplicity.
5. Differentiating and highlighting the highest priority sites: the IP rating was multiplied by the solar insolation rating resulting in 11 prioritization classes. Classes 1-4 were lumped together due to the sheer number of sites within the South Fork Trinity River basin. Table 3 shows the distribution of polygons in each priority rating.

Table 3: Metrics used to rank riparian restoration sites by priority. Intrinsic potential for coho salmon, solar insolation value were combined for a rating. The total number of each class of priority (i.e. low vs high).

Priority Rank	Intrinsic Potential Rating x Average Solar Radiation Rating	# of Sites in Class
Not a Priority	1 - 4	83
Lowest	5	12
Low	6	164
Moderately-Low	8	215
Moderate	10	126
Moderately-High	12	30
High	15	202
Highest	18	26

Riparian Restoration Site Field Verification (Ground Truthing)

Field Verification of Remote Sensing Modeling and Interpretation

Field visits were conducted on 20 “no-cover” sites to test the accuracy and reliability of aerial imagery interpretation. Ten of these twenty sites were randomly chosen using the Esri Arc GIS genrandompnts tool within the Spatial Ecology: Geospatial Modeling Environment toolset. Ten additional “no cover” sites were priority-selected “no-cover” planting sites; they are sites that in our professional opinion have good potential for restoration, have logistically desirable qualities, and mostly have willing landowners (Figure 8).

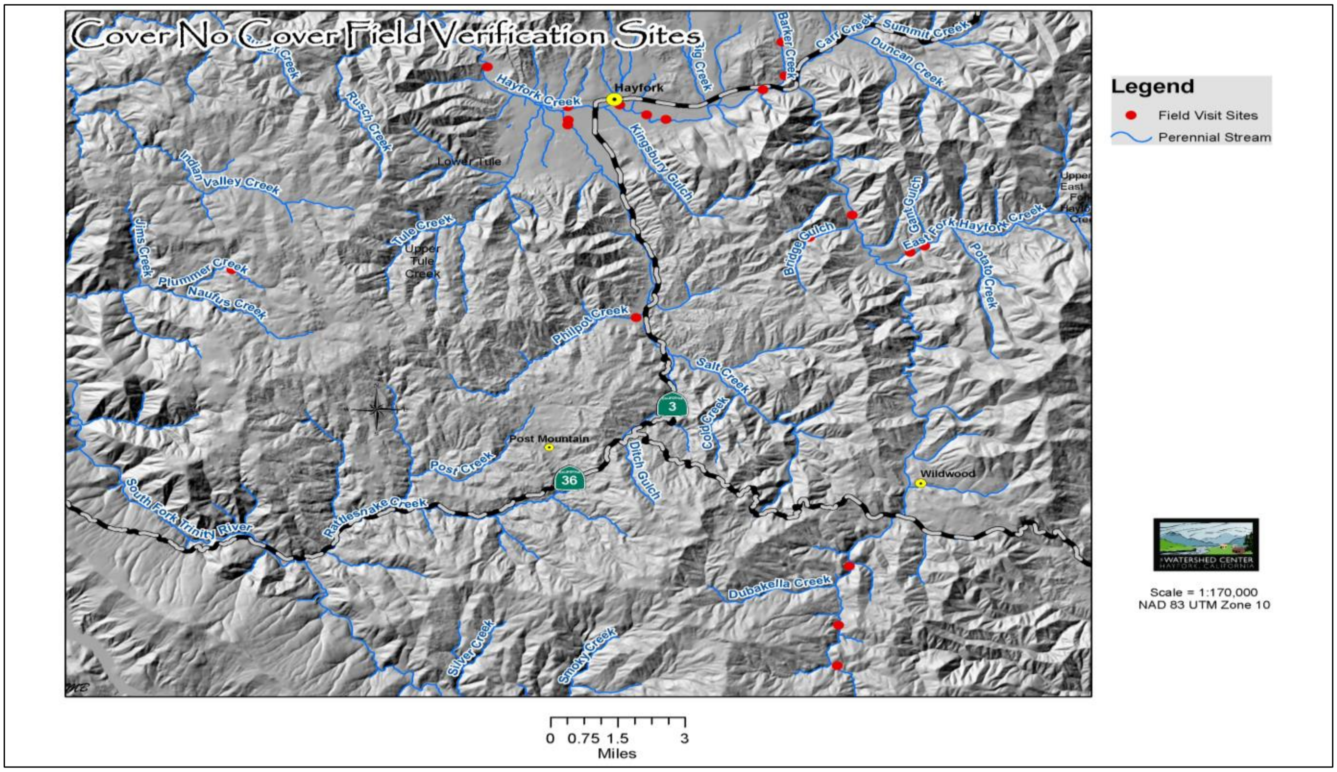

Figure 8: "Cover, no-cover" GIS Sites that were Field Verified (Ground Truthed)

Field Verification Data Collected:

- Vegetation: Visual inventory of vegetation and ground cover, recorded as percentages, with the most dominant cover element listed first (scientific names see Appendix 3A).
- Soil and geology: Physical assessment of substrate type and texture.
- Hydrology: A rough estimate of the current water table was determined by measuring multiple points with a level and stadia rod.
- Other: Locations of features of interest (such as high-water marks, bedrock outcrops, springs, noxious weeds) were collected utilizing a Trimble Nomad, and processed using Pathfinder Office.

RIPARIAN VEGETATION RESTORATION PLAN

Summary of Findings

The main products created in this Riparian Assessment are:

- Evaluation of existing species composition
  - Surveyed and evaluated past revegetation projects to determine which species mix is most appropriate and successful in producing shade and stabilizing stream banks.
    - Product = Past Revegetation Projects
  - Literature review and development of a table that lists appropriate plant species and their traits.
    - Product = Evaluation of Appropriate Plant Species table Appendix 3A

  - The evaluation resulted in the identification of the most suitable species for restoring riparian vegetation in 20 ground-truthed sites (see Field Verification Sites Visited)
- A suite of GIS models that assessed solar radiation potential which will help us determine the areas where planting will be most effective for shade production (Solar Insolation Model).
- An open future task is the evaluation of hydrologic conditions to determine viability of specific sites in terms of streambank stabilization and elevations for maximum plant survival. This evaluation will be added to the GIS modeling to refine the prioritizing of future planting sites.
- Assessment of 20 priority coho streams for riparian vegetation.
  - The evaluation resulted in the identification of suitable species for restoring riparian vegetation in 20 ground-truthed sites and a preliminary site design.
    - Product = Field Verification Sites Visited and Assessed and Preliminary Planting Design

Priority Planting Sites

Utilizing the metrics listed in the Prioritization Framework Methods section of this document we created a table of the top 50 riparian revegetation sites (Table 4). These sites are the hottest and most degraded sites that we believe have the ability to moderate stream temperatures in the SFTR if revegetated. Stream temperature was measured at 9 of the 50 sites, 8 of which were within the second highest of the six temperature classes (20-23°C, see Appendix 2 of this report "Stream Temperatures in the SFTR"). A detailed description of the site with priority 18 (Barker Cr: Cr Crossing) can be found below (Field Verification Sites Visited).

Table 4: The 50 riparian sites with highest restoration priority of 858 no cover sites in the SFTR watershed and associated prioritization metrics.

Planting Priority	Size (acres)	SiteName	Coho IP Rating	Solar Rating	IP x Solar	CO IP CURV	Mean Solar Value (Watt hours/ meter^2)	Latitude	Longitude
1	4.5	Hayfork Cr upstream of Goods Creek 1	3	6	18	0.89	805130	-123.066	40.3875
2	0.9	Little Barker Creek	3	6	18	0.69	803056	-123.109	40.5951
3	0.5	Hayfork Cr/ Wildwood 1	3	6	18	0.93	796205	-123.054	40.4183
4	0.4	Hayfork Cr/ Wildwood 2	3	6	18	0.75	796205	-123.052	40.4191
5	0.5	Hayfork Cr/ Wildwood 3	3	6	18	0.75	796205	-123.052	40.4199
6	11.7	Hayfork Cr upstream of Goods Creek 2	3	6	18	0.89	795066	-123.065	40.3861
7	1.3	Hayfork Cr/ Wildwood 4	3	6	18	0.93	794510	-123.055	40.4155
8	1.2	Hayfork Cr: Wilson Creek	3	6	18	0.93	794385	-123.056	40.4144
9	4.4	Bridge at Barker Creek	3	6	18	0.87	792780	-123.114	40.5835
10	20.1	Barker North Meadow 1	3	6	18	0.87	792780	-123.115	40.5832
11	1.4	Barker Valley 1	3	6	18	0.84	792780	-123.115	40.5858
12	5.6	Barker Valley 2	3	6	18	0.81	792780	-123.115	40.5887
13	0.7	Barker North Meadow 2	3	6	18	0.80	792780	-123.117	40.5896
14	0.8	Duncan Gulch 1	3	6	18	0.97	792033	-123.141	40.5748
15	0.8	Salt Creek: 13 Dips	3	6	18	0.95	791963	-123.152	40.4510
16	12.0	Hayfork Cr: Canon Ball	3	6	18	0.93	791624	-123.058	40.4139
17	1.7	Duncan Gulch 2	3	6	18	0.81	790540	-123.133	40.5794
18	8.6	Barker Cr: Cr Crossing	3	6	18	0.89	790073	-123.112	40.5768
19	8.9	Barker Cr: Little Barker Cr	3	6	18	0.75	789921	-123.115	40.5941
20	13.6	Slat Cr x Ditch Gulch 1	3	6	18	0.95	789832	-123.154	40.4507
21	0.8	Barker Cr: Sunshine Meadow Way	3	6	18	0.82	789294	-123.114	40.5935
22	4.5	Barker South Meadow	3	6	18	0.81	789221	-123.113	40.5753
23	1.0	Duncan Gulch 3	3	6	18	1.00	789091	-123.142	40.5735
24	2.5	East Fork Hayfork Cr 1	3	6	18	0.76	788817	-123.025	40.5002
25	2.7	East Fork Hayfork Cr 2	3	6	18	0.94	788817	-123.026	40.5013
26	3.5	Old Cold Creek Road 1	3	6	18	0.89	788256	-123.066	40.3859
27	6.9	East Fork Hayfork Cr: Rose Gulch	3	5	15	0.87	788088	-123.021	40.5006
28	0.3	Hayfork Cr/ Wildwood 5	3	5	15	0.93	787898	-123.059	40.4091
29	1.0	Hayfork Cr/ Wildwood 6	3	5	15	0.93	787898	-123.059	40.4096
30	1.0	Hayfork Cr/ Wildwood 7	3	5	15	0.93	787898	-123.060	40.4067
31	1.4	Hayfork Cr/ Wildwood 8	3	5	15	0.93	787898	-123.059	40.4082
32	0.6	Hayfork Cr/ Wildwood 9	3	5	15	0.93	787898	-123.060	40.4076
33	6.5	Hayfork Cr: Hall City Cr	3	5	15	0.72	787825	-123.059	40.4015
34	7.0	Duncan Gulch 4	3	5	15	0.93	787630	-123.140	40.5745
35	1.6	Old Cold Creek Road 2	3	5	15	0.90	787501	-123.067	40.3838
36	25.5	Big Creek Ranch 1	3	5	15	0.86	787372	-123.152	40.5787
37	6.8	Big Creek Ranch 2	3	5	15	0.86	787372	-123.150	40.5832
38	8.7	Big Creek Ranch 3	3	5	15	0.88	787372	-123.151	40.5693
39	3.3	Big Creek Ranch 4	3	5	15	0.88	787372	-123.150	40.5691
40	1.7	Big Creek Ranch 5	3	5	15	0.87	787372	-123.151	40.5805
41	1.4	Big Creek Ranch 6	3	5	15	0.87	787372	-123.151	40.5783
42	2.8	Big Creek Ranch 7	3	5	15	0.76	787372	-123.150	40.5739
43	5.0	Big Creek Ranch 8	3	5	15	0.86	787372	-123.151	40.5716
44	5.0	East Fork Hayfork Cr: Sims Creek	3	5	15	0.93	787051	-123.012	40.5040
45	0.7	Potato Creek	3	5	15	0.69	786518	-123.043	40.5036
46	2.9	Duncan Gulch 4	3	5	15	0.89	785679	-123.140	40.5704
47	5.9	Carr Creek	3	5	15	0.92	785609	-123.089	40.5752
48	4.3	East Fork Hayfork Cr 3	3	5	15	0.82	785549	-123.003	40.5068
49	8.6	Salt Cr: Ditch Gulch 2	3	5	15	0.82	785325	-123.157	40.4529
50	2.5	Duncan Gulch: Highway3	3	5	15	0.90	785271	-123.137	40.5572

Figure 9 shows some of the final products produced in this riparian assessment. It shows a subset of the full suite of data that is only focused on the Hayfork Valley, but data is available for the entire SFTR watershed.

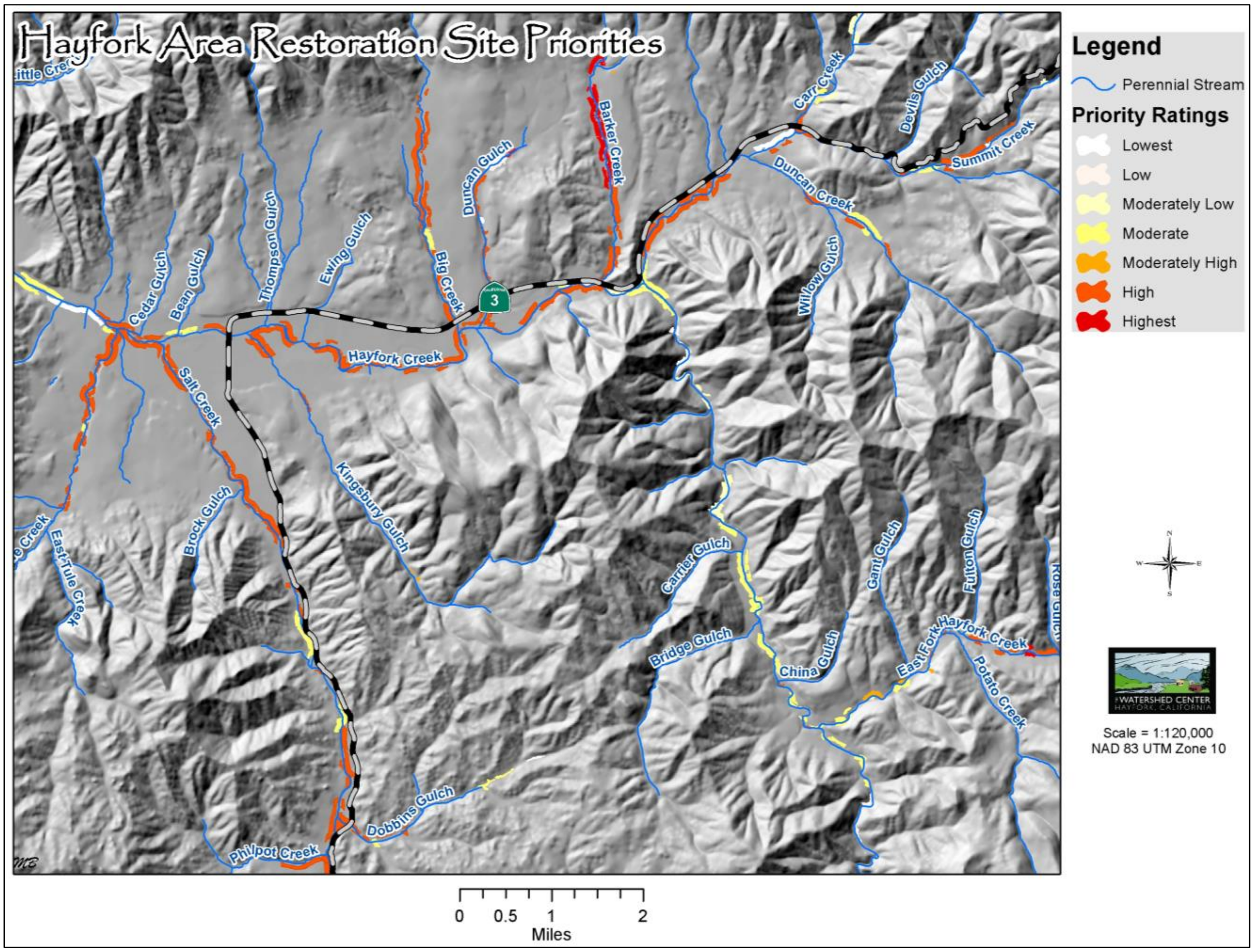

Figure 9: The Riparian Restoration Site Priorities in the Vicinity of Hayfork. The sites shown in this map are an exemplary subset of the full restoration site prioritization table.

Field Verification Sites Visited

Twenty sites were field visited in this study in order to confirm modeling results and collect information needed for future planting design. In the following site descriptions we included planting recommendations for no cover sites. In these sites it is advisable to plant phreatophytic species like cottonwood and willow that need to have a constant water source but are tolerant to direct sunlight. In already partially shaded sites, mesophytic species like big leaf maple and Oregon ash should be interplanted to complement the species mix. We didn't find Oregon ash in any of the groundtruthed sites; further research is needed to verify if Oregon ash is part of the potential natural riparian vegetation in the Hayfork Valley.

Hayfork Creek - Bradford

- Site selection: priority selected
- Ownership: Private
- Size: 88,335m^2,Elevation: 732m, Aspect: NW, N
- Height above stream surface: Due to neighboring private landowner access issues we were unable to determine this data.
- Substrate type: Cobble, sandy loam
- Existing cover: 30% willow, 30% yellow starthistle grassland, 10% ponderosa pine, 10% Western chokecherry and wild plum, 10% wedgeleafceanothus/ deerbrush, 5% black oak/white oak, 3% white alder, 1% grey pine, 1% rock outcrop.
- Solar insolation: 768,166Wh/m^2
- Priority: High

This site is located upstream of the town of Hayfork near the eastern most part of Hayfork Valley. Extensive mining history and wildfires have left a long flat stretch of completely exposed stream with virtually no riparian cover. Access and revegetation has been approved by the western most landowner; however, the majority of the unvegetated polygon is located on a property which just sold to a Hmong family. An interpreter will be needed to explain desired outcomes and secure access. This site is considered a high priority for revegetation efforts. Existing willow and alder trees are located mostly on the south side of Hayfork Creek, and little shade is provided because the width of the creek exceeds the potential for their canopy height to provide shade. Recommendations for this site are plantings of pine and oak species on the higher elevations of the bare corridor along both sides of the creek, which spans nearly ¾ mile. Sporadic plantings of cottonwood poles along the water's edge throughout the site on both sides of the creek is also recommended.

For this site, we included an exemplary preliminary planting design with planting polygons accompanied by a table describing each polygon (Attachment 3C).

Hayfork Creek-Oak Street (across from Hayfork Community Wetland Enhancement Site)

- Site selection: priority selected
- Ownership: Trinity County
- Size: 30,044m^2,Elevation: 707 m, Aspect: N, NE, NW, W, Height above stream surface: 3.4m
- Substrate type: Sandy loam, cobble
- Existing vegetation: 90% yellow starthistle grassland, 5% willow, 5% Armenian blackberry, <1% gray pine, ponderosa pine, black oak
- Solar insolation: 778,602 Wh/m^2
- Priority: High

This site shows the need for rehabilitation and revegetation due to the lack of any native dominant vegetation type. Stream shade at this site is minimal. Parts of this site experience flood inundation during winter months. Since it is located near the Oak Street Bridge, it experiences foot traffic and pedestrian access to the stream. In addition, it has historically been used as a homeless camp. Recent anti-camping laws for Trinity County owned land have reduced camping on site. Recommendations for this site are pioneer/floodplain species such as cottonwood trees/poles, willow poles, and alder. Plantings should be arranged strategically to allow foot traffic and conveyance of flood/storm water. Oak and pine species are recommended on higher ground, as the surrounding area is an oak woodland intermixed with conifer. Planting a mixed oak woodland in the unvegetated upland part of this site will shade the creek and provide a future large woody debris source. Manual removal of yellow star thistle is needed prior to planting.

Hayfork Creek -Riverview Rd (Trinity County gravel lot)

- Site selection: randomly generated
- Ownership: Trinity County / Private
- Size: 40,093m^2,Elevation: 707m, Aspect: NE, N, E, SW,
  Height above stream surface: 10m on south side
- Substrate type: Sandy loam
- Existing cover: 50% yellow starthistle grassland,25%bare ground/rock,20% willow,2%ponderosa pine, 2%gray pine,
- Solar insolation: 781,357Wh/m^2
- Priority: High

This site can be broken into two subsites: The south side of Hayfork Creek, owned by Trinity County, is being scoured, resulting in a steep (cliff) bank. The stream is severely downcut and channelized. Choke cherry is abundant on the greater than 20 foot tall, vertical streambanks. It is not tall enough to provide shade; however, it does stabilize the soil. The disconnected stream terrace immediately adjacent to the stream (county gravel yard) is mostly void of large vegetation. During the summer, much of the hot afternoon sun reaches the creek, exasperating undesirable temperatures. Some springs exist in the area (groundwater exiting the stratum midslope of the incised stream bank) that could be used as locations for long term riparian planting.

The north side of the creek is privately owned. It has willow growing immediately adjacent to the stream, and a large meadow further out. The meadow is used for grazing a herd of livestock. Exclusionary fencing is present and properly maintained. There are few trees on either side of the creek. Planting recommendations for this site are Ponderosa pine, Gray pine and possibly oak species at the top of the bank on the south side. The recommendation for the north side of the creek above the floodplain would be oak species. Floodplain species, such as cottonwood and alder, should be planted within the inner riparian corridor.

During March of 2016, four ponderosa pine and 2 gray pine saplings were planted. The saplings were approximately 3 years old. They were placed in close proximity to the cliff edge and in areas where tree gaps existed. Care was taken in the planting location selection to avoid disruption of long term gravel yard functionality. Each sapling was given protective anti-deer fencing and will be watered once a month from June-October.

Hayfork Creek-Shorey's (access to beaver dam area)

- Site selection: priority selected
- Ownership: Private
- Size: 17,181m^2,Elevation: 715m, Aspect: SW, S, NW, N, Height above stream surface: floodplain
- Substrate Type: Cobble with <5%sandy loam
- Existing cover:90% cobble sand bar, 5% willow,2% white alder, 2%blackcottonwood, 1 % gray pine

- Solar insolation:777,583Wh/m^2
- Priority: High

This site is located behind several private residences and has no public access; however, access is granted by the residents. Anthropogenic use and impacts are minimal. The site has great potential for revegetation, due to the existence of a variety of species in small abundances. Shade at this site is minimal, as it is a large river bar within the floodplain, mostly consisting of cobble, yet a small silt deposit has provided soil requisites for a few gray pine in an "island" within the bar. Although a few cottonwood trees are present at the edges of the polygon, regeneration is not observed and the population appears to be declining. Planting of cottonwood and willow species is recommended. This site has an active beaver population, and we recommend installation of physical barrier/protection of plantings (willow and cottonwood poles) during restoration activities.

Hayfork Creek- Bean Gulch

- Site selection: randomly generated
- Ownership: Private
- Size: 30,785m^2,Elevation: 707m, Aspect: predominantly S, few areas SW, Height above stream surface: floodplain
- Substrate type: Cobble, sandy loam
- Existing cover: 50% European grass (*Poa bulbosa*), 20% rock and bare soil, 10%marijuana, 5% arroyo willow, 3% black cottonwood,2% white alder
- Solar insolation: 783,190Wh/m^2
- Priority: Moderate

This site is a located within the Hayfork Creek floodplain and does not show an immediate need for restoration as the polygon lies behind an already well vegetated and properly functioning riparian corridor. It appears to have been chosen due to bare ground on the floodplain, however the existing vegetation immediately adjacent to the creek is thick and provides sufficient stream shade. Furthermore the entire "no-veg" area is within the high water mark and there are strips of cottonwood/willow assemblages throughout the site. Due to annual flow fluctuations and existing site characteristics, this site is not a planting priority. There is a marijuana plantation within the bankfull stream bed, which is cause for concern as it may lead to water quality issues and contribute garbage to downstream areas. It would benefit water quality, to have the marijuana garden moved out of the active flood plain.

Hayfork Creek- Mile Marker 13 Northwest (Wildwood Rd)

- Site selection: priority selected
- Ownership: National Forest
- Size: 28,555m^2,Elevation: 805m, Aspect: E, NE, few areas with SE, N, Height above stream surface: 1-4m
- Substrate type: Sand bar, cobble
- Existing cover: 90% sandbar/cobble, 5% willow, 2% grassland, 1% ponderosa pine, 1% white oak, 1% redbud
- Solar insolation: 757,513Wh/m^2
- Priority: Moderate

The North side of the creek is a sand bar with some cobble stone. There is no access other than by crossing the creek. The vegetation is sparse; however, the site has a shallow water table. Riparian tree species such as alder plugs or willow poles are recommended for this site. Additional investigation of adjacent riparian areas should determine whether this site is appropriate for cottonwoods.

Hayfork Creek- Mile Marker 13 Southeast (Wildwood Rd)

- Site selection: priority selected
- Ownership: National Forest
- Size: 4,171m^2,Elevation: 805m, Aspect: NW, W, Height above stream surface: 15m
- Substrate type: cobble (mining tailings), isolated wetlands
- Existing cover: 80% wedgeleaf ceanothus/ deerbrush, 2% white oak, 2% interior live oak, 2% Ponderosa pine*,* 2% grey pine, 1%white alder
- Solar insolation: 757,513Wh/m^2
- Priority: Moderate

The Southeast side consists of mining tailings with pockets of wetlands, soil accumulation and barren cobble interspersed throughout. Due to the varying site conditions there are islands of high biodiversity. In this area planting pine and oak species is recommended, in order to provide shade on the creek and for eventual LWD recruitment. Care should be taken, during planting design, to select locations with decent soil accumulation as well as a "nurse" feature to provide afternoon shade. The planting design should occur on site, and then be transferred to a map. Each planting location should be recorded with a highly accurate GPS device. The southeast side of the mile marker 13 site is priority over the north side.

East Fork Hayfork Creek- Four Bit Gulch (North Side)

- Site selection: priority selected
- Ownership: National Forest
- Size: 27,343m^2,Elevation: 835m, Aspect: S, SW, SE
  Height above stream surface: Ranges from <0.1m to >3m
- Substrate type: Ranges from cobble, sandy loam to organic wetland muck
- Existing cover: 30% grassland/meadow, 30% wedgeleaf ceanothus/ deerbrush, 10% mining tailings (exposed), 10% ponderosa pine, 5% sugar pine, 5% white oak
- Solar insolation: 717,371Wh/m^2
- Priority: Moderately-High

This site is in an area which was heavily mined and has miles of tailings, piled within the riparian corridor. Revegetation of the tailings is progressing (100+ years after the major mining impacts); however, planting could accelerate the process providing shade much quicker than natural revegetation rates. Fine sediment deposition and wetland hydrology has created complex and biologically diverse microsites. Recommendations for this site are oak and pine species on the upper bar/tailings, and various *Salix* species pole plantings on the lower, wetter areas as well as adjacent to the stream.

Hayfork Creek- Drinkwater Gulch

- Site selection: randomly generated
- Ownership: Private
- Size: 53,651m^2,Elevation: 683m, Aspect:W, NW, few areas with SW, S
  Height above stream surface: floodplain
- Substrate type: Sandy loam
- Existing vegetation: 80% grassland, 10% willow, 5% white alder, 3% white oak, 2% ponderosa pine

- Solar insolation: 733,922Wh/m^2
- Priority: Moderately-Low

This site is on a well maintained private property, which contains a large meadow. The creek is sufficiently shaded by a thick buffer of willows and alders. The property owners are not cooperative and do not wish further involvement. Further involvement is not desired as revegetation is not needed.

Hayfork Creek- Wild-Mad

- Site selection: randomly generated
- Ownership: National Forest
- Size: 5,358m^2,Elevation: 1,146m, Aspect: SW, W,
  Height above stream surface: data not available
- Substrate type: Ultramafic peridotite, mostly cobble with very little soil.
- Existing cover: 50% buck brush, 20% rock outcrop, 10% Jeffrey pine, 5% incense-cedar (saplings), 5% Jeffrey pine (saplings), 4% ultramafic forb assemblage, 2% sugar pine, 2% Douglas-fir
- Solar insolation: 757,940Wh/m^2
- Priority: Moderate

This site is on a hill slope above upper Hayfork Creek. Mineral soil is minimal and covered with a thick layer of peridotite pebbles. Vegetation conditions are typical for an ultramafic site. Although there are sparse trees at this site, the creek is sufficiently shaded by topography and inner riparian vegetation. This site has not been modified or impacted by humans. No restoration is needed.

East Fork Hayfork Creek-Sulfur Gulch

- Site selection: priority selected
- Ownership: National Forest
- Size: 27,946m^2,Elevation: 853m, Aspect: north bank S, SE, south bank NW, W, N,
  Height above stream surface: >1m
- Substrate type: Cobble and sandy clay-loam
- Existing cover: 50% ceanothus, 40% mining tailings,7% Willow, 1% Ponderosa pine, 1% interior live oak, 1% manzanita
- Solar insolation: 787,808Wh/m^2
- Priority: Moderately-High

This site is located on historic mining tailings. Natural revegetation is slowly occurring and planting on this site would help accelerate the process. There are many different conditions within the polygon, ranging from wetland, with deep organic soil accumulation to rock substrate, with a very thin (sometimes absent) soil. Planting design should occur on site. In addition, planting 4 times the number of trees desired is a good strategy to ensure higher survival outcomes. Planting sites should be located adjacent to a nurse feature. Ponderosa pine and live oak should be planted in the mining tailings on the south side and on the upper bank, which is perched 2m above the stream. Willows should be planted along the creek.

West Fork Hayfork Creek confluence-Rice Patty

- Site selection: randomly generated
- Ownership: National Forest
- Size:11.158m^2,Elevation: 1,195m, Aspect:SW, S,
  Height above stream surface: <1m, mining tailings

- Substrate type: Ultramafic, varied
- Existing Vegetation: 45% serpentine barrens , 15% wedgeleaf ceanothus, 15% Jeffrey pine, 5 % leather oak, 3% incense-cedar, 1% Douglas fir, 3% willows, 2% white alders, 10% snow
- Solar insolation: 776,079Wh/m^2
- Priority: Moderate

The site was heavily impacted by road development and mining activities. Three road prisms dissect the site within 100m of stream. These roads appear unused with abandoned maintenance. Due to the ultramafic site conditions, regeneration of sufficient riparian vegetation will not occur within a human lifespan. We recommend replanting of serpentine-affine species like incense-cedar and Jeffrey pine. Willow cuttings should be planted along the creek. Cuttings should be sourced directly at or adjacent to the planting location to assure genetic suitability for serpentine conditions. There is a small population of yellow star thistle which is a very high treatment priority due to the high concentration of endemic plants in the area.

Barker Creek-Chadwick/Stovall

- Site selection: randomly generated
- Ownership: Private
- Size: 69,810m^2,Elevation: 756m, Aspect: west bank E, SE, east bank W
- Height above stream surface: floodplain and agricultural floodplain
- Substrate type: Loam
- Existing Vegetation: 80% grassland/meadow, 5% willow, 5% black oak, 5% ponderosa pine, 5% alder
- Solar insolation: 755,125Wh/m^2
- Priority: High

This site is on a long-term homestead which is used for animal husbandry. Historically, the surrounding meadow was used for hay production; however the county no longer supports flood irrigation permits for this site. Currently there are herds of goats, cows and pigs grazing in the meadow. The stream is suffering from channelization and bank erosion, possibly due to upstream road conditions and development. Planting of shade providing trees such as oak or cottonwood is recommended streamside at the top of the bank. Furthermore repair of exclusionary fencing would benefit the stream by allowing for regeneration of woody riparian vegetation. Educational materials should be provided to landowners on the benefits of riparian vegetation and stream stage development.

Barker Creek- Creek crossing

- Site selection: randomly generated
- Ownership: Private
- Size: 34,909m^2,Elevation: 780m, Aspect: W, SW
- Height above stream surface:
- Substrate type:
- Existing Vegetation:
- Solar insolation: 790,073Wh/m^2
- Priority: Highest

This site is located within a natural meadow, adjacent to Barker Creek which runs along the western perimeter of the cover/no cover area. The riparian canopy itself (which is notably not within the non vegetated area) has 20-30 ft gaps intermittently, and consists of cottonwood, willow, white oak and ponderosa pine. A large grassy meadow sits above the creek bench to the east. There is evidence of tree mortality in recent years due to drought. This site would greatly benefit from shade provided by plantings of cottonwood poles and alder plugs creek side, as well as oak and ponderosa pine trees planted on the bench of the creek.

Bridge Creek-Bridge Gulch

- Site selection: randomly generated
- Ownership: National Forest
- Size: 19,235m^2,Elevation: 878m, Aspect: SE, S
- Height above stream surface: 15m
- Substrate type: Silt loam, limestone outcrop.
- Existing Vegetation Type: 50% mountain mahogany, 30% forb/ grass, 10% grey pine, 5% redbud, 5% limestone rock outcrop.
- Solar insolation: 707,289Wh/m^2
- Priority: Moderately-Low

This site is located on a steep south facing limestone slope well above the stream's water table, across the road from the creek and inner riparian area. The stream lies within a gulch which creates a microclimate significantly cooler than surrounding areas. During 2015 wildfires, the non-vegetated hillside was burned at high severity. Existing vegetation types were determined through forensic botany and observations of re-sprouting plant materials. The inner riparian corridor only experienced a low severity burn and is within a steep basin. It receives shade from the thick vegetation on the north slope, as well as shade from the topography. Outside the narrow strip of southside riparian vegetation, a road runs the length of the site. Planting is not recommended for this site. The vegetation type and quantity is typical for a Trinity County south facing hillside on limestone substrate.

Philpot Creek - Bower

- Site selection: randomly generated
- Ownership: Private
- Size: 47,550m^2,Elevation: 780m, Aspect: N, NE, Height above stream surface: ≤ 1 meter
- Substrate type: Serpentine sandy loam
- Existing Vegetation: 40% serpentine forb assemblage, 35% yellow starthistle grassland, 10% wedgeleaf ceanothus, 10% native grass,5% Alder, and< 1% serpentine hoary coffee berry
- Solar insolation: 782,812Wh/m^2
- Priority: High

The site is located in a valley on the south side of Philpot Creek. The meadow is not highly productive, due to ultramafic soil conditions. Legacy effects of cattle grazing in the meadow include patchy distribution of yellow starthistle and European annual grasses. In addition, the site caretaker suspects that large-scale marijuana cultivation activities, upstream from this location, have negatively impacted riparian tree mortality, water quality and deer herd viability. These negative effects have been further compounded by 5 years of consecutive drought. In 2015 the northern side of Philpot Creek was moderately burned by the Fork Complex wildfires. The wildfire, upstream water use and drought pressures have left this stream's riparian vegetation in a state of high mortality. Large woody debris recruitment from tree mortality is evident and likely to increase. Recommendations for this site include prescribed fire in the meadow to increase future fire resiliency and reduce non-native organic matter accumulation. Where no regrowth is present, cottonwood and willow poles taken from populations adjacent to the site would be planted within the floodplain and or terraces. The yellow starthistle grassland aggressively competes against the slow growth rate of serpentine affine species and ultimately changes soil chemistry, through organic matter accumulation. Post fire management should include treatment of yellow star thistle using integrated pest management and reseeding with Roemer's fescue (*Festuca romerei*), a native perennial grass which grows well on ultramafic sites.

Plummer Creek-Friend Mountain

- Site selection: randomly generated
- Ownership: National Forest
- Size: 120,753m^2,Elevation: 1,150m, Aspect: north bank SW, W, south bank NE, N, NW, Height above stream surface: >0.5m
- Substrate type: Ultramafic silt loam
- Existing vegetation: 80% fire-kill snags, 12% incense cedar, 8% Jeffrey pine
- Solar insolation: 762,090Wh/m^2
- Priority: Not a priority

This site is located high up in the Plummer Creek watershed. It is just above the anadromous extent of Plummer Creek. Although serpentine rock and vegetation assemblage was observed at the site, it is suspected that lithologic discontinuity occurs across the creek, based on the higher productivity and a shift in vegetation. Due to the steep topography the creek is effectively shaded throughout the day. In 2007 this site burned at high intensity, leaving only a few live trees, but many tall snags that provide additional shade to the creek. The residual live tree distribution is sufficient to reseed the area. Many healthy saplings were observed on site and will further shade these headwaters. Future large woody debris recruitment, from snags, is expected to contribute to healthy sediment accumulation. No restoration activities are recommended for this site.

Salt Creek- Patton

- Site selection: priority selected
- Ownership: Private
- Size: 65,373m^2,Elevation: 756m, Aspect:W, NE, SW, few areas of all aspects, Height above stream surface: no data available
- Substrate type: unknown, suspected to be ultramafic
- Existing vegetation: 90% meadow, 5% willow, 3% black cottonwood, 1% incense-cedar, 1% Jeffrey pine
- Solar insolation: 779,491Wh/m^2
- Priority: High

This site is on an agriculturally zoned private parcel and has likely been used for livestock grazing for many years. Grazing activity is impacting riparian vegetation. Within 10m of the creek there is only 50% vegetation cover, the other 50% are directly exposed to the sun. We assume that mixed ultramafic soil conditions occur on this site, due to the observed Jeffrey pine and incense-cedar assemblage. Cottonwood pole plantings would be desirable, with exclusionary fencing (previous NRCS fencing should be checked/ maintained). Contact with property owner has yet to be established. Due to assumed ultramafic site conditions, cuttings and/or poles taken should be sourced directly at or adjacent to planting location. NRCS and RCD planted in this site in the 90's, however, no data record has been found to date.

Salt Creek- Millsite east

- Site selection: priority selected
- Ownership: Private
- Size: 25,770m^2,Elevation: 707m, Aspect: W, SW, Height above stream surface: Not Recorded
- Substrate type: Loam and gravel
- 90% yellow starthistle grassland, 9% gravel, 1% gray pine
- Solar insolation: 780,582Wh/m^2
- Priority: High

This site has experienced long term industrial disturbance resulting in soil compaction, pollution and a high ratio of noxious weeds to native plants. The adjacent Salt Creek has a dense riparian corridor consisting almost entirely of large shrubs such as willow, choke cherry and Armenian blackberries. These shrubs are not of a height that can provide shade to the entire creek, as they do not create an overstory canopy; however, several cottonwood trees were observed growing in close proximity to the no cover site. The no cover site adjacent to the stream is in need of taller trees such as Ponderosa pine and cottonwood.

Salt Creek- Waterworks District

- Site selection: priority selected
- Ownership: Private
- Size: 47,784m^2,Elevation: 707m, Aspect: N, NE, NW, W, Height above stream surface: Not recorded
- Substrate type: Loam and gravel
- 90% yellow starthistle grassland, 9% barren gravel, 1% gray pine
- Solar insolation: 780,582Wh/m^2
- Priority: High

This site is immediately downstream of the Hayfork waste water treatment ponds. There is a natural open grassland within the polygon, which has potential for revegetation due to healthy alluvial soils found here. The adjacent creek is densely covered in large willow shrubs, choke cherry and thriving riparian plants. The bench area and flood plain could support cotton wood pole plantings, arranged to convey flood water flow. Above this area in the grassy meadow, planting Ponderosa or Oak species strategically to provide shade from the south would be recommended.

Data Gaps and Other Challenges

Information and Data Gaps

1. When creating the Solar Insolation Model the "whole year" was specified for the time configuration. It might have been more appropriate to use July and August values instead as the critical stream temperatures occur during that timeframe. The winter months could potentially be skewing the data, overestimating the effect of topographic shading.
2. When creating the "cover, no-cover" polygons, we did not assess any streams that did not contain anadromous fish; we stopped analyzing above any point of anadromy. This may not have been the best option because there are numerous non-anadromous tributaries (for example Indian Valley and Cold Camp creeks) where planting riparian vegetation could contribute to large potential reductions in stream temperature in very high quality anadromous streams like Butter Creek. Essentially, even though these streams are not utilized by anadromous fish, we could still help reduce stream temperatures in downstream fish bearing streams through riparian planting projects there.
3. We were not able to thoroughly analyze the locations of major mining efforts within the SFTR watershed. We did not find any quality obtainable data on mining locations and we did not have the resources to map the locations ourselves in this analysis. In looking for degraded riparian sites it would be likely that mining areas would be the most degraded of all. While many of these mined sites did rise to the surface of the analysis, using the mining areas as a component of the prioritization could have been useful.
4. Due to the decision to map the 100m riparian buffer for "cover, no-cover", a major inaccuracy in our modeling is that some areas listed as priority restoration sites actually do have good vegetative shading because the area mapped is located in the exterior of the riparian vegetation. Sometimes it was difficult to see the extent and quality of immediately adjacent riparian vegetation. See the Field Verification Sites Visited section for multiple examples of this inaccuracy.
5. An open future task is the evaluation of hydrologic conditions to determine viability of specific sites in terms of streambank stabilization and groundwater level for maximum plant survival. We anticipate conducting this as needed while creating final design plans and/or conducting restoration planting.
6. Missing groundwater connection to streams in the Hayfork Valley may be a major limiting factor in the current riparian vegetation condition. There is evidence that Hayfork Creek has incised significantly and because of local geology this has reduced the ability of surface water to connect with and recharge shallow groundwater aquifers and ultimately limits the area in which plants can establish and grow. Groundwater connections to stream temperature and riparian vegetation should be investigated further.
7. The WRTC has recently acquired a new aerial photograph set that has a much higher resolution (as small as 6 inch pixels in some cases) and we anticipate further refining the prioritized sites with this photo set.

Other Considerations

Low cost, small footprint planting efforts: The WRTC has been fairly successful at very low cost, low impact, riparian revegetation efforts over the last four years, even as we are experiencing a severe drought. Volunteer planting efforts on selective sites have proven to be somewhat successful with a success rate ranging from 8-25%, while the only costs have been staff labor costs to organize volunteers, collect plants, and in some cases purchase plants. The Hayfork High School horticulture program has been extremely helpful in propagating and planting vegetation. It should be noted that rather than conducting massive revegetation projects, sometimes it is appropriate to conduct small, low cost experiments to see which species establishes best in a particular zone and then return to that area with more intensive planting in future years.

Groundwater Connectivity: Another consideration is hydrologic connectivity. The Hayfork Valley is the location of the majority of loss of riparian vegetation from historic conditions (and the majority of top priority restoration sites) and it is likely that a large part of why that vegetation has been lost is due to the incision of Hayfork Creek and potential dewatering of the groundwater table throughout the valley. Beaver populations have been seen to be rebounding significantly in the last 4-5 years and their activities have been seen to increase groundwater connectivity with Hayfork Creek, dramatically increase riparian vegetation through raising the groundwater table (helping plants access water), and even potentially helping to aggrade the incised streambed (Figure 10) . If willow sticks used in their dams and lodges are not completely stripped of bark, they sprout. The authors of this report believe that groundwater connection may be tremendously important to stream temperatures in the Hayfork Valley. Interpretation of the aerial photos of the valley from 1944 suggest that the valley had significantly a higher groundwater table, crop fields appeared to have many more patches of lush vegetation than at the present.

Figure 10. Beaver dam at Hayfork Creek

Beaver Activity: While beavers seem to help overall riparian vegetation growth, they also use riparian vegetation as a primary food source. Another potential management tool that could be utilized to promote and speed upstream shading is fencing to protect riparian trees. Allowing a selective alder and cottonwood trees to grow may contribute greatly to overall streamshade.

Riparian Fencing: Efforts in the 1990's by NRCS and TCRCD promoted riparian exclusionary fencing and many of these sites now offer exemplary riparian corridor vegetation. One landowner with particularly impressive riparian vegetation (122cm DBH cottonwoods) utilizes what he calls "flash grazing" where he allows cows to graze the riparian corridor for short periods of time but does not allow them to stay for longer periods. Numerous other heavily grazed locations need riparian exclusionary fencing and additionally some areas that do have exclusionary fencing but do not use it should be provided education on the merits of proper riparian management.

Drought Mortality: The historic 2014-2015 drought has caused widespread mortality of riparian vegetation, particularly among alder species. Some of these sites will revegetate themselves rapidly, however many might not regenerate due to changes in water diversion rates and timber conversion activities.

Riparian Vegetation Education: common cultural beliefs may often negatively impact riparian vegetation. Many residents of this area believe that cutting riparian vegetation, especially alder and cottonwood, will increase the water availability in the streams. While there is some merit to thinning (see Effects of Changing Forest Age Structure and Density on a Forest's Water Yield), the overall long term impacts most certainly outweigh the short term benefits. There is also the misconception that all willows are invasive and therefore bad. Further education into properly functioning riparian corridors is needed for the residents of the SFTR watershed.

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