Spring 5-15-2020

Assessing Methods for Determining Reference Conditions for Riparian Restoration in Santa Clara County

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This Master's Project

Assessing Methods for Determining Reference Conditions for Riparian Restoration in Santa Clara County

by

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is submitted in partial fulfillment of the requirements for the degree of:

Master of Science
in Environmental Management

at the

University of San Francisco

Submitted: Received:

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Claire Mallen Date Aviva Rossi Ph.D(c) Date

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Abstract

Valley Water is the primary water wholesaler and flood control agency in Santa Clara County, providing services to 1.9 million residents. The operation and maintenance of infrastructure for water supply and flood control often require work within legally protected natural resources such as riparian ecosystems. Riparian ecosystems are dynamic and diverse ecosystems that provide our society with valuable services such as wildlife habitat, water quality, and recreation. However, the threat of human development on native ecosystems has led to the degradation and loss of 85-98% of riparian ecosystems nationwide. Today, federal, state, and regional laws mitigate further impacts to riparian ecosystems and require compensatory mitigation when impacts to jurisdictional areas cannot be avoided. Reference sites can improve the outcomes of mitigation and restoration projects by providing regionally appropriate models of near-pristine ecosystems that allow for the development of ecologically based standards for evaluating the success of projects. This study provides a methodology for reference site selection and field assessment to determine regionally appropriate reference conditions for riparian ecosystems. The methodology of this study includes a literature review and a comparative analysis of existing riparian condition assessment methods. To determine suitability of a riparian ecosystem to serve as a high quality- reference site, this study evaluated criteria such as land use, invasive species cover, distance to roads, and history of past fire. Results confirm that reference sites should not be chosen from areas classified as urban or agriculture land use, because of the negative impacts those land uses have on hydrology, geomorphology, and vegetation. Riparian areas classified as rangeland maybe be used if they have not been overgrazed, and riparian areas classified as protected land use may serve as the highest quality reference ecosystems. Reference ecosystems should also have less than 15% invasive tree and shrub cover; less than 30% invasive herb cover; be further than 50 meters than a road; and to ensure the ecosystem has not been disturbed, not burned in a fire for four years. A combination of two assessment methods, the California Native Plant Society's Vegetation Rapid Assessment and the California Rapid Assessment Method for wetland and riparian areas, provide the best method to measure parameters important for determining reference conditions and compensatory mitigation permit conditions such as vegetation, water quality, and habitat quality. By using this methodology for selecting reference sites and using field-assessment methods to define physical reference conditions, managers at Valley Water and agencies and nonprofits throughout California can gain a well-rounded understanding of reference conditions in their region. These regionally specific reference conditions will benefit restoration and mitigation project success, and help regulatory agencies apply regionally appropriate success criteria.

Acknowledgements

First, I would like to thank my family, Lisa, Kevin, Haley, Emily, and Zach for constantly supporting me throughout my pursuit of higher education. Second, I would like to thank Zooey Diggory and Doug Titus (Valley Water) for providing me with the opportunity to explore this topic at Valley Water and providing me with vital information and feedback. Third, I would like to thank Jennifer Buck-Diaz (California Native Plant Society) who provided additional information for this project. Lastly, I would like to thank my fellow students, advisors, and professors at the University of San Francisco, especially Aviva Rossi. Aviva Rossi provided invaluable guidance, support, motivation, and kindness throughout this process

1. Introduction

Valley Water, formerly the Santa Clara Valley Water District, is the principal water resources agency in Santa Clara County, supplying clean water, flood protection, and environmental stewardship for 1.9 million county residents (Santa Clara Valley Water District 2016; United States Census Bureau 2020). Valley Water was established in 1929 by the California State Legislature to address concerns of land subsidence and ground water quality (California State Legislature 1929). Today, Valley Water manages twelve dams, ten surface water reservoirs, three water treatment plants, one recycled water purification center, 393 acres of groundwater recharge ponds, and more than 275 miles of streams (Department of Water Resources 2019; Kassab and Cook 2016). The operation and maintenance of Valley Water infrastructure, and implementation of water supply and flood protection projects often require work within areas of legally protected natural resources. Valley Water works closely with regulatory agencies to mitigate any impacts to the environment that are unavoidable. Regulatory agencies issue project permits (site-specific) and programmatic permits (ongoing activities, not site-specific) so Valley Water can perform actions within their regulated jurisdictions. Project and programmatic permits outline the requirements of a compensatory mitigation project including mitigation ratios, longevity of site monitoring, and performance standards, also referred to as success criteria. Mitigation projects are typically monitored for three to five years before they are determined to be in or out of compliance (Van den Bosch and Matthews 2016). A project is in regulatory compliance if it meets or exceeds permit requirements and fails compliance if it does not meet permit requirements. Common success criteria for Valley Water mitigation include various vegetation, water, and habitat quality metrics (Titus and Diggory 2020). Another common permit condition for Valley Water compensatory mitigation is that if the project is not in compliance within the anticipated timeframe, it will be monitored until it is in compliance (Titus and Diggory 2020).

Currently, success criteria are often defined without using a local reference ecosystem for comparison, and are not uniform among projects, regions, or agencies (Kihslinger 2008; Matthews and Endress 2008; Titus and Diggory 2020). Projects which require permits from multiple agencies often have conflicting requirements, leaving the permittee to uphold highest criteria from each permit which can make achieving compliance difficult (Titus and Diggory 2020). Further, regulatory compliance is not always an indication of ecological restoration success (Ambrose et al. 2007; Matthews and Endress 2008). Projects that are in compliance at the end of the project period still may fail at restoring proper ecological function to riparian ecosystems and other sensitive habitats (Ambrose et al. 2007; Matthews and Endress 2008). In the same way, projects that fail compliance may actually be successful at restoring ecological function (Ambrose et al. 2007; Matthews and Endress 2008). In addition, regulatory compliance at the end of the project period does not ensure long-term compliance once the project period is over, and the site may return to a degraded state after site monitoring and maintenance is complete (Van den Bosch and Matthews 2016). Therefore, success criteria must be improved to represent current existing natural reference conditions (Brinson and Rheinhardt 1996; Matthews and Endress 2008).

The use of reference sites in mitigation planning can be beneficial because reference sites provide an example of existing natural conditions for that specific ecosystem within the same landscape (Cash 2013; Guyon and Battaglia 2018; Harris 1999; Titus and Diggory 2020; White and Walker 1997). Therefore, for mitigation projects to succeed at restoring proper ecological function, success criteria for riparian restoration projects should be standardized and be developed from regionally specific reference sites (Matthews and Endress 2008; Panorama Environmental 2015; Titus and Diggory 2020).

The purpose of this study is to determine a methodology for identifying reference conditions for mitigation and restoration planning, and to standardize success criteria for Santa Clara County. This study includes the development of a two-step process for defining regionally specific reference conditions. The first portion of this study seeks to identify methods for selecting reference sites within a large landscape using desktop methods. The second portion of this study looks at three ecosystem condition assessment methods to determine best management practices for collecting ambient ecosystem conditions to define reference condition for riparian ecosystems.

1.1 Riparian Ecology, Ecosystems Services, and Decline

The California Floristic Province covers most of California, extending north into Oregon and south into Baja California (Figure 1), and is one of the most biologically diverse regions in the world (Baldwin 2014; Lancaster and Kay 2013). The California Floristic Province is designated as one of Conservation International's 36 global biodiversity hotspots supporting 6,500 native vascular plants (Baldwin 2014). Over 25% of those native plant species are endemic to California, meaning they are only found in California (Baldwin 2014). The California Floristic Province includes many plant assemblages and ecosystem types such as: grasslands, chaparral, oak woodlands and savannas, conifer woodlands, wetlands, and riparian forests and scrub (Bartolome and Spiegal 1989; Sawyer et al. 2009). Riparian ecosystems have disproportionally high native biodiversity when compared to other ecosystem types and provide many valuable ecosystem functions and services (Grossinger, R. M. et al. 2007).

Figure 1. The California Floristic Province, one of 36 global biodiversity hotspots (Lukes 2016).

Riparian ecosystems are extremely diverse and dynamic ecosystems, and the definition of what constitutes a riparian ecosystem can vary widely between organizations (Gregory et al. 1991; Verry et al. 2004). Most definitions can at least agree that riparian ecosystems are transitional areas between terrestrial and aquatic ecosystems (e.g. rivers, streams, and wetlands) (Gregory et al. 1991; Harman et al. 2012; Riparian Habitat Joint Venture 2004; Riparian Habitat Joint Venture 2009; United States Department of the Interior 2015). Factors such as geology, hydrology, and varying inorganic and organic material input from surrounding hillslopes and vegetation create an ecosystem which is always in flux (Gregory et al. 1991; Harman et al. 2012; United States Department of the Interior 2015). The processes of a properly functioning riparian ecosystem can be depicted as a hierarchical pyramid (Figure 2). Hydrology forms the base of the pyramid, which drains water from the watershed into a channel (Harman et al. 2012; United States Department of the Interior 2015). Hydrology supports hydraulics, which is the movement of the water within the channel that then influences the movement of nutrients, sediment, and woody debris within the channel and adjacent floodplains (Harman et al. 2012; United States Department of the Interior 2015). Hydraulics determine the geomorphology of the channel by creating diverse stream beds and instream habitat for aquatic and terrestrial organisms (Harman et al. 2012; United States Department of the Interior 2015). Hydrology, hydraulics, and geomorphology influence the physicochemical components which determine temperature, dissolved oxygen, organic matter, and nutrient levels within the water which aquatic organisms and vegetation need to survive (Harman et al. 2012; United States Department of the Interior 2015). The previous four functions determine the biological component, which influences the biodiversity and life histories of aquatic and terrestrial organisms (Harman et al. 2012; United States Department of the Interior 2015).

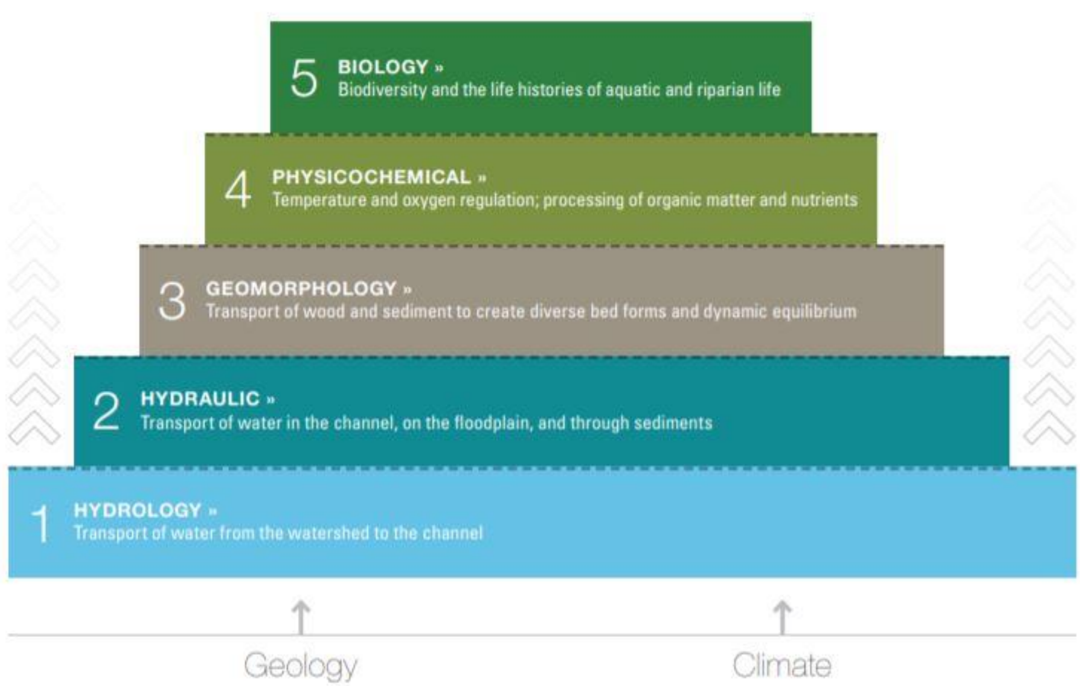

Figure 2. Pyramid of stream and riparian ecological functions (United States Department of the Interior 2015).

Variation in these biotic and abiotic processes support high nutrient availability and diverse, dynamic ecosystems like perennial to intermittent streams and dense riparian forests to sparsely vegetated gravel bars (Harman et al. 2012; Jones et al. 2010; Katibah 1984; Riparian

Habitat Joint Venture 2004). High nutrient availability supports riparian forests with complex structure and diverse plant species assemblages which provides critical habitat for native bird, mammal, reptile and amphibian populations (Jones et al. 2010; Naiman and Decamps 1997). More than 225 different wildlife species use California's riparian habitat as critical habitat and transportation corridors (Jones et al. 2010; Naiman and Decamps 1997; Riparian Habitat Joint Venture 2004). Riparian vegetation is integral to in-stream habitat by providing shade, nutrients, and structural components, for example logjams which provide shelter for fish, birds, and small mammals (Fessler 2015; Naiman and Decamps 1997; Riparian Habitat Joint Venture 2004). Riparian ecosystems are also significant for human health and safety. In 2015, 61% of the public water supply came from surface water sources like lakes, streams, and rivers that 87% of American rely on for safe, clean drinking water (Dieter et al. 2018). Properly functioning riparian ecosystems also provide other services such as: flood control, sediment storage, nutrient cycling, and recreation (Fessler 2015; Jones et al. 2010; Naiman and Decamps 1997).

Despite the importance of the above riparian ecological services, these ecosystems have been degraded and destroyed at an alarming rate. It is estimated that 85-98% of California's native riparian vegetation has been lost in the last 150 years due to land use and land conversion (Dawdy 1989; Katibah 1984; Riparian Habitat Joint Venture 2004). Therefore, it is imperative to mitigate the impact to and restore the function to California's riparian ecosystems.

1.2 Setting

Santa Clara County (SCC) is in the southern portion of the San Francisco Bay Area (Bay Area) and is bordered to the west by the Santa Cruz Mountains and to the east by the Diablo/ Hamilton Range (Figure 3) (Helley et al. 1994). The Santa Clara Valley floor, also referred to as the Santa Clara Valley, drains water from the mountains, into the foothills, then into the baylands of the San Francisco Bay (Santa Clara Valley Water District 2016). SCC has a Mediterranean climate with short mild winters and long dry summers (Null 1995) that influences the ecology of the region. SCC is home to many diverse ecosystems such as: grasslands, chaparral and coastal scrub, oak woodlands and savanna, conifer woodlands, freshwater and tidal marshes, and riparian forests and scrub (Sawyer et al. 2009). Today, SCC is highly developed with a population of 1.9 million and 23% of the County is classified as urban (Santa Clara County Department of Planning and Development 2020). The rest of SCC includes rural residential, agriculture, ranchland, and protected land uses (Santa Clara County Department of Planning and Development 2017; Santa Clara County Department of Planning and Development 2020).

A study of the Coyote Creek Watershed, one of the five major watersheds in Santa Clara County, and located in the eastern portion of the county, estimated that native vegetation types in the region have experienced 85-99.8% loss (Grossinger, R. M. et al. 2007). Despite the magnitude of human impact in Santa Clara County, the region remains biologically diverse (California Department of Fish and Game and Stermer 2003). SCC's remaining native ecosystems provide habitat for 20 legally protected species (Table 1) and seven California Department of Fish and Wildlife sensitive natural communities (California Department of Fish and Wildlife 2004; California Department of Fish and Wildlife 2019a; California Native Plant Society 2020). Although Santa Clara County and the greater Bay Area remain biological diversity hotpots, the region's native species and ecosystems are under constant pressure from human impact and require protection and restoration.

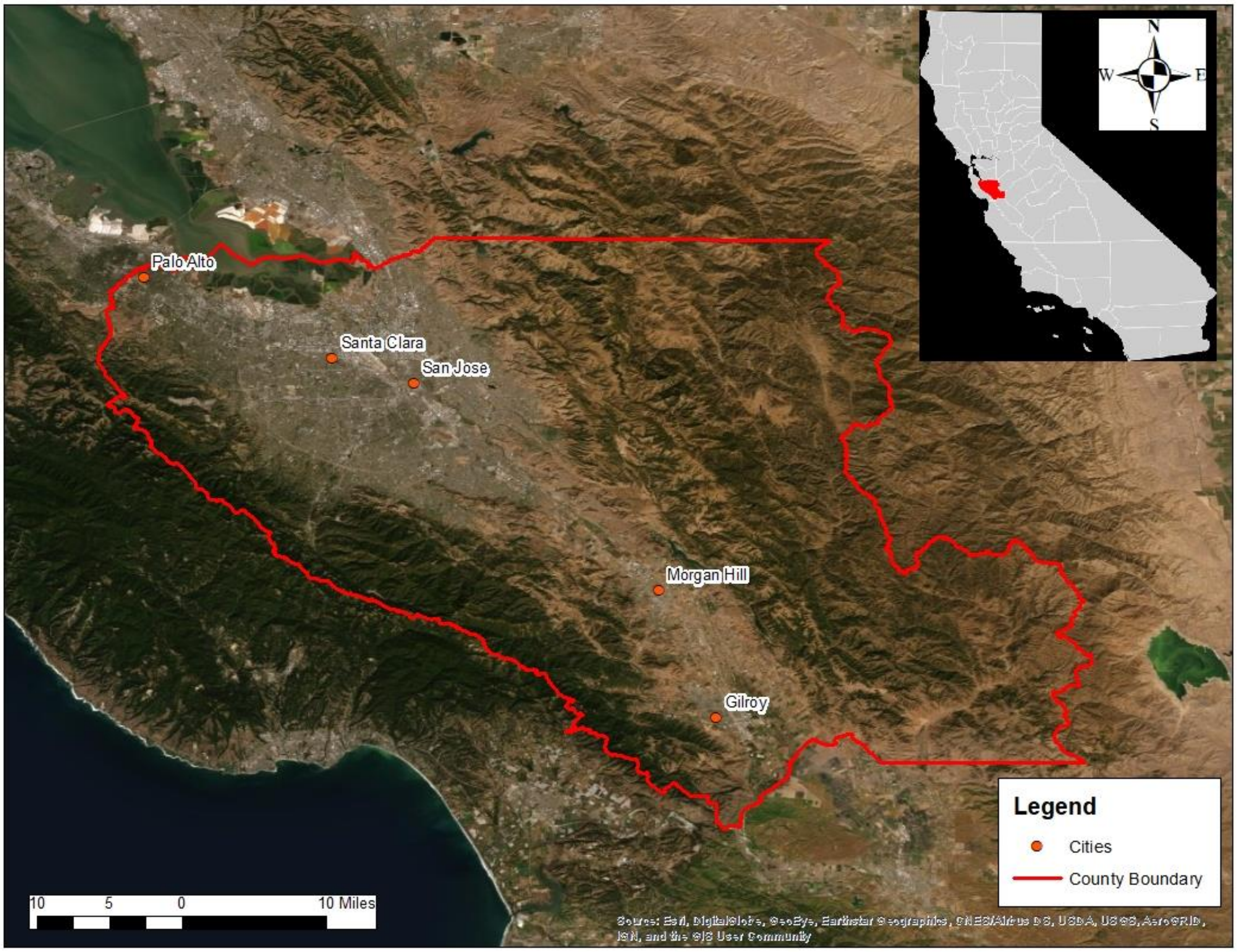

Figure 3. Map of Santa Clara County (Data Sources: ESRI 2020, County of Santa Clara 2020).

Table 1. Santa Clara County native species with special statuses.

		Status		
Species	Scientific Name	State/CNPS	Federal	Riparian
Invertebrates				
Bay checkerspot butterfly	*Euphydryas editha bayensis*		FT	
Amphibians and Reptiles				
California tiger salamander	*Amystoma californiense*	ST	FE, FT	Yes
California red-legged frog	*Rana draytonii*		FT	Yes
Foothill yellow-legged frog	*Rana boylii*	SC		
Western pond turtle	*Clemmys marmorata*	SCS		Yes
Birds				
Western burrowing owl				
Tricolored blackbird	*Agelaius tricolor*	ST		
Least Bell's vireo	*Vireo bellii pusillus*	SE	FE	Yes
California Ridgway's rail	*Rallus obsoletus obsoletus*	SE	FE	
Mammals				
Salt-marsh harvest mouse	*Reithrodontomys raviventris*	SE	FE	
San Joaquin kit fox	*Vulpes macrotis mutica*	ST	FE	
Plants				
Tiburon Indian paintbrush	*Castilleja affinis* ssp. *neglecta*	ST/1B	FE	
Coyote ceanothus	*Ceanothus ferrisiae*	1B	FE	
Mount Hamilton thistle	*Cirsium fontinale* var. *campylon*	1B		
Santa Clara Valley dudleya	*Dudley abramsii* ssp. *setchellii*	1B	FE	
Fragrant fritillary	*Fritillaria liliacea*	1B		
Loma Prieta hoita	*Hoita strobilina*	1B		Yes
Smooth lessingia	*Lessingia micradenia* var. *glabrata*	1B		
Metcalf Canyon jewelflower	*Streptanthus albidus* ssp. *albidus*	1B	FE	
Most beautiful jewelflower	*Streptanthus albidus* ssp. *peramoenus*	1B		

State/ California Native Plant society (CNPS)

SE	State Listed- Endangered
ST	State Listed- Threatened
SC	State Candidate for Listing
SCS	State Species of Concern
1B	Rare, Threatened, or Endangered in California and Elsewhere
Federal	
FE	Federal Listed- Endangered
FT	Federal Listed- Threatened

Adapted from California Department of Fish and Wildlife 2004; California Department of Fish and Wildlife 2019; California Native Plant Society 2020

1.2.1 History of Land Use

Santa Clara County is a region with diverse resources, once being referred to as the "Valley of Hearts Delight" for its expansive productive farmland (Brown, A. K. 2005). Today, SCC is known as "Silicon Valley" and has been at the center of technological innovation for over 20 years and is one of the most populated counties in the state of California (United States Census Bureau 2020). The history of human settlement in Santa Clara County is long, with archeological evidence demonstrating that the county has been inhabited for thousands of years (Booker 2013). Over time different groups of residents have had varying levels of impact on the environment, from the hunter and gatherer lifestyle to major resource extraction in the forms of farming, industry, and mining (Booker 2013; Brown 2005).

The first people to inhabit Santa Clara County were the Ohlone people (Booker 2013). The Ohlone lived in small villages and benefited from the abundant natural resources in the region (Booker 2013; Margolin 1978). The Ohlone people, like many Native Americans in California, used fire as a natural resource management strategy (Agee, James K. 2006). The Ohlone burned native chaparral ecosystems to convert the low productive ecosystem into grasslands for hunting, foraging and easy travel (Agee 2006; Brown 2005). Prior to European settlement in the 1800s, the county looked drastically different. The foothills and mountain ranges were covered with grasslands, chaparral, oak woodlands and savannas, and conifer woodlands and forests (Beller et al. 2010; Grossinger, R. et al. 2006; Grossinger et al. 2007; Sawyer et al. 2009). Historically, the tidal and lower areas of the valley supported a complex mosaic of salt and freshwater wetlands including tidal marshes, salt ponds, wet meadows, freshwater marshes, and springs (Figure 4) (Beller et al. 2010; Grossinger et al. 2006; Grossinger et al. 2007; Grossinger, Robin et al. 2008). Oak savannas and woodlands dominated the valley floor which were interspersed by meandering rivers and creeks which were surrounded by up to 304.8-meter-wide riparian corridors of willow (*Salix* ssp.) forests to even broader sycamore (*Platanus racemosa*) alluvial woodlands (Beller et al. 2010; Brown 2005; Grossinger et al. 2006; Grossinger et al. 2008). Due to the porosity of the soil substrate, many rivers and creeks in Santa Clara County were discontinuous, meaning above ground streams would disappear by percolating underground and continue flowing subsurface (Beller et al. 2010; Brown 2005; Grossinger et al. 2006; Grossinger et al. 2008). When creeks were above surface, corridors were lined with willow forests, when the creek drained and went subsurface, sycamore alluvial woodlands were present (Brown 2005).

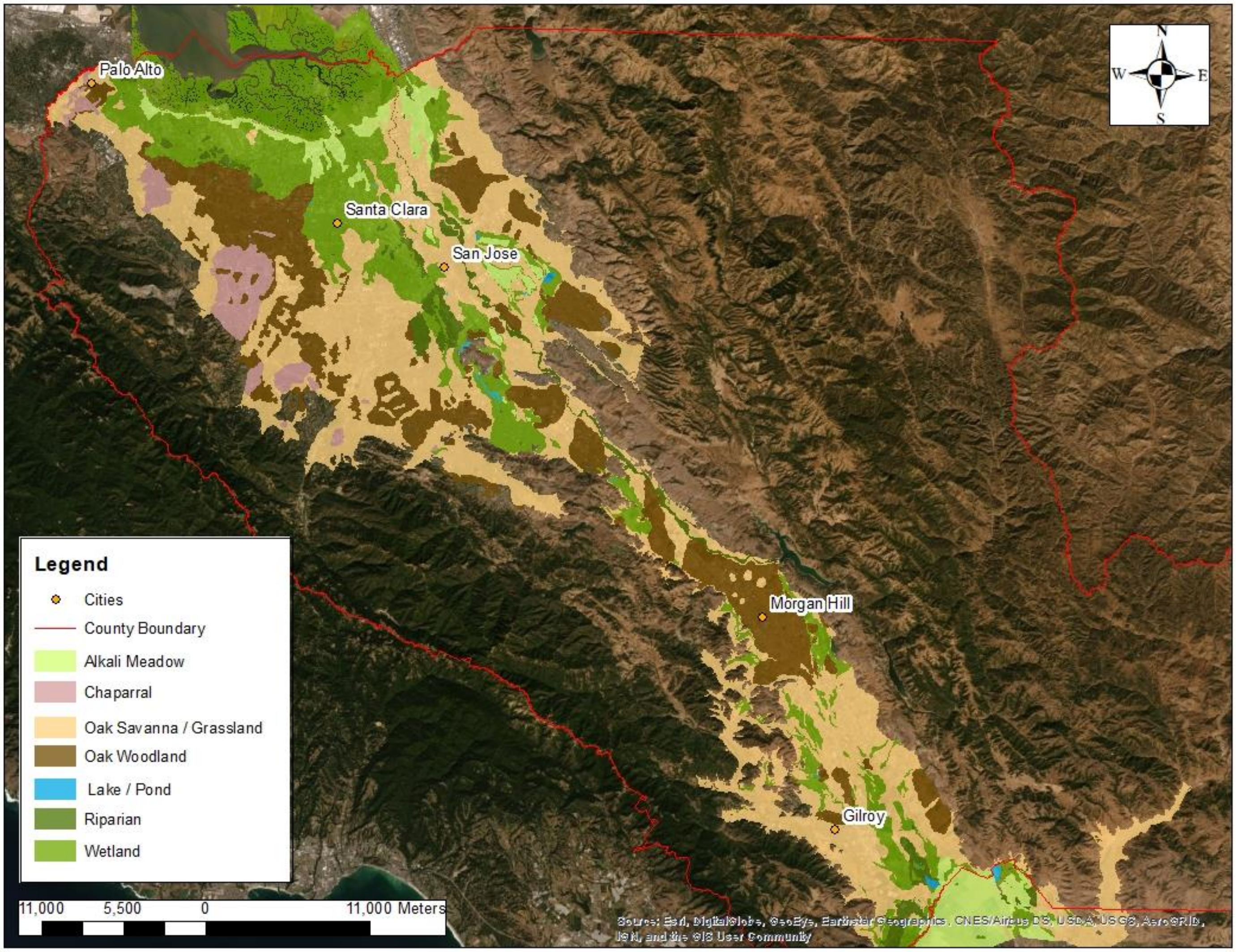

Figure 4. Historical extent of native ecosystems in the now urban developed valley floor (Data Source: San Francisco Estuary Institute 2015).

Early farming, industry, and mining by European settlers transformed the environment. In 1777, Spanish missionaries established Mission Santa Clara along the banks of the Guadalupe River in the modern-day city of Santa Clara (Brown 2005; Gentilcore 1961). Missionaries brought sheep and cattle for livestock and cut down large oaks to plant orchards and grains, such as barley (*Hordeum* ssp.) and wheat (*Triticum* ssp.), to support mission life (Brown 2005; Gentilcore 1961). Early changes to native ecosystems were noticeable as early as 1782, when mission priests observed the degradation of native grassland species by livestock overgrazing (Brown 2005). The population of the region steadily grew through the 1800s and 1900s, and this time period saw major changes in the natural environment (Beller et al. 2010; Brown 2005; Grossinger et al. 2006; Grossinger et al. 2008). Cattle ranches transitioned into dairy farms, and wheat fields were converted to row crops and orchards (Santa Clara Valley Water District 2016). Farmers dug wells to extract groundwater and dammed or diverted streams for irrigation, and drained wetlands and cut down riparian forests to increase productive land availability (Brown 2005).

The change in land use led to both loss and degradation of native ecosystems. Dairies, orchards, wineries, and canneries released fine sediments, pesticides, and industrial waste into the waterways (Santa Clara Valley Water District 2016). Cinnabar mines established in the upper watershed extracted and processed mercury for more than half a century, contributing to the legacy of mercury pollution in Santa Clara County waterways and in the San Francisco Bay (Thomas et al. 2002). Continuous ground water extraction led to land subsidence of three to six meters (Brown 2005; Poland and Ireland 1988), causing soil compaction, salt-water intrusion, and increased flood risk (Santa Clara Valley Water District 2016). In 1929, in reaction to land subsidence, flood control, and concerns about groundwater quality, the Santa Clara Valley Water Conservation District, the predecessor to Valley Water, was established (California State Legislature 1929). The first goal of the Santa Clara Valley Water Conservation District was to construct reservoirs to capture rainwater and recharge aquifers, restoring the quality of groundwater resources (Santa Clara Valley Water District 2016). The creation of dams drastically changed the hydrograph of downstream riparian habitats, with increased dry season flows for groundwater management and decreased winter flows for flood protection (Grossinger et al. 2007). With steadier summer flows, streams that were adapted to seasonally dry stream channels, such as sycamore alluvial woodlands, transitioned into willow dominated riparian forests (Grossinger et al. 2007).

The population of Santa Clara County continued to grow post- World War II from 30,000 in 1940 to 291,000 in 1950 (Santa Clara Valley Water District 2016). Rapid urban development saw the increase in paving of large areas with impervious surfaces, introducing toxic chemicals into the waterways, and continued mass flooding (Santa Clara Valley Urban Runoff Pollution Prevention Program 2019; Santa Clara Valley Water District 2016). In the 1950s and 60s urban streams in northern Santa Clara County were engineered into straight channels retained by tall concrete levees to control stream flow by transporting water quickly through urban areas to decrease flooding (Figure 6) (Santa Clara Valley Water District 2016). Even with massive changes to the landscape through agriculture, industry, mining, and urbanization, native riparian cover still remains.

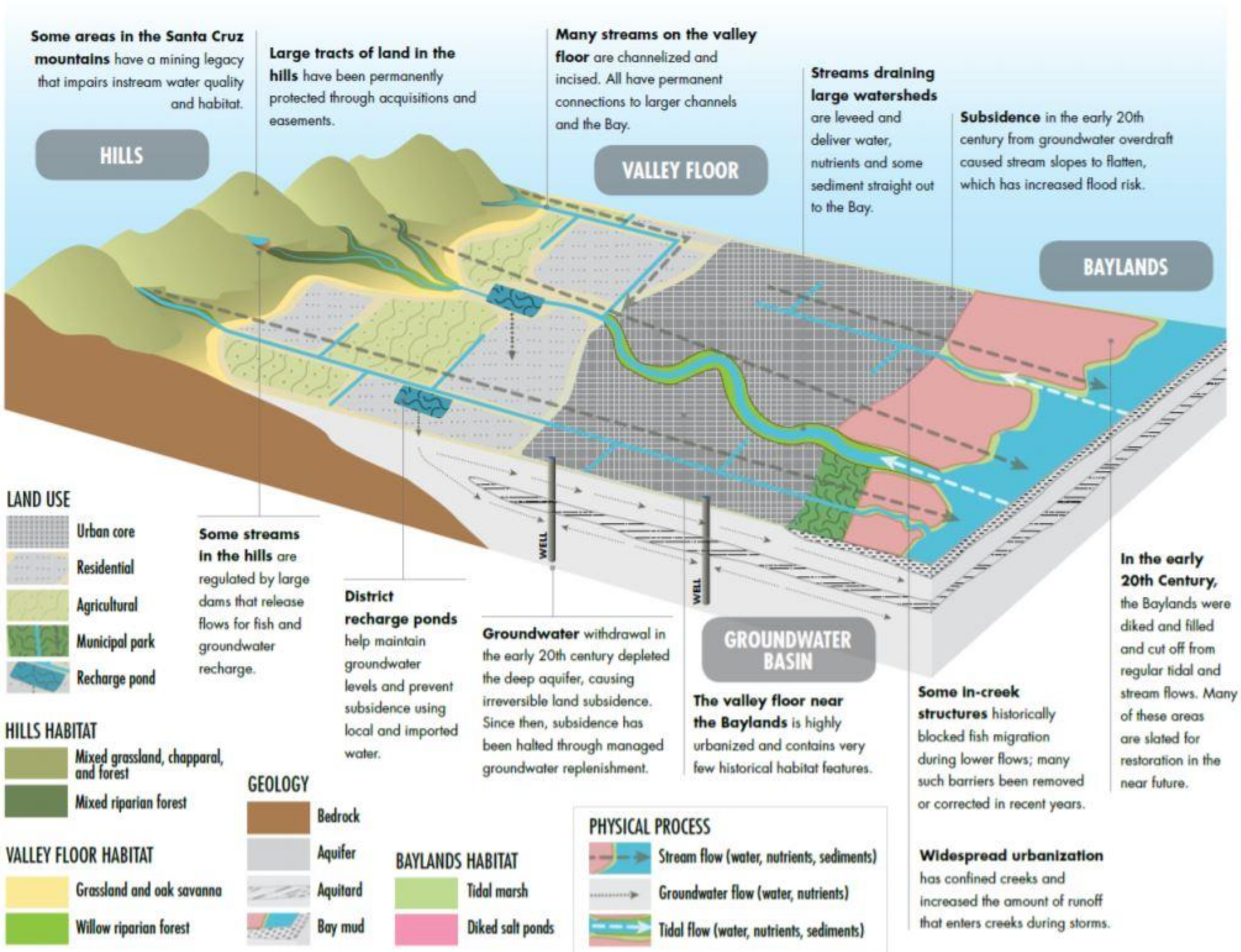

Figure 6. Graphic of modified stream hydrology within urban Santa Clara County (Santa Clara Valley Water District 2016).

1.2.2 Contemporary riparian ecosystems

Today, riparian ecosystems in Santa Clara County exist in narrow corridors due to historical clearing, development, and land conversion and are under constant threat from various land use types, new development, invasive species infestations, wildfire, and encampments of unsheltered people (Lowe et al. 2020; Poff et al. 2012). Despite historical and current threats, there are three native remaining riparian land cover types in Santa Clara County (Sawyer et al. 2009). Contemporary riparian vegetation types include willow riparian forest, woodland, and scrub; Central California sycamore alluvial woodlands; and mixed riparian woodland and forest (ICF International 2012; Sawyer et al. 2009). These ecosystem types vary in species diversity, canopy cover, and structure (Sawyer et al. 2009). Willow riparian forests, woodland, and scrub are often found along the active channel on intermittent and perennial streams throughout Santa Clara County (ICF International 2012; Sawyer et al. 2009). Willow riparian forest communities are the most densely populated, while woodlands and scrub, are less populated with scattered trees and shrubs (Sawyer et al. 2009). Dominant species include yellow willow (*Salix lasiandra*), red willow (*Salix laevigata*), arroyo willow (*Salix lasiolepis*), and narrowleaf willow (*Salix exigua*) (Sawyer et al. 2009). Central California sycamore alluvial woodlands are found on broad alluvial floodplains and have open to moderately closed canopies with sparse understory vegetation (Sawyer et al. 2009). Dominant species of sycamore alluvial woodlands include California sycamore (*Platanus racemosa*), white alder (*Alnus rhombifolia*), Fremont cottonwood (*Populus fremontii*), bay laurel (*Umbellularia californica*), oaks (*Quercus* spp.) and willows (*Salix* spp.) (Sawyer et al. 2009). Mixed riparian woodlands and forests are like willow riparian forests, in that they are both found along the active channel of intermittent and perennial streams; however they are not dominated by one single species (ICF International 2012). Mixed riparian forests can be dominated sycamores, willows, and oaks with a dense herbaceous understory (ICF International 2012). Due to major losses in Central California sycamore alluvial woodlands, they are considered a global sensitive natural community by the California Department of Fish and Wildlife (California Department of Fish and Wildlife 2019b) and are protected under several state and federal laws. In addition to Central California sycamore alluvial woodlands, all riparian ecosystems are protected under different regional, state, or federal laws to preserve their valuable ecosystem services of water quality, critical habitat, and species diversity (State of California 1970a; State of California 1970b; United States 1972a; United States 1973).

1.3 Regulatory Framework

Prior to the implementation of major federal and state environmental legislation in the late 1960s and 1970s, environmental law in the United States was decentralized and disorganized (Elliott et al. 1985; Lazarus 2001). Prior to the 1970s, lawsuits were brought by individuals or small groups which were circulated through common law courts across the country (Elliott et al.

1985). The first generation of federal environmental laws were enacted between 1969 - 1985 (Lazarus 2001) and included the National Environmental Policy Act in 1969 (United States 1969), the Clean Air Act in 1970 (United States 1970), the Clean Water Act in 1972 (United States 1972), and the Endangered Species Act in 1973 (United States 1973). In this same period the state of California enacted similar environmental legislation including the California Environmental Quality Act in 1970 (State of California 1970) and the California Endangered Species Act in 1970 (State of California 1970). These laws all expanded the regulation of federal and California state government on private industry and land use (Elliott et al. 1985; Lazarus 2001; Purdy 2018). Each environmental regulation concerns a specific environmental jurisdiction, such as: water, air, and designated species; and gives power to a specific regulatory agency to protect that resource.

The most important federal, state, and regional laws which regulate riparian ecosystems for water quality and critical habitat include the Clean Water Act (United States 1972), the federal and California Endangered Species Act (State of California 1970), the state Porter-Cologne Water Quality Act (State of California 1969), the California Department of Fish and Wildlife Fish and Game Code (California Department of Fish and Game 1961), and the Coastal Zone Management Act (United States 1972b). Under sections 404 and 401 of the Clean Water Act, the "dredge and fill" and discharge of any pollutant into the waters of the United States (WOTUS) are regulated by the United States Army Corps of Engineers, and in California, by the State Water Resources Control Board, and it's Regional Water Quality Control Boards (United States 1972). WOTUS refers to all waters in the country that are used for interstate commerce, including wetlands, lakes, rivers, streams, etc. (United States 1972). The definition of WOTUS expands and contracts with different administrations (Environmental Protection Agency and United States Army Corps of Engineers 2015; Environmental Protection Agency and United States Army Corps of Engineers 2020). In 2015, the Obama administration adopted the Clean Water Rule, that clarified WOTUS to include streams and wetlands that had significant hydrological and ecological connection to traditional navigable and interstate waters (Environmental Protection Agency and United States Army Corps of Engineers 2015). However, in 2020 the Trump administration repealed the Clean Water Rule and adopted the Navigable Waters Protection Rule that narrows the definition and further details twelve categories that are no longer considered WOTUS (Environmental Protection Agency and United States Army Corps of Engineers 2015). Despite changes in federal law, California state law continues to hold high environmental standards. The California state Porter-Cologne Water Quality Act regulates both point and nonpoint sources of pollutions into waters of the state and is regulated by the State Water Resources Control Board and the Regional Water Quality Control Boards (State of California 1969). The definition of waters of the state are broader than the definition of WOTUS, in California waters of the state refers to any surface water or ground water within the state (State of California 1969). The Coastal Zone Management Act regulates the dredging and disposal of sediment in the San Francisco Bay, and all activities within 30.48 meters of the bay shoreline (State of California 1965). The Coastal Zone Management Act is regulated by the San Francisco Bay Conservation and Development Commission (State of California 1965).

There are many state and federal laws and agencies which regulate critical habitat quality including the federal and California Endangered Species Act (State of California 1970; United States 1973), California Environmental Quality Act (State of California 1970), and the California Department of Fish and Game Codes (California Department of Fish and Game 1961). The federal and California Endangered Species Act regulates the “taking” of any designated fish or wildlife species worldwide (State of California 1970; United States 1973). “Take” in this context means to harass, harm, wound, or even attempt to engage with a protected species listed as threatened or endangered under the federal and California Endangered Species Act (State of California 1970; United States 1973). The federal Endangered Species Act is regulated by the United States Fish and Wildlife Service and National Marine Fisheries Service (United States 1973). In Santa Clara County the federal Endangered Species Act is also regulated by the Santa Clara Valley Habitat Agency through a habitat conservation plan (Valley Habitat Plan) which allows for county agencies to work within endangered species habitat (ICF International 2012). The California Endangered Species Act is regulated by the California Department of Fish and Wildlife (State of California 1970). The California Department of Fish and Wildlife also regulates riparian ecosystems and native species through the Fish and Game Code (California Department of Fish and Game 1961). The Fish and Game Code established the Lake and Streambed Alteration Program (Section 1602) which regulates impacts to any river, stream, or lake (California Department of Fish and Game 1961). The Fish and Game Code also established the Native Plant Protection Act (Section 1900) to prohibit the take of endangered or rare native plants (California Department of Fish and Game 1961). Lastly, the California Environmental Quality Act requires all public agencies to analyze and publicly disclose any impact their projects may have on the environment, find reasonable alternatives, and mitigate those impacts that cannot be avoided (State of California 1970). Like the California Environmental Quality Act, all agencies require mitigation of impacts to their jurisdictions when that impact cannot be avoided.

1.4 Riparian Restoration and Mitigation Design

Ecological restoration is the procedure of assisting the recovery of a damaged or destroyed natural ecosystem (Jackson et al. 1995). Restoration happens at a variety of scales, purposes, and contexts. The specific purpose driving the restoration project guides the planning, implementation, monitoring, and overall success of the project (Clewell et al. 2005; Society for Ecological Restoration International Science & Policy Working Group 2004). Restoration efforts can be minimal or highly manipulative on the landscape to reach the project goals (Clewell et al. 2005; Riparian Habitat Joint Venture 2009). These varying levels include;

1. Restoring a degraded or damaged ecosystem to its former state
2. Reconstructing an ecosystem that was destroyed with the same ecosystem type
3. Conversion of one type of ecosystem from the same bioregion to replace an ecosystem which was removed from a landscape that became irreversibly altered (i.e. in urban settings where original hydrologic conditions cannot be restored)
4. Substitution of a replacement ecosystem where an altered environmental can no longer support any naturally occurring type of ecosystem in the same bioregion (i.e. introducing an ecosystem with a combination of native species that suit the new site conditions)

5. Substitution of a potential replacement ecosystem, because no reference system exists to serve as a model for restoration (i.e. in areas where land use conversion happened centuries prior and destroyed all remnant ecosystems) (Clewell et al. 2005)

Compensatory mitigation is a legally required type of restoration stemming from federal, state, or regional regulatory agency requirements and aims to restore, enhance, or create specific species or habitat that has been impacted (Robb 2002; Wilkinson et al. 2002). Several compensatory mitigation methods have been established since the creation of environmental regulations requiring compensation in the 1970s (Bendor 2009). These methods include permittee responsible mitigation, mitigation banking, and in-lieu fee mitigation (Bendor 2009). Permittee responsible mitigation requires the developer to restore, create from scratch, or preserve the specified ecosystem on the development site or another designated location (Bendor 2009; Wilkinson et al. 2002). Mitigation banking and in-lieu fee mitigation require the developer to pay into a bank (mitigation banking) or pay a fee to a public agency (in-lieu fee) which can use the money to fund restoration projects on their own (Bendor 2009; Wilkinson et al. 2002). Valley Water often conducts permittee responsible mitigation for impacts to riparian ecosystems and additionally conducts in in-lieu fee mitigation for impacts under the Valley Habitat Plan (Titus and Diggory 2020).

Successful restoration projects require defined goals and objectives which steer the planning, implementation, and monitoring processes (Riparian Habitat Joint Venture 2009; Society for Ecological Restoration International Science & Policy Working Group 2004). In compensatory mitigation, goals are set by the regulatory agency in the form of performance standards or success criteria. Common success criteria include vegetation metrics related to the ecosystem type, such as percent vegetation cover, planted species mortality, and decrease in nonnative species cover (Kihslinger 2008; Matthews and Endress 2008; Teal et al. 1997; Titus and Diggory 2020). For projects which are permitted under the Endangered Species Acts and Fish and Game Code, success criteria may also include parameters evaluating water and habitat quality (State of California 1970; Titus and Diggory 2020; United States 1973). Success criteria are often set without reference to similar natural ecosystems, differ among permits and regions, and currently there are no guidelines for developing ecological performance standards at the regional, state, or federal level (Kihslinger 2008; Matthews and Endress 2008). The use of reference sites in mitigation planning and the development of success criteria would help standardize criteria among permits, regions, and agencies.

Reference sites are integral in restoration planning because they provide a model for the ecosystem being restored (Humphries 2016). A reference site is a near pristine ecosystem which serves as a benchmark for the ecosystem being restored (Clewell et al. 2005; Humphries 2016). A reference ecosystem should have similar flora, fauna, functions, processes, and successional stages to the ecosystem being restored, prior to degradation (Palmer et al. 2005; Society for Ecological Restoration International 2017). While the specific definition and characteristics of a reference site have not been developed, general guidance exists (Harris 1999). Depending on the ecosystem, the community should be complex in structure and species diversity; have high native species cover and minimal exotic species cover; and be floristically and structurally like the other reference ecosystems in the region (Harris 1999). Due to large variability in ecosystems, it is best to determine reference conditions from multiple reference sites (Steyer et al. 2003; White and Walker 1997). Four broad types of reference information should be used to determine a reference condition:

1. contemporary information from the site to be restored
2. historical information from the site to be restored
3. contemporary information from reference sites
4. historical information from reference sites (White and Walker 1997)

Gathering contemporary information from the site includes the collection of direct evidence on trends, such as succession, change in components, and exotic species invasions (White and Walker 1997). Historical data from the site and from reference sites may be used to discover direct evidence for changes in the ecosystem (White and Walker 1997). Sources for historical data may include ecological descriptions, species lists, and maps; historical and current aerial and ground level photographs; herbarium and museum specimens; historical accounts from oral histories; and paleoecological evidence (Society for Ecological Restoration International Science & Policy Working Group 2004; White and Walker 1997). Contemporary information from reference sites provide direct evidence of composition, structure, and dynamics under current environmental conditions (White and Walker 1997). Determining reference conditions based on high-quality contemporary sites also provides information on ecosystems which are self-sustaining under similar environmental conditions, therefore the restored ecosystem will have low maintenance costs (White and Walker 1997). Gathering historical and contemporary data from the site to be restored and from reference sites can be challenging for several reasons. Due to limitation in historical and contemporary data, they should be used collectively to determine accurate reference conditions. This study will focus on two of the reference information type, focusing on historical information and heavily on contemporary information from reference sites. These two sources of information from reference sites will help determine reference conditions for riparian ecosystems in Santa Clara County to standardize and define success criteria for compensatory mitigation.

At Valley Water some informal precedent for using reference ecosystems in mitigation and restoration projects has been established. Reference sites were used for mitigation projects on the Guadalupe River and San Francisquito Creek (Titus and Diggory 2020). However, they were identified on a case-by-case basis with no quantitative or specific conditions for determining their suitability as a high-quality reference site (Titus and Diggory 2020). In addition, the reference site selected for the Guadalupe River did not serve as a high-quality reference site because it included degraded portions of the Guadalupe River (Titus and Diggory 2020). Without extensive knowledge of an area, it can be difficult to know where to locate high quality reference sites within a large landscape. One way to overcome this is by quantifying the potential quality of site based on the amount of human influence. By using publicly available datasets that document human impact, we can determine suitability of high-quality habitats within a large landscape at the desktop.

Even though pristine ecosystems with no human impact do not exist anymore, especially in developed Santa Clara County, there are still natural areas remaining with minimal disturbance, which represent properly functioning environments (Lowe et al. 2020). Properly functioning riparian ecosystems will have minimal human impact, support high native species diversity and structural complexity, and have minimal nonnative plant species cover (Harman et al. 2012; United States Department of the Interior 2015). The most common threats to riparian ecosystem function include certain land use types, like: agriculture, grazing, mining, recreation, timber harvesting, and urbanization; climate change; disturbances such as diseases and insects, drought, fire, and floods; change in hydrology such as dam construction, flow regulation, water diversion, and groundwater depletion; invasive species; and roads (Alemu et al. 2017; Dwire and Kauffman 2003; Hanna et al. 2020; Hardison et al. 2009; King and Rier 1996; Matlack 1993; Meyer et al. 2005; Sudduth and Meyer 2006). These threats on riparian ecosystems can alter all functions of riparian ecosystems such as hydrology, geomorphology, and riparian vegetation which can have a cascading effect on water quality, flow capacity, and wildlife habitat (Alemu et al. 2017; Dwire and Kauffman 2003; Hanna et al. 2020; Hardison et al. 2009; King and Rier 1996; Matlack 1993; Meyer et al. 2005).

1.5 Summary

Riparian ecosystems are dynamic and diverse ecosystems that provide our society with valuable ecosystem services such as clean drinking water, flood protection, and recreation opportunities (Naiman and Decamps 1997). The threat of human development on native ecosystems has led to the degradation and loss of riparian ecosystems in Santa Clara County and countrywide (Grossinger et al. 2007; Katibah 1984). Federal, state, and regional laws protect against further impact to riparian ecosystems and require compensatory mitigation when impact to jurisdictional areas cannot be avoided (California Department of Fish and Game 1961; State of California 1970; State of California 1970; United States 1972; United States 1973). Regulatory permits outline the conditions of a mitigation project including monitoring time frame and success criteria (Kihslinger 2008; Matthews et al. 2008; Teal et al. 1997). Common success criteria include a specific amount of total vegetation cover, nonnative species cover, and planted species mortality (Kihslinger 2008). Success criteria are often set without referring to regional ecological conditions and are not standardized among permits or regions (Kihslinger

2008; Matthews et al. 2008). The use of reference sites in mitigation planning and the development of success criteria can help standardize success criteria and will correspond better with regional conditions. This study outlines a methodology for identifying reference conditions for mitigation and restoration planning for Santa Clara County.

2. Methods

This assessment is based on a literature review of existing peer-reviewed literature, government reports, and vegetation and riparian ecosystem assessment-protocols. The information synthesized from the literature review was used to recommend a methodology for selecting reference sites within a large landscape. The information synthesized was also used to recommend an assessment method to use in the field to define reference conditions for riparian ecosystems in Santa Clara County.

2.1 Methods for Site Selection Criteria

To determine a methodology for selecting reference sites using desktop methods, I first conducted a peer-reviewed literature search of existing literature. I used the Google Scholar and Environment Complete database through the University of San Francisco library to obtain information about regulatory jurisdiction over riparian ecosystems, the use of reference sites in ecological restoration, which human activities negatively impact riparian ecosystem quality and how this information can impact the suitability of an ecosystem to serve as a reference ecosystem. The literature searches retrieved many documents, therefore, to determine which articles to use for my literature review, I read abstracts to determine the content was appropriate and used the journal ranking information from Scimago to ensure the article was published in a reputable journal. If the article was in a journal with a ranking in the 4th quartile, I checked that the article was at least cited by twenty-five peer-reviewed articles to ensure the information was sound. Lastly, I interviewed mitigation experts at Valley Water to understand the regulatory framework regarding mitigation permitting and common permit conditions.

2.2 Methods for Monitoring and Assessment Protocol

Once potential reference sites are identified based on the analysis of site selection criteria and located using existing spatial layers, the potential reference sites would need to be surveyed to assess current site condition. This study compared and contrasted three methods to assess riparian ecosystem condition and vegetation community condition:

- Rapid Stream-Riparian Assessment Method (Stacey et al. 2006),
- California Native Plant Society and California Department of Fish and Wildlife Vegetation Rapid Assessment (California Native Plant Society 2001), and
- the California Rapid Assessment Method for Wetland and Riparian Areas (California Wetlands Monitoring Workgroup 2013)

The comparison will determine which method is best suited for assessing reference condition for mitigation planning efforts and standardizing success criteria.

3. Results

There are many anthropogenic threats on riparian ecosystems which influence proper ecosystem functioning (Poff et al. 2012). Quantifying the impact of different threats on riparian ecosystems is a way to measure the quality of an ecosystem without having to assess site quality in the field. Therefore, using this information this study determined which threats would be effective metrics to quantify the suitability of specific riparian ecosystems as reference sites. Parameters such as land use and disturbances such as invasive species, roads, and fire were chosen because they were found to have significant ecological impacts on riparian ecosystems. These parameters were also chosen because they can be easily quantified and can be easily downloaded through various online sources such as local, state, and federal government websites (Calflora 2020; California Invasive Species Council 2020a; County of Santa Clara 2020; Data.gov 2020; Fire and Resource Assessment Program 2020; Santa Clara County Department of Planning and Development 2017; Santa Clara County Department of Planning and

Development 2020). These datasets can either be used separately or overlaid to establish a site suitability model in ArcGIS to locate high quality reference sites within a large landscape.

Following site selection, the reference site needs to be surveyed to define existing reference conditions. It is important to choose a method which measures similar parameters to the success criteria that are outlined in compensatory mitigation projects because that defines whether the project is successful or not. Common mitigation success criteria often include parameters describing the success of riparian vegetation; such as percent vegetative cover, percent mortality, and percent cover of invasive species (Kihslinger 2008; Matthews and Endress 2008; Teal et al. 1997; Titus and Diggory 2020). However, it is also common for success criteria to include parameters for water quality and assessing instream habitat such as channel complexity (Titus and Diggory 2020). In restoration and mitigation planning it is also important to determine regionally appropriate plant species which will establish themselves readily once planted. A planting plan is also important in riparian and restoration planning because plant placement in relation to other species and to the stream can determine whether the plant will survive or not. Therefore, in determining reference conditions in the field, it is important to note the diversity within the reference site (i.e. which plants are found there) and the proximity to the stream (i.e. hydrophytic plants should be planted closer to the channel). When selecting an assessment method for defining reference conditions it should have parameters for riparian vegetation composition and structure, water quality, and in stream habitat quality.

When defining reference conditions from a set of existing reference sites, it is important to gather a large sample of sites per riparian vegetation type, in order to understand the variability within specific vegetation types. Therefore, for this study I chose predominantly rapid assessment methods because they can be applied quickly, can be used by most personnel, and are cost effective which increases the capacity to record more samples (Carletti et al. 2004).

3.1 Site Selection Criteria

3.1.1 Land Use

Land use refers to how land is used by humans who often modify the natural landscape for settlement or resource extraction purposes (Natural Resources Conservation Service 2012; United States Department of Agriculture 2019). Land use conversions from natural land covers have transformed Santa Clara County's and the world's land surface for thousands of years (Beller et al. 2010; Brown 2005; Foley et al. 2005; Grossinger et al. 2007; Grossinger et al. 2008). Land use has significant impacts on riparian ecosystems effecting natural hydrological, geomorphological, and biological processes (Alemu et al. 2017; Brown, S. S. and King 1987; Foley et al. 2005; Hanna et al. 2020; Hardison et al. 2009; Jun et al. 2011; King and Rier 1996; Meyer et al. 2005; Sudduth and Meyer 2006; Swales 1982). Therefore, land use type is an important consideration when selecting specific riparian ecosystems for reference sites. This study focuses on four major land uses in Santa Clara County: urban, agriculture, rangeland, and protected areas (Figure 5) (County of Santa Clara 1994a). This study compares the impact each land use type has on riparian systems and determines which land use should be considered when selecting reference sites.

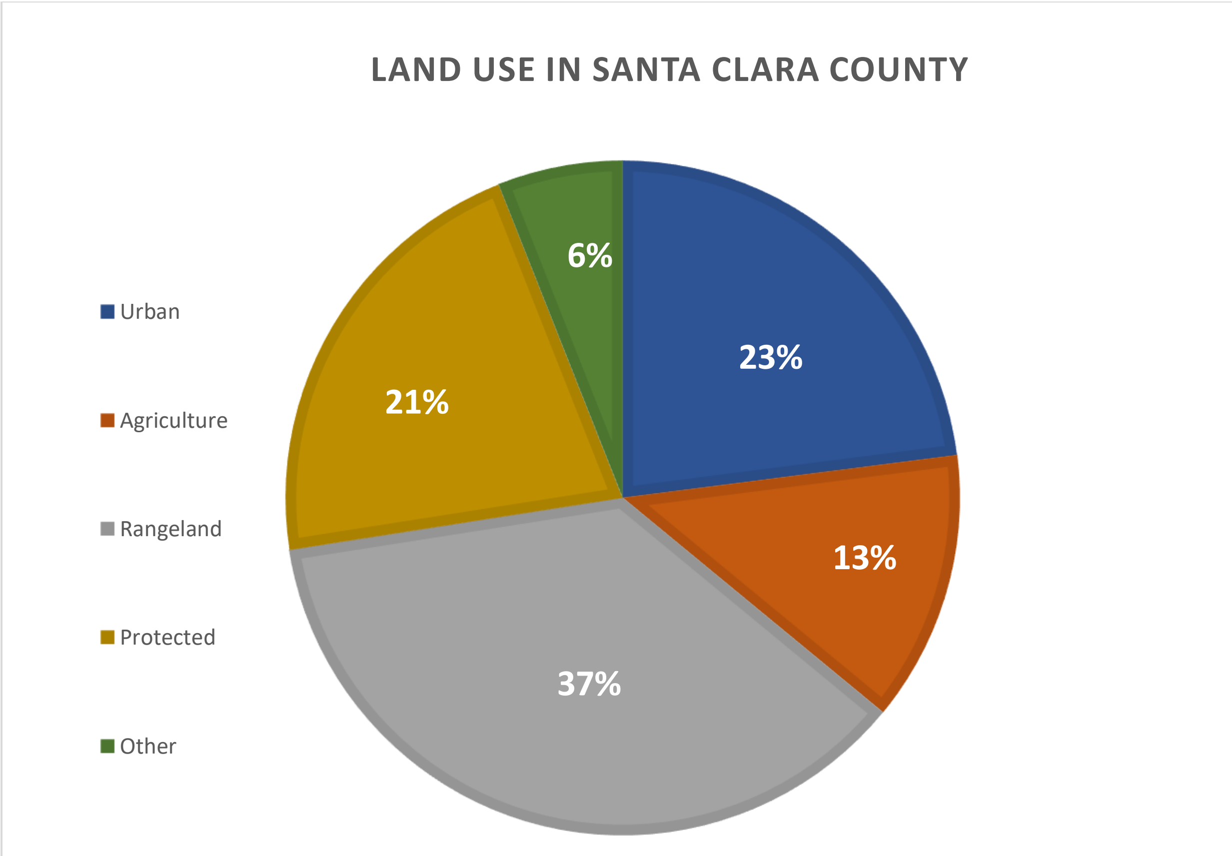

Figure 5. Major land use classifications in Sant Clara County (Santa Clara County Department of Planning and Development 2017; Santa Clara County Department of Planning and Development 2020)

3.1.1.1 Urban Land Use

The urban land use classification refers to densely populated and developed areas and can also include commercial, industrial, transportation, and residential land uses (County of San Mateo 2013). 23% of Santa Clara County is classified as urban land use and many of the county's major streams and river flow through the urban center in the northern portion of the county (County of Santa Clara 1994; Santa Clara County Department of Planning and Development 2017; Santa Clara County Department of Planning and Development 2020; Santa Clara Valley Urban Runoff Pollution Prevention Program 2019). Urban streams in Santa Clara County have poor ecological function due to increased channelization, increased impervious surfaces, and decreased riparian vegetation corridor (Burton et al. 2005; Cavaillé et al. 2013; Groffman et al. 2003; Hardison et al. 2009; Lowe et al. 2020; Meyer et al. 2005; Oneal and Rotenberry 2008).

Increased impervious surfaces within urban centers and residential areas like concrete and asphalt sidewalks, roads, and parking lots, decrease water percolation and increase urban runoff into the waterway (Hanna et al. 2020; Hardison et al. 2009; Meyer et al. 2005). Channelization, impervious surfaces, and upstream flow regulation from dams can alter the hydrologic regime by causing incision in urban streams (Hardison et al. 2009). Incision occurs when an increased volume of water erodes the stream bed, causing the stream bed to drop in elevation which can alter the water table, affecting soil properties and riparian vegetation communities (Groffman et al. 2003). Direct flow of urban runoff also affects riparian ecosystems by directly introducing pathogens and pollutants into the system (Groffman et al. 2003; Hardison et al. 2009; Meyer et al. 2005; Santa Clara Valley Urban Runoff Pollution Prevention Program 2019). Santa Clara County urban streams have been found to carry harmful pollutants such as trash, pesticides, insecticides, mercury, polychlorinated biphenyls (PCBs), and selenium (Santa Clara Valley Urban Runoff Pollution Prevention Program 2019).

In addition to hydrologic, geomorphologic, and water quality impairments, urban land use also has negative impacts on riparian vegetation. Negative impacts include decreased species richness and change in species composition (Alemu et al. 2017; Burton et al. 2005; Cavaillé et al. 2013; Oneal and Rotenberry 2008). Urban riparian ecosystems are found to have less canopy cover than streams with other land uses, which can negatively impact water temperature and instream habitat (Burton et al. 2005). Urban streams also have less species diversity (Moffatt et al. 2004) and increased nonnative species cover (Burton et al. 2005). In summary, due to negative impacts of urban land use on hydrological, geomorphological, and biological processes, riparian ecosystems with urban land use should not be used when selecting a reference site.

3.1.1.2 Agriculture Land Use

The agriculture land use classification refers to land that is used for livestock pasture and crops that are produced for human consumption (Natural Resources Conservation Service 2012). 13% of Santa Clara County is classified as agriculture land use and has been a productive center of agricultural activities for hundreds of years (Brown 2005; Santa Clara County Department of

Planning and Development 2017; Santa Clara County Department of Planning and Development 2020). Riparian ecosystems in agricultural settings are often impaired by sedimentation and nutrients from agricultural runoff, soil compaction, erosion, channel destabilization, and reduced riparian vegetation quality (Alemu et al. 2017; Boyd et al. 2017; Hanna et al. 2020; Jun et al. 2011; Kauffman and Krueger 1984; Kaweck et al. 2018; King and Rier 1996; Sarr 2002; Stanford et al. 2020; Szaro and Pase 1983). Streams adjacent to agriculture have higher levels of sediment and nutrients due to agricultural runoff which can cause high turbidity and algal growths, impairing water quality and instream aquatic habitat (Jun et al. 2011; King and Rier 1996). Riparian ecosystems that are grazed by livestock can suffer from soil compaction, erosion, and channel destabilization which can affect water quality, channel morphology, and water percolation (Boyd et al. 2017; Kauffman and Krueger 1984; Kaweck et al. 2018; Leininger and Schulz 1990; Sarr 2002; Stanford et al. 2020; Szaro and Pase 1983). Decreased water quality, changes in channel morphology, and water percolation can have cascading impacts on the quality of riparian vegetation along agricultural streams (Cavaillé et al. 2013; Jun et al. 2011). Riparian ecosystems in agricultural areas are also found to have lower tree biodiversity than riparian ecosystems in protected land uses (Hanna et al. 2020). Riparian vegetation in agricultural areas are also impacted by clearing for routine tilling and to increase arable land (Alemu et al. 2017; Jun et al. 2011). Due to impaired water quality, geomorphology, and reduced vegetation diversity and buffer width, riparian ecosystems within agriculture land should not be used as reference sites.

3.1.1.3 Rangeland

The rangeland land use classification refers to natural areas of grasslands, shrublands, or woodlands that are grazed by livestock or wild animals (Natural Resources Conservation Service 2012). Rangelands can include native or nonnative vegetation however the vegetation is not as heavily managed as an agricultural pasture (Natural Resources Conservation Service 2020). In Santa Clara County, the County General Plan uses the designation “ranchland” to refer to areas with native vegetation that allows for livestock grazing, mineral extraction, hunting, and low intensity recreation, residential development, or commercial, industrial, or institutional uses

(County of Santa Clara 1994). 36.6% of Santa Clara County is classified as ranchland and has been used for this purpose for hundreds of years (Brown 2005; Santa Clara County Department of Planning and Development 2017; Santa Clara County Department of Planning and Development 2020). For the purposes of this study, the term rangeland will encompass both rangeland and ranchland. The intensity of grazing on rangelands, either by wildlife or domestic livestock, can affect water quality, channel stabilization, and riparian vegetation (Boyd et al. 2017; Kauffman and Krueger 1984; Kaweck et al. 2018; Leininger and Schulz 1990; Sarr 2002; Stanford et al. 2020; Szaro and Pase 1983). The presence of livestock in riparian areas can impair water quality by adding organic and inorganic sediments and bacterial pollutants into the waterway and increase soil compaction which can decrease water percolation and increase erosion (Fleischner 1994; Kaweck et al. 2018). Channel incision is also common in overgrazed areas (Kauffman and Krueger 1984) which can lower the water table and impact riparian vegetation (Groffman et al. 2003). Riparian ecosystems in grazed rangelands have more bare ground, less species diversity, and less herbaceous, shrub, and tree canopy cover than ungrazed areas (Boyd et al. 2017; Kaweck et al. 2018; Leininger and Schulz 1990; Sarr 2002; Szaro and Pase 1983). Even though grazing has large impacts on water quality, geomorphology, and riparian vegetation, riparian ecosystems tend to recover quickly once livestock is removed (Szaro and Pase 1983). Studies show that it can take anywhere from five to ten years for a riparian ecosystem to significantly recover from livestock grazing once livestock is removed (Leininger and Schulz 1990; Rickard and Cushing 1982). Therefore, rangelands may serve as potential reference sites if riparian areas are not overgrazed and have not been grazed in several years, allowing the vegetation to recover. To use rangelands for reference sites one must research about the site to learn about grazing history and other land management practices.

3.1.1.4 Protected lands

The protected land use classification is land that is owned by the government or other authorities which preserve and protect the land for natural, archaeological, historical, and aesthetic resources (Natural Resources Conservation Service 2012). In Santa Clara County, 21.5% of land is classified as open space reserve, other public open lands, and regional parks; all three categories will be referred to as protected lands for the purpose of this study (Santa Clara County Department of Planning and Development 2017; Santa Clara County Department of Planning and Development 2020). Riparian areas in the foothill regions of Santa Clara County, which tend to be classified as protected land use, are found to be in relatively good condition with wide channel corridors and are surrounded by undeveloped land (Lowe et al. 2020).

In Santa Clara County, public lands are owned and managed by agencies such as Santa Clara County Parks, the San Francisco Public Utilities Commission, Valley Water, Midpeninsula Regional Open Space District, Santa Clara Valley Open Space Authority, California State Parks, and California Department of Fish and Wildlife (California Department of Parks and Recreation 2020; Midpeninsula Regional Open Space District 2018; Santa Clara County Parks 2020a; Santa Clara Valley Open Space Authority 2020a; Schauss 2005). These agencies conserve and protect public lands for resource conservation, recreation, agriculture, and rangeland purposes (California Department of Parks and Recreation 2020; Midpeninsula Regional Open Space District 2018; Santa Clara County Parks 2020; Santa Clara Valley Open Space Authority 2020; Schauss 2005). Some protected lands are open to the public for recreation while some protected lands are restricted to the public. Riparian ecosystems on protected lands may serve as the best land use type for selecting reference sites because of the limited human impact (Hanna et al. 2020). When access is allowed, like Santa Clara County Parks, Midpeninsula Regional Open Space District, Santa Clara Valley Open Space Authority, and California State Parks, rules are established to minimize human impact (California Department of Parks and Recreation 2020; Midpeninsula Regional Open Space District 2014; Santa Clara County Parks 2020; Santa Clara County Parks 2020b; Santa Clara Valley Open Space Authority 2020b; Schauss 2005). Public land rules include restrictions for hiking off trail; dogs, or when dogs are allowed, require dogs to be on leash; and prohibit removing any vegetation (California Department of Parks and Recreation 2020; Midpeninsula Regional Open Space District 2018; Santa Clara County Parks 2020; Santa Clara County Parks 2020; Santa Clara Valley Open Space Authority 2020; Schauss 2005). Riparian ecosystems within protected lands on average have improved water quality and higher tree biodiversity than agriculture land use (Hanna et al. 2020). In summary, riparian ecosystems within protected lands have less human impact and, therefore, may provide high quality reference ecosystem. However, when selecting a reference site on protected lands it is important to know the specific site history since many protected lands may have had different land uses historically, such as protected lands that are leased for rangeland.

3.1.2 Invasive species

Invasive plant species are nonnative plants that have been introduced to a new country, region, or ecosystem where they were not previously found (Richardson et al. 2000). Invasive plants are a threat to native ecosystems because they can reproduce without human intervention, outcompete native species, and once established can create monocultures (Richardson et al. 2000; Santoro et al. 2012). Riparian ecosystems are especially susceptible to nonnative plant species invasion because rivers act as a conduit for nonnative plant propagules and provide linkages between upland and aquatic ecosystems (Foxcroft et al. 2007; van Oorschot et al. 2017). Monocrops of invasive species along riparian corridors can alter hydrology by over-stabilizing banks and damming the channel (van Oorschot et al. 2017; Watts and Moore 2011). Monocultures also decrease species richness contributing to habitat loss for a variety of wildlife species (van Oorschot et al. 2017).

Due to the long human history and urbanization of Santa Clara County, nonnative invasive plants are a large problem in the region. Therefore, there is a high probability that there are nonnative species in high functioning native ecosystems in the region. In the central coast of California, ranging from Marin County to Santa Barbara County, there are 217 identified nonnative species that are found in riparian ecosystems (California Invasive Plant Council 2020). The California Invasive Species Council (Cal-IPC) is a nonprofit organization whose mission is to protect the biodiversity of California through the management of invasive plant species (California Invasive Species Council 2020b). Cal-IPC maintains an inventory of nonnative plant species found throughout the state of California and rates each species based on invasion potential (California Invasive Plant Council 2020). Cal-IPC ratings include high, moderate, and limited; high refers to species which have significant environmental impacts on their introduced ecosystem and are widely distributed throughout the state such as English ivy (*Hedera helix*) or Himalayan blackberry (*Rubus armeniacus*) (California Invasive Plant Council 2020). Moderate refers to species which have moderate, but not severe, impact on their introduced ecosystem and can range between wide and limited distribution such as poison hemlock (*Conium maculatum*) and bull thistle (*Cirsium vulgare*) (California Invasive Plant Council 2020). Limited refers to species that have minor impact on their introduced ecosystem and have a limited distribution throughout the state such as foxglove (*Digitalis purpurea*) and calla lily (*Zantedeschia aethiopica*) (California Invasive Plant Council 2020).

Because of the high amount of invasive species in the central coast region, the Cal-IPC rating for each species and a percent cover threshold should be used to determine whether the site should be used as a reference site. Cal-IPC rated high plants are invasive species which have the potential for creating monocrops and outcompeting native species, while moderate and limited species have a less significant impact on native ecosystems. Therefore, reference sites with a high percent of Cal-IPC high rated species should not be used as reference and species rated moderate or limited should be disregarded.

A threshold for percent cover of invasive plants was determined using the California Rapid Assessment Method for wetland and riparian areas (CRAM). The CRAM protocol uses percent invasion of Cal-IPC rated invasive plants to determine the quality of the ecosystem (California Wetlands Monitoring Workgroup 2013). The CRAM manual determines thresholds for invasive species percent coverage of the site, then attributes the threshold to a letter-rating (A-D), which is used in addition to other metrics to determine the overall site quality (Table 2) (California Wetlands Monitoring Workgroup 2013). Sites with the highest rating (A), or highest quality have 0-15% invasive species cover and the second highest quality site (B) have 16-30% invasive species cover (California Wetlands Monitoring Workgroup 2013). Out of the 217 Cal-IPC rated invasive species in central coast region, 87 are rated limited, 89 are rated moderate, and 41 are rated high (California Invasive Plant Council 2020). Out of the 41 Cal-IPC rated high invasive plants in the central coast region, 32 species or herbaceous, grass, or grass-like species, and 9 species are tree or shrub species (Figure 7) (California Invasive Plant Council 2020). This study suggests that the pre-determined thresholds for invasive species cover from CRAM should be used to determine suitable invasive species cover in reference riparian ecosystems.

Tree and shrub species are dominant species within riparian ecosystems, therefore a high percent cover of invasive trees and shrubs in a riparian canopy can have a significant impact on surrounding vegetation composition and structure (Naiman and Decamps 1997; Richardson et al. 2007). In addition, 21%, less than a quarter, of the Cal-IPC rated high invasive species in the central coast region are tree and shrub species (California Invasive Plant Council 2020). Therefore, in accordance with CRAM invasive species thresholds, when selecting a reference site in the field, or in the office with available invasive species cover datasets, a reference site should have no more than 15% Cal-IPC rated high invasive trees and shrubs. In the central coast region, 78% of the Cal-IPC rated high invasive species are herbaceous plants and there is a high risk of observing highly invasive herbaceous plants in riparian ecosystems in Santa Clara County (California Invasive Plant Council 2020). Therefore, when selecting a reference site, the site should have no more than 30% Cal-IPC rated high invasive herbaceous species cover.

Table 2. Score ratings for invasive species percent cover, modified from CRAM manual.

Rating	Percent Invasion
A	0-15%
B	16-30%
C	31-45%
D	46-100%

(California Wetlands Monitoring Workgroup 2013)

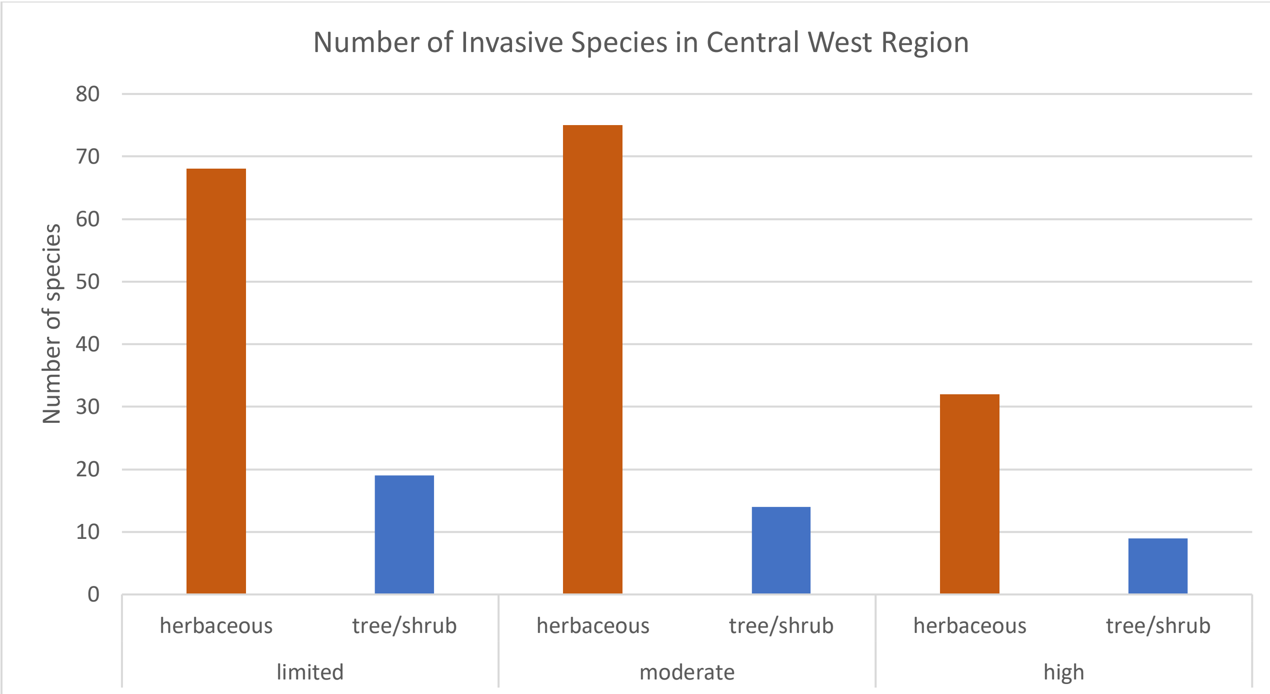

Figure 7. Number of nonnative species in the central west coast region of California, by lifeform and Cal-IPC rating (California Invasive Plant Council 2020).

3.1.3 Other Disturbances

Human caused disturbances such as the presence of roads, the increase in human caused fires, the creation of dams and artificial water bodies, and encampments of unsheltered people, can have large impacts on riparian ecosystems. For the purposes of this study, only the disturbances caused by roads and fires will be discussed. Roads and fires can alter hydrology, geomorphology, and vegetation quality by increasing soil compaction, erosion, pollution, and the spread of invasive species (Dwire and Kauffman 2003; Matlack 1993; Pettit and Naiman 2007; Quarles et al. 1974; Trombulak and Frissell 2000).

3.1.3.1 Roads

Paved and dirt roads can decrease riparian ecosystem function by increasing sedimentation and incision, causes habitat fragmentation disrupting habitats, and increases public access (Matlack 1993; Quarles et al. 1974; Trombulak and Frissell 2000; Wales 1972). Vehicular traffic can contribute heavy metals, salts, organic molecules, and added nutrients into adjacent soil and water which is then absorbed by plants and animals (Quarles et al. 1974). Pollutants may impact plant health by decreasing recruitment and affecting root and mycorrhizae structure (Trombulak and Frissell 2000). Roads provide easy transportation of nonnative species by facilitating multiple vectors, including vehicles, animals, and humans (Trombulak and Frissell 2000). Roads also allow for increased access into natural areas such as riparian ecosystems (Matlack 1993). Increased human traffic can impact vegetation on the forest floor, stripping away leaf litter, causing soil compaction and altering water movement through the system (Matlack 1993). Impacts from contaminants and human traffic decrease with distance to roads (Matlack 1993; Quarles et al. 1974; Wales 1972), therefore when selecting a reference site, you should not consider sites directly adjacent to a road. It is estimated that contaminants such as lead drop significantly from the soil and from vegetation at 10 meters and 30 meters (Quarles et al. 1974). Similarly, vegetation impacts from human traffic can be observed up to 50 meters from a human disturbance like a road or trail (Matlack 1993).

A buffer distance from roads was determined by using the Queensland, Australia Department of Environment and Resource Management, Method for the Establishment and Survey of Reference Sites for BioCondition reference site selection criteria (Eyre et al. 2011). This protocol recommends several qualitative parameters for reference sites and recommends that reference sites should be at least 50 meters from a roadway (Eyre et al. 2011). Therefore, in accordance with the BioCondition protocol, when selecting reference sites for riparian ecosystem in Santa Clara County, the site should be at least 50 meters from a roadway.

3.1.3.2 Fire

Wildfire is a natural process within many California native ecosystems, including riparian ecosystems (Agee 2006). Wildfires were more frequent prior to European settlement however years of fire suppression efforts from early European settlers and modern land managers has led to an accumulation of fuels and alteration of natural fire regimes (Agee 2006). Wildfire in riparian ecosystems are not as frequent and are generally less severe than in drier upland community types; fire return interval (time in between fires) can be as much as double the fire return interval in upland types (Dwire and Kauffman 2003; Pettit and Naiman 2007) and fire frequency (how often fires occur) in riparian areas can range from 10 to 500 years (Agee, J. K. 1998). This is because riparian ecosystems have more available surface water, saturated soils, cooler air temperatures, and higher humidity than adjacent upland communities (Dwire and Kauffman 2003). Frequent, high-intensity fires can have negative impacts on riparian ecosystems by increasing erosion, impacting water quality, changing plant species composition and abundance, changing community structure, and allowing invasions of nonnative species (Dwire and Kauffman 2003; Pettit and Naiman 2007). Therefore, riparian areas which have burned recently may not be suitable reference sites because of altered vegetation community and structure (Dwire and Kauffman 2003; Pettit and Naiman 2007). Although, since riparian ecosystems are dynamic ecosystems adapted for disturbances such as flood, riparian herbs, shrubs, and trees can recover rapidly after fire (Havlina 1995; Kauffman and Martin 1990; Pettit and Naiman 2007). Following severe stand-replacing fires, willow species (*Salix* spp.) have been found to survive post fire and returned to pre-fire conditions four years post fire (Havlina 1995). When selecting a reference site, you should not choose a site that has recently burned because changes in composition may occur and the current vegetation community may not represent reference conditions however, due to rapid recovery of riparian herbaceous and shrub species, it is recommended to not use a site that has burned in the last 4 years.

There are many other disturbances that can negatively impact riparian ecosystems such as erosion or encampments of unsheltered people. These disturbances may not be observed until you arrive on site and should be determined on a case by case basis.

Table 3. Synthesis table reference site selection parameters.

Parameter		Selection Threshold	Sources
Land Use Type	Urban	No	Cavaillé et al. 2013, Burton et al. 2005, Oneal and Rotenberry 2008, Groffman et al. 2003, Meyer et al. 2005, Hardison et al. 2009, Hanna et al. 2020, Santa Clara Valley Urban Runoff Pollution Prevention Program 2019
	Agriculture	No	King and Rier 1996, Jun et al. 2011, Kaweck et al. 2018, Boyd et al. 2017, Stanford et al. 2020, Sarr 2002, Kauffman and Krueger 1984, Szaro and Pase 1983, Leininger and Schulz 1990
	Rangeland	Ok if livestock rotated or left to rest for 5 years	Kaweck et al. 2018, Boyd et al. 2017, Stanford et al. 2020, Sarr 2002, Kauffman and Krueger 1984, Szaro and Pase 1983, Leininger and Schulz 1990
	Protected	Yes	Hanna et al. 2020, Schauss 2005
Invasive Species	Tree/shrub	< 15% cover	Richardson et al. 2000, Foxcroft et al. 2007, van Oorschot et al. 2017, Watts and Moore 2011, California Wetlands Monitoring Workgroup 2013
	Herbaceous	< 30% cover	
Disturbance	Road	> 50 m	Wales 1972, Matlack 1993, Trombulak and Frissell 2000, Quarles et al. 1974, Eyre et al. 2011
	Fire	> 4 years	Dwire and Kauffman 2003, Pettit and Naiman 2007, Agee 1998, Havlina 1995, Kauffman and Martin 1990

3.1.4 Data Sources

Selecting reference sites often requires an intimate and extensive knowledge of the region which may be difficult for agencies who do not have time or resources for field reconnaissance. Using various publicly available spatial datasets which quantify human disturbance on the landscape can help agencies locate suitable reference sites from the office. Land use, invasive species, roads, and fire were chosen as qualifying parameters because they are publicly available datasets that are accessible through local, state, and federal government websites. The idea is that these datasets can either be used separately or overlaid to establish a site suitability model to locate high quality reference sites within a large landscape.

3.1.4.1 Base Map

To get started, choose a recent, high-resolution image to use as a base map. A recent high-resolution photo will permit observation of patterns within the landscape that cannot be observed in the following datasets and correct for some error present in the following datasets (Russell et al. 1997). In Santa Clara County high resolution orthoimagery is available for free through the Santa Clara County government Geographic Information Services program (County of Santa Clara 2020). A digital orthoimage is taken from several aerial photographs which are stitched together to create a final image (United States Geologic Survey 2020). Orthophotos of the county exist for multiple years including 2001, 2006, 2012, 2016, 2017, 2018, and 2019 (County of Santa Clara 2020). If a county government does not provide orthoimages for download, orthoimagery can be downloaded from the United States Geologic Survey for a majority of the country (United States Geologic Survey 2020). The most recent photo available for the study region should be used to observe the most current existing environmental conditions.

3.1.4.2 Land Cover

Second, one must obtain a land cover dataset representing the existing vegetation type on the ground. Vegetation maps can vary in scale, from fine scale to coarse scale depending on the purpose of the map and can be downloaded from a variety of sources. The scale of a vegetation map refers to the level of vegetation classification that the vegetation communities are mapped to. In the United States, vegetation is classified and mapped using the National Vegetation Classification hierarchy which separates vegetation communities based on physiognomy, biogeography, and floristics (Table 4) (United States Vegetation Classification 2020). The broadest class within the National Vegetation Classification starts at formation class and narrows down through formation subclass, formation, division, macro group, group, alliance, and association (United States Vegetation Classification 2020). LANDFIRE, a program run by the United States Forest Service and United States Department of the Interior, provides land cover datasets for vegetation and wildland fuels for natural resource planning purposes (LANDFIRE 2020a). LANDFIRE's existing vegetation type dataset provides division or macro-group level vegetation cover for the entirety of the United States, including Hawaii and Alaska (LANDFIRE 2020b). Since riparian ecosystems commonly exists in narrow corridors due to land use changes, a division or macro-group level map like the LANDFIRE existing vegetation type dataset may not provide detailed enough information. The LANDFIRE existing vegetation type dataset minimum mapping unit is 30 meter by 30 meter square, therefore riparian ecosystems smaller than 90 square meters may not be represented on the map (LANDFIRE 2020).

Table 4. Definitions of National Vegetation Classification.

Upper Levels: Physiognomy Plays a Predominant Role	
Formation Class	Broad combinations of general dominant growth forms that are adapted to basic temperature (energy budget), moisture, and substrate conditions. Examples: Shrubland & grassland and Polar & high montane vegetation classes
Formation Subclass	Combinations of general dominant and diagnostic growth forms that reflect global macroclimatic factors driven primarily by latitude and continental position, or that reflect the aquatic environment. Examples: Mediterranean scrub & grassland and Temperate & boreal alpine vegetation subclasses
Formation	Combinations of dominant and diagnostic growth forms that reflect global macroclimatic conditions as modified by altitude, seasonality of precipitation, substrates, and hydrologic conditions. Examples: Mediterranean scrub and Alpine scrub, forb meadow & grassland formations
Middle Levels: Floristics Physiognomy Plays Predominant Roles	
Division	Combinations of dominant and diagnostic growth forms and a broad set of diagnostic plant species that reflect biogeographic differences in composition and continental differences in mesoclimate, geology, substrates, hydrology, and disturbance regimes. Examples: Mediterranean California scrub and Western North American alpine scrub forb meadow & grassland divisions.
Macrogroup	Combinations of moderate sets of diagnostic plant species and diagnostic growth forms that reflect biogeographic differences in composition and subcontinental to regional differences in mesoclimate, geology, substrates, hydrology, and disturbance regimes. Examples: California chaparral (*Adenostoma fasciculatum, Heteromeles arbutifolia macrogroup*) and Rocky Mountain alpine scrub meadow & grassland macrogroups
Group	Combinations of relatively narrow sets of diagnostic plant species (including dominants and codominants), broadly similar composition, and diagnostic growth forms that reflect regional mesoclimate, geology, substrates, hydrology, and disturbance regimes. Examples: California xeric chaparral (with Adenostoma *fasciculatum and Ceanothus cuneatus*), Rocky Mountain and North Pacific alpine turf & fell-field (*Carex breweri, Carex spectabilis and Festuca brachyphylla*) groups.
Lower Levels: Floristics Plays a Predominant Role	
Alliance	Diagnostic species, including some from the primary layer, which has moderately similar composition that reflects regional to subregional climate, substrates, hydrology, moisture/nutrient factors, and disturbance regimes. Examples: Arctostaphylos *viscida alliance*, Calamagrostis *muiriana alliance*.
Association	Diagnostic species, usually from multiple growth forms or layers, which have similar composition that reflects topo-edaphic climate, substrates, hydrology, and disturbance regimes. Examples: Arctostaphylos *viscida* / Salvia *sonomensis shrubland* association, Calamagrostis *muiriana-Vaccinium cespitosum herbaceous* association.

(United States Vegetation Classification 2020)

Depending on the region, more fine scale vegetation maps may exist through the California Department of Fish and Wildlife's Vegetation Classification and Mapping Program (VegCAMP) or other agency projects. VegCAMP's main goal is to survey, classify, and produce an alliance level map for the entire state of California (California Department of Fish and Wildlife 2020a). Vegetation datasets can be downloaded for free from the VegCAMP website (California Department of Fish and Wildlife 2020b) or viewed on the California Department of Fish and Wildlife Biogeographic Information and Observation System (BIOS) database (California Department of Fish and Wildlife 2020c). A Santa Clara County-wide alliance level vegetation map does not exist yet, however there are efforts to begin mapping efforts 2020. In Santa Clara County there are two more fine scale vegetation maps which are useful for locating riparian ecosystems, the Aerial Information Systems (AIS) riparian vegetation dataset and the Santa Clara Valley Habitat Agency land cover dataset (Aerial Information Systems 2010; ICF International 2012). In July 2010, Valley Water contracted AIS to create a fine scale vegetation map within a defined area of interest (Figure 8), to the alliance level (Aerial Information Systems 2010). The AIS dataset includes other important parameters for determining the quality of the site including cover class values for woody vegetation and nonnative species (Aerial Information Systems 2010). The Santa Clara Valley Habitat Plan Land Cover dataset, which was produced as a part of the establishment of the Valley Habitat Plan, provides a group-level vegetation map of the central portion of Santa Clara County (Figure 8) (ICF International 2012). Even though the map excludes large portions of the northern Santa Cruz Mountains and Diablo Range, it depicts land cover for the three remaining riparian vegetation types in SCC (ICF International 2012). Lastly if fine scale vegetation maps do not exist for the region, a dataset for the creeks in the region can be used to locate riparian ecosystems. This will not be as reliable as confirmed mapped riparian types but may be a good point of reference.

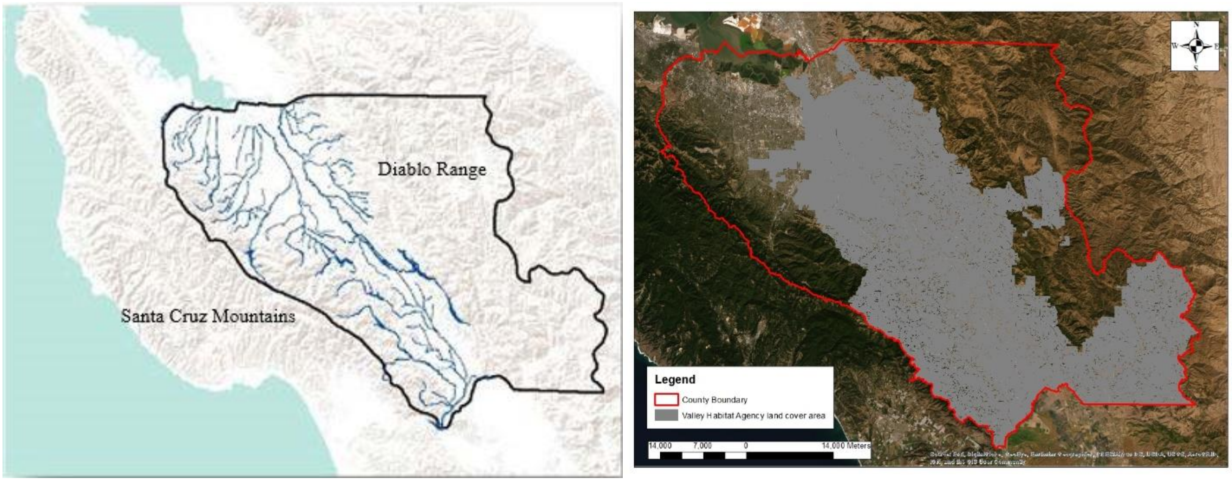

Figure 8. AIS stream vegetation dataset and Valley Habitat Agency Land Cover dataset coverage (Aerial Information Systems 2010; ICF International 2012).

3.1.4.3 Land Use

To quantify impact land use on the landscape, land use classification maps can be found at many county government websites or through the local government planning department. Land use datasets can also be downloaded for all counties in California from the California Department of Conservation Farmland Mapping and Monitoring Program to depict urban and agriculture lands (California Department of Conservation 2019). The Farmland Mapping and Monitoring Program data should only be used as a last resort because the data does not always reflect zoning designations and is not designed for parcel specific planning, which may be not be fine scale enough when looking at riparian corridors (California Department of Conservation 2019). In Santa Clara County, land use data can be found through the Santa Clara County Planning Office GIS data portal (Santa Clara County Department of Planning and Development 2017; Santa Clara County Department of Planning and Development 2020). In SCC, the ‘Urban Service Areas’ and ‘General Plan’ dataset depict land use classifications for inside and outside of the urban service areas (Santa Clara County Department of Planning and Development 2017; Santa Clara County Department of Planning and Development 2020).

3.1.4.4 Invasive Species

Invasive species mapping is the only parameter which may be difficult to quantify using desktop methods. Depending on the region, the area may have detailed invasive species maps through Calflora Weed Manager, or Cal-IPC Weed Mapper (Calflora 2020; California Invasive Species Council 2020), however even these can be incomplete. In Santa Clara County, the AIS stream vegetation dataset includes nonnative species cover, which is a useful starting point to determine the location of invasive species infestations within riparian corridors (Calflora 2020; California Invasive Species Council 2020). Unless a county has a well-established invasive species mapping and monitoring program which periodically maps invasive weeds in the study region, invasive species cover should be verified in the field.

3.1.4.5 Other Disturbances

Road data can be downloaded for free from the United States open source data platform Data.gov (Data.gov 2020). The USGS National Transportation Dataset on Data.gov includes all roads (dirt, gravel, paved), in the United States including United States territories (Data.gov 2020). The Fire and Resource Assessment Program (FRAP) run by the California Department of Forestry and Fire Protection maintains a dataset which includes fire perimeter data for the whole state of California starting in 1878 (Fire and Resource Assessment Program 2020). The FRAP fire perimeter dataset is a multi-agency dataset and includes attributes for year, cause of fire, and total area burned (Fire and Resource Assessment Program 2020).

Table 4. Synthesis of data sources used for selecting reference sites.

Parameter	Data Source Santa Clara County	 California/ United States
Base Map	High resolution orthoimagery (County of Santa Clara 2020)	USGS high resolution orthoimagery (United States Geologic Survey 2020)
Land Cover	AIS riparian vegetation dataset (Aerial Information Systems 2010), Valley Habitat Agency land cover (ICF International 2012)	LANDFIRE Existing Vegetation Type (LANDFIRE 2020b), VegCAMP fine scale vegetation maps (California Department of Fish and Wildlife 2020b)
Land Use	SCC Urban Service Areas and General Plan datasets (Santa Clara County Department of Planning and Development 2017; Santa Clara County Department of Planning and Development 2020)	Check local government websites, California Department of Conservation Farmland Mapping and Monitoring Program data (California Department of Conservation 2019)
Roads	USGS National Transportation Dataset (Data.gov 2020)	
Fire	FRAP Fire Perimeter dataset (Fire and Resource Assessment Program 2020)	
Invasive Species	Calflora Weed Manager (Calflora 2020), Cal-IPC Weed Mapper (California Invasive Species Council 2020)	

3.2 Monitoring and assessment protocol

There are several methods which have been developed previously for the purposes of assessing wetland and riparian ecosystem condition and vegetation community condition (Sutula et al. 2006). There is a wide range of variability among these methods, from qualitative biological based methods, to hydrogeomorphic functional assessment methods, to rapid assessment methods (Fennessy et al. 2007). This study focuses on rapid assessment methods because they can be conducted quickly to increase sample size, are cost effective, and can be conducted by the lay person after a short training (Fennessy et al. 2007). Assessment methods were also evaluated on the parameters they measure to assess suitability for defining reference conditions (vegetation, water quality, and habitat quality), the amount of time to complete one assessment, and the training they require. These methods were selected because they are all rapid assessment methods which assess the condition of existing riparian, wetland, and vegetation communities. The first method, the Rapid Stream- Riparian Method is not widely used in California and was developed for the arid southwest (Stacey et al. 2006) and was chosen to determine whether commonly used methods can incorporate methods from lesser used methodologies. The following two methods, the California Native Plant Society Vegetation Rapid Assessment and the California Rapid Assessment Method for wetland and riparian areas are two widely used methods by California government agencies, non-profit agencies, and consultants (California Native Plant Society 2001; California Wetlands Monitoring Workgroup 2013).

3.2.1 Rapid Stream- Riparian Assessment Method

The Rapid Stream-Riparian Assessment method (RSRA) was developed by a group of biologists, ecologists and geomorphologists in 2006 to create a method to evaluate existing condition of stream and riparian ecosystems in the arid Southwest (Stacey et al. 2006). The methodology is a rapid assessment and is only meant to take a team of two to three people with minimal training, two to three hours to conduct one field assessment (Stacey et al. 2006). Therefore, the method is widely usable by conservationists, agency personnel, ranchers, and any interested lay person after some initial training (Stacey et al. 2006). The method is a condition assessment, meaning that after indicators are measured, they are categorized into a bin with a score of 1 (lowest quality) to 5 (highest quality). All numerical scores are averaged to establish an overall mean score which determines overall site quality. An overall mean score of 1-2 indicates the ecosystem is not functioning properly, a mean score of 2-4 indicates some components may be healthy while others are not, and a score of 4-5 indicates the ecosystem is healthy and is like a reference ecosystem (Stacey et al. 2006).

The RSRA method could be useful for determining existing reference conditions if an agency is already using this method because it includes measurements for riparian vegetation, water quality, and aquatic and terrestrial habitat. However, if an agency is choosing a method to begin a study defining reference conditions this method should not be used. One reason is that it does not require the field crew to record specific plant species within the survey area, which is important in project planning. It also includes parameters which are not directly relevant to determine reference conditions such as mammalian herbivory and beaver activity. Even though the presence of wildlife is an important indicator of habitat quality, it is not relevant for determining reference conditions for mitigation planning and can waste time in the field.

3.2.2 Vegetation Rapid Assessment

The California Native Plant Society (CNPS) and California Department of Fish and Wildlife Vegetation Rapid Assessment (RA) is a vegetation and habitat sampling method that is used to quickly assess information about composition, habitat quality, and site quality for all vegetation types (California Native Plant Society 2001). The methodology is a rapid assessment which is meant to take a field crew of two people 10-30 minutes per assessment and can be conducted after just a two-day training (Buck-Diaz 2020). The methodology records information about site location, geology and soil, slope, site history, disturbances, tree diameter, height classes, ages classes, and total vegetation cover. The rapid assessment form also includes space for up to 20 dominant plant species observed within the plot, and their percent cover. The RA is used by many California and national agencies such as the California State Parks System and the United States Forest Service.

The RA method is a useful method for determining reference conditions because it includes detailed information on vegetation and site information like species diversity and percent cover, soil type, and exposure. The method does not include any parameters on water quality or habitat quality. If this method is used it would be beneficial to add parameters to include water quality and habitat quality indicators.

3.2.3 California Rapid Assessment Method for wetland and Riparian Areas

The California Rapid Assessment Method for wetland and riparian areas (CRAM) was developed by technical experts in government agencies, non-governmental organizations, and academia (California Wetlands Monitoring Workgroup 2013). CRAM is a rapid assessment which is meant to take a field crew of two people a half a day or less to conduct one assessment and can be conducted after a week-long training course. CRAM can be used for ambient condition monitoring, monitoring potential project impacts, and compliance monitoring. CRAM uses four main attributes, landscape context and buffer, hydrology, physical structure, and biotic structure, to assess the condition of the ecosystem being surveyed. Once metrics and sub metrics are measured, each measurement is given a letter rating (A-D), letter scores are converted into a corresponding numeric score, and a final attribute score is calculated.

CRAM is a useful method because it focuses on a broad set of riparian characteristics which are directly relevant for defining reference conditions. The CRAM methodology includes parameters for hydrology, vegetation composition and structure, and habitat quality. One of the drawbacks of this method is that it is a more specialized method which requires a higher level of training and requires more time to conduct a survey.

Table 5. Synthesis of rapid assessment methods.

Protocol and Source	Parameters Measured: Vegetation	Water Quality	Habitat Quality
Rapid Stream-Riparian Assessment (Stacey et al. 2006)	Plant community cover and structural diversity, Dominant shrub and tree recruitment and age distribution, Non-native herbaceous and woody plant cover, Mammalian herbivory impacts on ground cover, shrubs, and small trees	Algal growth, Channel shading and solar exposure	Loss of perennial flows, Pool distribution, Underbank cover, Cobble embeddedness, Diversity of aquatic invertebrates, Large woody debris, Overbank cover and terrestrial invertebrate habitat, Riparian shrub and tree canopy cover and connectivity Fluvial habitat diversity
CNPS Rapid Assessment (California Native Plant Society 2001)	Tree DBH, Shrub age, Herbaceous, shrub, and tree layer height and cover class, Species richness and cover	N/A	N/A
California Rapid Assessment Method (California Wetlands Monitoring Workgroup 2013)	Number of layers present (i.e. herbaceous, shrub, tree), Number of co-dominant species, Percent invasion Horizontal interspersion, Vertical biotic structure	Water source, Channel stability, Hydrologic connectivity	Structural patch richness (physical surfaces/ features that provide habitat), Topographic complexity (i.e. micro- and macro-topography)

4 Discussion and Recommendations

Reference ecosystems are a great tool in restoration and mitigation planning, however there is no singular reference site selection method (Cash 2013; Harris 1999). Reference ecosystems should be structurally diverse, have high species diversity, low human impact, and minimal invasive-species cover (Harris 1999; Humphries 2016; Palmer et al. 2005). Reference site location is often selected on a project by project basis and requires an extensive knowledge of local environmental conditions which can be limiting (Titus and Diggory 2020). This study recommends a methodology for selecting reference sites and assessing reference site condition using desktop methods in the office to identify sites and rapid assessment methods in the field to assess physical condition.

4.1 Site Selection Methods

By using publicly available datasets from regional, state, and federal governments you can find information for the study region regarding parameters which quantify human impact and disturbances which influence proper ecosystem function. This study recommends using land use type, absence of invasive species, presence of roads, and history of fire to determine whether the site will serve as a high-quality reference site. Riparian ecosystems with land use classified as urban or agriculture should not be used because of extensive impacts from pollution, erosion, channel incision, and altered native species composition and structure (Burton et al. 2005; Groffman et al. 2003; Hanna et al. 2020; Hardison et al. 2009; Jun et al. 2011; Kauffman and Krueger 1984; King and Rier 1996; Meyer et al. 2005; Oneal and Rotenberry 2008; Szaro and Pase 1983). Riparian areas classified as rangeland may be used if site history is known and has not been intensively grazed, and vegetation has had time to recover for at least five years (Boyd et al. 2017; Kaweck et al. 2018; Sarr 2002). Riparian areas classified as protected may serve as the highest quality land type because protected lands often have limited human impact and are conserved for their ecosystem services, however one must confirm site history to ensure the area has not been grazed or used for agriculture for at least 5 years (Hanna et al. 2020; Schauss 2005). While selecting a reference site based on land use classification it is important to acknowledge edge effects. Edge effects are the influence that one ecosystem has on an adjacent ecosystem (Murcia 1995), such as riparian ecosystems classified with urban land use adjacent to riparian areas that are protected. It is possible that some negative impacts from urban land use may have negative impacts on protected areas. Therefore, if selecting a reference site downstream or close to a change in land use classification, use caution and best professional judgement when assessing the site.

Although there are many nonnative and invasive plant species in Santa Clara County, and throughout California, reference ecosystems should have minimal invasive species cover.

Therefore, there should be no more than 15% cover of Cal-IPC rated high invasive tree and shrub species and no more than 30% Cal-IPC rated high herbaceous species within site (California Wetlands Monitoring Workgroup 2013). Lastly, reference sites should be relatively intact and should not have signs of past disturbance such as roads or fire. Consequently, a reference site should not be closer than 50 meters from any road (Eyre et al. 2011; Quarles et al. 1974) and should not have burned in the last 4 years to ensure habitat complexity (Dwire and Kauffman 2003; Kauffman and Martin 1990).

4.2 Site Field Assessments

Once the site has been selected a field verification needs to be conducted to assess whether the site is a high-quality reference site and to record ambient conditions to define reference conditions. This study reviewed three rapid assessment methods: the Rapid Stream-Rapid Assessment (Stacey et al. 2006); the California Native Plant Society Vegetation Rapid Assessment (California Native Plant Society 2001); and the California Rapid Assessment Method for wetland and riparian areas (California Wetlands Monitoring Workgroup 2013). Out of the three methods the CRAM method fits the best with the common success criteria parameters of vegetation, water quality, and habitat quality. However, CRAM is the longest method, requiring up to a half-day per assessment and a weeklong training before being able to conduct assessments (California Wetlands Monitoring Workgroup 2013). These requirements may decrease the repeatability of the method and decrease sample size which may negatively impact the significance of results. Attending a weeklong training course, or hiring consultants with the training, may also be expensive for smaller agencies who want to conduct this condition assessment study. The CNPS RA is a quick method which includes detailed vegetation parameters but does not include any parameters on water quality or habitat quality (Buck-Diaz 2020; California Native Plant Society 2001). Managers looking to define reference conditions in the field should modify the CNPS RA and CRAM methods to include the detailed vegetation parameters from the CNPS RA and include the CRAM water quality and habitat quality parameters to create a more comprehensive method.

Lastly, this study recommends adding one more metric to the methodology; wetland indicator status for all dominant species (trees, shrubs, and herbs) found in the plot. Wetland indictor status originated in the National List of Plant Species that Occur in Wetlands in 1988 (Reed 1988) and was further developed by the United States Fish and Wildlife Service, United States Army Corps of Engineers, the United States Environmental Protection Agency, and the Natural Resources Conservation Service (Lichvar, Robert et al. 2012). In 2006 the Army Corps of Engineers assumed responsibility of the National List of Plant Species that Occur in Wetlands and maintains an updated list, now titled the National Wetland Plant List (Lichvar, R. W. et al. 2016; Lichvar et al. 2012). The National Wetland Plant List assigns a wetland indicator status for plants commonly found in wetland ecosystems and their adjacent uplands, if a plant species is not on the list, it is considered an obligate upland (Lichvar et al. 2016; Lichvar et al. 2012). The National Wetland Plant List is used for many purposes such as wetland delineation, ecosystem assessments, mitigation, and habitat restoration (Lichvar et al. 2012). These statuses are not exclusive for wetlands and can also be used to describe riparian species. Indicator statuses include;

- Obligate wetland: species almost always occurs in wetlands
- Facultative wetland: species usually occurs in wetland, but can occur in non-wetlands
- Facultative: species occurs in wetlands and non-wetlands
- Facultative upland: species usually occurs in non-wetlands, but can occur in wetlands
- Obligate upland: species almost never occurs in wetlands (Lichvar et al. 2012)

Wetland indicator status is beneficial in defining reference conditions for riparian ecosystems because it can help inform mitigation and restoration project planting plans. Determining wetland indicator status for each dominant species informs managers which plants need to be planted in wetter areas and which plants need to be planted in drier areas. This will improve the survival of planted species within a mitigation project and ensuring the project will be in compliance with permit conditions for low plant mortality.

If time is a limiting factor in completing a reference vegetation study, this study recommends using the CNPS RA and adding wetland indicator status because it provides detailed measurements on vegetation, which is the most common success criteria outlined in compensatory mitigation permits.

Overall, this methodology will allow managers to gain a well-rounded understanding of reference conditions in their region and will allow them to negotiate with regulatory agencies if permit conditions are significantly different than existing reference conditions. This methodology can also benefit regulatory agencies, who can use this data to standardize permit conditions and success criteria for the region.

4.3 Future Studies

In spring 2020 the methodology for site selection and field assessment described in this document will be piloted. The methodology will be used in a Valley Water reference vegetation study, to determine reference vegetation conditions for remaining native vegetation communities county-wide. Additional research to refine site-selection methods and building a GIS model to automate the site-selection process would be valuable. Additional parameters could include elevation, distance to artificial water bodies, distance to trails within protected areas, and distance from known encampments of unsheltered people.

5. Conclusion

Riparian ecosystems are extremely diverse and dynamic ecosystems that are integral to sustain the quality of human life. Despite the valuable ecosystem services riparian ecosystems provide, only 2% of California's historic riparian ecosystems remain (Dawdy 1989; Katibah 1984; Riparian Habitat Joint Venture 2004). Major federal, state, and regional laws established in the 1960s through 1970s aimed at protecting, conserving, and re-creating riparian ecosystems through conservation, restoration, and compensatory mitigation (Elliott et al. 1985; Lazarus 2001). However, unrealistic success criteria within the compensatory mitigation process has impeded the success of compensatory mitigation projects (Kihslinger 2008; Matthews and Endress 2008). Standardized, regionally specific success criteria based on natural reference sites are an effective tool to ensure that mitigation projects are meeting compliance and are restoring ecological function (Matthews and Endress 2008). With the site selection and site-condition assessment methodology created through this study, managers at Valley Water and throughout California, can quickly locate high-quality reference sites within a large landscape from the office and conduct several rapid assessments with minimal training to determine reference conditions for their region. These reference conditions can be used to either inform mitigation and restoration planning, help managers negotiate permit conditions with regulatory agencies, or help regulatory agencies standardize success criteria throughout the region. In defining regional reference conditions for riparian ecosystems, managers can ensure their restoration and mitigation projects are successful at restoring proper ecological function and conserve our riparian ecosystems into the future.

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